

CSE 484 / CSE M 584: Computer Security and Privacy

Software Security: Buffer Overflow Attacks

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Announcements

- Things Due:
 - Ethics form: Due Wednesday
 - Homework #1: Due Friday
- Office Hours:
 - Now scheduled, see course website
 - Via Zoom – find links on Canvas
 - Mine are right after class today (and all Mondays)
- Lab 1 coming up!
 - We will be sending out a sign-up form today
 - Section this week will be very important for lab 1
- Zoom Breakouts
 - You can join self-selected “Zoom Breakout” groups in Canvas, I will start using them Wednesday – **keep scrolling in Canvas until that group set loads**

TOWARDS DEFENSES

Approaches to Security

- Prevention
 - Stop an attack
- Detection
 - Detect an ongoing or past attack
- Response
 - Respond to attacks
- The threat of a response may be enough to deter some attackers

Whole System is Critical

- Securing a system involves a whole-system view
 - Cryptography
 - Implementation
 - People
 - Physical security
 - Everything in between
- This is because “security is only as strong as the weakest link,” and security can fail in many places
 - No reason to attack the strongest part of a system if you can walk right around it.

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Whole System is Critical



Attacker's Asymmetric Advantage



Attacker's Asymmetric Advantage



- Attacker only needs to win in one place
- Defender's response: Defense in depth

not "security through obscurity"

From Policy to Implementation

- After you've figured out what security means to your application, there are still challenges:
 - Requirements bugs
 - Incorrect or problematic goals
 - Design bugs
 - Poor use of cryptography
 - Poor sources of randomness
 - ...
 - Implementation bugs
 - Buffer overflow attacks
 - ...
 - Is the system **usable**?

Many Participants

- Many parties involved
 - System developers
 - Companies deploying the system
 - The end users
 - The adversaries (possibly one of the above)
- Different parties have different goals
 - System developers and companies may wish to optimize cost
 - End users may desire security, privacy, and usability
 - But the relationship between these goals is quite complex (will customers choose features or security?)

Better News

- There are a lot of defense mechanisms
 - We'll study some, but by no means all, in this course
- It's important to understand their limitations
 - “If you think cryptography will solve your problem, then you don't understand cryptography... and you don't understand your problem” -- Bruce Schneier

SOFTWARE SECURITY

Adversarial Failures

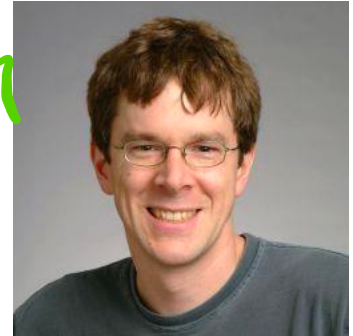
- Software bugs are bad
 - Consequences can be serious
- Even worse when an **intelligent adversary** wishes to **exploit** them!
 - Intelligent adversaries: Force bugs into “**worst possible**” conditions/states
 - Intelligent adversaries: Pick their targets
- **Buffer overflows bugs**: Big class of bugs
 - Normal conditions: Can sometimes cause systems to fail
 - Adversarial conditions: Attacker able to violate security of your system (control, obtain private information, ...)

vulnerability
↓
vs.
exploit

BUFFER OVERFLOWS

A Bit of History: Morris Worm

- Worm was released in 1988 by Robert Morris
 - Graduate student at Cornell, son of NSA chief scientist
 - Convicted under Computer Fraud and Abuse Act, **CFRA** 3 years probation and 400 hours of community service
 - Now an EECS professor at MIT
- Worm was intended to propagate slowly and harmlessly measure the size of the Internet
- Due to a coding error, it created new copies as fast as it could and overloaded infected machines
- \$10-100M worth of damage



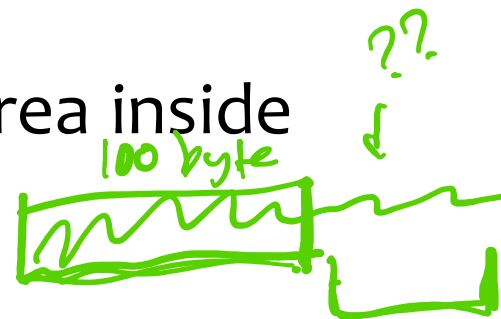
Morris Worm and Buffer Overflow

- One of the worm's propagation techniques was a **buffer overflow attack** against a vulnerable version of `fingerd` on VAX systems
 - By sending special string to finger daemon, worm caused it to execute code creating a new worm copy

Buffer overflows remain a common source of vulnerabilities and exploits today!
(Especially in embedded systems.)

