4. Access Control

Computer Security Courses @ POLIMI

What is Access Control?

- A binary decision:
  - Access either *allowed* or *denied*
  - What could *possibly* go wrong?
- Scale goes wrong!
  - You cannot explicitly *list* the answers
  - Need to condense them in *rules*
- Questions
  - How do we *design* the access rules?
  - How do we *express* the access rules in practice?
  - How do we appropriately *apply* them?

Who Does it? The Reference Monitor

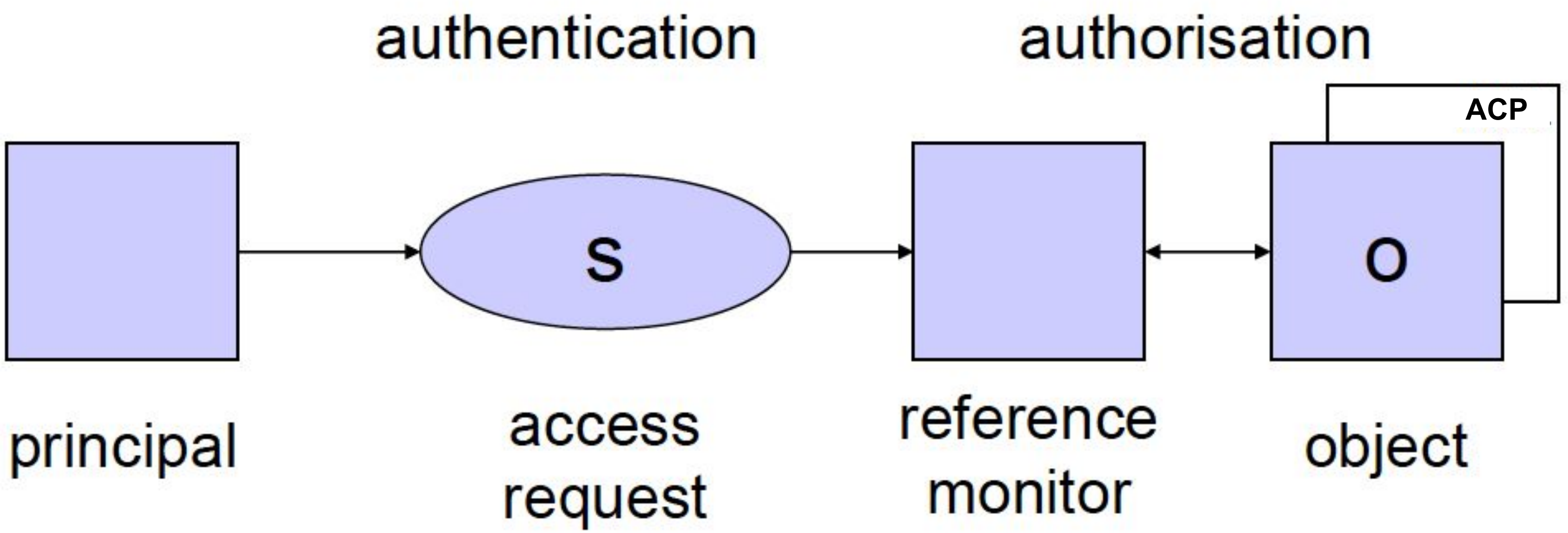
Enforces access control policies ("who does what on which resource"). All modern kernels have a reference monitor implementation.

Requirements for the RM:

- Tamper proof
- Cannot be bypassed
- Small enough to be verified/tested

J. Anderson, 1972 "Computer Security Technology Planning Study"

Authentication & Authorization



Authentication & Authorization

- **Authentication**: reference monitor verifies the identity of the principal (user) making the request:
    - User enters username and password.
    - If the values entered are correct, the user is "authenticated".
        - We could say: "The machine now runs on behalf of the user".
    - This might be intuitive, but it is imprecise.
        - Log on creates a **<u>process</u>** that runs with access rights assigned to the user.
        - Typically, the process runs under the user identity of the user who has logged on.

Authentication & Authorization

- **Authentication**: reference monitor verifies the identity of the principal (user) making the request.
- **Authorization**: reference monitor decides whether access is granted or denied.
    - Reference monitor has to find and evaluate the security policy relevant for the given request.

"Easy" in centralized systems but in distributed systems,

- how to find all relevant policies?
- how to make decisions if policies may be missing?

Users & User Identities

- Requests to reference monitor do not come directly from a user or a user identity, but from a **process**.
- The active entity making a request within the system is called the **subject**.
- You must distinguish between these concepts:
  - **User**: person;
  - **Principal (User identity)**: name used in the system, possibly

    associated with a user; Active entity.
  - **Subject: Process** running under a given user identity**.**
  - **Object**: Passive entity – file or resource.
  - **Access operations**: Vary from basic memory access (read, write) to method calls in object-oriented systems.

Access control models

Can be roughly divided in

- Discretionary Access Control (DAC)
- Mandatory Access Control (MAC)
- Role-Based Access Control (RBAC)

Difference between DAC and MAC

- who assigns privileges

RBAC abstracts roles from identities

Discretionary Access Control

- Resource <u>owner</u> *discretionarily* decides its access privileges
  - Stefano creates a file
    - Assigns Federico the privilege of reading it
- If this sounds “normal” it is because **all** off-the-shelf OSs implement DAC
  - Windows
  - Linux and other UNIX flavors
  - Mac OS X
  - Also applications, social networks…mostly DAC!

