

CSE 484: Computer Security and Privacy

Software Security: Buffer Overflow Defenses + Misc

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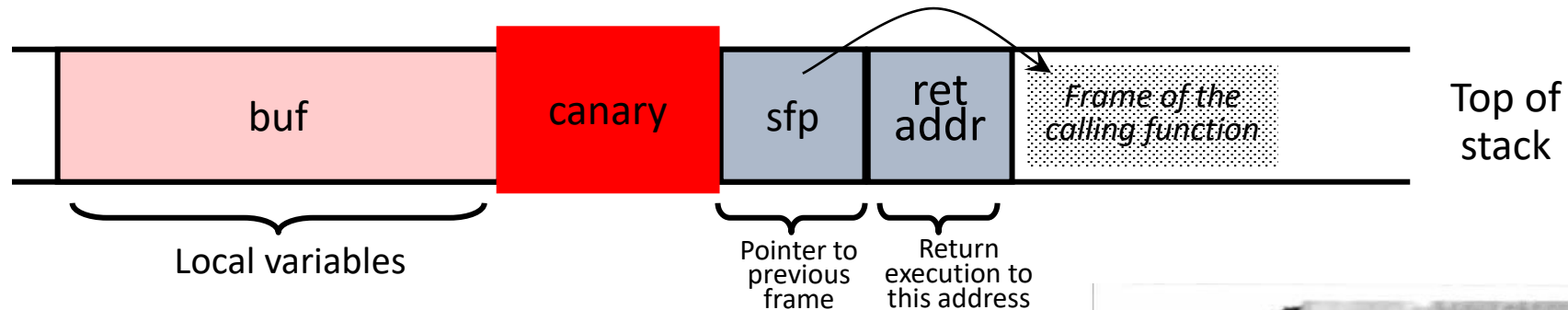
Thanks to Franz Roesner, Dan Boneh, Dieter Gollmann, Dan Halperin, David Kohlbrenner, Yoshi Kohno, Ada Lerner, John Manferdelli, John Mitchell, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

Admin

- Lab 1: April 21
 - That is, spoils 1-3
 - When you are 'done,' stop changing those files.
 - Start early! You are encouraged to finish spoils 1-3 before April 21, and start on the other spoils before the final deadline
- Next Wednesday:
 - Gennie Gebhart, Acting Activism Director, Electronic Frontier Foundation (EFF)
 - <https://www.eff.org/about/staff/gennie-gebhart>
 - Title: Surveillance Self-Defense and Security Work in Civil Society

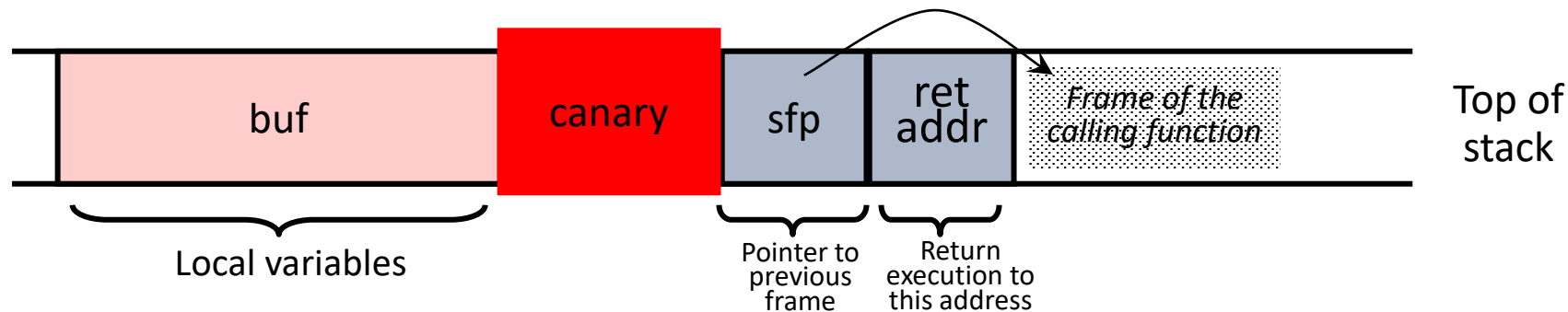
Defense: Run-Time Checking: StackGuard

- Embed “**canaries**” (**stack cookies**) in stack frames and verify their integrity prior to function return
 - Any overflow of local variables will damage the canary



Defense: Run-Time Checking: StackGuard

- Embed “canaries” (stack cookies) in stack frames and verify their integrity prior to function return
 - Any overflow of local variables will damage the canary



