Computer Security
04r. Pre-exam 1 Concept Review

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Spring 2018
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 enforce 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
  – An owner and a 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
- **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 have 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

- Access control lists vs. capability lists

Access control list

<table>
<thead>
<tr>
<th>domains of protection (subjects)</th>
<th>objects</th>
<th></th>
<th>objects</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>F₀</td>
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<td>Printer</td>
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<td>D₀</td>
<td>read</td>
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Capability list

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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**
  – Another access control matrix that gets checked first
  – 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
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
  – 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

- **IFS** – internal field separator: change the definition of how the shell parses arguments (it doesn’t have to be whitespace)

- 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

• Homograph Attacks
  – Not an injection attack but a social engineering one – confuses users
  – Similar characters may be represented in different languages or different symbols in Unicode: you can often write the same text using different characters
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
• The more a program interacts with its environment (users, files, networks), the more opportunities there are for attack

• **Relative Attack Surface Quotient**
  – A metric Microsoft created to estimate how vulnerable a system might be
  – Each type of attack gets a “bias” – a risk assessment
  – Roughly, sum up all possible interactions with each interaction multiplied by its bias
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