Examples of DAC systems

- UNIX
  - **Subjects**: users, groups
  - **Objects**: files (everything, really)
  - **Actions**: read, write, execute
- Windows (not the 95/98/ME branches)
  - **Subjects:** with *roles* instead of *groups*, multiple ownership of users and roles over files
  - **Objects**: files and “other” resources
  - **Actions**: delete, change permissions, change ownership.

Permissions (r, w, x) **Subjects (user, group)** **Objects (files, dirs, ...)**

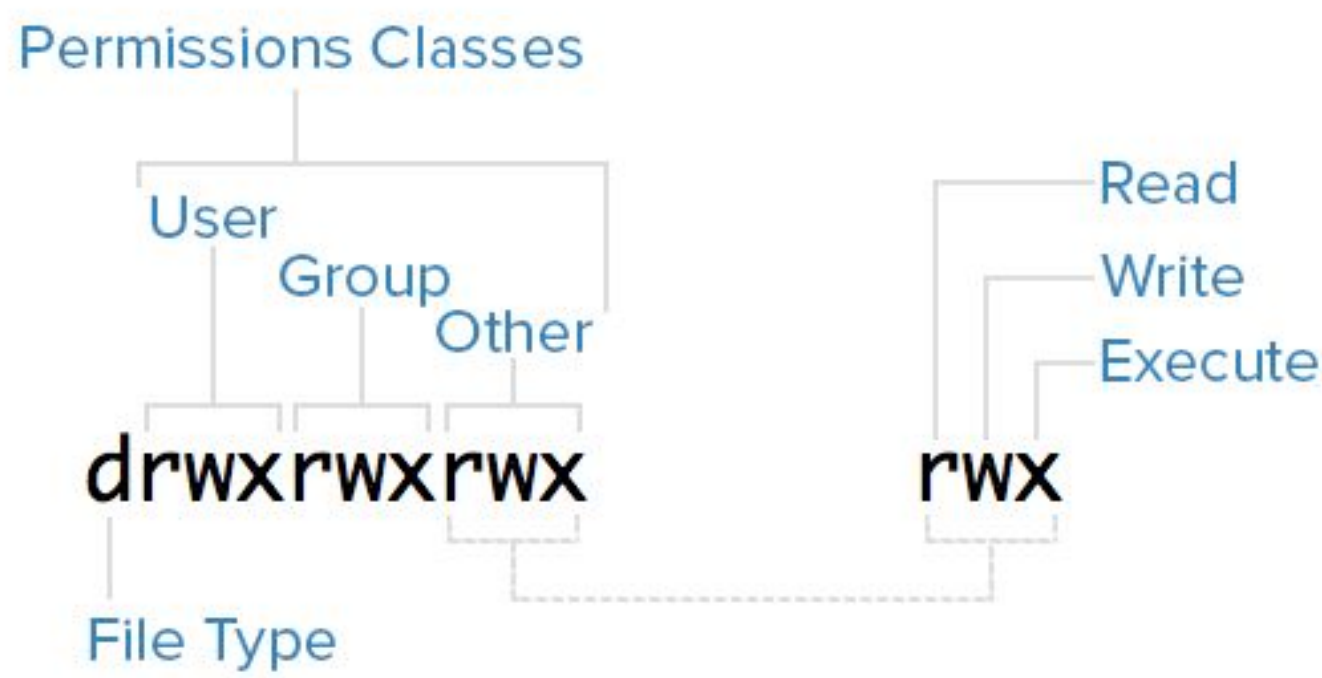
```
lrwxr-xr-x    1 phretor  staff        30 Jul  3  2011 .irssi -> /Users/ph
-rw-r--r--    1 phretor  staff       140 Dec  1  2012 .jackdrc
drwxr-xr-x    3 phretor  staff       102 Feb 21  2008 .jmf
-rwxrwxrwx@   1 phretor  staff        41 Dec  9  2012 .khlbshcrc
-rw-------    1 root     staff        51 Oct 27  2008 .lesshst
drwxr-xr-x    4 phretor  staff       136 Jan  4  2008 .lftp
drwx------    4 phretor  staff       136 Jul 22  2009 .links
drwxr-xr-x    3 phretor  staff       102 Apr  1  2013 .m2
lrwxr-xr-x    1 phretor  staff        32 Jul  3  2011 .mailcap -> /Users/
drwxr-xr-x    3 phretor  staff       102 Jan  7  2008 .mldonkey
drwxr-xr-x    4 phretor  staff       136 Jan 25 16:29 .mono
lrwxr-xr-x    1 phretor  staff        31 Jul  3  2011 .mutt.d -> /Users/p
lrwxr-xr-x    1 phretor  staff        36 Jul  3  2011 .muttprintrc -> /Us
lrwxr-xr-x    1 phretor  staff        31 Jul  3  2011 .muttrc -> /Users/p
drwxr-xr-x   11 phretor  staff       374 Jan 31  2008 .ncftp
drwxr-xr-x    8 phretor  staff       272 Dec  7 19:59 .neocomplcache
drwxr-xr-x    8 phretor  staff       272 Oct 21  2012 .neocon
drwxr-xr-x   11 phretor  staff       374 Feb  9  2013 .npm
lrwxr-xr-x    1 phretor  staff        38 Jul  3  2011 .offlineimaprc -> /
drwxr-xr-x   15 phretor  staff       510 Feb  4 22:23 .oh-my-zsh
drwxr-xr-x    6 phretor  staff       204 Apr 20  2013 .parentseye
drwxrwxr-x    3 phretor  staff       102 Dec 24  2010 .pip
drwx------    6 phretor  staff       204 Apr  5  2008 .psi
-rw-------    1 phretor  staff        90 Mar 17  2010 .psql_history
```

