Computer Security

04r. Pre-exam 1 Concept Review

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Key ideas from the past four lectures

Computer security

- What computer security addresses:
  - **Confidentiality**
    - Allow only authorized users to access data & resources
    - Privacy: limit what information will be shared with others
    - Privacy is a reason for confidentiality
  - **Integrity**: trustworthiness of data & resources
    - Data integrity: data hasn't been corrupted
    - Origin integrity/destination integrity: validate who is sending and who is receiving
    - System integrity: system works properly and has not been subverted
  - **Availability**
    - The system is available for use and performs properly

No easy answers

- Security is hard
  - Software is incredibly complex
  - Systems are complex: cloud + local; 3rd party components; multiple admins
- If it was easy, we wouldn't have massive security breaches year after year
  - No magic solutions

Security goals

- Prevention: prevent attackers from violating security policy
  - Implement mechanisms that users cannot override
  - *Example: ask for a password*
- Detection: detect & report attacks
  - Important when prevention fails
  - Indicates & identifies weaknesses with prevention
  - Also: detect attacks even if prevention is successful
- Recovery: stop the attack, repair damage
  - … Or continue to function correctly even if attack succeeds
  - Forensics: identify what happened so you can fix it
  - *Example: restoration from backups*

Policies & Mechanisms

Policy: description of what is or is not allowed
- E.g., users must have a password

Mechanisms: implement and enforce policies
- E.g., password entry & authentication

Definitions

- Vulnerability
  - A weakness in the implementation or operation of a system
  - Bugs, bad configuration, lack of access controls
- Attack
  - A means of exploiting a vulnerability
  - E.g., buffer overflow, social engineering
- Threat
  - An adversary that is capable of attacking
- Trusted Computing Base (TCB)
  - All hardware & software of a computing system critical to its security
    - Example: operating system & system software
    - If the TCB is compromised, you have no assurance that any aspect of the system is secure

Threat categories

- Disclosure: Unauthorized access to data
  - *Snooping (wiretapping)*
- Deception: Acceptance of false data
  - *Injection of data, modification of data, denial of receipt*
- Disruption: Interruption or prevention of correct operation
  - *Modification of the system, denial of service, delays*
- Usurpation: Unauthorized control of some part of a system
  - *Modification, spoofing an identity, escalation of privileges*

Access Control

Protection & Access Control

Protection

- The mechanism that provides and enforces controlled access of resources to processes
- A protection mechanism *enforces* security policies

Access control

- Ensure that authorized users can do what they are permitted to do … *and no more*

The Operating System

- Protect the OS from applications
- Make sure it stays in control
- Basic OS mechanisms
  - Hardware timer – periodically gives control to the OS
  - Scheduler – decides which process gets to run
  - Memory Management Unit (MMU) – provides private memory spaces and memory protection (read/write/execute access)
  - User & kernel mode execution – only the kernel can access privileged instructions

Access control: subjects & objects

- Subject: the thing that needs to access resources
  - Often the user
- Object: the resource the subject may access
- Access control: defines how subjects may access objects

Unix (POSIX) access control

- Each object (file, device) has
  - One owner and one group
  - Read, write, and/or execute permissions for the owner, group, and other (everyone else)
- Each subject (user) has
  - One user ID
  - Membership in one or more groups
- For directories
  - Execute permission = search permission
  - Write access = you can create/delete files or directories within that directory

POSIX file operations

- chmod: set file permissions
- chown: change file ownership of a file
- chgrp: change group ownership of a file
- Programs run with the permissions of the user who runs the program
- setuid: permission bit that causes an executable file to run with the ID of the file owner, not the user who is executing the file
  - WARNING! Many set UID programs run as root (administrator) and are attractive targets. If you can take control of that program then you get administrative privileges

Principle of least privilege

- Principle of least privilege
  - At each abstraction layer, every element (user, process, function) should be able to access ***only*** the resources necessary to perform its task
- Privilege separation
  - Divide a program into multiple parts: high & low privilege components

Access control matrix

- Table defining what a subject (user) can do to an object (file)
- Access control lists: store permissions with an object
- Capability lists: store permissions with a subject

objects — *domains of protection (subjects)*

	F_0	F_1	Printer
D_0	read	read-write	print
D_1	read-write-execute	read	
D_2	read-execute		
D_3		read	print
D_4			print

Access control list

objects

	F_0	F_1	Printer
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Capability list

DAC vs. MAC

- DAC = Discretionary Access Control
  - Users get to set access permissions
- MAC = Mandatory Access Control
  - Administrators set access permissions that users cannot overwrite

Multi-Level Security Models

- The **Bell-LaPadula** model is all about confidentiality
  - Simple security property:
    - You cannot read data from higher clearance levels than you are
  - Star *-property:
    - You cannot create data that is a lower clearance level than you are
  - Discretionary security property
    - Users can control access with ACLs only *after* MAC is enforced
- The **Biba** model is similar but is all about integrity
  - Simple integrity property:
    - You cannot read an object from a lower integrity level than you are
    - *Example: A process will not read a system configuration file created by a lower-integrity-level process*
  - Star *-property:
    - You cannot write to an object of a higher integrity level than you are
    - *Example: A web browser may not write a system configuration file*

