# Buffer Overflows

COMP 435
Fall 2017
Prof. Cynthia Sturton

## Administrative

- Exam Mon., Nov. 6
  - Covers material since last exam, including today's lecture
  - Review in OH Fri., Nov. 3, 10-12 FB 354
- Poster group info due tomorrow (or lose points!)
  - Group sign-up using google form
  - OR Email instr-435-cs@cs.unc.edu to be grouped
- Assignment 3 due Wed., Nov. 8
  - Can work on it after the exam
  - New this time: Sakai will stay open for resubmissions

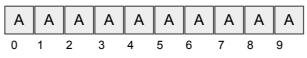


## Buffers



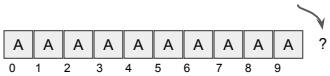
## Buffers

```
char sample[10];
int i;

for (i=0; i<=9; i++)
  sample[i] = 'A';
```



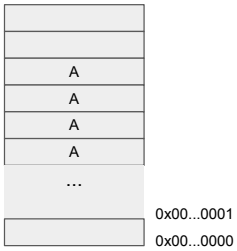
## Buffers

```
char sample[10];
int i;

for (i=0; i<=9; i++)
  sample[i] = 'A';

sample[10] = 'B';
```



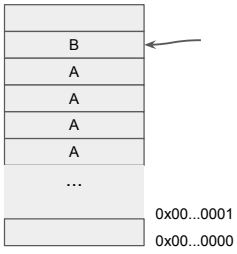



## Buffers in Memory






## Buffers in Memory






## Terminology

- Buffer Overflow
- Buffer Overrun
- Buffer Overflow Attack
- Stack Smashing

# Buffer Overflow Attack

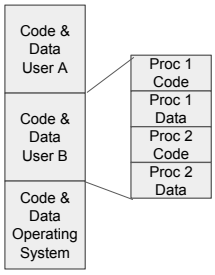


## Buffer Overflow Attack

- 1988 Morris Worm
- 2014 Heartbleed

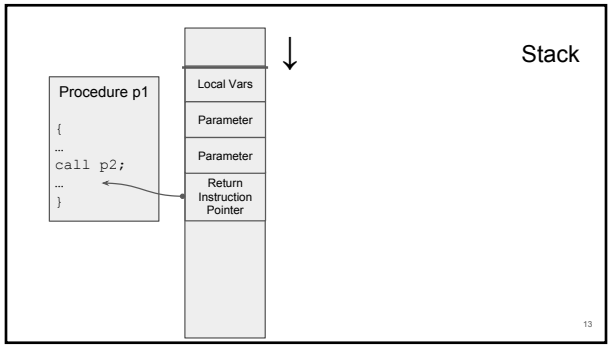


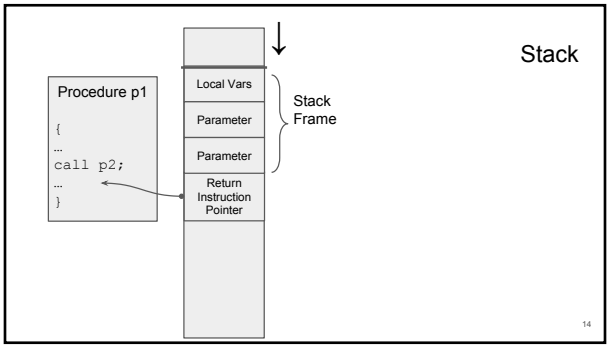
## Memory Layout






## Memory Layout: one process

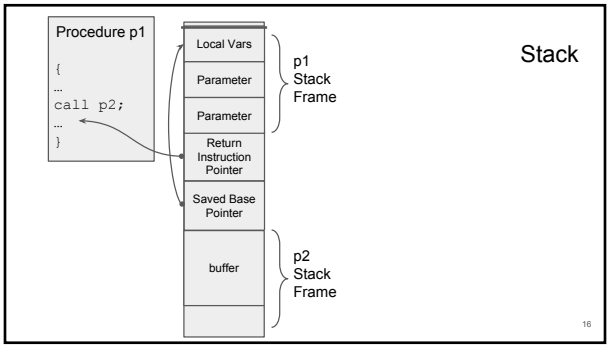



## Procedure p2

```
int p2(char *input){
  char buffer[100];
  strcpy(buffer, input);
  return 0;
}
```

15



## An Attack

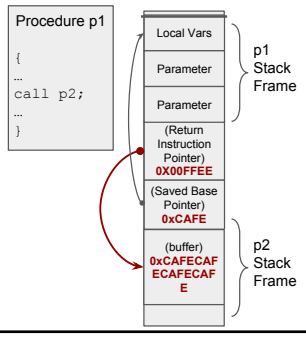
```
int p2(char *input){
  char buffer[100];
  strcpy(buffer, input);
  return 0;
}
```

input →

0xCAFECAFECAFECAFE...00FFEE



## Compromised Stack



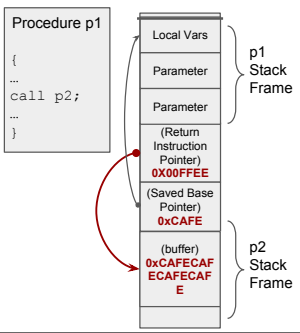



## Defense: Canary

- Add a secret value to the stack
- Check value before returning



## Compromised Stack



## Attack

Guess Canary



## Defense: W xor X

Regions of memory can be either writable or executable

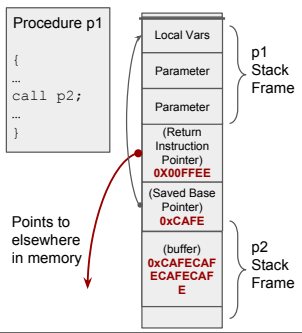


## Attack: Return to LibC

Point to existing code in the system



## Compromised Stack



## Attack: Return oriented programming

Point to “gadgets” within the existing code



## Current State

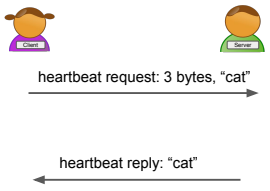