Attacks on Memory Buffers

- **Buffer** is a pre-defined data storage area inside computer memory (stack or heap)
- Typical situation:
 - A function takes some input that it writes into a **pre-allocated buffer**.
 - The developer **forgets to check** that the size of the input isn't larger than the size of the buffer.
 - **Uh oh.**
 - “Normal” bad input: crash
 - “Adversarial” bad input : take control of execution



Stack Buffers

buf

uh oh!

- Suppose Web server contains this function

```
void func(char *str) {  
    char buf[126];  
    ...  
    strcpy(buf, str);  
    ...  
}
```

Handwritten annotations:
- A green arrow points from the word "untrusted" to the parameter `str`.
- A green arrow points from the word "null terminated (00)" to the second parameter `str` in the `strcpy` function call.
- A green arrow points from the word "untrusted" to the first parameter `buf` in the `strcpy` function call.

- No bounds checking on `strcpy()`
- If `str` is longer than 126 bytes
 - Program may crash
 - Attacker may change program behavior

Example: Changing Flags

buf

1 (:-) !)

- Suppose Web server contains this function

```
void func(char *str) {  
    char buf[126];  
    ...  
    strcpy(buf, str);  
    ...  
}
```

- **Authenticated** variable non-zero when user has extra privileges
- Morris worm also overflowed a buffer to overwrite an authenticated flag in fingerd

Memory Layout

- **Text region:** Executable code of the program
- **Heap:** Dynamically allocated data
- **Stack:** Local variables, function return addresses; grows and shrinks as functions are called and return



Stack Buffers

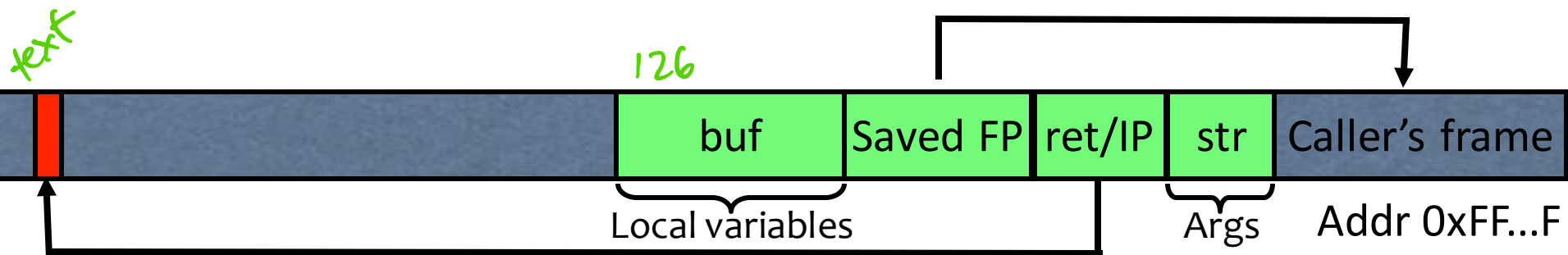
- Suppose Web server contains this function:

```
void func(char *str) {  
    char buf[126];  
    strcpy(buf, str);  
}
```

Allocate local buffer
(126 bytes reserved on stack)

Copy argument into local buffer

- When this function is invoked, a new **frame** (activation record) is pushed onto the stack.



Execute code at this address after func() finishes

What if Buffer is Overstuffed?

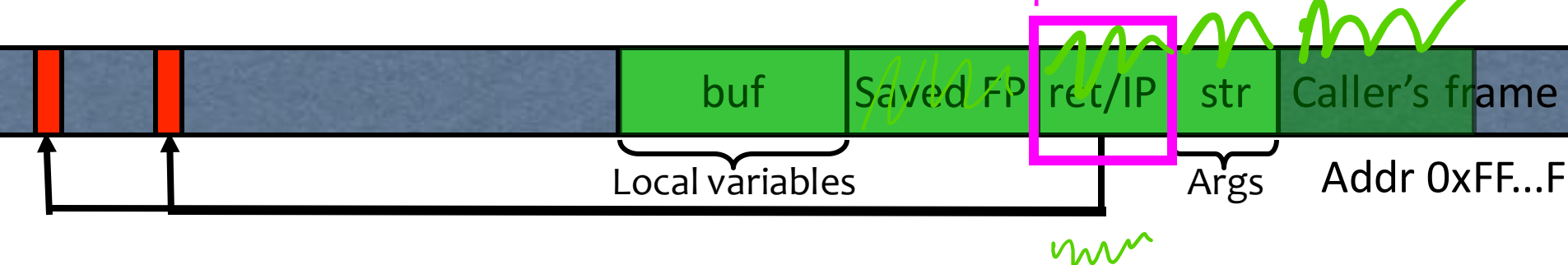
- Memory pointed to by str is copied onto stack...

```
void func(char *str) {  
    char buf[126];  
    strcpy(buf, str);  
}
```

strcpy does NOT check whether the string at *str contains fewer than 126 characters

