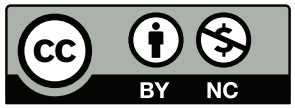
Access Control



Security Begins on the Host

- Even without a network, hosts must enforce the CIA trilogy
- Something on the host — the operating system aided by the hardware — must provide those guarantees

Access Control

- Hardware
- Software
  - Operating systems
  - Databases
  - Other multi-access programs
- Distributed

Hardware

- What is the *minimum* necessary?
- What do other mechanisms buy us?

Minimum Functionality

- Protect the OS from applications
- Protect applications from each other
- Change state from application to OS
- Timer interrupt

Why a Timer?

- Availability is a security feature
- Must prevent uncooperative applications from hogging CPU
- Not going to discuss this more here, but it's a major topic in W4118 (Operating Systems)

Historical Mechanisms

- Single privileged mode bit — restrict ability to execute certain instructions
- Memory protection
- Interrupts — hardware and software — cause state transition

What Are Privileged Instructions?

- Ability to do I/O without the OS's intervention — allowing that could bypass file permission checking
- Ability to manipulate timers
- Ability to access other programs' memory without OS intervention

Example: IBM System/360 Mainframe

- Designed in the early 1960s
- Much of the architecture still in use. . .
- 4-bit protection key associated with each 4K block of memory, plus read-protect bit
- Single "supervisor mode" bit
- 4-bit state key of 0 can write to anything
- But — operating systems of that time didn't use the hardware to its full capabilites

Memory-Mapped Control

- On some machines, privileged operations work by memory access
- If applications have no access to such memory, they can't do sensitive things
- But — must have way to enter privileged state

Multics

- Virtual memory
- "Ring" structure — 8 different privilege levels (i386 has rings, too)
- OS could use rings 0-3; applications could use 4-7.
- (Original design had 64 rings!)
- Each ring is protected against higher-numbered rings
- Special form of subroutine call to cross rings
- Most of the OS didn't run in Ring 0

What is the Advantage of Rings?

- A single bit is theoretically sufficient
- Assurance!
- Don't need to trust all parts of the system equally
- "Principle of Least Privilege"

Assurance

- How do you *know* something is secure
- Much harder to provide later than features
- A *trustable* secure system has to be designed that way from the beginning: designed, document, coded, and tested — and maybe proved

Underlying Principles of Privilege

- Two basic approaches to privilege: identity and attribute
- Hardware protection is *attribute*: the state of various registers controls what can and cannot be done
- Easier to manage in a single system

What is the role of the OS?

- Protect itself
- Separate different applications
- More?

Operating Systems and Hardware

- The hardware provides the minimum functionality
- The OS has to provide its own services on top of that
- Must manage access to I/O devices as well

What Protections do Operating Systems Provide?

- User authentication (why?)
- File protection
- Process protection
- Resource scheduling (CPU, RAM, disk space, etc)

User Authentication

- (Much more on this later)
- Why authenticate users?
- Most operating system privileges are granted by identity, not attributes
- Procedure:
  - Authenticate user
  - Grant access based on userid

File Permissions

- Besides user authentication, the most visible aspect of OS security
- Read protection — provide confidentiality
- Write protection — provide integrity protection
- Other permissions as well

Classical Unix File Permissions

- All files have "owners"
- All files belong to a "group"
- Users, when logged in, have one userid and several groupids.
- 3 sets of 3 bits: read, write, execute, for user, group, other
- (512 possible settings. Do they all make sense?)
- Written `rwxrwxrwx`
- 111 101 001: User has read/write/exec; group has read/exec; other has exec-only
- Some counter-intuitive settings are very useful

Permission-Checking Algorithm

```
if curr_user.uid == file.uid
        check_owner_permissions();
else if curr_user.gid == file.gid
        check_group_permissions();
else
        check_other_permissions();
fi
```

Note the `else` clauses — if you own a file, "group" and "other" permissions aren't checked

Execute Permission

- Why is it separate from "read"?
- To permit *only* execution
- Cannot copy the file
- Readable only by the OS, for specific purposes