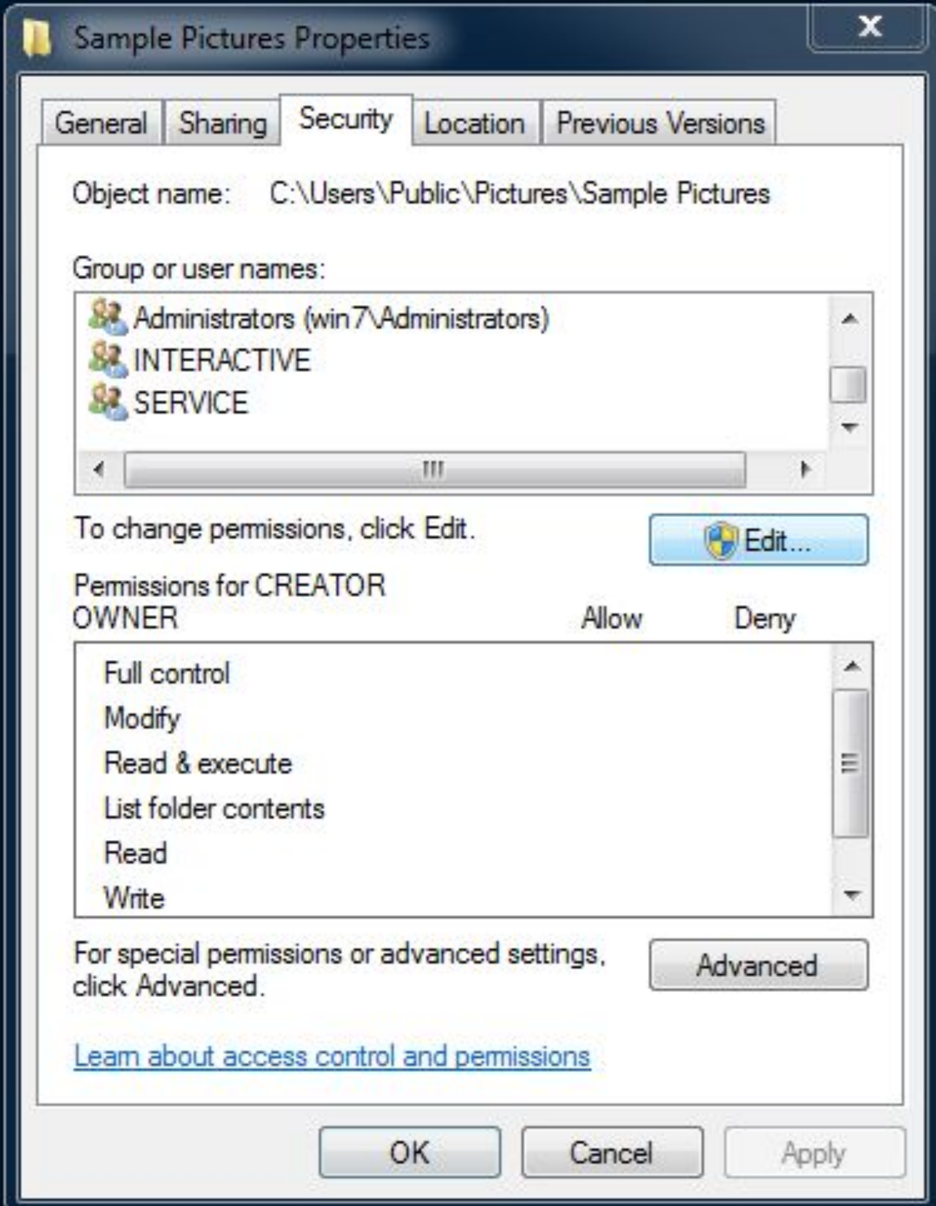
UNIX Permissions

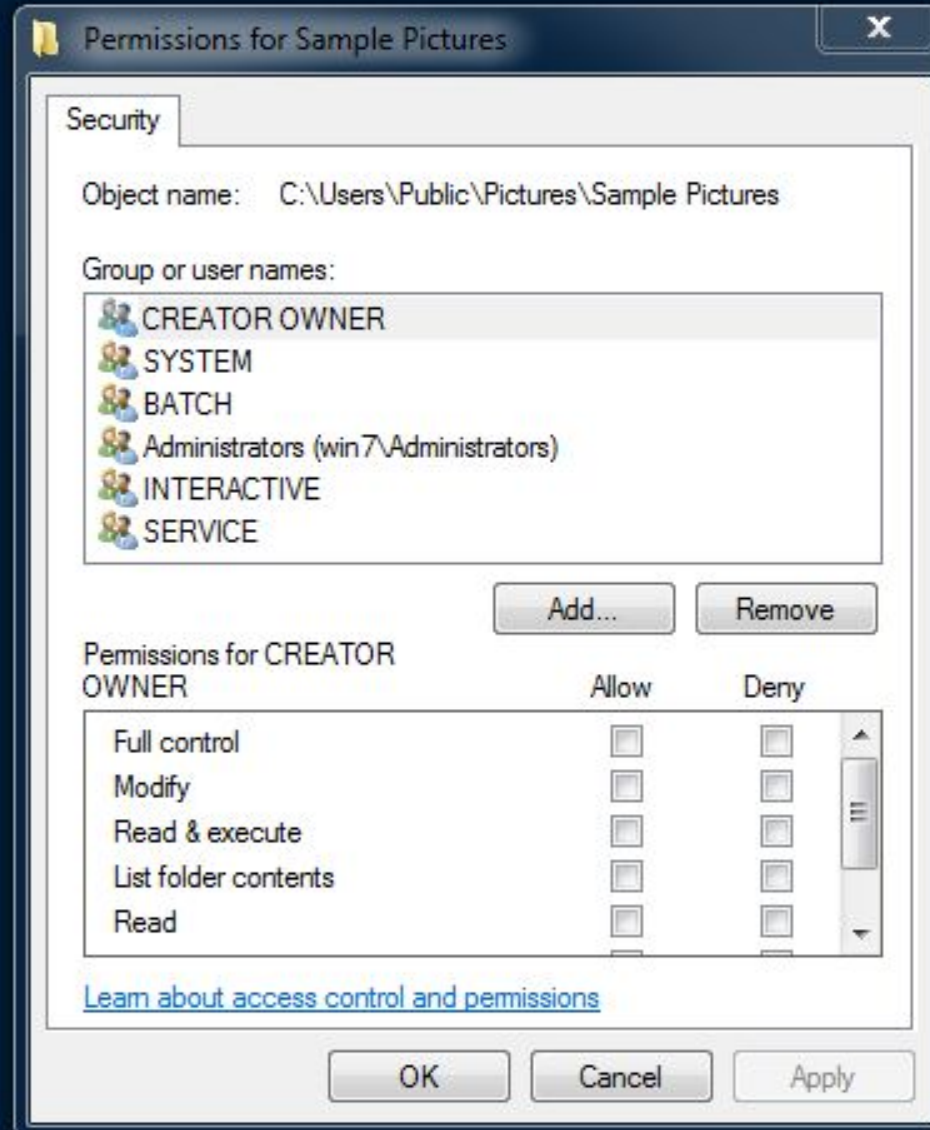
Mode Owner Group File Size Last Modified Filename

```
drwxrwxrwx 2 sammy sammy       4096 Nov 10 12:15 everyone_directory
drwxrwx--- 2 root  developers  4096 Nov 10 12:15 group_directory
-rw-rw---- 1 sammy sammy         15 Nov 10 17:07 group_modifiable
drwx------ 2 sammy sammy       4096 Nov 10 12:15 private_directory
-rw------- 1 sammy sammy        269 Nov 10 16:57 private_file
-rwxr-xr-x 1 sammy sammy      46357 Nov 10 17:07 public_executable
-rw-rw-rw- 1 sammy sammy       2697 Nov 10 17:06 public_file
drwxr-xr-x 2 sammy sammy       4096 Nov 10 16:49 publicly_accessible_directory
-rw-r--r-- 1 sammy sammy       7718 Nov 10 16:58 publicly_readable_file
drwx------ 2 root  root        4096 Nov 10 17:05 root_private_directory
```

Permissions “Triads”




Sample Pictures Properties
General
Sharing
Security
Location
Previous Versions
Object name: C:\Users\Public\Pictures\Sample Pictures
Group or user names:
Administrators (win7\Administrators)
INTERACTIVE
SERVICE
To change permissions, click Edit.
Edit...
Permissions for CREATOR OWNER
Allow
Deny
Full control
Modify
Read & execute
List folder contents
Read
Write
For special permissions or advanced settings, click Advanced.
Advanced
Learn about access control and permissions
OK
Cancel
