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 Reference Monitor:

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

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

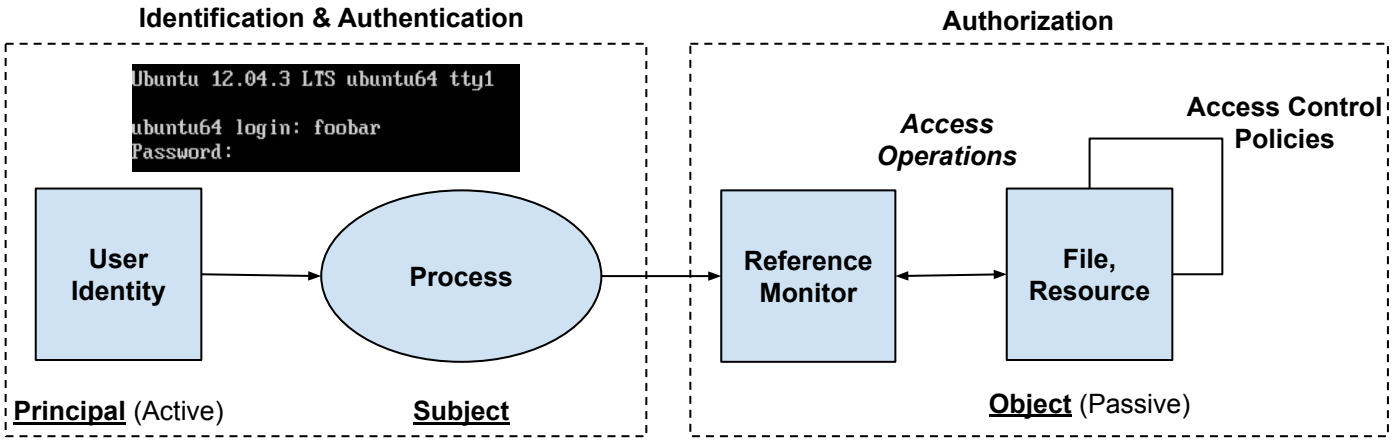
Authentication & Authorization

The reference monitor has to find and evaluate the security policy relevant for the given request:

- verifies the identity of the principal making the request
- decides whether access is granted or denied.

"Easy" in centralized systems but in distributed systems...

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



Access control models

Can be roughly divided in

in chronological order

- Discretionary Access Control (DAC) --> the most used in OSs
- 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 owner *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

In unix everything is a file (also devices) so I can treat files and devices the same way