Directory Permissions

- "write": create a file in the directory
- "read": list the directory
- "execute": trace a path through a directory

Example: Owner Permissions

```
$ id
uid=54047(smb) gid=54047(smb) groups=0(wheel),3(sys),54047(smb)
$ ls -l not_me
----r--r--  1 smb  wheel  29 Sep 12 01:35 not_me
$ cat not_me
cat: not_me: Permission denied
```

I own the file but don't have read permission on it

Example: Directory Permissions

```
$ ls -ld oddball
dr--r--r--  2 smb  wheel  512 Sep 12 01:36 oddball
$ ls oddball
cannot_get_at
$ ls -l oddball
ls: cannot_get_at: Permission denied
$ cat oddball/cannot_get_at
cat: oddball/cannot_get_at: Permission denied
```

I can read the directory, but not trace a path through it to `oddball/cannot_get_at`

Deleting Files

- What permissions are needed to delete files?
- On Unix, you need write permission on the parent directory
- You can delete files that you can't write. You can also write to files that you can neither create nor delete
- Other systems make this choice differently

Historical Note

- Unix has *never* been fond of asking "do you really mean that?"
- That said, at least as long ago as February 1973 the original Bell Labs Unix `rm` command prompted if you tried to delete a file you couldn't write
- In other words, the Unix model is philosophically correct but perhaps incorrect from a human factors perspective

Access Control Lists

- 9-bit model not always flexible enough
- Many systems (Multics, Windows XP and later, Solaris, some Linux) have more general *Access Control Lists*
- ACLs are explicit lists of permissions for different parties
- Wildcards are often used

Sample ACL

```
smb.*        rwx
4187-ta.*    rwx
*.faculty    rx
*.*          x
```

Users "smb" and '4187-ta" have read/write/execute permission. Anyone in group "faculty" can read or execute the file. Others can only execute it.

