# CSE 127 Discussion
# Week 3

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April 14, 2020

Zoom

# This discussion is being recorded

# Logistics

- PA1 due yesterday…still have late days if needed
- PA2 released yesterday on webpage
  - Due April 23rd (next Thursday) at 12:30 PM Pacific time
- Partners!
  - If you want a partner you need to stick with them
  - Partners are for helping each other out!
  - Please fill out google form by Friday April 17th EOD
    - https://forms.gle/mwQ9EpknejtVHLoe8
    - Link also on Piazza
- Today
  - Buffer Overflow Basics
  - PA2 overview
  - Open Office hours

# Buffer Overflow Review

- Format string vulnerabilities
- Heap vulnerabilities
- Integers

# Format String Vulnerabilities

- printf()
  - What's the problem with printf?
- Variadic function – variance in what can be input

| Parameter | Meaning | Passed as |
|---|---|---|
| %d | decimal (int) | value |
| %u | unsigned decimal (unsigned int) | value |
| %x | hexadecimal (unsigned int) | value |
| %s | string ((const) (unsigned) char *) | reference |
| %n | number of bytes written so far, (* int) | reference |

# Format String Vulnerabilities

- printf()
  - What’s the problem with printf?
- Variadic function – variance in what can be input
- What do the follow printf vulnerabilities do?
  - printf(“\x10\x01\x48\x08 %x  %x  %x  %x  %s”)
  - printf(“%s\n”)
  - printf("%08x %08x %08x %08x %08x\n”)

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- printf("\x10\x01\x48\x08 %x  %x  %x  %x  %s")
  - will print out the content's in the memory address 0x10014808

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- printf(“%s\n”)
  - Take the previous stack word, interpret as pointer (reference), and print memory at address as string

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- printf(“%s\n”)
  - Take the previous stack word, interpret as pointer (reference), and print memory at address as string
- printf("%08x %08x %08x %08x %08x\n”)
  - Retrieve five parameters from the stack, display as 8digit padded hexadecimal numbers

# Heap Vulnerabilities

- Dynamically allocated memory in program
- Programmer is responsible for many of the details
  - Variable liveliness and validity
  - In stack this is not the case
- Heap are kept in doubly-linked lists (bins)
- malloc() and free() are common commands that can get a user in trouble
  - Trouble because of differences in expectation vs reality
- Double free and use after free

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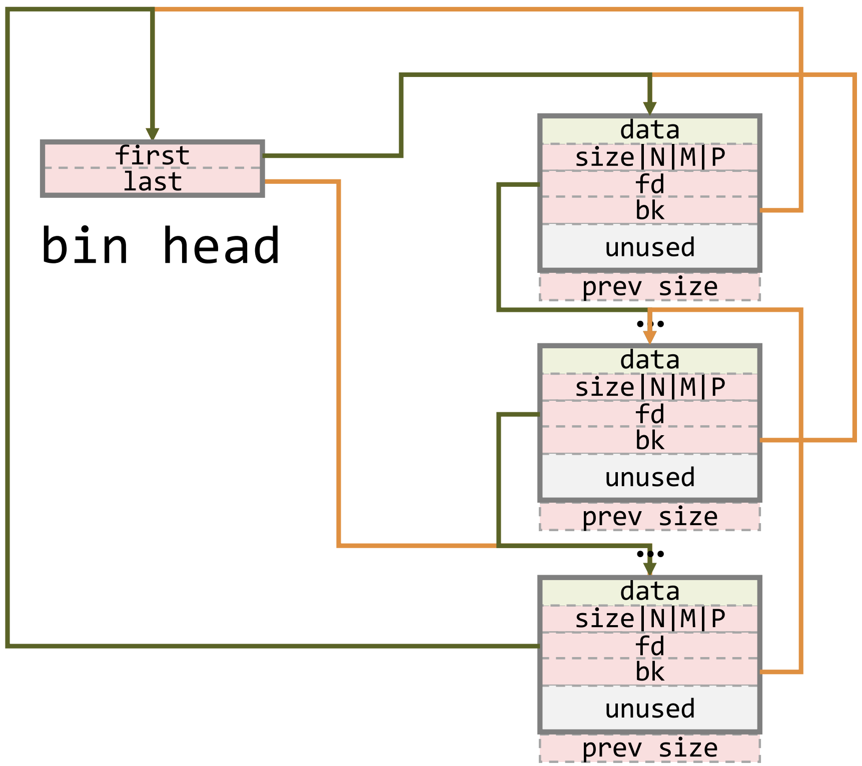
# Free List

