

# Computer Security

## 02. Access Control

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## Protection is essential to security

### Protection

- The **mechanism** that provides and enforces controlled access of resources to processes (=users=subjects)
- A protection mechanism **enforces** security policies

Includes:

- User accounts & user authentication
- User privileges: access rights
  - File protection
- Resource scheduling & allocation
  - Thread priorities, memory pages
- Quotas (sometimes)

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## Co-located resources

- **Earliest computers**
  - Single-user batch processing – no shared resources
  - No need for access control – access control was physical
- **Later ... shared storage & timesharing systems**
  - Multiple users share the same computer
  - User accounts & access control important
- **Even later ... PCs**
  - Back to single-user systems
  - ... but software is less trusted
- **Now: networked PCs + mobile devices + IoT devices + ...**
  - Shared access: cloud computing, file servers, university systems
  - Program isolation on servers
  - Need to enforce **access control**

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## Access control

- Ensure that authorized users can do what they are permitted to do ... **and no more**
- **Real world**
  - Keys, badges, guards, policies
- **Computer world**
  - Hardware
  - Operating systems
  - Web servers, databases & other multi-access software
  - Policies

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## OS controls access to resources

- CPU
- Memory
- Files & devices
- Network

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## Fundamental Mechanisms

- Protect the operating system from applications
- Protect applications from each other
- Allow the OS to stay in control

The OS and hardware are the fundamental parts of the Trusted Computing Base (TCB)

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### Hardware timer

- OS kernel requests timer interrupts
  - One of several timer devices:
    - Programmable Interval Timer (PIT)
    - HPET (High Precision Event Timer)
    - or APIC timer (one per CPU)
  - Most current Intel Linux systems use APIC
- Applications cannot disable this
  - Ensures that the OS can always regain control

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### Processes

Timer interrupts ensure OS can examine processes while they are running

#### OS Process Scheduler

- Decides whether a process had enough CPU time and it is time for another process to run
- Avoid **starvation**: ensure all processes will get a chance to run
  - This would be an **availability** attack
- Prioritize threads
  - Based on user, user-defined priorities, interactivity, deadlines, "fairness"
  - One process should not adversely affect others

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### Memory Management Unit

All modern CPUs have a **Memory Management Unit (MMU)**

- OS provides each process with **virtual memory**
  - Gives each process the illusion that it has the entire address space
  - One process cannot see another process' address space
  - Enforce access rights
    - Read-only
    - Read-write
    - Execute

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### Page translation

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### Logical vs. physical views of memory

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### User & kernel mode

**Kernel mode** = privileged, system, or supervisor mode

- Access restricted regions of memory
- Modify the memory management unit (page tables)
- Set timers
- Define interrupt vectors
- Halt the processor
- Etc.

- Getting into kernel mode
  - Trap: explicit instruction
    - Intel architecture: *INT* instruction (interrupt)
    - ARM architecture: *SWI* instruction (software interrupt)
  - Violation
  - Hardware interrupt (e.g., receipt of network data or timer)

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### Protection Rings

- All modern operating systems support two modes of operation: **user & kernel**
- Multics** defined a ring structure with 6 different privilege levels
  - Each ring is protected from higher numbered rings
  - Special call (**call gates**) to cross rings: jump to predefined locations
  - Most of OS did not run in ring 0
- Intel x86, IA-32, and IA-64 support 4 rings
- Today's OSEs only use
  - Ring 0: kernel
  - Ring 3: user

Note: hypervisors (**virtual machine monitors**) run at a 3<sup>rd</sup> privilege level

- In many systems, this is **ring -1** for the hypervisor, 0 for the kernel and 3 for user programs

[https://en.wikipedia.org/wiki/Protection\\_ring](https://en.wikipedia.org/wiki/Protection_ring)

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### Subjects and Objects

- Subject:** the thing that needs to access resources
  - Typically the user, also called the **principal**
- Object:** the resource the subject may access
  - Typically the file
- Access control**
  - Define what operations subjects can perform on objects

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### User authentication

Must be done before we can do access control

- Establish user identity – determine the **subject**
  - Operating system privileges are granted based on user identity

Steps

- Get user credentials (e.g., name, password)
- Authenticate user by validating the credentials
- Access control: grant further access based on user ID