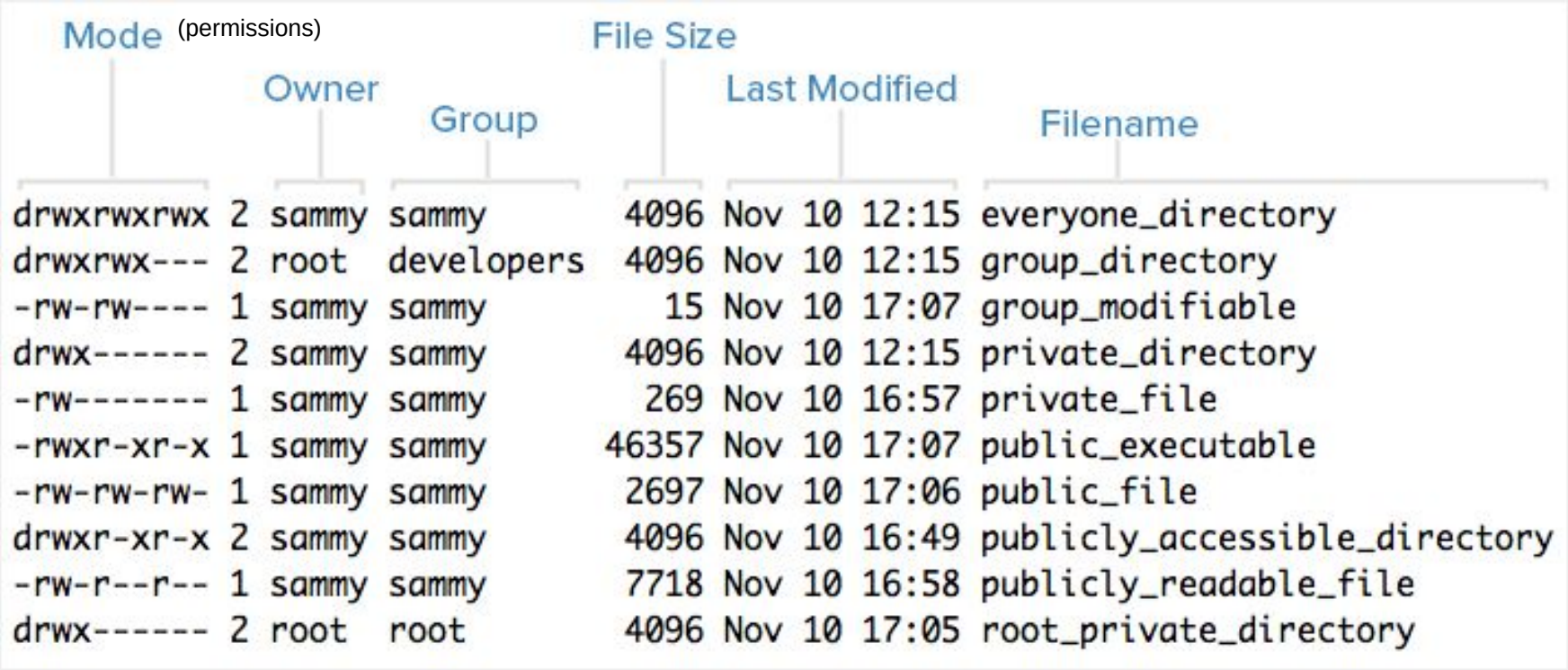
- UNIX
  - **Subjects**: users, groups
  - **Objects**: files (everything, really)
  - **Actions**: read, write, execute
- Windows (not the 95/98/ME branches)
  - **Subjects:** with *roles* instead of *groups*, multiple ownership of users and roles over files
  - **Objects**: files and “other” resources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