Other MAC models

- **Type Enforcement (TE) Model**
  - An access control matrix that gets checked first
    - This is managed by an administrator
  - Subjects assigned to domains; objects assigned to types
  - Matrix defines domain-domain and domain-type transitions
- **Role-Based Access Control (RBAC) model**
  - Users are assigned roles (job functions)
  - Access permissions are granted to roles
  - Access rights have a *session*: you get them to do a task
  - Commonly used in database systems
    - Roles: *delete users, modify a user's pay, view users, …*

Multilateral Security

- In addition to levels, a level may have compartments
  - You can only access resources if you have been granted access to that compartment
  - E.g., {Top Secret, Elvis}
    - can access {Top Secret}, {Secret, Elvis}, {Secret}
    - Cannot access {Top Secret, UFO}, {Secret, UFO}
- Lattice model
  - Implements multilevel security with labels per level
  - Directed graph that defines access rights among clearance levels and compartment labels

Chinese Wall Model

- Defines conflict classes: groups of competing companies
  - Designed for businesses where employees have to avoid conflict of interest
- Basic rule
  - A subject can access objects from a company as long as it never accessed objects from competing companies.

Program Hijacking

Stack-based buffer overflow

- Buffer limits not checked
  - Often because unsafe functions like strcpy, strcat, and sprintf are used
- Overflow overwrites frame pointer & stack pointer
- If the stack pointer is changed, the return address is changed
  - Write code into the buffer
  - Overflow the buffer to set the return address
  - When the function returns, it branches to the new code

Off-by-one Buffer Overflows

An off-by-one stack overflow can only modify one byte of the top of the stack, which holds the frame pointer

- When a function returns, the modified frame pointer becomes the reference point for all local variables
- It also becomes the new stack pointer when a new function is called
- (see homework assignment)

Heap & text segment overflows

- A buffer overflow can overwrite adjacent variables that are allocated in higher memory
  - The program will use these modified variables

Printf format attacks

If an attacker can change the printf format string

- Read the stack
  - Read any address on the stack (using %x, for example)
  - If you don't supply arguments, printf will match %x with the next item on the stack
- Modify memory
  - Use "%x" to set where we write in memory: each %x skips one word on the stack
  - Use "%.Nx" to generate N bytes of output – this allows you to set the value you will write
  - Use %n to write the value – it prints the # of bytes output so far

Defenses

- Data Execute Protection (DEP)
  - Operating system turns off execute permission for stack and heap memory
  - Attacks:
    - *return-to-libc*: overflow a return address to a desired point in the C library
    - *Return-Oriented-Programming (ROP):* overflow a stack of return addresses to various points in libraries or the program – the return from one function takes you to the next entry point
- Address Space Layout Randomization (ASLR)
  - Load programs and libraries into different memory locations so addresses are different each time
- Stack Canaries
  - Compiler places a random # on the top of the stack and checks it before returning from a function

SQL Injection Attacks

- If user input becomes part of a SQL query, it can change the type of query – or add additional commands

```
SELECT * from logininfo WHERE username = paul AND password = 'abcde'

SELECT * from logininfo WHERE username = paul AND password = '' OR 1=1 -- ;'
```

- Validate all input!
- Safest prevention = use parameterized queries – don't make user input part of the command

Shell injection attacks

- Use of *system()* and *popen()* in programs
  - These invoke the shell. Same risk as SQL injection if user input is part of the command
- PATH variable: change the order in which the shell looks for programs
- LD_PRELOAD: preload libraries, possibly overriding functions that the program uses with your own
- LD_LIBRARY_PATH: similar attack – tell the OS where to look for libraries

App-level name parsing

- Parsing pathnames to make sure a user-supplied name stays within a subdirectory can be trickly
  - **http://poopybrain.com/../../../etc/passwd**
- Escaped Unicode characters make it harder
  - Single-byte characters have multi-byte equivalents: "/" = 0x2f = 0xc0af

TOCTTOU Attack

- Time Of Check To Time Of Use
  - If you check the condition and then do something, you may introduce a race condition
  - An attacker may change something after you check the condition but before you do the operation
    - Example: change a link to a user-readable file to a privileged file

App confinement

- chroot: change root directory for a process & its children
  - If an attacker becomes root, he may be able to escape by creating a device file that gives access to the disk or to memory
- FreeBSD Jails
  - Same namespace protection like chroot
  - But you can take power away from root for processes in the jail
    - No ability to create devices, raw sockets, mounting filesystems
  - Way more secure

App confinement

- Linux namespaces
  - Provide a private namespace for directory structure, network, process ID, user/group IDs, IPC, hostname
- Linux capabilities
  - Selectively take away power if a process becomes root.
  - Disallow file owner changes, permission changes, sending signals, creating raw sockets, changing root, etc.
- Linux control groups
  - Limit how much resources a process can use (CPU, memory, files, network)

The end