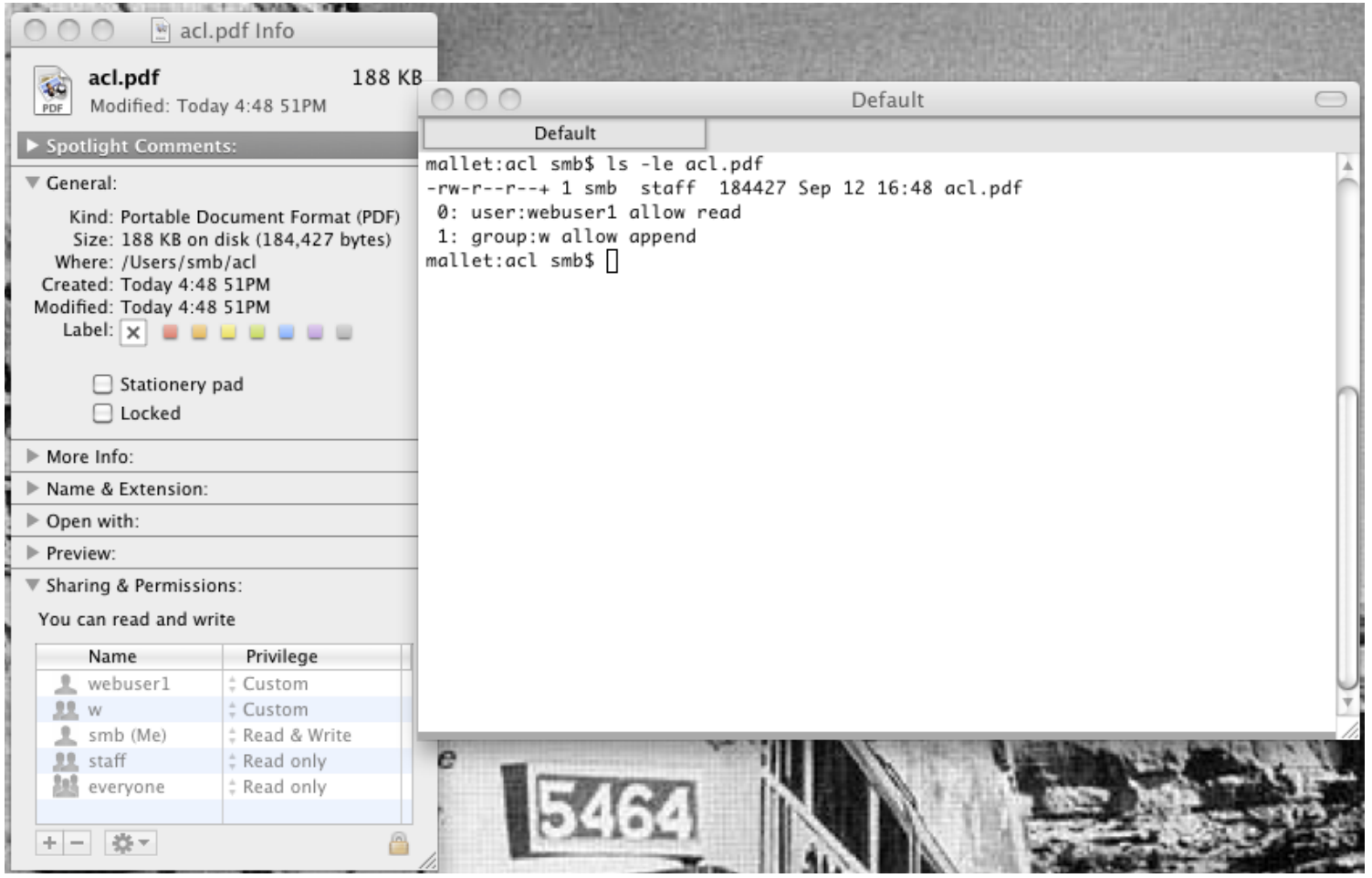
Order is Significant

With this ACL:

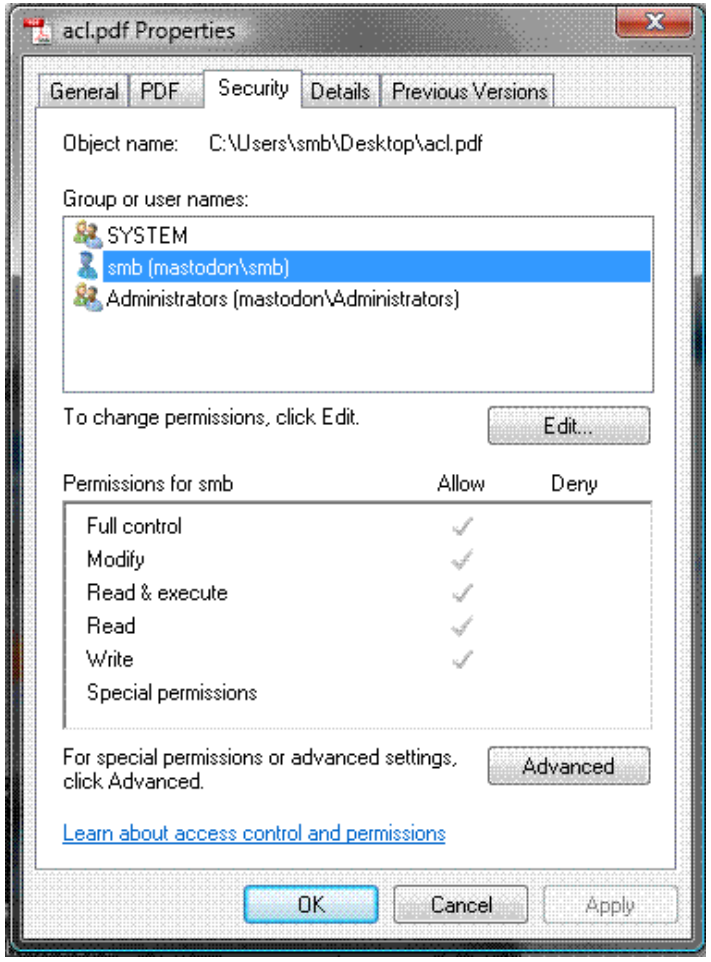
```
*.faculty    rx
smb.*        rwx
4187-ta.*    rwx
*.*          x
```