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### Domains of Protection

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### Domains of protection

- Subjects** (users, processes) interact with **objects**
  - Objects include:
    - hardware (CPU, memory, I/O devices)
    - software: files, processes, semaphores, messages, signals
- A process should be allowed to access only objects that it is authorized to access
  - A process operates in a **protection domain**
  - Protection domain defines the objects the process may access and how it may access them

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### Modeling Protection: Access Control Matrix

Rows: domains (subjects or groups of subjects)

Columns: objects

Each entry represents an access right of a domain on an object

		Objects		
		F <sub>0</sub>	F <sub>1</sub>	Printer
Subjects domains of protection	D <sub>0</sub>	read	read-write	print
	D <sub>1</sub>	read-write-execute	read	
	D <sub>2</sub>	read-execute		
	D <sub>3</sub>		read	print
	D <sub>4</sub>			print

An Access Control Matrix is the primary abstraction for protection in computer security

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### We may need some more controls

- Domain transfers**
  - Allow a process to run under another domain's permissions
  - Why?
    - Log a user in – how would you run the first user's process?
- Copy rights**
  - Allow a user to grant certain access rights for an object
- Owner rights**
  - Identify a subject as the owner of an object
  - Can change access rights on that object for any domain
- Domain control**
  - A process running in one domain can change any access rights for another domain

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### Access Control Matrix: Domain Transfers

Switching from one domain to another is a configurable policy

		objects							
		F <sub>0</sub>	F <sub>1</sub>	Printer	D <sub>0</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>
Subjects domains of protection	D <sub>0</sub>	read	read-write	print	-	switch	switch		
	D <sub>1</sub>	read-write-execute	read			-			
	D <sub>2</sub>	read-execute				switch	-		
	D <sub>3</sub>		read	print					
	D <sub>4</sub>			print					

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### Access Control Matrix: Delegation of Access

**Copy:** allow delegation of rights

- Copy a specific access right on an object from one domain to another
  - Rights may specify either a copy or a transfer of rights

		objects							
		F <sub>0</sub>	F <sub>1</sub>	Printer	D <sub>0</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>
Subjects domains of protection	D <sub>0</sub>	read	read-write	print	-	switch	sw		
	D <sub>1</sub>	read-write-execute	read*						
	D <sub>2</sub>	read-execute				switch	-		
	D <sub>3</sub>		read	print					
	D <sub>4</sub>			print					

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### Access Matrix: Object Owner

**Owner:** allow new rights to be added or removed

- An object may be identified as being *owned* by the domain
- Owner can add and remove any right in any column of the object

		objects							
		F <sub>0</sub>	F <sub>1</sub>	Printer	D <sub>0</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>
Subjects domains of protection	D <sub>0</sub>	read <b>owner</b>	read-write	print	-	switch	sw		
	D <sub>1</sub>	read-write-execute	read*						
	D <sub>2</sub>	read-execute				switch			
	D <sub>3</sub>		read	print					
	D <sub>4</sub>			print					

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### Access Control Matrix: Domain Control

**Control:** change entries in a row

- process executing in Domain *i* can change access rights for any object in Domain *j*

		objects							
		F <sub>0</sub>	F <sub>1</sub>	Printer	D <sub>0</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>
Subjects domains of protection	D <sub>0</sub>	read <b>owner</b>	read-write	print	-	switch	switch		
	D <sub>1</sub>	read-write-execute	read*			-			control
	D <sub>2</sub>	read-execute				switch	-		
	D <sub>3</sub>		read	print					
	D <sub>4</sub>			print					

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### This gets messy!

