Secure Programming II

"I'm paranoid, but am I paranoid enough?"

Special Techniques for Secure Programs

- Buffer overflows are bad in any case
- Some problems are only a risk for security-sensitive programs
- But what is a "security-sensitive program"?
- A security-sensitive program is one that runs with one set of permissions and accepts input from somone with different (especially lesser) permissions
- Includes most network servers and setUID programs, and many system daemons

SetUID Programs Are More Sensitive

- Anyone on the local machine can invoke them
- Many environmental influences that can be controlled by the invoker
- On the other hand, network daemons can be accessed remotely

Macro Injection Attacks

- Suppose a program is querying an SQL database based on valid userID and query string:

```
sprintf(buf, "select where user=\"\%s\" &&
    query=\"%s\"", uname, query);
```

- What if **`query`** is

```
    foo" || user="root
```

- The actual command passed to SQL is

```
    select where user="uname" && query = "foo" ||
        user="root"
```

- This will retrieve records it shouldn't have
- Stored SQL procedures are much safer

What Was Wrong with That Slide?

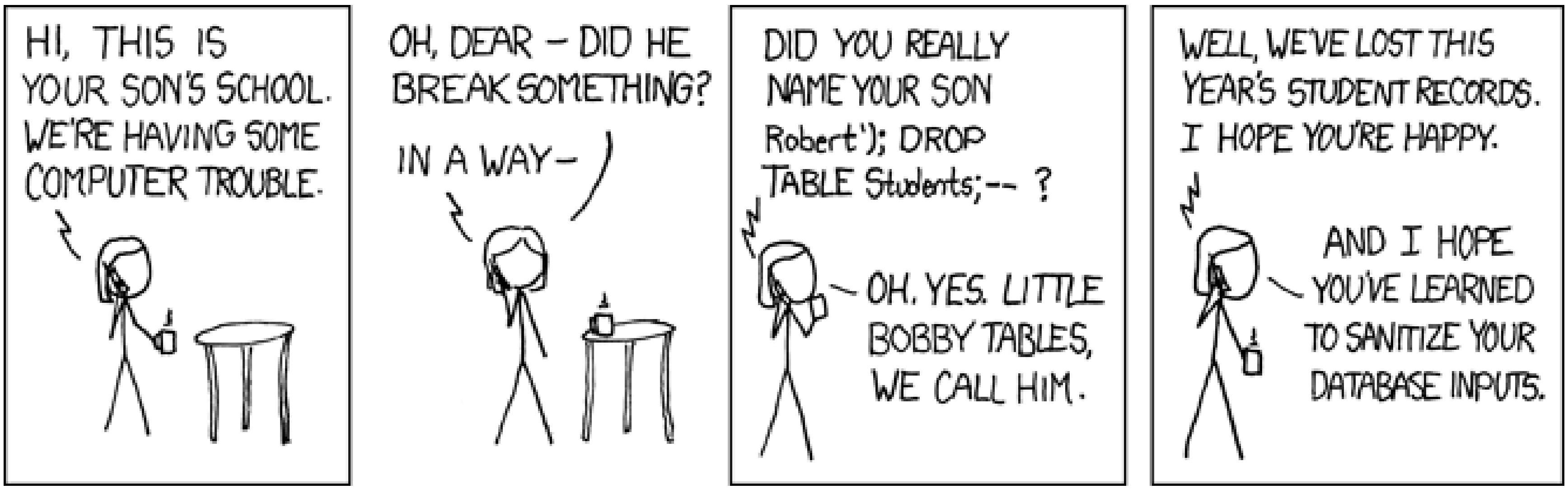
Did You Notice?

- I wrote **`sprintf`** instead of **`snprintf`**
- I was mostly trying to save room on a complex slide
- I was also curious to see who'd notice. . .

More Generally

- If you invoke an external program, be aware of its parsing rules
- Especially serious for languages like Shell, Perl, and Python, where data can be converted to statements and executed
- Example: what delimits different arguments to the shell?
- Blank, tab, newline? Why?