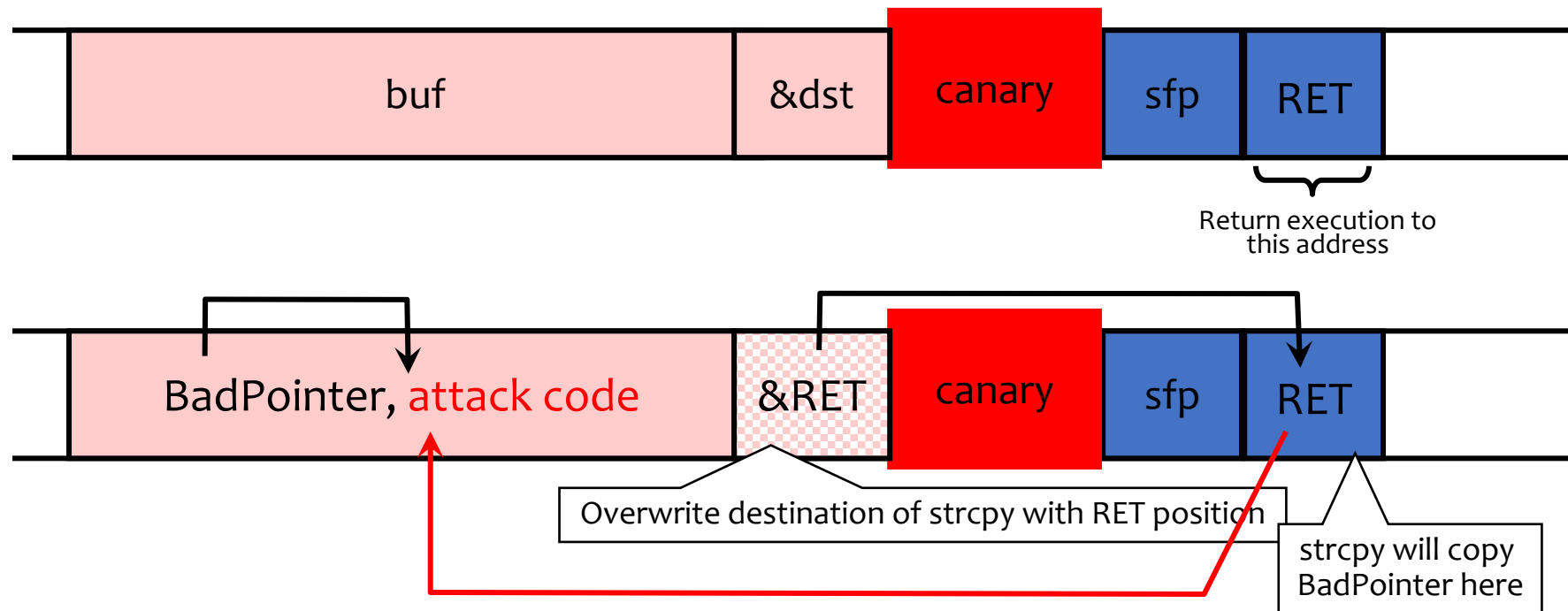
- Choose random canary string on program start
 - Attacker can't guess what the value of canary will be
- Canary contains: “\0”, newline, linefeed, EOF
 - String functions like strcpy won't copy beyond “\0”

StackGuard Implementation

- StackGuard requires code recompilation
- Checking canary integrity prior to every function return causes a performance penalty
 - For example, 8% for Apache Web server at one point in time
- Canvas Quiz

Defeating StackGuard

- StackGuard can be defeated
 - A single memory write where the attacker controls both the value and the destination is sufficient
- Suppose program contains `copy(buf,attacker-input)` and `copy(dst,buf)`
 - Example: `dst` is a local pointer variable
 - Attacker controls both `buf` and `dst`



ASLR: Address Space Randomization

- Randomly arrange address space of key data areas for a process
 - Base of executable region
 - Position of stack
 - Position of heap
 - Position of libraries
- Introduced by Linux PaX project in 2001
- Adopted by OpenBSD in 2003
- Adopted by Linux in 2005

ASLR: Address Space Randomization

- Deployment (examples)
 - Linux kernel since 2.6.12 (2005+)
 - Android 4.0+
 - iOS 4.3+ ; OS X 10.5+
 - Microsoft since Windows Vista (2007)
- Attacker goal: Guess or figure out target address (or addresses)
- ASLR more effective on 64-bit architectures

Attacking ASLR

- **NOP sleds and heap spraying** to increase likelihood for adversary's code to be reached (e.g., on heap)
- **Brute force attacks or memory disclosures** to map out memory on the fly
 - Disclosing a single address can reveal the location of all code within a library, depending on the ASLR implementation

Defense: Shadow stacks

- Idea: don't store return addresses on the stack!
- Store them on... a **different stack!**
 - *A hidden stack*
- On function call/return
 - **Store/retrieve the return address from shadow stack**
- Or store on both main stack and shadow stack, and compare for equality at function return
- 2020/2021 Hardware Support emerges (e.g., Intel Tiger Lake, AMD Ryzen PRO 5000)

Challenges With Shadow Stacks

- Where do we put the shadow stack?
 - Can the attacker figure out where it is? Can they access it?
- How fast is it to store/retrieve from the shadow stack?
- How *big* is the shadow stack?
- Is this compatible with all software?
- (Still need to consider data corruption attacks, even if attacker can't influence control flow.)

