CSE 484 / CSE M 584: Computer Security and Privacy

Software Security (Misc)

Autumn 2020

Franziska (Franzi) Roesner
franzi@cs.washington.edu

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

Last Words on Buffer Overflows…

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 slides** and **heap spraying** to increase likelihood for custom code (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

Other Possible Solutions

- 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"

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: Questions 1+2 on Canvas

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

Implicit Cast

- Consider this code:

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

```
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;
```

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—implflaws.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 Tile 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
- 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
- Better: Time how long it takes to reject a CandidatePasswd. Then try all possibilities for first character, then second, then third, ...
  - Total tries: 256*8 = 2048

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

Other Examples

- Plenty of other examples of timings attacks
  - Timing cache misses
    - Extract cryptographic keys…
    - Recent Spectre/Meltdown attacks
- Also many other side channels
  - Power analysis
  - Other sensors
    - Example: Accelerometer to extract phone passcode

Software Security: So what do we do?

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

General Principles

- Check inputs
- Check all return values
- Least privilege
- Securely clear memory (passwords, keys, etc.)
- Failsafe defaults
- Defense in depth
  - Also: prevent, detect, respond

- NOT: security through obscurity

General Principles

- Reduce size of trusted computing base (TCB)
- Simplicity, modularity
  - But: Be careful at interface boundaries!
- Minimize attack surface
- Use vetted components
- Security by design
  - But: tension between security and other goals
- Open design? Open source? Closed source?
  - Different perspectives

Does Open Source Help?

- Different perspectives…
- Happy example?
  - Linux kernel backdoor attempt thwarted (2003)
    (http://www.freedom-to-tinker.com/?p=472)
- Sad example?
  - Heartbleed (2014)
    - Vulnerability in OpenSSL that allowed attackers to read arbitrary memory from vulnerable servers (including private keys)

Vulnerability Analysis and Disclosure

- What do you do if you've found a security problem in a real system?
- Say
  - A commercial website?
  - UW grade database?
  - Boeing 787?
  - TSA procedures?