Apply


Permissions for Sample Pictures
Security
Object name: C:\Users\Public\Pictures\Sample Pictures
Group or user names:
CREATOR OWNER
SYSTEM
BATCH
Administrators (win7\Administrators)
INTERACTIVE
SERVICE
Add...
Remove
Permissions for CREATOR OWNER
Allow
Deny
Full control
Modify
Read & execute
List folder contents
Read
Learn about access control and permissions
OK
Cancel
Apply

General model of DAC systems

- We need to model the following entities:
  - **Subjects** who can exercise privileges (a.k.a., rights)
  - **Objects** on which privileges are exercised
  - **Actions** which can be exercised
- **Protection state**: a triple (S, O, A)
  - A: matrix with S rows and O columns
  - $A[s,o]$: privileges of subject s over object o

	file1	**file2**	**directoryX**
Alice	Read	Read, Write, Own	
Bob	Read, Write, Own	Read	Read, Write, Own
Charlie	Read, Write		Read

Lampson ‘71, Graham and Denning ‘72, **H**arrison, **R**uzzo and **U**llmann ‘76 -> **HRU model**

Transitions in the HRU model

- **Basic operations**
  - create (or destroy) subject <s>
  - create (or destroy) object <o>
  - add (or remove) <*permission*> into *[s,o]* matrix
- **Transitions**: sequences of basic operations
  - *"create file (subject u; file f)"*:
    - create object f
    - add “own” into *[u,f]*
    - add “read” into *[u,f]*
  - Is this right?