- An access control matrix does not address everything we may want
- Processes execute with the rights of the user (domain)
  - But sometimes they need extra privileges
    - Read configuration files
    - Read/write from/to a restricted device
    - Append to a queue
- We don't want the user to be able to access these objects
  - So we need a 3-D access control matrix: (subjects, objects, processes)
- This gets messy!
  - One solution is to give an executable file a temporary domain transfer
    - Assumption is this is a trusted application that can access these resources
  - When run, it assumes the privileges of another domain

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### Implementing an access matrix

A single table to store an access matrix is impractical

- Big size: # domains (users) × # objects (files)
- Objects may come and go frequently
- Lookup needs to be efficient

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### Implementing an access matrix

#### Access Control List

– Associate a column of the table with each object

		objects					
		F <sub>0</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	F <sub>3</sub>	Printer
Subjects domains of protection	D <sub>0</sub>	read owner	read- write	read- execute	read		print
	D <sub>1</sub>	read-write- execute	read	read- execute	read	write	
	D <sub>2</sub>	read- execute		read- execute		write	
	D <sub>3</sub>		read	read- execute			print
	D <sub>4</sub>			read- execute		write	print

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### Example: Limited ACLs in POSIX systems

**Problem:** an ACL takes up a varying amount of space

- Won't fit in a fixed-size inode

**UNIX Compromise:**

- A file defines access rights for three domains:
  - the **owner**, the **group**, and **everyone else**
- Permissions
  - Read, write, execute, directory search
  - Set user ID on execution
  - Set group ID on execution
- Default permissions set by the *umask* system call
- *chown* system call changes the object's owner
- *chgrp* system call changes the object's owner
- *chmod* system call changes the object's permissions

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### Example: Full ACLs in POSIX systems

*What if we really want a full ACL?*

- **Extended attributes:** stored outside of the inode
  - Hold an ACL
  - And other name:value attributes
- Enumerated list of permissions on users and groups
  - Operations on all objects:
    - *delete, readattr, writeattr, readextattr, writeextattr, readsecurity, writesecurity, chown*
  - Operations on directories
    - *list, search, add\_file, add\_subdirectory, delete\_child*
  - Operations on files
    - *read, write, append, execute*
  - Inheritance controls

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### Implementing an access matrix

#### Capability List

– Associate a row of the table with each domain

		objects					
		F <sub>0</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	F <sub>3</sub>	Printer
Subjects domains of protection	D <sub>0</sub>	read owner	read- write	read- execute	read		print
	D <sub>1</sub>	read-write- execute	read	read- execute	read	write	
	D <sub>2</sub>	read- execute		read- execute		write	
	D <sub>3</sub>		read	read- execute			print
	D <sub>4</sub>			read- execute			

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### Capability Lists

- List of objects together with the operations allowed on the objects
- Each item in the list is a **capability**: the operations allowed on a specific object
  - Also called a **ticket** called or **access token**
- A process presents the capability along with a request
  - Possessing the capability means that access is allowed
- **The capability is a protected object**
  - A process cannot modify its capability list

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### Capability Lists

- Advantages
  - Run-time checking is more efficient
  - Delegating rights is easy
- Disadvantages
  - Changing a file's permissions is hard
  - Hard to find all users that have access to a resource
- Not used in mainstream systems in place of ACLs
  - Limited implementations: Cambridge CAP, IBMAS/400
- BUT
  - Used for single sign-on services and other authorization services such as Oauth and Kerberos (sort of)
  - Access Tokens – used in Microsoft systems, including Azure
    - Identifies user's identity & rights associated with user's accounts (not objects!)

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### POSIX file permissions

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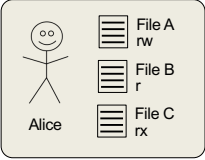
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### File permissions

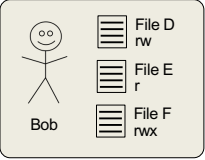
- Access isn't all or nothing
- Objects can have different access permissions

**UNIX permission model**

- Access permissions: read (r), write (w), execute (x)
  - All independently set
- Each file has an owner



Alice



Bob

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### How do you share files?

- Groups & everyone else (other)
- A user has one **user ID** but may belong to multiple groups
  - One current default group ID for new objects
  - Multiple groups
- Other = all others (users who are not the owner or group members)
- File access permissions are expressed as:
 

```

            rwxrwxrwx
            |  |  |
            user group other
            
```

```

            $ ls -l /bin/ls
            -rwxr-xr-x 1 root wheel 38624 Dec 10 04:04 /bin/ls
            
```

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### Permission checking

if you are the owner of the file  
*only* owner permissions apply

if you are part of a group the file belongs to  
*only* group permissions apply

else "other" permissions apply

I cannot read this file even if I'm in the *localaccounts* group:

```

    $ ls -l testfile
    ----rW---- 1 paul localaccounts 6 Jan 30 10:37 testfile
    
```

