CS105 – Computer Systems Spring 2021

Problem Session 5: Buffer Overflow Attacks

February 24, 2021

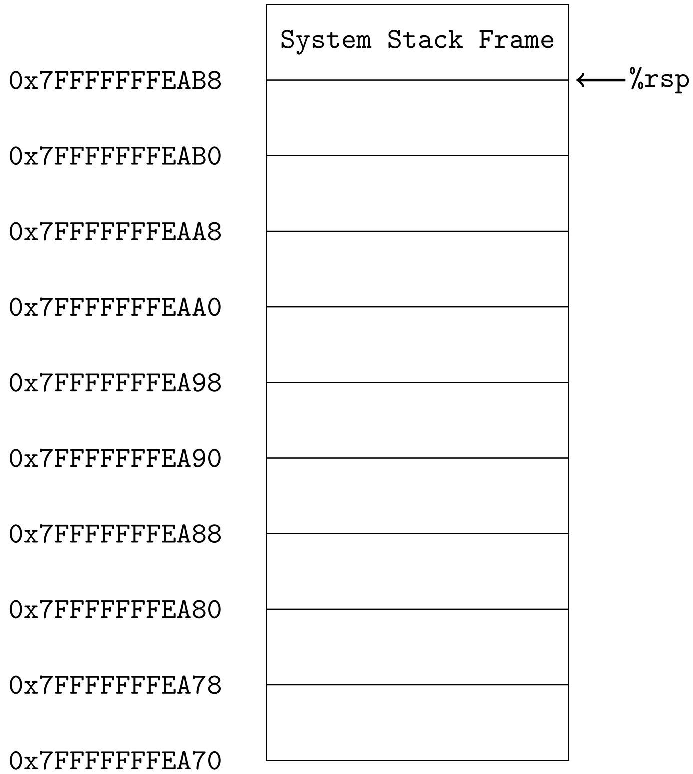
Tired of being thwarted by meddling 105 students, Dr. Evil tracks down an unsuspecting student who has put off taking CS 105 and convinces them to run the following program.

Consider the following C program and the corresponding machine code:

```
#include <stdio.h>

int isPosInt(char * s){
    char * p = s;
    while(*s != '\n'){
        if(*s < 48 || *s > 57){
            return 0;
        }
        s++;
    }
    return 1;
}

void getPosInt(char * s, int n){
    int done = 0;
    while(!done){
        gets(s, stdin);
        done = isPosInt(s);
    }
}

int main(int argc, char ** argv){
    int MAX_LEN = 12;
    char buf[MAX_LEN];
    getPosInt(&buf, MAX_LEN);
    printf("%s\n", buf);
}
```

```
0x4005fc <main>:
    0x4005fc <+0>:  sub    $0x18,%rsp
    0x400600 <+4>:  mov    $0xc,%esi
    0x400605 <+9>:  mov    %rsp,%rdi
    0x400608 <+12>: callq  0x4005c6 <getPosInt>
    0x40060d <+17>: mov    %rsp,%rdi
    0x400610 <+20>: callq  0x400470 <puts@plt>
    0x400615 <+25>: mov    $0x0,%eax
    0x40061a <+30>: add    $0x18,%rsp
    0x40061e <+34>: retq

0x4005c6 <getPosInt>:
    0x4005c6 <+0>:  push   %rbp
    0x4005c7 <+1>:  push   %rbx
    0x4005c8 <+2>:  sub    $0x8,%rsp
    0x4005cc <+6>:  mov    %rdi,%rbx
    0x4005cf <+9>:  mov    %esi,%ebp
    0x4005d1 <+11>: mov    $0x0,%eax
    0x4005d6 <+16>: jmp    0x4005f1 <getPosInt+43>
    0x4005d8 <+18>: mov    0x200a61(%rip),%rsi
                           # 0x601040 = &stdin
    0x4005df <+25>: mov    %ebp,%edx
    0x4005e1 <+27>: mov    %rbx,%rdi
    0x4005e4 <+30>: callq  0x400490 <gets@plt>
    0x4005e9 <+35>: mov    %rbx,%rdi
    0x4005ec <+38>: callq  0x4005a6 <isPosInt>
    0x4005f1 <+43>: test   %eax,%eax
    0x4005f3 <+45>: je     0x4005d8 <getPosInt+18>
    0x4005f5 <+47>: add    $0x8,%rsp
    0x4005f9 <+51>: pop    %rbx
    0x4005fa <+52>: pop    %rbp
    0x4005fb <+53>: retq

0x4005a6 <isPosInt>:
    // more assembly code
```

