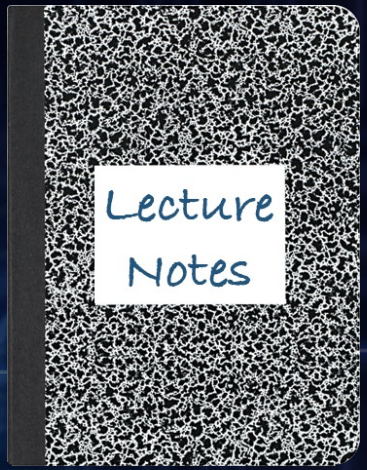
CS 419: Computer Security

Week 6: Access Control

Part 2: Discretionary Access Control



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Discretionary Access Control

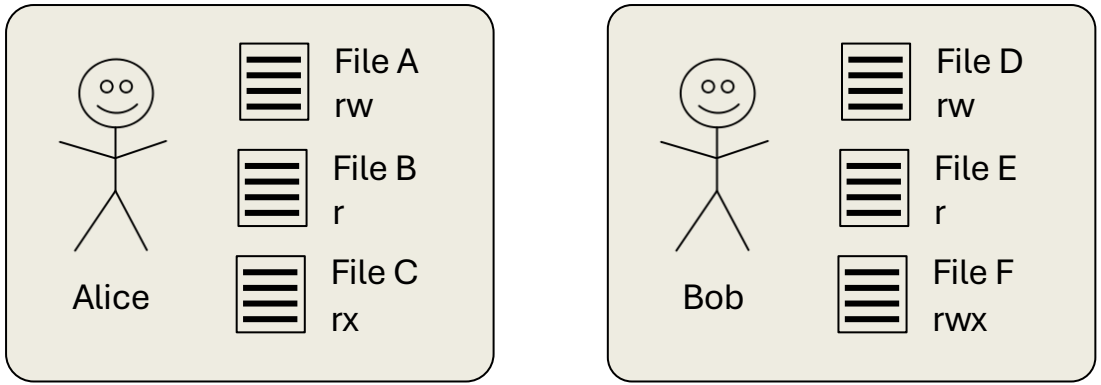
- Discretionary Access Control (DAC)
  - Whoever creates an object becomes the owner
  - The resource owner is in charge of controlling access to the resource
- Easily maps to the access control matrix
  - Each column is stored as an **Access Control List** attached to the object
- Earliest – and still dominant – form of access control
  - Highly intuitive: they're your files and you decide who can do what to them

The UNIX (POSIX) Permission Model

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

UNIX (POSIX) permission model

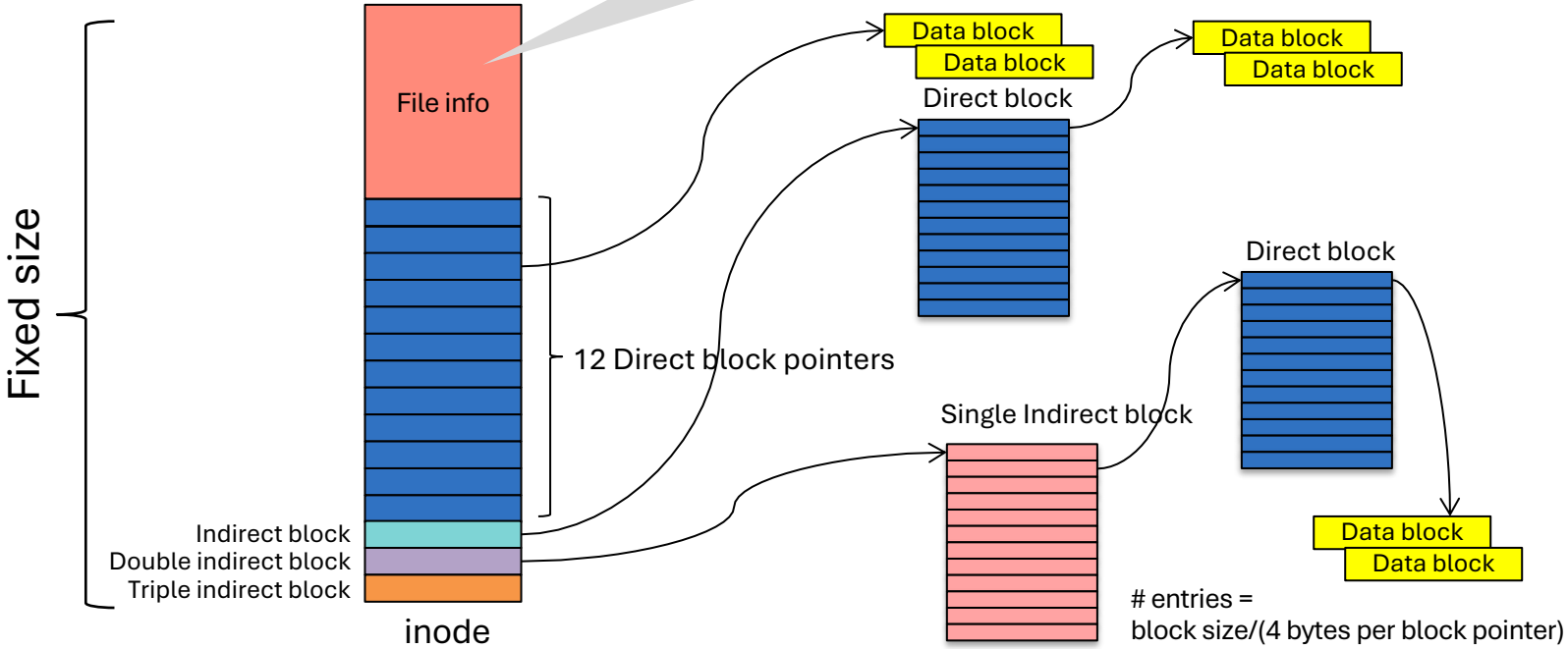
- Access permissions: read (r), write (w), execute (x)
  - All independently set
- Each file has an owner



