CSE 484: Computer Security and Privacy

Software Security (Misc)

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Admin

• Lab 1 checkpoint *next Wednesday night!*
  • That is, *sploits 1-3*
  • When you are ‘done’ you stop changing those files.

```bash
chmod -w sploit0.c
+rw
```
Last Words on Buffer Overflows...
Defenses

• **ASLR** – Randomize where the stack/heap/code starts
  - **Counters:** Information disclosures, sprays and sleds

• **Canaries** – Put a value on the stack, see if it changes
  - **Counters:** Arbitrary writes

• **DEP** – Mark sections of memory as non-executable, e.g. the stack
  - **Counters:** ROP, JOP, Code-reuse attacks in general, JIT

\[\text{write xor execute}\]
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

• Maybe encrypt/randomize the shadow stack data?
Challenges With Shadow Stacks

- Where do we put the shadow stack?
  - Can the attacker figure out where it is?

- How fast is it to store/retrieve from the shadow stack?

- How big is the shadow stack?
  - Is it a full stack? Just reads?

- Is this compatible with all software?
Other Possible Solutions

- Use safe programming languages, e.g., Rust (or Java?)
  - What about legacy C code?
  - (Though Rust 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:

```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: January 15th on Canvas

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

• 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);
}

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

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

- 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.

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

(from [www-inst.eecs.berkeley.edu—implflaws.pdf](http://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 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");

```bash
rm myfile.txt
ln myfile.txt
file myfile.txt
```
Password Checker

• Functional requirements
  • $\text{PwdCheck(RealPwd, CandidatePwd)}$ should:
    • Return TRUE if RealPwd matches CandidatePwd
    • Return FALSE otherwise
  • RealPwd and CandidatePwd are both 8 characters long
Password Checker

- **Functional requirements**
  - $\text{PwdCheck}(\text{RealPwd}, \text{CandidatePwd})$ should:
    - Return **TRUE** if $\text{RealPwd}$ matches $\text{CandidatePwd}$
    - Return **FALSE** otherwise
  - $\text{RealPwd}$ and $\text{CandidatePwd}$ are both 8 characters long

- **Implementation (like TENEX system)**

```c
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

```
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
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
  • Sensors — accelerometers
  • EM Outputs — TEMPEST
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

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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?