CSE 451: Operating Systems
Winter 2004

Module 23
Operating System Security

Ed Lazowska
lazowska@cs.washington.edu
Allen Center 570

Outline

- Overarching goal: safe sharing
- Authentication
- Authorization
- Reference Monitors
- Contemporary security problems

Safe sharing

- Protecting a single computer with one user is easy
  – Prevent everybody else from having access
  – Encrypt all data with a key only one person knows
- Sharing resources safely is hard
  – Preventing some people from reading private data (e.g., grades)
  – Prevent some people from using too many resources (e.g., disk space)
  – Prevent some people from interfering with other programs (e.g., inserting key strokes / modifying displays)

Why is security hard?

- Security slows things down
- Security gets in the way
- Security adds no value if there are no attacks
- Only the government used to pay for security
  – the Internet made us all potential victims
- Bugs R Us

Trusted Computing Base (TCB)

- Think carefully about what you are trusting with your information
  – if you type your password on a keyboard, you're trusting:
    - the keyboard manufacturer
    - your computer manufacturer
    - your operating system
    - the password library
    - the application that's checking the password
  – how about typing your credit card number to a web service?
    - how about giving your credit card to a waiter?
- TCB = set of components (hardware, software, wetware) that you trust your secrets with
- Public web kiosks should *not* be in your TCB
- Should your OS?
  – but what if it is promiscuous? (e.g., IE and active-X extensions)
- How about your compiler?
  – a great read: "Reflections on Trusting Trust"

Security techniques

- Authentication (who are you) – identifying users and programs
- Authorization (what are you allowed to do) – determining what access users and programs have to things
  – complete mediation: check every access to every protected object
- Auditing (what's been going on) – record what users and programs are doing for later analysis

Authentication

- How does a computer know who I am?
  - user name / password
    - how does it store the password?
    - how does it check the password?
    - how secure is a password?
  - public/private keys
  - one-time keys
  - biometrics
- What does the computer do with this information?
  - assign you an identifier
    - UNIX: 32 bit number stored in process structure
    - Windows NT: 27 byte number, stored in an *access token* in kernel

Aside on encryption

- Encryption: takes a key and data and creates ciphertext
  - $\{\text{Attack at dawn}\}_{\text{key=h8JkS!}}$ = 29vn&#9njs@a
- Decryption: takes ciphertext and a key and recovers data
  - $\{\text{29vn\&\#9njs@a}\}^{\text{key=h8JkS!}}$ = Attack at dawn
  - without key, can't convert data into ciphertext or vice-versa
- Hashing: takes data and creates a fixed-size fingerprint, or hash
  - H(Attack at Dawn) = 183870
  - H(attack at dawn) = 465348
  - can't determine data from hash or find two pieces of data with same hash

Storing passwords

- CTSS (1962): password file {user name, user identifier, password}

Bob, 14, “12.14.52”
David, 15, “allison”
Mary, 16, “!ofotc2n”

If a bad guy gets hold of the password file, you're in deep trouble!

- Unix (1974): encrypt passwords with passwords

$K=[0]_{\text{allison}}$

Bob: 14: S6Uu0cYDVdTAk
David: 15: J2ZI4ndBL6X.M
Mary: 16: VW2bqvTalBJKg

David's password, “allison,” is encrypted using itself as the key and stored in that form. Password can be checked by the system. No problem if someone steals the file – except for *dictionary attacks*

- Unix (1979): salted passwords

$K=[0]_{\text{allison392}}$

Bob: 14: T7Vs1dZEWeRcL: 45
David: 15: K3AJ5ocCM4ZM$: 392
Mary: 16: WX3crwUbmCKLf: 152

Encryption is computed after affixing a number to the password. Thwarts pre-computed dictionary attacks

Guessing passwords

- 26 letters used, 7 letters long
  - 8 billion passwords (33 bits)
  - Checking 100,000/second breaks in 22 hours
    - System should make checking passwords slow
- But most people's passwords are not random sequences of letters!
  - girlfriend's/boyfriend's/spouse's/dog's name
- Dictionary attacks have traditionally been incredibly easy

Making it harder

- Using symbols and numbers and longer passwords
  - 95 characters, 14 characters long
  - $10^{27 \text{ passwords}} =$ 91 bits
  - Checking 100,000/second breaks in 10^{14} years
- Require frequent changing of passwords
  - guards against loaning it out, writing it down, etc.