SQL Injection Attacks



(From `http://xkcd.com/327/`)

IFS

- The shell variable IFS lists the delimiters used when parsing command lines
- If you can change it, you can control the shell's parsing
- (The exact effects are subtle, because of the risks of just accepting it blindly—know your semantics!)

Other Sensitive Environment Variables

- **PATH** Search path for finding commands
  - If "**.**" is first,, you'll execute a command in the current directory. What if it's booby-trapped?
  - Secure programs should always use absolute paths or reset **PATH**
- **ENV** With some shells, a file to execute on startup
- **LD_LIBRARY_PATH** The search path for shared libraries
- **LD_PRELOAD** Extra modules loaded at runtime

Some of these are disabled for setUID programs, to minimize the risks

Search Paths

- What directories do programs come from? Components of programs?
- (Important for correctness as well as security—complex issue for Multics, in the 1960s.)
- Choices: program specification, user specification, system directories, current directory, location of base program, location of data file, probably more

File Descriptors

- Normally, file descriptor 0 is stdin, 1 is stdout, and 2 is stderr
- The **`open()`** system call allocates the first available file descriptor, starting from 0
- Suppose you close fd 1, then invoke a setUID program that will open some sensitive file for output
- Anything it prints to stdout will overwrite that file
- Similar tricks for fd 0

Some Other Inherited Attributes

current directory	
root directory	*see* ***chroot()***
resource limits	*see* ***getrlimit()***
umask	
timers	*see* ***getitimer()***
signal mask	
open files	*See the FIOCLEX option to* ***ioctl***
Current uid	
Effective uid	

Process Creation on Windows

- The `CreateProcess` call creates processes on Windows
- Executing a new program is part of the process creation mechanism
- 10 parameters control the program to be executed, window creation, priority, security attributes, file inheritance, and much more
- The Windows call does more for you, but is it simpler?
- Do programmers have a better understanding of what is inherited, and the implications of those things?

Why Do These Matter?

- Will such a program misbehave?
- Will it core dump after having read a sensitive file? (Some systems prevent core dumps of setUID programs.)
- If the program terminates prematurely, will it leave some crucial resource locked?

Access Control

- Some privileged programs need to read or write user-specified files
- Example: local mailer, as we saw last week
- Other examples: web server (remote), lpr (setUID)
- Very tricky. . .

Remote Access Control

- Don’t want to offer all system files to, say, web users
- Operating system doens’t help—too many files are world-readable
- Web server must implement its own access control
- Several different levels

Filename Parsing

- User supplies pathname; application must check for validity
- Administrator specifies list of accessible files and/or directories
- Sometimes, wildcards—*, ?, and more—are permitted
- Application must *parse* supplied filename
- Remarkably difficult

The “..” Problem

- Attackers try to get at other files
- Simplest attack: put `..` in the path
- `http://example.com/../../../../etc/passwd`
- The `..` can occur later:
- `http://example.com/a/b/../../../../etc/passwd`
- If directory **`/dir`** is legal, what about **`/dir/../dir/file`**? Do you want to count levels?
- Watch out for **`/dir///../../file`**—replicated `/`'s counts as a single one
- Note that **`/foo..bar/bletch`** is legal

Application Syntax Issues

- Applications can have their own weird syntax
- Example: in URLs, %xx can specify two hex digits for the character. **`%2F`** is the same as **`/`**
- When is that expanded?
- How is **`/foo%2F..%2Fetc/passwd`** processed?

Unicode

- Standard for representing (virtually) all of the world's scripts
  - ☞ There are proposals for Klingon and Tengwar ("Elvish") codepoints
- *Many* problems!
- Some symbols look the same, but have different values: ordinary /—technically called "solidus"—is U+002F, but U+2044, "fraction slash", looks the same
- "Combining characters" and "grapheme joiners" make life even more complicated. Thus, **á** can be U+00C1 or the two-character sequence U+0041,U+0301
- Comparison rules have to be application-dependent—and watch out for false visual equivalences; these have already been used for attacks, especially with Cyrillic domain names

Cyrillic Homograph Attack on "Paypal"

Glyph	Unicode value in Cyrillic
P	U+0420
a	U+0430
y	U+0443
p	U+0440
a	U+0430
l	U+006C (ASCII)

Operating Systems Don't Have Such Problems

- Conceptually, you're trying to permit certain subtrees.
- The application is trying to map a string into a subtree
- The OS has one mapping function; the application has another
- The OS doesn't care about the tree structure for access control; it uses its own mechanisms
- The OS stores permissions with the data; no separate parse is needed

File Access by SetUID Programs

- Some commands—**`lpr`**, for example—need to write to restricted places, but also read users' files
- Need permissions to write to spool directory; need user permissions to read users' files
- How can this be done?