"ls -l" on terminal

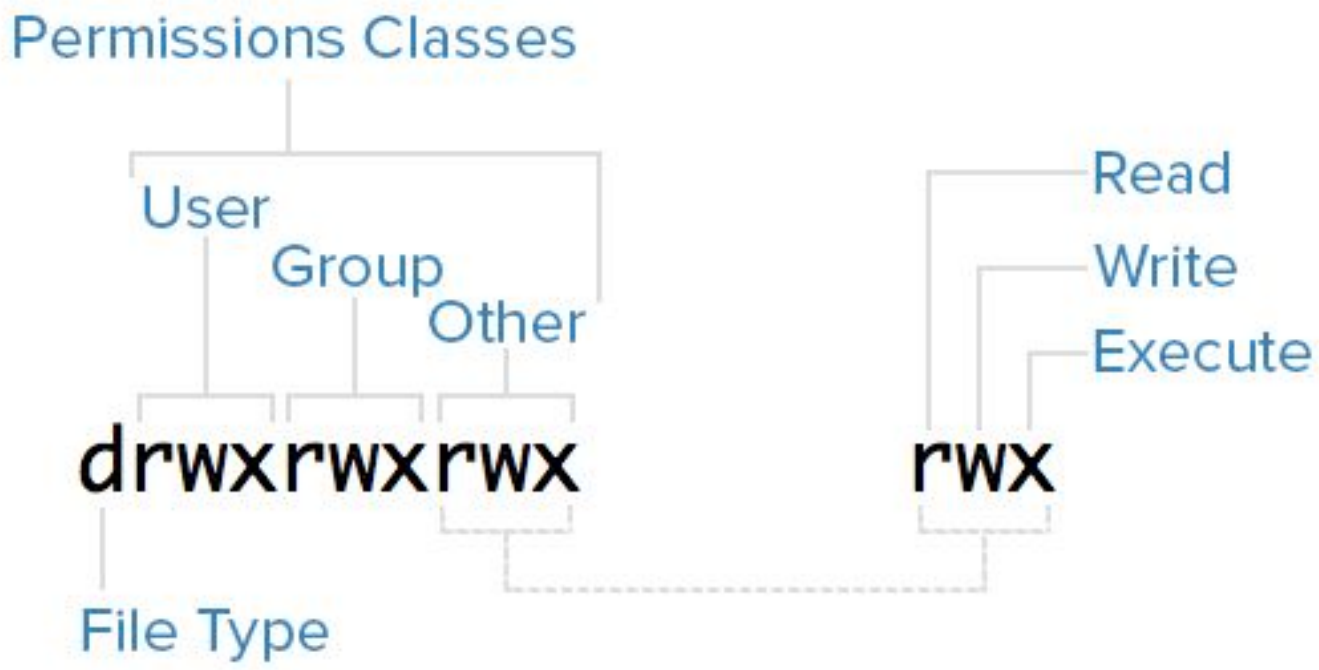
Permissions (r, w, x) **Subjects (user, group)** **Objects (files, dirs, ...)**

```
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

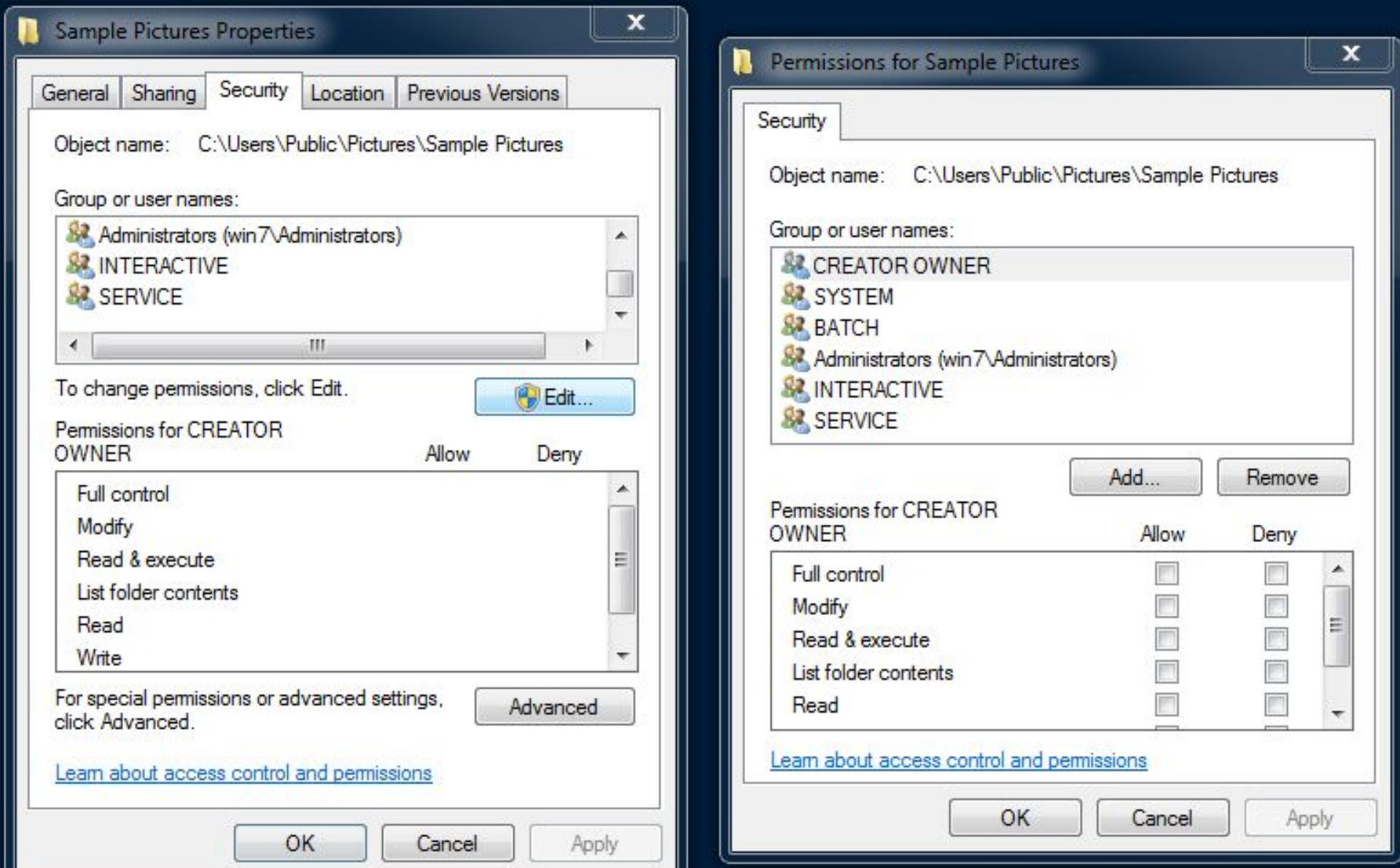


Permissions “Triads”



each letter is a flag, if you see the letter the flag is true, if you see a dash the flag is false

Each triad can be expressed as binary number (1 true, 0 false), and it's usefult to convert the concatenation of these binary numbers in base eight so each triad is represented by a single digit:
es: 755 base eight --> 111101101 -> rwxr-xr-x


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