- Free chunks are kept in circular doubly-linked lists (bins)



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# Double Free

```
a = malloc(10);     // 0xa04010
b = malloc(10);     // 0xa04030
c = malloc(10);     // 0xa04050

free(a);
free(b);  // To bypass "double free or corruption (fasttop)" check
free(a);  // Double Free !!

d = malloc(10);     // 0xa04010
e = malloc(10);     // 0xa04030
f = malloc(10);     // 0xa04010   - Same as 'd' !
```

https://heap-exploitation.dhavalkapil.com/attacks/double_free.html

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```

The state of the particular fastbin progresses as:

1. 'a' freed.
   > head -> a -> tail
2. 'b' freed.
   > head -> b -> a -> tail
3. 'a' freed again.
   > head -> a -> b -> a -> tail

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   > head -> b -> a -> tail
3. 'a' freed again.
   > head -> a -> b -> a -> tail
4. 'malloc' request for 'd'.
   > head -> b -> a -> tail [ 'a' is returned ]
5. 'malloc' request for 'e'.
   > head -> a -> tail [ 'b' is returned ]
6. 'malloc' request for 'f'.
   > head -> tail [ 'a' is returned ]

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# Integer Overflow/Conversion

- Bounds check (types)
  - What if we take a signed long and truncate it into an unsigned short?
  - This changes the value
  - 0010 0000 0000 0000 0000 0000 0000 0000 →
  - 0000 0000 0000 0000

# Integer Overflow/Conversion

- Signed vs unsigned
  - Signed: MSb is the sign bit (0 is positive, 1 is negative)
  - Unsigned: MSb is just the largest bit
- Example 0xFFFFFFFF (0xF = 1111)
  - Signed: -1
  - Unsigned: 4294967295

# Integer Overflow/Conversion

- Exercise: take two minutes and write out the unsigned and signed versions of a 4 bit integer from 0000 to 1111

Unsigned

| bits | value |
|---|---|
| 0000 | 0 |
| 0001 | 1 |
| 0010 | 2 |
| 0011 | 3 |
| 0100 | 4 |
| 0101 | 5 |
| 0110 | 6 |
| 0111 | 7 |
| 1000 | 8 |
| 1001 | 9 |
| 1010 | 10 |
| 1011 | 11 |
| 1100 | 12 |
| 1101 | 13 |
| 1110 | 14 |
| 1111 | 15... |

Signed

| bits | value |
|---|---|
| 0000 | 0 |
| 0001 | 1 |
| 0010 | 2 |
| 0011 | 3 |
| 0100 | 4 |
| 0101 | 5 |
| 0110 | 6 |
| 0111 | 7 |
| 1000 | -8 |
| 1001 | -7 |
| 1010 | -6 |
| 1011 | -5 |
| 1100 | -4 |
| 1101 | -3 |
| 1110 | -2 |
| 1111 | -1 |

# Integer Overflow/Conversion

- Helps us do some fun things with multiplication too…

4160749577 * 32 = 4160749557 * 2^5 =
4160749577 << 5

4160749577 =
0b1111100…..1001
<< 5 = 0b00…..100100000
= 1(32) + 1(256) = 288

# Integer Overflow/Conversion

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4160749577 =
0b1111100…..1001
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Notice the MSb!
What unsigned number can we multiply by 32 to get (the same answer)?

# Integer Overflow/Conversion

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4160749577 << 5

4160749577 =
0b1111100…..1001
<< 5 = 0b00…..100100000
= 1(32) + 1(256) = 288

Notice the MSb!
Unsigned: 4160749577
Signed: -134217719

-134217719 * 32 = 288

# PA2 Overview

- Going to produce buffer overflow exploits
  - Going to put theory to practice!
  - Won't be working on countermeasures
  - Four exploits in total
  - #1 – 3 are stack based
  - #1 is based off of Aleph One's paper
  - #4 is heap based (and extra credit!)
- generatesrc.py generates target using the base and is randomized using YOUR PID
  - Follow instructions on the assignment in order!
- Your buffer sizes and offsets will differ from everyone else's

```
├── sploit1
│   ├── assignment.toml
│   ├── Makefile
│   ├── shellcode.h
│   └── sploit1.c
├── sploit2
│   ├── assignment.toml
│   ├── Makefile
│   ├── shellcode.h
│   └── sploit2.c
├── sploit3
│   ├── assignment.toml
│   ├── Makefile
│   ├── shellcode.h
│   └── sploit3.c
├── sploit4
│   ├── assignment.toml
│   ├── Makefile
│   ├── shellcode.h
│   └── sploit4.c
└── targets
    ├── base
    │   ├── generatesrc.py
    │   ├── target1.c
    │   ├── target2.c
    │   ├── target3.c
    │   └── target4.c
    ├── Makefile
    ├── tmalloc.c
    └── tmalloc.h
```