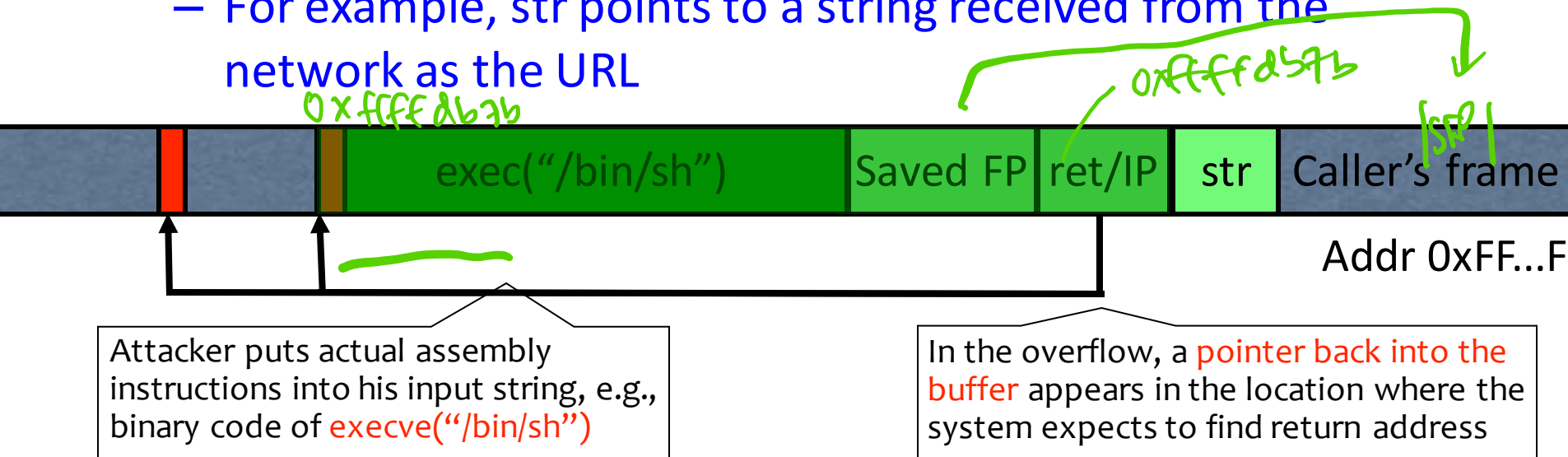
- If a string longer than 126 bytes is copied into buffer, it will overwrite adjacent stack locations.

This will be interpreted as return address!



Executing Attack Code

- Suppose buffer contains attacker-created string
 - For example, str points to a string received from the network as the URL




- When function exits, code in the buffer will be executed, giving attacker a shell (“**shellcode**”)
 - **Root shell** if the victim program is setuid root

Buffer Overflows Can Be Tricky...

- Overflow portion of the buffer must contain **correct address of attack code** in the RET position
 - The value in the RET position must point to the beginning of attack assembly code in the buffer
 - Otherwise application will (probably) crash with segfault
 - **Attacker must correctly guess in which stack position his/her buffer will be when the function is called**

Problem: No Bounds Checking

- strcpy does not check input size
 - strcpy(buf, str) simply copies memory contents into buf starting from *str until “\0” is encountered, ignoring the size of area allocated to buf
- Many C library functions are unsafe
 - strcpy(char *dest, const char *src)
 - strcat(char *dest, const char *src)
 - gets(char *s)
 - scanf(const char *format, ...)
 - printf(const char *format, ...) 

Does Bounds Checking Help?

- strncpy(char *dest, const char *src, ¹²⁶size_t n)
 - If strncpy is used instead of strcpy, no more than n characters will be copied from *src to *dest
 - Programmer has to supply the right value of n

- Potential overflow in httpasswd.c (Apache 1.3):

```
strcpy(record, user);  
strcat(record, " : ");  
strcat(record, cpw);
```

Copies username ("user") into buffer ("record"), then appends ":" and hashed password ("cpw")

- Published fix:

```
strncpy(record, user, MAX_STRING_LEN-1);  
strcat(record, " : ");  
strncat(record, cpw, MAX_STRING_LEN-1);
```

Breakout Activity

Canvas -> Quizzes -> Oct 5

(This is the first one that will be graded. Reminder that you have 5 “freebies” for the quarter.)

Misuse of strncpy in httpasswd “Fix”

- Published “fix” for Apache httpasswd overflow:

```
strncpy(record, user, MAX_STRING_LEN-1);  
strcat(record, ":")  
strncat(record, cpw, MAX_STRING_LEN-1);
```

what is this?
😊

MAX_STRING_LEN bytes allocated for record buffer