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### Execute permission

- Distinct from read
- You may have **execute-only** access
  - This takes away your right to copy the file ... or inspect it
  - But the OS can load it & run it

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### Windows

- Windows has users & groups but more permissions
  - Read, write, execute
  - Also: delete, change permission, change ownership
- Users & resources can be partitioned into groups & domains
  - Each domain can have its own administrator
    - HR can manage users
    - Individual departments can manage printers
- Trust can be inherited in one or both directions
  - Department resources domains may trust the user domain
  - User domain may not trust department resources domains

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### What about directories?

- Directories are just files that map names to inode numbers
- Permissions have special meaning
  - Write = permission to create a file in the directory
  - Read = permission to list the contents of a directory
  - Execute = permission to search through the directory
- If you have write access to the directory of a file, you can delete the file
  - Even if you don't have write access to the file itself
- If you don't have write access to the directory
  - You cannot create or delete a file ... even if you have write access to it

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### Where are user IDs and group IDs stored?

On Linux, user ID information in the password file, /etc/passwd (which does not contain passwords anymore!)

```
root:x:0:0:System Administrator:/root:/bin/sh
```

- User name
- (password)
- User ID
- Default group ID
- User's full name
- Home directory
- Login shell

Group IDs are stored /etc/group

- wheel:x:0:root
- certusers:x:29:root,\_jabber,\_postfix,\_cyrus,\_calendar,\_dovecot

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### Changing permissions

The **chmod** command

user = read, write, execute  
group = read, execute  
other = -none-

- Set permissions
 

```
$ chmod u=rwx,g=rx,o= testfile
```

```
$ ls -l testfile
```

```
-rwxr-x--- 1 paul localaccounts 6 Jan 30 10:37 testfile
```
- Add permissions
 

```
$ chmod go+w testfile
```

```
$ ls -l testfile
```

```
-rwxrwx-w- 1 paul localaccounts 6 Jan 30 10:37 testfile
```
- Remove permissions
 

```
$ chmod o-w testfile
```

```
$ ls -l testfile
```

```
-r-xrwx--- 1 paul localaccounts 6 Jan 30 10:37 testfile
```

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### Changing permissions

Or the old-fashioned way – specify an octal bitmask

- Set permissions
 

```
$ chmod 754 testfile
```

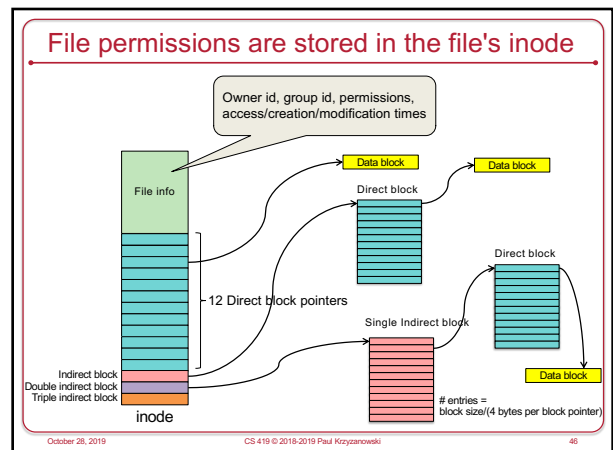
```
$ ls -l testfile
```

```
-rwxr-xr-- 1 paul localaccounts 6 Jan 30 10:37 testfile
```

7	5	4	
rwx	r-x	r--	
user	group	other	

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## Sometimes groups aren't enough

### Access Control Lists (ACL)

- Explicit list of permissions for users
- Supported by most operating systems
  - Windows ≥ XP
  - macOS ≥ 10.4
  - Linux ≥ ext3 file system + acl package

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## ACLs and ACEs

**Access Control List (ACL)** = list of **Access Control Entries (ACE)**

- ACE identifies a user or group & permissions
  - Files: read, write, execute, append
  - Directories:
    - list, search, read attributes, add file, add sub-directory, delete contents
- "Inheritance" permission
  - directory's file contents can inherit one set of ACLs
  - Directories inherit another set of ACLs
- Wildcards are often supported
- See `chmod` on macOS or `setfacl` on Linux