Transitions in the HRU model

- **Basic operations**
  - create (or destroy) subject $<s>$
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- **Transitions**: sequences of basic operations
  - *"create file (subject u; file f)"*:
    - create object f
    - add “own” into $[u,f]$
    - add “read” into $[u,f]$
  - Is this right? No, we need to check if f existed before, otherwise u would be stealing it away!
  - We need an “if” construct for modeling transitions

Safety problems

- From an initial configuration, given a sequence of transitions, can s obtain a right r on f?
  - Obviously, yes if the owner o allows it!
  - But, if the owner does not?
    - If it happens, set of commands **unsafe by design**!
- More formally
  - Given an initial protection state and set of transitions, is there **any sequence of transitions that leaks** a certain right r (for which the owner is removed) into the access matrix?
  - If not, then the system is safe with respect to right r
- In a generic HRU model (with infinite resources): **undecidable** problem
  - Decidable in mono-operational systems, (substantially useless, e.g., you cannot create a file and own it)
  - .. or <u>if subjects/objects are finite</u>.

Common DAC Implementations

- Reproduction of HRU models
- Access matrix is a sparse matrix
- Alternative implementations:
  - **Authorizations table:** records non-null triples S-O-A, typically used in DBMS
  - **Access Control Lists:** records by column (i.e., for each **object**, the list of subjects and authorizations)
  - **Capability Lists:** records by row (i.e., for each **subject**, the list of objects and authorizations)

Access Control vs Capability Lists

Access Control Lists

- Focus on the object
- ACLs ≡ columns of the access control matrix

fun.com	Alice: {exec}	Bill: {exec,read,write}

Capability Lists

- Focus on the subject
- Capabilities ≡ rows of the access control

Alice	edit.exe: {exec}	fun.com: {exec,read}

ACLs vs Capability Lists

ACLs

- efficient with **per object** operations
- Most common case
- Some systems (e.g., POSIX) use abbreviated ACLs
- Cannot have multiple owners (partially achievable via groups).

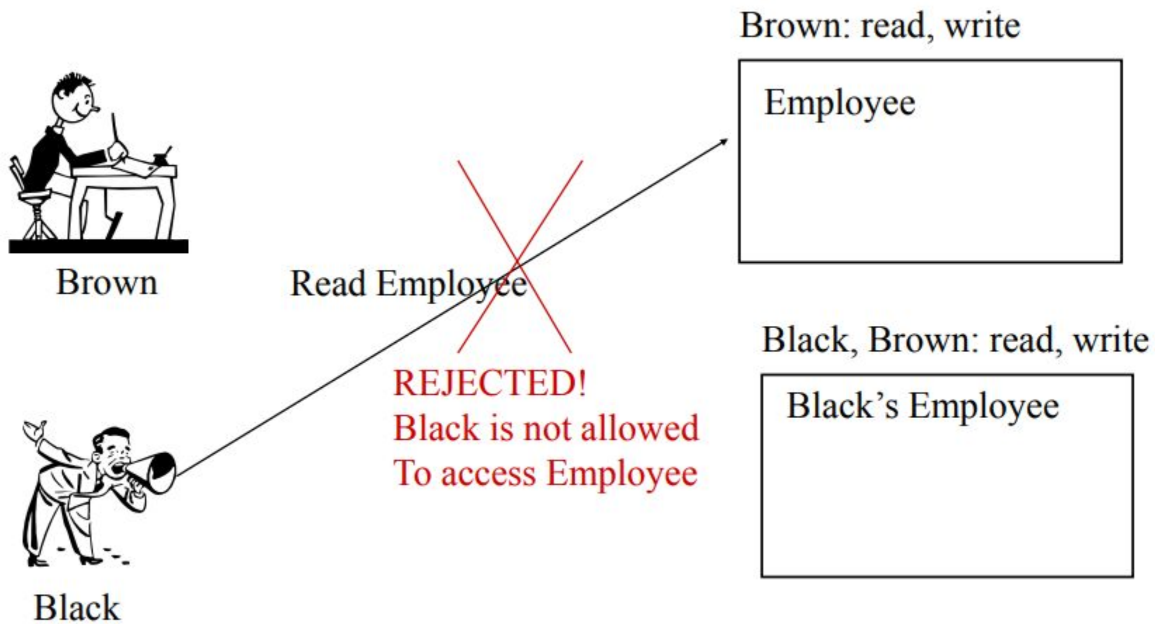
Capabilities

- efficient with **per subject** operations
- Usually **objects** change and **subjects** stay, so inefficient
- Capabilities are optional in POSIX (Linux and BSD).