I would not have write access to the file

MacOS ACLs


acl.pdf Info
acl.pdf
188 KB
Modified: Today 4:48 51PM
Spotlight Comments:
General:
Kind: Portable Document Format (PDF)
Size: 188 KB on disk (184,427 bytes)
Where: /Users/smb/acl
Created: Today 4:48 51PM
Modified: Today 4:48 51PM
Label:
Stationery pad
Locked
More Info:
Name & Extension:
Open with:
Preview:
Sharing & Permissions:
You can read and write
Name
Privilege
webuser1
Custom
w
Custom
smb (Me)
Read & Write
staff
Read only
everyone
Read only
Default
Default
mallet:acl smb$ ls -le acl.pdf
-rw-r--r--+ 1 smb staff 184427 Sep 12 16:48 acl.pdf
0: user:webuser1 allow read
1: group:w allow append
mallet:acl smb$
5464

Windows Vista ACLs



Linux/Solaris ACLs

```
$ getfacl acl.pdf
# file: acl.pdf
# owner: smb
# group: smb
user::rw-
user:postfix:-w-
group::r--
group:landscape:--x
mask::rwx
other::r--
```

The standard Unix permissions are translated into ACL entries

Setting File Permissions

- Where do initial file permssions come from?
- Who can change file permissions?

Unix Initial File Permissions

- Unix uses "umask" — a set of bits to *turn off* when a program creates a file
- Example: if umask is 022 and a program tries to create a file with permissions 0666 (rw for user, group, and other), the actual permissions will be 0644.
- Default system umask setting has a great effect on system file security
- Set your own value in startup script; value inherited by child processes

Why Umask?

- Suppose files were always created with rw,r,r permissions
- What's wrong with the application simply changing the file permissions after creating the file?
- Race conditions

Multics Initial File Permissions

- Directories contain "initial access control list" — values set by default for new files
- Common setting:

```
smb.faculty        rw
*.sysdaemon        r
*.*                -
```

- If group "sysdaemon" doesn't have read permission, the file can't be backed up!
- Linux and Solaris also have default ACLs for new files

MAC versus DAC

- Who has the right to set file permissions?
- Discretionary Access Control (DAC) — the file owner can set permissions
- Mandatory Access Control (MAC) — only the security officer can set permissions
- *Enforce* site security rules
- Note: viruses and other malware change change DAC permissions, but *not* MAC permissions

Implementing MAC

- Often side-by-side with DAC: system has both
- Processes need to pass both sets of permissions to access files
- Or — can have a special ACL-changing attribute in an ACL:

```
security_officer.wheel   p
```

- But — can `security_officer` give him/herself privileges?
- In reality, MAC is often used for classification levels (next class), rather than ACLs

Privileged Users

- `Root` or `Administrator` can override file permissions
- This is a serious security risk — there is no protection if a privileged account has been compromised
- There is also no protection against a rogue superuser. . .
- Secure operating systems do not have the concept of superusers

Database Access Control

- Often have their own security mechanisms
- Permit user logins, just like operating systems
- Some have groups as well
- Permissions are according to database concepts: protect rows and columns
- Different types of operations: select, insert, update, delete, and more

Databases versus OS Security

- The database has many objects in a single OS file
- The OS can control access to the file
- The DBMS has to control access to objects within the file
- The set of database users is not the same as the set of OS users

Access Control Formalisms

- Access control can be modeled formally. What does this buy us?
- There are theorems that can be proved
- For example, if ACLs permit negation there are undecidable questions

Access Control Formalisms (cont.)

- For the general case:
- Model using a Turing machine.
- Turing machine enters a special state if the access control is faulty.
- Contradiction!