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## Example ACL

```
pxk.*    rwx
419-ta.* rwx
*.faculty rx
*.*      x
```

- Users `pxk` and `419-ta` have `read-write-execute` access
- Users in the faculty group have `read-execute` access
- Others only have `execute` access

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## Search order

ACEs are evaluated in the order they are entered into the ACL

In this case, I don't have write access to the file:

```
419-ta.*    rwx
*.faculty   rx ← This is me ← This appears first & has priority
pxk.*       rwx ← So is this
*.*         x ← So is this
```

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## Search order: ACLs + permissions

In systems like Linux that integrate ACLs with 9-bit permissions:

1. If you are the owner of the file, only owner permissions apply
2. If you are part of a group the file belongs to, only group permissions apply
3. Else search through the ACL entries to find an applicable entry
4. Else other permissions apply

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## Initial file permissions

On Unix-derived systems (Linux, macOS, Android, \*BSD):

- `umask` = set of permissions applications cannot set on files
  - Bitmask (octal) of bits that will be turned off
- To disallow read-write-execute for everyone but the owner
  - `umask = 000 111 111 = 077`
- Default `umask` on macOS & Ubuntu is `022`
  - `022 = 000 010 010 = --- -w- -w-`
  - This takes away `write` access from group & other
  - By default new files are readable by all and writable only by the owner

See the `umask` command and `umask` system call man pages

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### Watch out for race conditions!

- Suppose we create a file readable by all: `rwXr--r--`  
`rwX, r, r`
- But then we change the permissions to `rwX-----`  
`rwX, -, -`

<p><b>GOOD</b></p> <p>Create a file: <code>rwX-r--r-</code>                  Change permissions to <code>rwX-----</code>  <i>[Attacker opens the file for reading]</i>                  Do your work</p>	<p><b>BAD</b></p> <p>Create a file: <code>rwX-r--r-</code>  <i>[Attacker opens the file for reading]</i>                  Change permissions to <code>rwX-----</code>                  Do your work</p>
--	---

- We don't know when the attacker will hit
- Once the attacker has the file open, changing permissions does not take access away
  - Access rights are only checked when the file is opened!

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### Giving files away

- You can change the owner of a file  
`chown alice testfile`  
 - Changes the file's owner to alice
- You can change the group of a file too  
`chgrp accounting testfile`  
 - Changes the file's group to accounting

... but you have to be the owner to do either

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### Changing user & group IDs

- `root = uid 0 = super user`
  - Access to everything
- How do you log in?
  - login program runs as `uid=0`
  - Gets your credentials
  - Authenticates you
  - Then:
 

```
chdir(home_directory);
setgid(group_id);
setuid(user_id);
execve(user_shell, ...);
```

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### Changing user ID temporarily

- What if some files need special access?
  - A print program needs to access the printer queue
  - A database needs to access its underlying files
- An executable file normally runs under the user's ID
- A special permission bit, the "**setuid bit**" changes this
  - Executable files** with the setuid bit will run with the *effective UID* set to the owner of the file
  - Directories** with the setuid bit set will force all files and sub-directories created in them to be owned by the directory owner
- Same thing with groups – the **setgid** permission bit
  - Executable files with this bit set will run with effective gid set to the gid of the file.

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### 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

- Even if an element is compromised, the scope of damage is limited
- Consider:
  - Good:** You cannot kill another user's process
  - Good:** You cannot open the `/etc/hosts` file for writing
  - Good:** Private member functions & local variables in functions limit scope
  - Violation:** a compromised print daemon allows someone to add users
  - Violation:** a process can write a file even though there is no need to
  - Violation:** admin privileges set by default for any user account

Least privilege is often difficult to define & enforce

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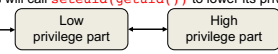
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### Privilege Separation

Divide a program into multiple parts: high & low privilege components

Example on POSIX systems

- Each process has a **real** and **effective** user ID
- Privileges are evaluated based on the effective user ID
  - Normally, `uid == euid`
- An executable file may be tagged with a **setuid bit**
  - `chmod +sx filename`
  - When run: `uid = user's ID`  
`euid = file owner's ID (without setuid, runs with user's ID)`
- Separating a program
  - Run a **setuid** program
  - Create a communication link to self (*pipe, socket, shared memory*)
  - `fork`
  - One of the processes will call `seteuid(getuid())` to lower its privilege

User interaction →  →

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### Setuid can get you into trouble!