We have trained the attackers very well!



## Heartbleed



## TLS Heartbeat



## TLS Heartbleed Attack


heartbeat request: 64 Kbytes, “cat”

heartbeat reply:
“cat0xCAFEPasswordKeys”



## History of Heartbleed

- Bug introduced to code repository Dec 2011
- Published for comment Feb 2012
- Included and enabled by default in OpenSSL March 2012
- First discovered March 2014



## Current State

Buffer overflow and overruns are the major source of vulnerabilities in SW



## Integer Overflows

```
int *vulnerable(int *array, int len) {
    int *myarray;
    myarray = malloc(len * sizeof(int));
    if (myarray == NULL) {
        return -1;
    }
    for (i = 0; i < len; i++) {
        myarray[i] = array[i];
    }
    return myarray;
}
```

## Overflow Countermeasures

- Bounds Checking
- Input validation & sanitization
- Use safe utilities
- Least privilege
- Sandboxing



## Bounds Checking

- Manual code review
- Static analysis
- Dynamic analysis



## Input Validation & Sanitization

- Use a template

  (919) 555-1234



## Input Validation & Sanitization

- Use a template

  (919) 555-1234

- Templates prescribe good behavior

## Templates are Difficult

(919) 555-1234

1-919-555-1234

+1 919 555 1234

919 555 1234

919.555.1234



## Input Validation & Sanitization

The length of buffer writes should be dictated by buffer size, not by user-provided input



## Input Validation & Sanitization

Never trust user-supplied input



## Use Safe Utilities

strcpy vs strncpy

```
char str1[]= "hello";
char str2[6];

/* copy to terminating null '\0' */
  strcpy (str2, str1);

/* copy only 6 chars */
  strncpy (str2, str1, 6);
```

## Use Safe Utilities

- strcpy vs strncpy
- strcmp vs strncmp
- sprintf vs snprintf



## Least Privilege

Subject should have access to fewest number of objects necessary to do its work



## Least Privilege

- Code should have only the permissions needed
- Limits the damage done by compromise



## Sandboxing

Contain sections of code within a specified address range

## Programming Language

The choice of language plays a role as well

Type Safety

Memory Safety



## In-class Exercise