Do longer passwords work?

- People can't remember 14-character strings of random characters
- People write down difficult passwords
- People give out passwords to strangers
- Passwords can show up on disk
- If you are forced to change your password periodically, you probably choose an even dumber one
  - "feb04" "mar04" "apr04"
- How do we handle this in CSE?

Sniffing passwords

- Incredibly, until just a couple of years ago we all entered cleartext passwords on the network!
  - including wireless LANs, where packet sniffing is duck soup!

Authorization

- How does the system know what I'm allowed to do?
  - logically, an authorization matrix:
    - objects = things that can be accessed
    - subjects/principals = things that can do the accessing (users or programs)

	Alice	Bob	Carl
/etc	Read	Read	Read Write
/homes	Read Write	Read Write	Read Write
/usr	None	None	Read

- Actual implementation is either
  - Access Control Lists (ACLs)
  - capabilities

  (discussed back when we did file systems)
- Most systems use both, in different circumstances

Protection domain concept

- A protection domain is the set of objects and permissions on those objects that executing code may access
  - e.g. a process
    - memory
    - files
    - sockets
  - also: a device driver, a user, a single procedure
- Capabilities:
  - protection domain defined by what is in the capability list
- ACLs
  - protection domain defined by the complete set of objects code could access

How does this get implemented?

- Originally:
  - every application had its own security checking code,
  - separate set of users
  - separate set of objects
  - separate kinds of ACLs, capabilities
- This makes the trusted computing base huge!!!
  - you have to trust all applications do to this correctly!
- Modern approach: a single reference monitor
  - manages identity
  - performs all access checks
  - small, well-tested piece of code

Modern security problems

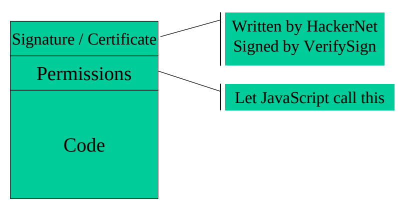
- Confinement
  - How do I run code that I don't trust?
    - e.g., RealPlayer, Flash
  - How do I restrict the data it can communicate?
  - What if trusted code has bugs?
    - e.g., Internet Explorer
- Concept of "Least Privilege"
  - programs should only run with the *minimal* amount of privilege necessary
- Solutions
  - Restricted contexts – let the user divide their identity
  - ActiveX – make code writer identify self
  - Java – use a virtual machine that intercepts all calls
  - Binary rewriting – modify the program to force it to be safe

Restricted contexts

- Add extra identity information to a process
  - e.g., both username and program name (mikesw:navigator)
- Use both identities for access checks
  - add extra security checks at system calls that use program name
  - add extra ACLs on objects that grant/deny access to the program
- Allows users to sub-class themselves for less-trusted programs

ActiveX

- All code comes with a public-key signature
- Code indicates what privileges it needs
- Web browser verifies certificate
- Once verified, code is completely trusted



Java

- All problems are solved by a layer of indirection
  - All code runs on a virtual machine
  - Virtual machine tracks security permissions
  - Allows fancier access control models - allows stack walking
- JVM doesn't work for other languages
- Virtual machines can be used with all languages
  - Run virtual machine for hardware
  - Inspect stack to determine *subject* for access checks

Binary rewriting

- Goal: enforce code safety by *embedding* checks in the code
- Solution:
  - Compute a mask of accessible addresses
  - Replace system calls with calls to special code

Original Code:

```
lw   $a0, 14($s4)
jal  ($s5)
move $a0, $v0
jal $printf
```

Rewritten Code:

```
and $t6,$s4,0x001fff0
lw   $a0, 14($t6)
and  $t6,$s5, 0x001fff0
jal  ($t6)
move $a0, $v0
jal $sfi_printf
```