# Setting

- target[1-4].c are vulnerable pieces of code that each read a string from the command line
- Your exploit is the string you pass in
- COULD run the attack by running $ ./target1 <attack_string>
- But that's difficult
  - Hard to type the string and fix things in place
  - Some of the strings could be very long
- So we call the strings from C programs called sploit[1-4].c
- sploit[1-4].c is the programmatic version of calling ./target[1-4] from the command line
- **ONLY MODIFY SPLOIT[1-4].c. DO NOT CHANGE TARGET.**

# Shellcode

```
shellcode.c
-----------------------------------------------------------------------------
#include <stdio.h>

void main() {
   char *name[2];

   name[0] = "/bin/sh";
   name[1] = NULL;
   execve(name[0], name, NULL);
}
-----------------------------------------------------------------------------
```

```
0x8000130 <main>:       pushl  %ebp
0x8000131 <main+1>:     movl   %esp,%ebp
0x8000133 <main+3>:     subl   $0x8,%esp
0x8000136 <main+6>:     movl   $0x80027b8,0xfffffff8(%ebp)
0x800013d <main+13>:    movl   $0x0,0xfffffffc(%ebp)
0x8000144 <main+20>:    pushl  $0x0
0x8000146 <main+22>:    leal   0xfffffff8(%ebp),%eax
0x8000149 <main+25>:    pushl  %eax
0x800014a <main+26>:    movl   0xfffffff8(%ebp),%eax
0x800014d <main+29>:    pushl  %eax
0x800014e <main+30>:    call   0x80002bc <__execve>
0x8000153 <main+35>:    addl   $0xc,%esp
0x8000156 <main+38>:    movl   %ebp,%esp
0x8000158 <main+40>:    popl   %ebp
0x8000159 <main+41>:    ret
```

http://phrack.org/issues/49/14.html#article

```
static char shellcode[] =
  "\xeb\x1f\x5e\x89\x76\x08\x31\xc0\x88\x46\x07\x89\x46\x0c\xb0\x0b"
  "\x89\xf3\x8d\x4e\x08\x8d\x56\x0c\xcd\x80\x31\xdb\x89\xd8\x40\xcd"
  "\x80\xe8\xdc\xff\xff\xff/bin/sh";
```

# Setuid

- Bit that allows elevation of privilege
- The targets run as their owner (root)
- Student can execute as root as long as it’s executing ‘target[1-4]’
- Root shell!
  - Student can now run ‘rm –rf /’ (but maybe don’t do this ☺ )

```
student@CSE127:~/hw2/sploits$ ./sploit1
# whoami
root
#
```

# General Workflow

- 1) Find the vulnerability (one of the examples from lecture or discussion)

- 2) Create an exploit to use that vulnerability
  - exploit the difference Expectation vs. reality

```c
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

int bar(char *arg, char *out)
{
  strcpy(out, arg);
  return 0;
}

int foo(char *argv[])
{
  char buf[768];
  bar(argv[1], buf);
}

int main(int argc, char *argv[])
{
  if (argc != 2)
    {
      fprintf(stderr, "target1: argc != 2\n");
      exit(EXIT_FAILURE);
    }
  foo(argv);
  return 0;
}
```

# What is the vulnerability? (you find this!)

target1.c

# What is the exploit?
# (you write this!)

sploit1.c

# Tips and Tricks

- Avoid 0x00
  - You can’t null terminate!
- 0x90 NOP
  - NOP sled
  - Good for padding
- memcpy and loops are your friends
  - Don’t write an 800 byte buffer by hand
- Refer to Aleph One for sploits 1-2

# Questions to ask yourself

- How can I get the program to return to an address I control? What do I need to overwrite?
- What if I write X more bytes than the buffer allows? Where does that put me in the stack/heap?
- Where in the program is there a bounds check? Can I get past the bounds check?
- How can I use negative numbers or signed/unsigned ints to mask my end goal?

# Open Office Hours & Questions