CSE 451: Operating Systems
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Module 22
Operating System Security

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

Outline

- Overarching goal: safe sharing
- Trusted Computing Base (TCB)
- General principles
- 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

Principle of Least Privilege

- Figure out exactly which capabilities a program needs to run, and grant it only those
  - not always easy, but: start out granting none, run program, and see where it breaks. add new privileges as needed.
- Unix: concept of root is not a good example of this
  - some programs need to run as root just to get a small privilege, such as running with a port < 1024
    - e.g., ftpd

Principle of Complete Mediation

- Check **every** access to **every** object
  - in rare cases, can get away with less (caching)
    - but only if sure nothing relevant in environment has changed…and there is a lot that's relevant!
- e.g., NFS and file handles
  - NFS is not a good example of complete mediation
  - NFS protocol:
    - client contacts remote "mountd" to get a filehandle to a remotely exported NFS filesystem
      - this is done when remote system is mounted
      - remote mountd checks access control at mount time
    - filehandle is a capability: client presents it to read/write file
      - access control is not checked after mount time!
    - use network sniffer to get filehandle
      - access exported filesystem without access control check

Principle of Fail-Safe Defaults

- Start by denying all access, then allow only that which has been explicitly permitted
  - oversights will then show up as "false negatives"
    - somebody is denied access that should be given it
  - opposite leads to "false positives"
    - somebody is given access that shouldn't get it
    - bad guys usually don't report this kind of failure…
- Examples:
  - Irix shipped with "xhost +" by default
    - Allows the world to open windows on your screen and grab the keystrokes you type

"Security through Obscurity" = bad

- Security through obscurity
  - attempting to gain security by hiding the implementation details of a system
  - claim: a secure system should be secure even if all implementation details are published
    - in fact, a system grows more secure as people scour over implementation details and find flaws
    - rely on mathematics and sound design to keep secure
- Counterexample: GSM cell phones
  - GSM committee designed their own crypto algorithm, but hid it from the world - "impossible to clone"
    - social engineering + reverse engineering revealed the algorithm
    - it turned out to be very weak
      - could essentially play questions with identity chip on cell phone, and eventually learn its secret key in a few hours

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? (IE and Active-X extensions)
  - ow about your compiler?
    - a great read: "Reflections on Trusting Trust"

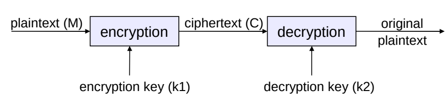
Security techniques

- 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: $E_{k1}(M) = C$
- Decryption: takes ciphertext and a key and recovers data: $D_{k2}(C) = M$
- Symmetric algorithms (aka secret-key algorithms):
  - k1 = k2 (or can get k2 from k1)
- Public-Key Algorithms
  - decryption key (k2) cannot be calculated from encryption key (k1)
  - encryption key can be made public!
    - encryption key = "public key", decryption key = "private key"
- 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

$K=[0]_{allison}$

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

$K=[0]_{allison392}$

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} 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?

Cool password attack

- VMS password checking flaw
  - password checking algorithm:

```
for (I=0; I<password.length( ); I++) {
    if password[I] == supplied_password[I]
        return false;
}
return true;
```

  - can you see the problem?
    - hint: think about virtual memory…
    - another hint: think about page faults…
    - final hint: who controls where in memory supplied_password lives?

Login spoofers

- Login spoofers are a specialized class of Trojan horses
  - Can be circumvented by requiring an operation that unprivileged programs cannot perform
  - E.g. start login sequence with a key combination user programs cannot catch, CTRL+ALT+DEL on Windows

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

Modern security problems

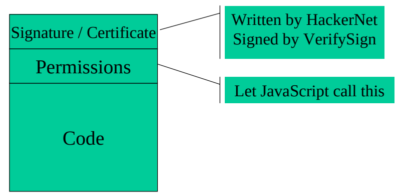
- Confinement
  - How do I run code that I don't trust?
    - e.g., RealPlayer, Flash
  - How do I restrict the data it can communicate?
  - What if trusted code has bugs?
    - e.g., Internet Explorer
- Concept of "Least Privilege"
  - programs should only run with the *minimal* amount of privilege 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
```


Attacks: Trojan Horses

- A malicious program disguised as an innocent one
- Login spoofers are a specialized class of Trojan horses
  - Can be circumvented by requiring an operation that unprivileged programs cannot perform
  - E.g. Start login sequence with a key combination user programs cannot catch, CTRL+ALT+DEL on Windows

Attacks: Viruses and Worms

- Viruses: passive code attached to other programs
  - E.g. a program that modifies MS Word
- Worms: code that actively replicates itself and does not depend on the execution of another program to spread
  - E.g. the Internet worm
- Buffer overflow
  - C string libraries hard to use correctly
    - e.g. easy to write outside string bounds
  - Most OS code is written in C, many systems have vulnerabilities
  - If a string is stored on the stack, someone can modify the behavior of a program by going off the end of the string and changing a return address stored on stack

Attacks: Denial of service

- Attacker sends legitimate-looking requests for service to a service provider
- Service provider commits the necessary resources to provide the service
  - Ports, buffer space, bandwidth
- The resources are wasted, legitimate users get diminished service
  - Usually launched from many computers controlled by attackers
- Possible whenever the cost to ask for service is far cheaper than the cost of providing it
  - Challenge-response mechanism