Other Big Classes of Defenses

- Use safe programming languages, e.g., **Java**
 - What about legacy C code?
 - (Though Java doesn't magically fix all security issues 😊)
- **Static analysis** of source code to find overflows
- **Dynamic testing**: “fuzzing”

- (And other defenses as well, e.g., **PointerGuard**)

Fuzz Testing

- Generate “random” inputs to program
 - Sometimes conforming to input structures (file formats, etc.)
- See if program crashes
 - If crashes, found a bug
 - Bug may be exploitable
- Surprisingly effective

- Now standard part of development lifecycle

Other Common Software Security Issues...

Another Type of Vulnerability

- Consider this code:

```
char buf[80];
void vulnerable() {
    int len = read_int_from_network();
    char *p = read_string_from_network();
    if (len > sizeof buf) {
        error("length too large, nice try!");
        return;
    }
    memcpy(buf, p, len);
}
```

```
void *memcpy(void *dst, const void * src, size_t n);
```

```
typedef unsigned int size_t;
```

Another Example

```
size_t len = read_int_from_network();  
char *buf;  
buf = malloc(len+5);  
read(fd, buf, len);
```

Breakout Groups

(from www-inst.eecs.berkeley.edu—implflaws.pdf)

Implicit Cast

- Consider this code:

```
char buf[80];
void vulnerable() {
    int len = read_int_from_network();
    char *p = read_string_from_network();
    if (len > sizeof buf) {
        error("length too large, nice try!");
        return;
    }
    memcpy(buf, p, len);
}
```

If **len** is negative, may copy huge amounts of input into buf.

```
void *memcpy(void *dst, const void * src, size_t n);
```

```
typedef unsigned int size_t;
```

Integer Overflow

```
size_t len = read_int_from_network();  
char *buf;  
buf = malloc(len+5);  
read(fd, buf, len);
```

- What if `len` is large (e.g., `len = 0xFFFFFFFF`)?
- Then `len + 5 = 4` (on many platforms)
- Result: Allocate a 4-byte buffer, then read a lot of data into that buffer.

(from [www-inst.eecs.berkeley.edu—impl/flaws.pdf](http://www-inst.eecs.berkeley.edu/~impl/flaws.pdf))

Another Type of Vulnerability

- Consider this code:

```
if (access("file", W_OK) != 0) {  
    exit(1); // user not allowed to write to file  
}  
  
fd = open("file", O_WRONLY);  
write(fd, buffer, sizeof(buffer));
```

- **Goal:** Write to file only with permission
- What can go wrong?

TOCTOU (Race Condition)

- TOCTOU = “Time of Check to Time of Use”

```
if (access("file", W_OK) != 0) {  
    exit(1); // user not allowed to write to file  
}  
  
fd = open("file", O_WRONLY);  
write(fd, buffer, sizeof(buffer));
```

- **Goal:** Write to file only with permission
- Attacker (in another program) can change meaning of “file” between `access` and `open`:
`symlink("/etc/passwd", "file");`

Password Checker

- Functional requirements
 - `PwdCheck(RealPwd, CandidatePwd)` should:
 - Return `TRUE` if `RealPwd` matches `CandidatePwd`
 - Return `FALSE` otherwise
 - `RealPwd` and `CandidatePwd` are both 8 characters long

Password Checker

- Functional requirements
 - PwdCheck(RealPwd, CandidatePwd) should:
 - Return TRUE if RealPwd matches CandidatePwd
 - Return FALSE otherwise
 - RealPwd and CandidatePwd are both 8 characters long
- Implementation (like TENEX system)

```
PwdCheck (RealPwd, CandidatePwd) // both 8 chars
  for i = 1 to 8 do
    if (RealPwd[i] != CandidatePwd[i]) then
      return FALSE
  return TRUE
```

- Clearly meets functional description

Attacker Model

```
PwdCheck (RealPwd, CandidatePwd) // both 8 chars
  for i = 1 to 8 do
    if (RealPwd[i] != CandidatePwd[i]) then
      return FALSE
  return TRUE
```

- Attacker can guess **CandidatePwds** through some standard interface
- Naive: Try all $256^8 = 18,446,744,073,709,551,616$ possibilities
- Is it possible to derive password more quickly?