File permissions are stored in the file's inode

Problem: an ACL takes up a varying amount of space – Won't fit in a fixed-size inode

Stores:
owner id, group id, permissions, access/creation/modification times



Limited ACLs in POSIX systems

UNIX Compromise:

A file defines access rights for only three domains:

(1) **owner (user)**, (2) **group**, (3) **everyone else**

Permissions

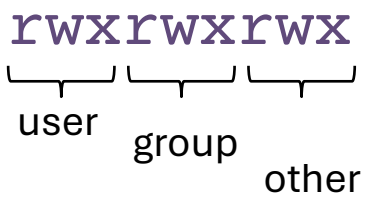
- Read, write, execute (files), search (dirs)
- Set user ID: execute with user permissions of the file's owner
- Set group ID: execute with the group permissions of the file's group

System calls to manage access rights

- umask: changes the default permissions
- chown: changes the object's owner
- chgrp: changes the object's group
- chmod: changes the object's permissions

How do you share (or restrict) files?

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




```
$ ls -l /bin/ls
-rwxr-xr-x  1 root  wheel  154624 Sep 25 03:03 /bin/ls
```

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 users 15 Oct 13 20:00 testfile
```

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

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

Changing Permissions

Changing permissions: chmod

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  15 Oct 13 15:08 testfile
```

- **Add permissions**

```
$ chmod go+w testfile
$ ls -l testfile
-rwxrwx-w-  1 paul localaccounts  15 Oct 13 15:08 testfile
```

Add write access to group and other

- **Remove** permissions

```
$ chmod o-w testfile
$ ls -l testfile
-rwxrwx---  1 paul localaccounts  15 Oct 13 15:08 testfile
```

Remove write access from other

Setting permissions (original method)

Or the old-fashioned way – specify an octal bitmask

Set permissions

```
$ chmod 754 testfile
$ ls -l testfile
-rwxr-xr--  1 paul  localaccounts  15 Oct 13 15:08 testfile
```

7	5	4
111	101	100
rwx	r-x	r--
user	group	other

Initial file permissions

umask = default permissions for newly created files & directories

- Bitmask of permission 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

The possibility of race conditions

```
#!/bin/bash
myapp >secretfile
chmod go-r secretfile
```

Suppose we create a file readable by all: `rwxr--r--`

`rwx, r, r`

- And then we change the permissions to `rwx------`

`rwx, -, -`

GOOD	BAD
Create a file: `rwx-r--r-`	Create a file: `rwx-r--r-`
Change permissions to `rwx------`	*[Attacker opens the file for reading]*
[Attacker opens the file for reading]	Change permissions to `rwx------`
Do your work	*Do your work*

- 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!**

Race conditions

- The *creat* and *open* system calls let you specify the file permissions when creating a file
  - However, not all languages provide a system call interface
- **Example: Python**

```
filepath = "myfile.txt"
with open(filepath, "w") as f:
    os.chmod(filepath, 0o600)   # remove read access
    f.write("testing")
```

  - This has a race condition.
    However, you can use os.open instead of open and specify permissions.
  - Once you try setting/changing permissions, your code is no longer portable