General DAC shortcomings

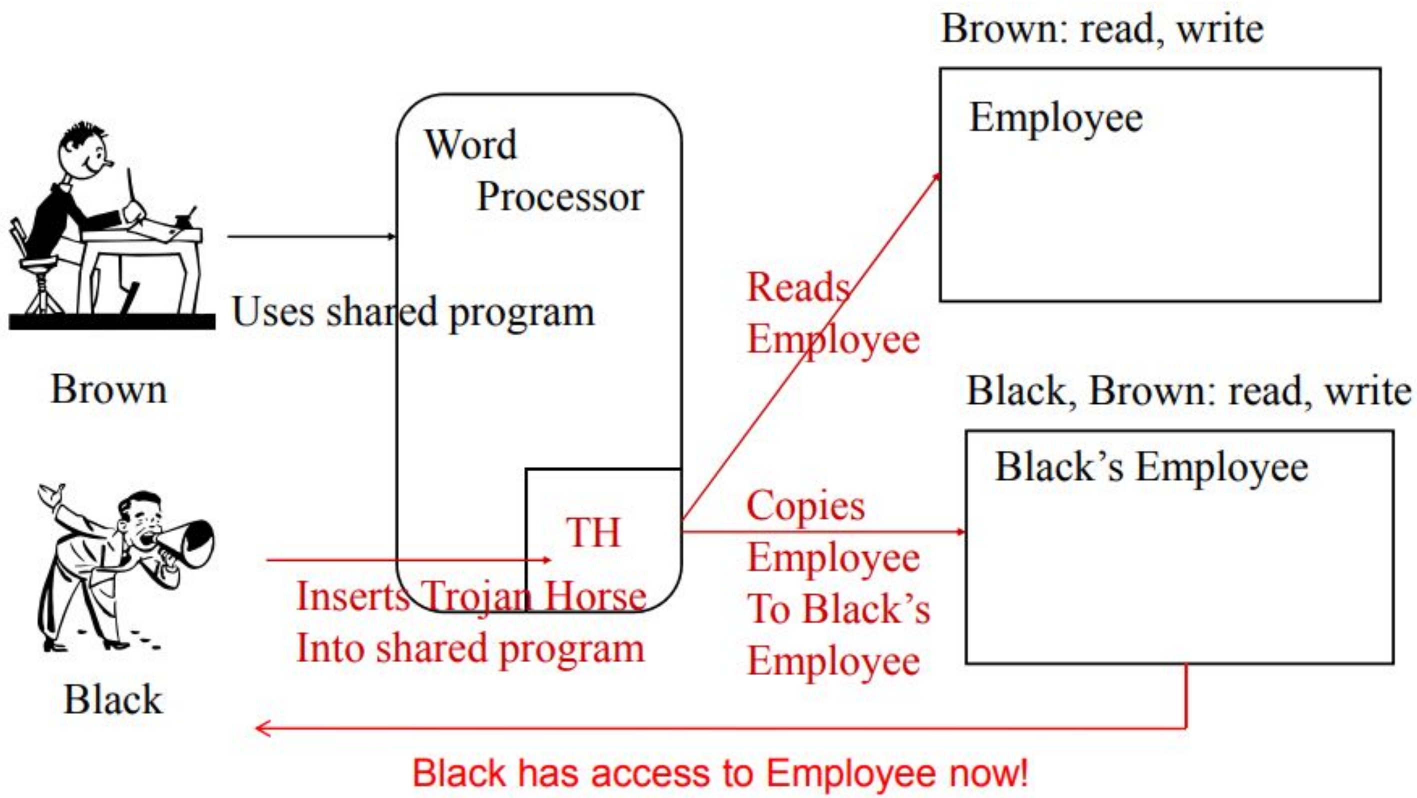
- Cannot prove safety
- Control access to objects but not to the data inside objects (granularity)
  - Susceptible to *malicious user* problem
  - Susceptible to *trojan horse* problem: malicious program running with privileges of the user
- Problems of <u>scalability and management</u>
  - each user-owner can potentially compromise security of the system with their own decisions

DAC and Trojan Horse



credits: https://www.comp.nus.edu.sg/~tankl/cs5322/slides/mac2.pdf

DAC Trojan Horse Problem



credits: https://www.comp.nus.edu.sg/~tankl/cs5322/slides/mac2.pdf

Mandatory Access Control (MAC)

Idea: do not let owners assign privileges.

Privileges are set by a security **administrator**:

- E.g., defines a **classification** of *subjects* (or "clearance") and *objects* (or "sensitivity").