First Attempt: Access() System Call

```
if (access(file, R_OK) == 0) {
    fd = open(file, O_RDONLY);
    ret = read(fd, buf, sizeof buf);
    ....
}
else {
    perror(file);
    return -1;
}
```

What's wrong?

Several Problems

- Only useful if setUID root – other UIDs can't open read-protected files.
- (I didn't check the return code on the `open()` call. . .)
- Race conditions
- Generic name: TOCTTOU (Time of Check to Time of Use)

Race Conditions

- There is a window between the **`access()`** call and the **`open()`** call
- The attack program can create a link to a readable file, invoke **`lpr`** in the background, then remove the link and replace it with a link to a protected file
- The probability of success is low but not zero—and the attacker only has to win once

Temporary Files

- The same attack can happen on files in **`/tmp`**
- The standard C library subroutine **`mktemp()`** is vulnerable to this
- Alternatives: **`mkstemp()`** or **`mktemp()`** with the **`O_CREAT | O_EXCL`** flags to **`open()`**
- Caution: if **`open()`** is used that way, generate a new template if EEXIST is returned

Shedding SetUID

- A setUID program can give up and then regain its setUID status:

```
save_uid = geteuid();
seteuid(getuid());
fd = open(file, O_RDONLY);
seteuid(save_uid);
```

- Better alternative: run unprivileged most of the time, but assume setUID status only when doing privileged operations

☞ But—watch for SIGINT, buffer overflows; injected code can reassume privileges, too

Lock Directories

- Have a parent directory that's mode 700, and a 777 subdirectory
- While privileged, do a **`chdir()`** to the subdirectory
- Give up privileges; write files in this subdirectory

Use a Subprocess

- Fork, and have a non-privileged subprocess open the user's files
- Option 1: copy the file contents to the parent process over a pipe—safe but slow
- Option 2: send the *file descriptor* via **`sendmsg()`**/**`recvmsg()`** over a Unix-domain socket

Issues with Message-Passing Systems

- File-opening permissions
- Authentication
- Other issues?

Opening Files

- How does the server open a private file? Two ways. . .
- The client opens the file and passes the open file descriptor
- The client sends some sort of access right—a *capability*—to the server

☞ Note: a file descriptor is a form of capability, but can't be used over a network

Authentication

- Who is allowed to send messages to the server?
- How does the server know the client's identity?
- Two solutions: support from the OS or cryptographic authentication

☞ Think System V Shared Memory

☞ Cryptographic authentication works over a network

Other Issues?

- The buggy code problem doesn't go away
- It's very similar to the network security problem; it hasn't been solved, either

The Fundamental Problem

- The real issue: interaction
- To be secure, a program must minimize interactions with the outside
- All interactions must be controlled

RASQ

- RASQ: Relative Attack Surface Quotient
- Microsoft metric of how vulnerable an application is
- Roughly speaking, it measures how many input channels it has
- Must reduce RASQ

Not All Channels Are Equal

- Some channels are easier to exploit
- Some are more accessible to attackers
- Some have a bad track record

RASQ Examples

- Weak ACLs on shared files: .9—names are generally known; easy to attack remotely
- Weak ACLs on local files: .2—only useful to attacker after initial compromise
- Open sockets: 1.0—potential target

Generic Defenses

- Better OS
- What's a secure OS? *One that makes it easy to write security-sensitive programs*
- Most don't qualify. . .

Minimize Chances for Mistakes

- Eliminate unnecessary interactions
- Example: per-process or per-user **`/tmp`**
- Avoid error-prone primitives (i.e., minimize the chances of *comprehension* mistakes)
- Tight specification of input and environment—and check that it's all true