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

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, …);
```

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.

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

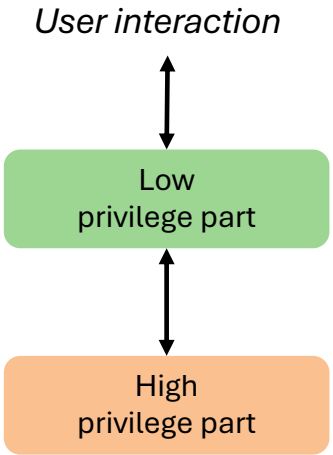
Least privilege is often difficult to define & enforce

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
  1. Run a *setuid* program
  2. Create a communication link to self (*pipe*, *socket*, shared memory)
  3. *fork*
  4. One of the processes will call `seteuid(getuid())` to lower its privilege



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/Linux systems

Access Control on Windows

- Initially, nothing: one trusted user
  - Any process could modify or delete any file
- Windows NT (1993) – major rearchitecture of the OS
  - Introduced user accounts and Access Control Lists
  - Rights could be assigned to objects: files, registry keys, devices, processes
  - Windows 2000 brought NT to Microsoft's consumer Oses
- Windows has users & groups, full ACLs, and more permissions
  - Read, write, execute
  - Also: delete, change permission, change ownership

Access Control on Windows

- Integration with Microsoft's Active Directory (centralized authentication service)

- Users & resources can be partitioned into groups & domains
  - Domains: grouping of users & computers that share a centralize authentication under Active Directory
    - Users belong to a domain
  - 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

Linux Full Access Control Lists

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
  - Not Android or iOS

Example: Full ACLs in POSIX systems

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

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
  - Files and directories can inherit ACL entries from the parent
- See *chmod* on macOS, *setfacl* on Linux, or *icacls* on Windows

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

Simple Linux ACL example

Give two users read access to a file without making the file world-readable or changing the group ownership

```
$ ls -l project.txt
-rw-r--r-- 1 paul users 4782 Oct 12 21:32 project.txt
```

Grant read access to bob and charles:

```
$ setfacl -m u:bob:r -m u:charles:r project.txt
$ getfacl project.txt
# file: project.txt
# owner: paul
# group: users
user::rw-
user:bob:r--
user:charles:r--
group::r--
mask::r--
other::r--
```

macOS ACL examples (1)

- Create a file

```
$ echo hello > hi.txt
$ cat hi.txt
hello
```

- List the file
  - Show ACEs with -e option to ls

```
$ ls -l hi.txt
-rw-r--r--  1 paul  wheel  6 Sep 13 23:01 hi.txt
$ ls -le hi.txt
-rw-r--r--  1 paul  wheel  6 Sep 13 23:01 hi.txt
```

No ACL!

macOS ACL examples (2)

- Take away read & write access
  - Add an access control entry with `chmod +a`
  - Remove an access control entry with chmod –a

```
$ chmod +a "paul deny read,write" hi.txt
```

- See what we have

```
$ ls -le hi.txt
-rw-r--r--+ 1 paul  wheel  6 Sep 13 23:01 hi.txt
 0: user:paul deny read,write
```

ACL

- Add append access

```
$ chmod +a "paul allow append" hi.txt
$ ls -le hi.txt
-rw-r--r--+ 1 paul  wheel  6 Sep 13 23:01 hi.txt
 0: user:paul deny read,write
 1: user:paul allow append
```

ACL

macOS ACL examples (3)

- Try reading and writing to the file

```
$ echo "new data" >hi.txt
bash: hi.txt: Permission denied
$ cat hi.txt
cat: hi.txt: Permission denied
```

- But we can append

```
$ echo "appended data" >>hi.txt
$ ls -l hi.txt
-rw-r--r--+ 1 paul  wheel  20 Sep 13 23:16 hi.txt
```

- Useful for granting users append-only access to a log file

It's bigger: 20 bytes vs. 6

macOS ACL examples (4)

- Remove Access Control Entry #0

```
$ ls -le hi.txt
-rw-r--r--+ 1 paul  wheel  20 Sep 13 23:16 hi.txt
 0: user:paul deny read,write
 1: user:paul allow append
$ chmod -a# 0 hi.txt
$ ls -le hi.txt
-rw-r--r--+ 1 paul  wheel  20 Sep 13 23:16 hi.txt
 0: user:paul allow append
```

`chmod -a# N` removes rule *N*

The “deny read, write” entry is gone

- Now we can see the file

```
$ cat hi.txt
hello
appended data
```

The End