The **classification** is composed of:

- A strictly ordered set of **secrecy levels.**
- A set of **labels.**

SELinux Administration

File Help

(example of MAC rules in SELinux)

Select:

- Status
- Boolean
- File Labeling
- User Mapping
- SELinux User
- Translation
- Network Port
- Policy Module

Revert Customized

Filter

Active	Module	Description	Name
☐	apache	Allow httpd to act as a FTP server by listening on the	httpd_enable_ftp_server
☐	apache	Allow HTTPD to run SSI executables in the same dom	httpd_ssi_exec
☐	apache	Allow Apache to communicate with avahi service via	allow_httpd_dbus_avahi
☑	apache	Allow httpd to use built in scripting (usually php)	httpd_builtin_scripting
☐	apache	Allow http daemon to send mail	httpd_can_sendmail
☐	apache	Allow httpd to access nfs file systems	httpd_use_nfs
☑	apache	Unify HTTPD to communicate with the terminal. Nee	httpd_tty_comm
☐	apache	Allow Apache to use mod_auth_pam	allow_httpd_mod_auth_ntlm_winbind
☐	apache	Allow HTTPD scripts and modules to connect to the r	httpd_can_network_connect
☑	apache	Unify HTTPD handling of all content files	httpd_unified
☐	apache	Allow apache scripts to write to public content. Dire	allow_httpd_sys_script_anon_write
☑	apache	Allow httpd to read home directories	httpd_enable_homedirs
☐	apache	Allow Apache to modify public files used for public fil	allow_httpd_anon_write
☐	apache	Allow Apache to use mod_auth_pam	allow_httpd_mod_auth_pam
☐	apache	Allow httpd to access cifs file systems	httpd_use_cifs
☑	apache	Allow httpd cgi support	httpd_enable_cgi
☐	apache	Allow HTTPD scripts and modules to network connect	httpd_can_network_connect_db
☐	apache	Allow httpd to act as a relay	httpd_can_network_relay
☐	bind	Allow BIND to write the master zone files. Generally	named_write_master_zones
☐	cdrecord	Allow cdrecord to read various content. nfs, samba, r	cdrecord_read_content
☐	cron	Enable extra rules in the cron domain to support fcro	fcron_crond
☐	cvs	Allow cvs daemon to read shadow	allow_cvs_read_shadow
☑	domain	Allow unlabeled packets to work on system	allow_unlabeled_packets
☐	exim	Allow exim to connect to databases (postgres, mysq	exim_can_connect_db
☐	exim	Allow exim to create, read, write, and delete unprivile	exim_manage_user_files
☐	exim	Allow exim to read unprivileged user files.	exim_read_user_files
☐	ftp	Allow ftp to read and write files in the user home dire	ftp_home_dir
☐	ftp	Allow ftp servers to login to local users and read/writ	allow_ftpd_full_access
☐	ftp	Allow ftp servers to use nfs used for public file trans	allow_ftpd_use_nfs

Secrecy Levels (US example)

Top Secret

$>$

Secret

$>$

For Official Use Only (FOUO)

$>$

Unclassified

Secrecy Levels (NATO example)

COSMIC Top Secret

>

NATO Secret

>

NATO Confidential

>

Unclassified

Example (labels)

Policy

Energy

Finance

ATOMAL

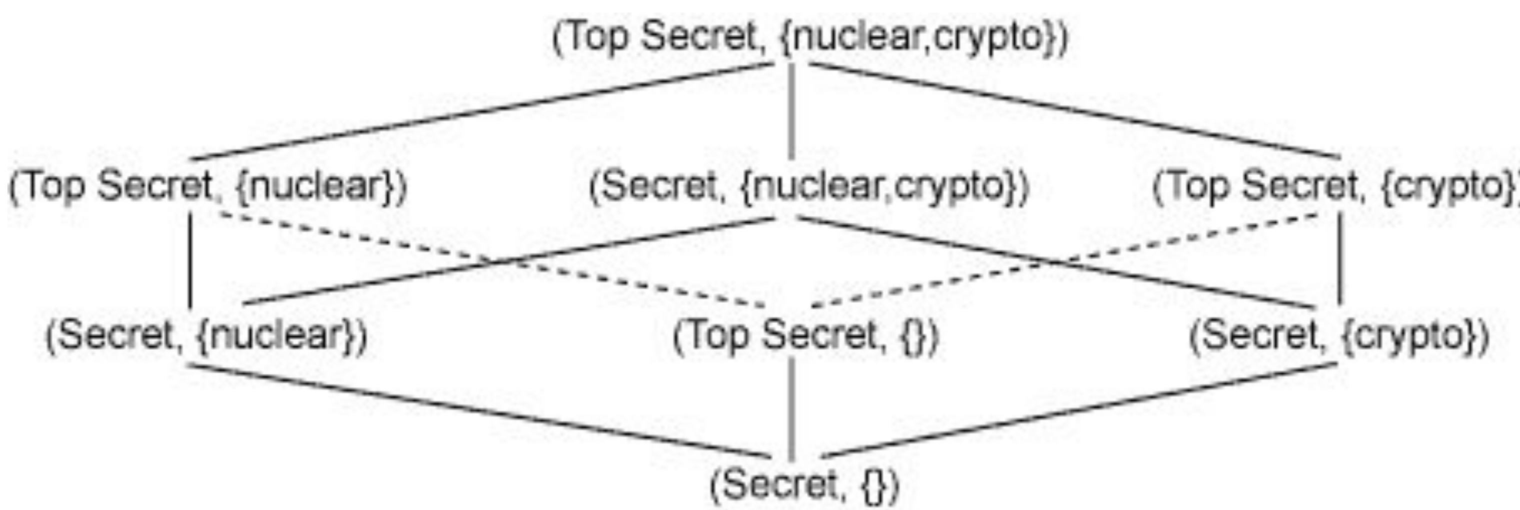
NOFORN

Secrecy Levels + Labels = Lattice (LBAC)

Classification = *partial order relationship*.