- Most *setuid* programs ran as root
- If they were compromised, the whole system was compromised
- This was one of the best attack vectors for Unix/Solaris/Linux systems

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### Other Access Control Models

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### What's wrong with ACLs?

- Users are in control
  - `chmod o+rw secret.docx`
  - Now everyone can read and modify `secret.docx`
- Doesn't work well in environments where management needs to define access permissions
- No ability to give time-based or location-based permissions
- Access is associated with objects
  - **Hard to turn off access for a subject** - except by locking the user
  - Otherwise have to go through each object and remove user from the ACL
    - ... but you're still stuck with default access permissions and wondering how other users will set access rights in the future

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### Access Control Models: MAC vs. DAC

**DAC: Discretionary Access Control**

- A subject (domain) can pass information onto **any** other subject
- In some cases, access rights may be transferred e.g., `chown`
- *Users are in charge of access permissions*
- *Most systems use this*

**MAC: Mandatory Access Control**

- Policy is centrally controlled
- Users cannot override the policy
- *Administrators are in charge of access permissions*

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### MLS: Multi-Level Security Systems

Handle multiple levels of classified data in one system

**Bell-LaPadula Model**

- Designed for the military
- Based on U.S. military classification levels

Top Secret

Secret

Confidential

Unclassified

**Motivation:**  
Preserve confidentiality. If one program gets hacked, it will not be able to access data at higher levels of classification

If you have confidential clearance:

- You can **access** confidential & unclassified data
- You can **create** confidential, secret, and top-secret data

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### Bell-LaPadula Base OS Model

Designed to address security concerns in the Air Force

- **Reference Monitor**
  - Component of the OS that would manage access control decisions
- **Trusted Computing Base (TCB)**
  - Set of components whose correct functioning is sufficient to ensure the security policy is being enforced
  - If the TCB fails, the security policy could be breached

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### Bell-LaPadula (BLP) Access Model

- Objects are classified into a hierarchy of sensitivity levels
  - Unclassified, Confidential, Secret, Top Secret
- Each user is assigned a clearance
- “No read up; no write down”
  - Cannot read from a higher clearance level
  - Cannot write to a lower clearance level
- Assumes vulnerabilities exist and staff may be careless
- Need a “trusted subject” to declassify files

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### Bell-LaPadula (BLP) Model Properties

Every subject & object gets a security **label** (e.g., confidential, secret)

- The Simple Security Property** – *mandatory rules for reading*
  - No Read Up (NRU)
  - A subject cannot read from a higher security level
- \*-Property (star-property)** – *mandatory rules for writing*
  - No Write Down (NWD)
  - A subject cannot write to a lower security level
- The Discretionary Security Property**
  - Access control matrix can be used for **DAC** *after* MAC is enforced

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### BLP Tranquility Principle

- Tranquility principle:** security labels never change during operation
- Weak tranquility principle:** labels may change but in a way that does not violate security policy
  - Implements the principle of least privilege
  - If owner has Top Secret clearance, a program will run at the lowest clearance level and get upgraded only when it needs to access data at a higher level
- BLP gets complicated
  - Changes in security policy in real time can result in access being revoked – even in the middle of an operation
- Difficult to use BLP in practice
  - Networking, servers, collaborative work

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### No Write Down?

If you can write up, can a Confidential user overwrite Secret data?