1. Below is a diagram of the stack at the beginning of function `main` (that is, when `%rip = 0x4005fc`).



   (a) Draw a detailed diagram of the stack immediately before the function `gets` is called (that is, when `%rip = 0x4005e4`). If you cannot determine from the provided information what value is stored at some address, enter a `?` in the corresponding box. Assume that the initial value in register `%rbp` is `0`. Assume that initial value in register `%rbx` is `0x400620`.

   (b) Add arrows to the above diagram to show the current values stored in `%rsp` and `%rdi`

2. Assume that Dr. Evil has somehow included an evil function located in memory at address `0x406147`. Construct an example exploit string that would cause the evil function to get executed after `main` returns. Assume the machine is little endian.

3. Maybe Dr. Evil was unable to include his evil function in the code. Assume that he instead enters a carefully constructed exploit string so that at the point immediately before main returns, the state of the stack is shown below.

Address (bottom of box)	Bytes	
0x7FFFFFFFEB10	0a 00 00 00 00 00 00 00	
0x7FFFFFFFEB08	1e 06 40 00 00 00 00 00	
0x7FFFFFFFEB00	47 47 47 47 47 47 47 47	
0x7FFFFFFFEAF8	47 47 47 47 47 47 47 47	
0x7FFFFFFFEAF0	42 6f 6f 6d 21 00 00 00	
0x7FFFFFFFEAE8	0d 06 40 00 00 00 00 00	
0x7FFFFFFFEAE0	61 68 61 68 61 68 61 00	
0x7FFFFFFFEAD8	47 47 47 47 4d 77 61 68	
0x7FFFFFFFEAD0	47 47 47 47 47 47 47 47	
0x7FFFFFFFEAC8	10 06 40 00 00 00 00 00	
0x7FFFFFFFEAC0	dc ea ff ff ff 7f 00 00	
0x7FFFFFFFEAB8	2a 04 40 00 00 00 00 00	⟵%rsp

You should interpret the sequence of bytes in each box as as the hex-encoding of the eight byte sequence starting at the address labeled at the bottom of the box and ending one byte before the address labeled at the top of the box. So, for example, the byte at address `0x7FFFFFFFEAB8` is `2a` and the byte at `0x7FFFFFFFEABF` is `00`

Hint: You may assume the Pomona server is a little-Endian machine.

Hint: Observe that the address in `%rsp` immediately before main returns will be `0x7FFFFFFFEAB8`.

Assume that the byte at address `0x40042a` is `0x5f` (the byte-level encoding of `pop %rdi`) and the byte at address `0x40042b` is `0xc3` (the byte-level encoding of `ret`). A table of potentially useful ASCII encoding is given below.

0a	21	42	4d	61	68	6d	6f	77
\n	!	B	M	a	h	m	o	w

(a) Fill in the table below with the values in each of the following registers when `%rip` stores each of the values. Each line of the table should correspond to one assembly instruction (so line 1 will describe the state of the registers after the instruction `retq` from line 0 completes, line 2 will describe the state of the registers after the instruction from line one completes, etc.) The initial line (immediately before the main function returns) has been filled out to help you get started. Treat any function calls as one instruction (i.e., "step over" them same as `nexti` would in `gdb`).

Hint: Remember that `%rip` stores the address of the next instruction to execute.

Hint: For addresses on the stack, it's fine to just use the last two bytes (e.g., `eab8` instead of `0x7fffffffeab8`).

	`%rip`	`(%rip)`	`%rsp`	`%rdi`
0	`0x40061e`	`retq`	`0x7fffffffeab8`	`0x7fffffffeab8`
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

(b) What gets printed after the main function returns?

Hint: `puts` prints the string passed in as its first argument.