Dominance in a lattice is defined as:

$\{C_1,L_1\} \geq \{C_2,L_2\} \Leftrightarrow C_1 \geq C_2$ and $L_2 \subseteq L_1$



(reflexive, transitive, antisymmetric property)

Bell-LaPadula Model (BLP) - 1

Defines two MAC rules:

1. **Rule 1** (no read up, "simple security property")
   A subject s at a given secrecy level **cannot read** an object o at a **higher** secrecy level.
1. **Rule 2** (no write down, "star property")
   A subject s at a given secrecy level **cannot write** an object o at a **lower** secrecy level.

Defines one DAC rule:

Rule 3 (Discretionary Security Property) states the use of an access matrix to specify the discretionary access control.

Bell-LaPadula Model (BLP) - 2

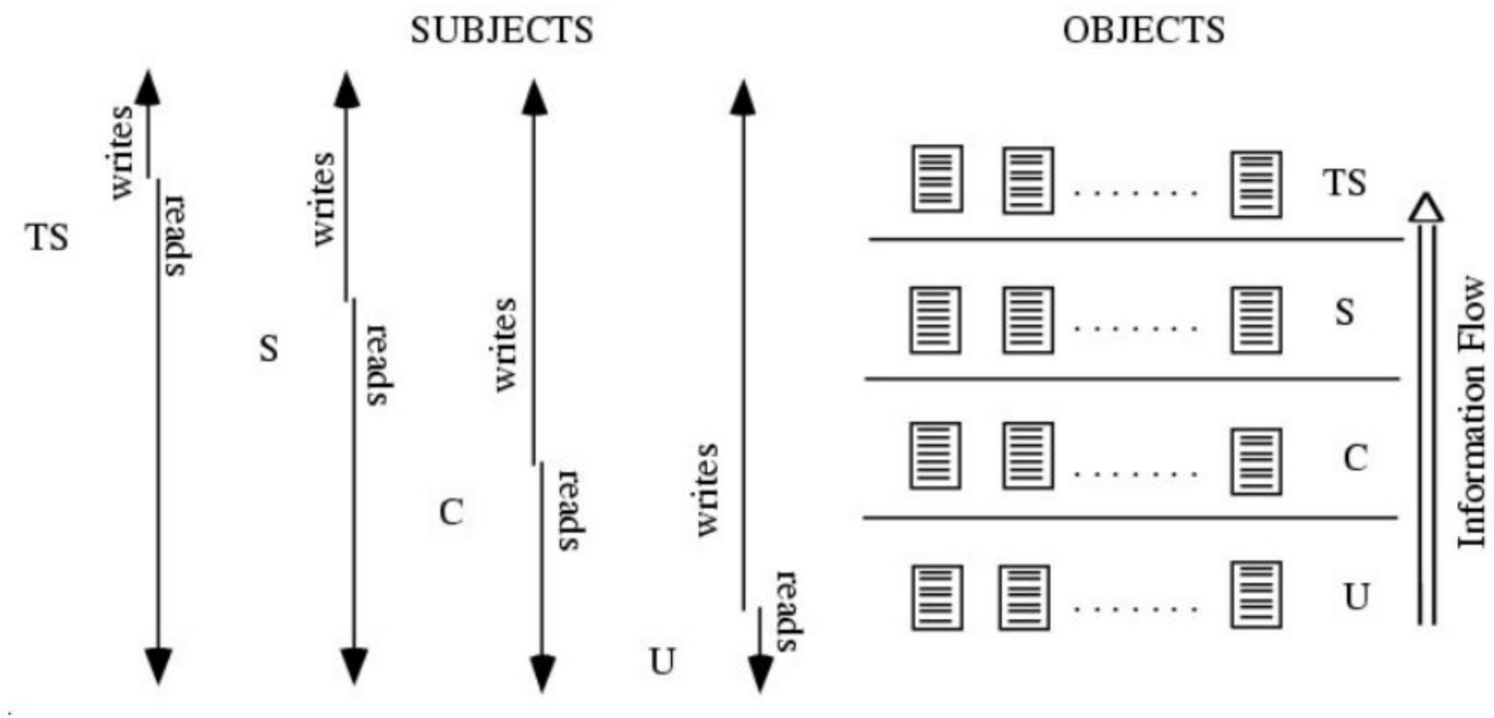
Tranquility property: secrecy levels of objects cannot change dynamically.

Result: monotonic flow of information toward higher secrecy levels

- need of **trusted subjects** who can declassify or sanitize documents

Limitations: does not address integrity. There are other models for integrity, e.g. http://en.wikipedia.org/wiki/Biba_Model

MAC Information Flow



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Conclusions

Access control, or authorization, defines *subjects*, *objects*, and *actions* in a system.

Access control **models** define how actions are (un)assigned to subjects and objects.

DAC are more common and “natural” than **MAC**, but can coexist.