- That’s an attack on availability

- Usually: allow overwriting files when the process’ security labels match exactly

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### Type Enforcement Model (TE)

**Secondary Access Control Matrix that gives MAC priority over DAC**

- Domains and Types
  - Assigns subjects to **domains**
  - Assigns objects to **types**
  - Matrix defines permitted **domain-domain** and **domain-type** interactions
- SE Linux = Security-Enhanced Linux
  - Both subjects and objects are **types**
  - Matrix defines allowed **type pairs**
  - Each process has a **security ID**, user ID, and group ID
  - Security modules may be added with rules that operate on SIDs

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### Role-Based Access Control (RBAC)

- More general than Bell-LaPadula
- Designed to allow enforcement of both MAC & DAC properties
- Access decisions do not depend on user IDs but on **roles**
  - Administrators define **roles** for various job functions
  - Each role contains **permissions** to perform certain operations
  - Users are assigned one or more roles
- Roles are **job functions**, not **permissions**
  - “update customer information” is a role
  - “write to the database” is **not** a role
- Enables fine-grained access
  - Roles may be defined in application specific ways (e.g., “move funds”)

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### RBAC Rules

- **Role assignment**
  - A subject can execute an operation only if the subject has been assigned a role
- **Role authorization**
  - A subject's active role must be authorized for that subject
  - Ensures that users can only take on roles for which they have been authorized
- **Transaction authorization**
  - A subject can execute a transaction only if the transaction is authorized through the subject's role membership

RBAC is essential to database security

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### Aren't roles == groups?

- **Group** = collection of users
  - Does not enable management of user-permission relationships
- **Role** = collection of permissions
  - Permissions can be associated with users and groups
- Roles have a **session**
  - Users can activate a role
- In SE Linux, RBAC is built on top of TE (type enforcement)
  - Users mapped to roles at login time
  - Roles are authorized for domains
  - Domains are given permissions to types

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### RBAC Benefits

- RBAC is hugely popular in large companies
  - Driven by regulations such as HIPAA and Sarbanes-Oxley
- Makes it easy to manage movement of employees
- Makes it easy to manage "separation of duty" requirements
- Can manage complex relationships
  - Doctor X wants to view records of Patient Y
  - Doctor needs roles of "Doctor" and "attending doctor with respect to Y"
  - Roles allow specification of **only if**, **not if** or **if and only if** relations
- RBAC can simulate MAC and DAC

See <http://csrc.nist.gov/groups/SNS/rbac/faq.html>

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### Biba Integrity Model

- Bell-LaPadula was designed to address **confidentiality**
- Biba is designed to ensure **data integrity**

Confidentiality = constraints on who can *read* data

Integrity = constraints on who can *write* data

**Motivation:**  
Preserve data integrity. If one program gets hacked, it will not be able to modify data at higher levels of integrity

**Biba model properties**

- **Simple Security Property** = A subject cannot read an object from a lower integrity level  
Subjects may not be corrupted by objects from a lower level  
(no read down)
- **Star property** = A subject cannot write to an object at a higher integrity level  
Subjects may not corrupt objects at a higher level than the subject  
(no write up)
- A process cannot request higher access

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### An example of where Biba is useful

The Biba model fits many real-world applications

- ECG device
  - Runs a calibration process, which stores a calibration file
  - Runs user processes, that run ECG tests
- Normal users cannot write the calibration file but can read it
  - Can read data at higher levels (calibration = higher data level)
    - User process can read calibration data – but cannot modify it
- Calibration process can write data to lower levels
  - Calibration process can write to the user process – but cannot read user data
- Works well when you need to get data from a trusted device

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### Biba Problems

- Like Bell-LaPadula, it doesn't always fit the real world
- Microsoft offers **Mandatory Integrity Control** (Biba model)
  - User's access token gets assigned an integrity level
  - File objects are marked with an integrity level:
    - **System**: Critical files
    - **Medium**: Regular users and objects
    - **High**: Elevated users
    - **Low**: Internet Explorer, Adobe Reader, etc.
  - New process gets the **minimum** of the user integrity level and the file integrity level
  - Default policy = **NoWriteUp**
    - Goal: Anything downloaded with IE can read files but cannot write them – limit damage done by malware
    - Trusted subjects would have to overwrite the security model
      - Users get used to the pop-up dialog boxes asking for permission!
  - Microsoft dropped the **NoReadDown** restriction
    - Did not end up protecting the system from users

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### Access Models: Summary

- **Discretionary Access Control**
  - Works great when it's ok to put the user is in charge
- **Mandatory Access Control**
  - Needed when an organization needs to define policies
  - **Bell-LaPadula (BLP)**
    - Oldest & most widely studied model – synonymous with MLS
    - Designed to protect confidentiality
    - Doesn't work well outside of the DoD ... and is clunky within the DoD
  - **Type Enforcement (TE)**
    - Simple MAC model to override DAC
  - **Role-Based Access Control (RBAC)**
    - Identifies roles and assigns users to roles
    - Made popular by business needs
    - Most actively used MAC model
  - **Biba Model**
    - Opposite of Bell-LaPadula: concerned with integrity, not confidentiality

