CSE 484 / CSE M 584: Software Security (Continued)

Winter 2022

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Announcements

• Lab 1:
  • Out
  • Target 3 and 7 still extra credit (even though we now have working solutions) (still encourage everyone to do them)
  • Quiz section this week: Definitely attend re: one of the targets! (Heap structures)
• Next week: Monday: I will be at the lecture hall (but still using Zoom)
• Next week: Wednesday: I will be at the lecture hall (but still using Zoom)
• Next week: Friday: Emily McReynolds via Zoom (everyone via Zoom)
Review Slide: Buffer Overflow: Causes and Cures

• Classical memory exploit involves code injection
  • Put malicious code at a predictable location in memory, usually masquerading as data
  • Trick vulnerable program into passing control to it

• Possible defenses:
  1. Prevent execution of untrusted code
  2. Stack “canaries”
  3. Encrypt pointers
  4. Address space layout randomization
  5. Code analysis
  6. ...

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Correction + Updates from Last Time

• Return-to-libc: May not be available to attacker on all platforms because systems may use registers as part of calling into / returning from functions

• Return-oriented programing: More flexible

• Return-oriented programming paper: 
  https://hovav.net/ucsd/papers/s07.html
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 emerged (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, Rust
  • 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”
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:

```c
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);
}
```

```c
void *memcpy(void *dst, const void * src, size_t n);
typedef unsigned int size_t;
```
Another Example

```c
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)
Another Type of Vulnerability

• Consider this code:

```c
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 Tile of Use”

```c
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

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  • 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

- 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?

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

• Assume there are no “typical” bugs in the software
  • No buffer overflow bugs
  • No format string vulnerabilities
  • Good choice of randomness
  • Good design

• The software may still be vulnerable to timing attacks
  • Software exhibits input-dependent timings

• Complex and hard to fully protect against
Hey what about if its over a network?

- “Remote timing attacks are practical” - 2005
  - David Brumley, Dan Boneh
Other Examples

• Plenty of other examples of timings attacks
  • Timing cache misses
    • Extract cryptographic keys...
    • Recent Spectre/Meltdown attacks
  • Duration of a rendering operation
    • Extract webpage information
  • Duration of a failed decryption attempt
    • Different failures mean different thing (e.g., Padding oracles)
Side-channels

• **Timing** is only one possibility

• **Consider:**
  • Power usage
  • Audio
  • EM Outputs