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### Security Risks

- **Even if the mechanisms work perfectly, policies may fail**
  - DAC: you're trusting the users or a sysadmin to set everything up correctly
  - MAC
    - User or role assignment may be incorrect
    - Collaboration needs to be considered
    - Models like Bell-LaPadula and Biba require overrides to function well
- **Corruption**
  - Attacks may change the definition of roles or the mapping of users to roles
  - This is an attack on the Trusted Computing Base
- **Users**
  - Most malware is installed willingly
  - Users thus give it privileges of – at least – normal applications
  - As far as the operating system is concerned, it is enforcing defined policy

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### Security Risks

- **Even administrators should not be able to read all files**
  - Many security systems enforce this
  - Edward Snowden should not have been able to copy sensitive documents onto a thumb drive ... even if NSA policy banned thumb drives
- **General assumption has been that programs are trusted and run with the user's privileges**
- **Worked well for system programs**
- **Do you trust the game you installed on your phone?**
- **Need to consider better application isolation**
  - Android turned Linux into a single-user system
  - User IDs are used on a per-application bases

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### Program-Based Control

- **A lot of access decisions must be handled by programs, not the OS**
  - Database users and the access each user has within the database
  - Microsoft Exchange & Active Directory administrators
  - Mail readers
  - Web services: users are unlikely to have accounts on the system
  - Movement of data over a network
    - How do you send access permissions to another system?
    - Digital rights management = requires trusted players
- **Programs may implement RBAC (e.g., Exchange) or other mechanisms**
  - But the OS does not help

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### Multi-Lateral Security

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### Multi-Level Security

- **Subjects and objects have assigned classification labels**
- **Rules control what you can read or write**

Bell-LaPadula

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### Multilateral Security

Each security level may be divided into compartments

- Usually applied to the top-secret level
- TS/SCI = Top-Secret / Special Compartmentalized Intelligence
- You will be granted access to specific compartments
  - Formalized description of “need to know”

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### Compartmentalization

- Subjects & objects get security labels (compartments) in addition to security classification labels
- If you do not have clearance for the label, you cannot access the data
  - {TOP SECRET, UFO} cannot be read by someone with {TOP SECRET} clearance
  - Neither can {SECRET, UFO}

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### Lattice Model

Graph representing access rights of different labels & levels

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### Lattice model

- Data from two compartments  $\Rightarrow$  third compartment
  - Creates more isolation
  - Does not help with sharing
- One option
  - Allow multiple compartments at a lower level to be readable by a higher level

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### Multi-level & Lattice models

- Do not help downgrading data
  - Need special roles to re-label or declassify data
- Handling searches across compartments is difficult
  - No single entity will likely have rights to everything

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### Chinese Wall model

**Chinese wall** = rules designed to prevent conflicts of interest

- Common in financial industry
  - E.g., separate corporate advisory & brokerage groups
- Also in law firms and advertising agencies
- Separation of duty
  - A user can perform transaction A or B but not both
- Three layers of abstraction
  - Objects: files that contain resources about one company
  - Company groups = set of files relating to one company
  - Conflict classes: groups of competing company groups:
    - { Coca-cola, Pepsi }
    - { American Airlines, United, Delta, Alaska Air }

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## Chinese Wall model

**Basic rule**  
A subject  $s$  can access objects from a company as long as it never accessed objects from competing companies.

**Simple Security property**

- A subject  $s$  can be granted access to an object  $o$  only if the object
  - Is in the same company group as objects already accessed by  $s$
  - or
  - $o$  belongs to a different conflict class.

**\*-property**

- Write access is allowed only if
  - Access is permitted by the simple security property
  - and
  - No object was read which is in a different company dataset than the one for which write access is requested *and* contains **unsanitized** information
    - *Sanitization* = disguising a company's identity
    - This means that you could read data across the wall **ONLY** if it's anonymized

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The end

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