The matrix is usually sparse

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?

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    - 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 if subjects/objects are finite.

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

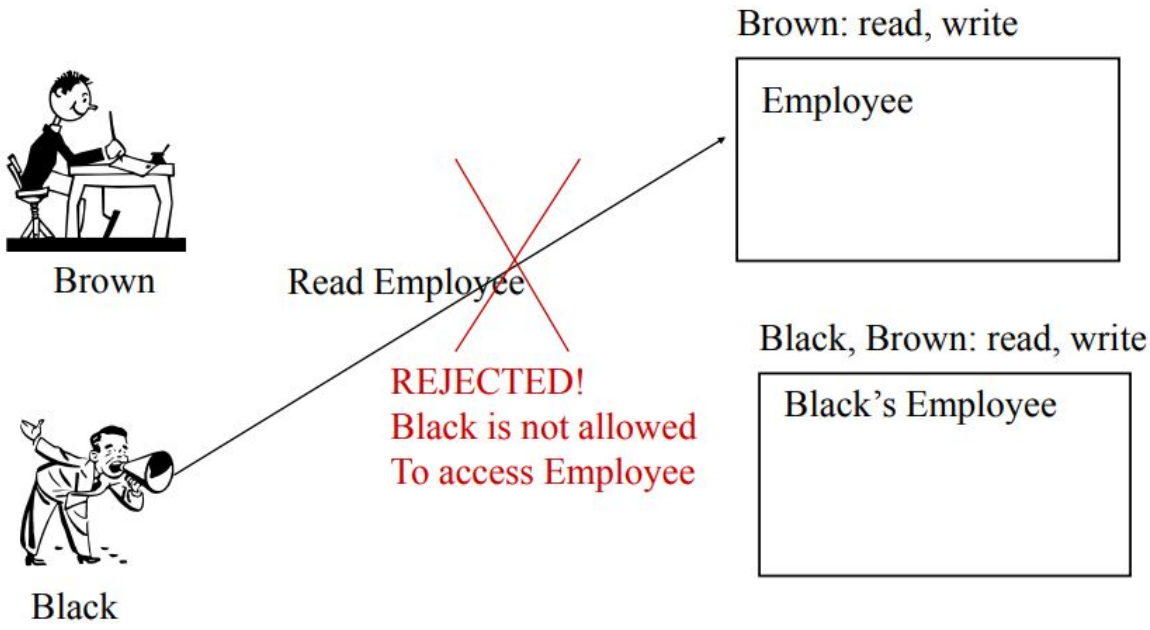
- efficient with **per subject** operations
- Usually **objects** change and **subjects** stay, so inefficient
- Capabilities are optional in POSIX (Linux and BSD).

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 scalability and management
  - each user-owner can potentially compromise security of the system with their own decisions

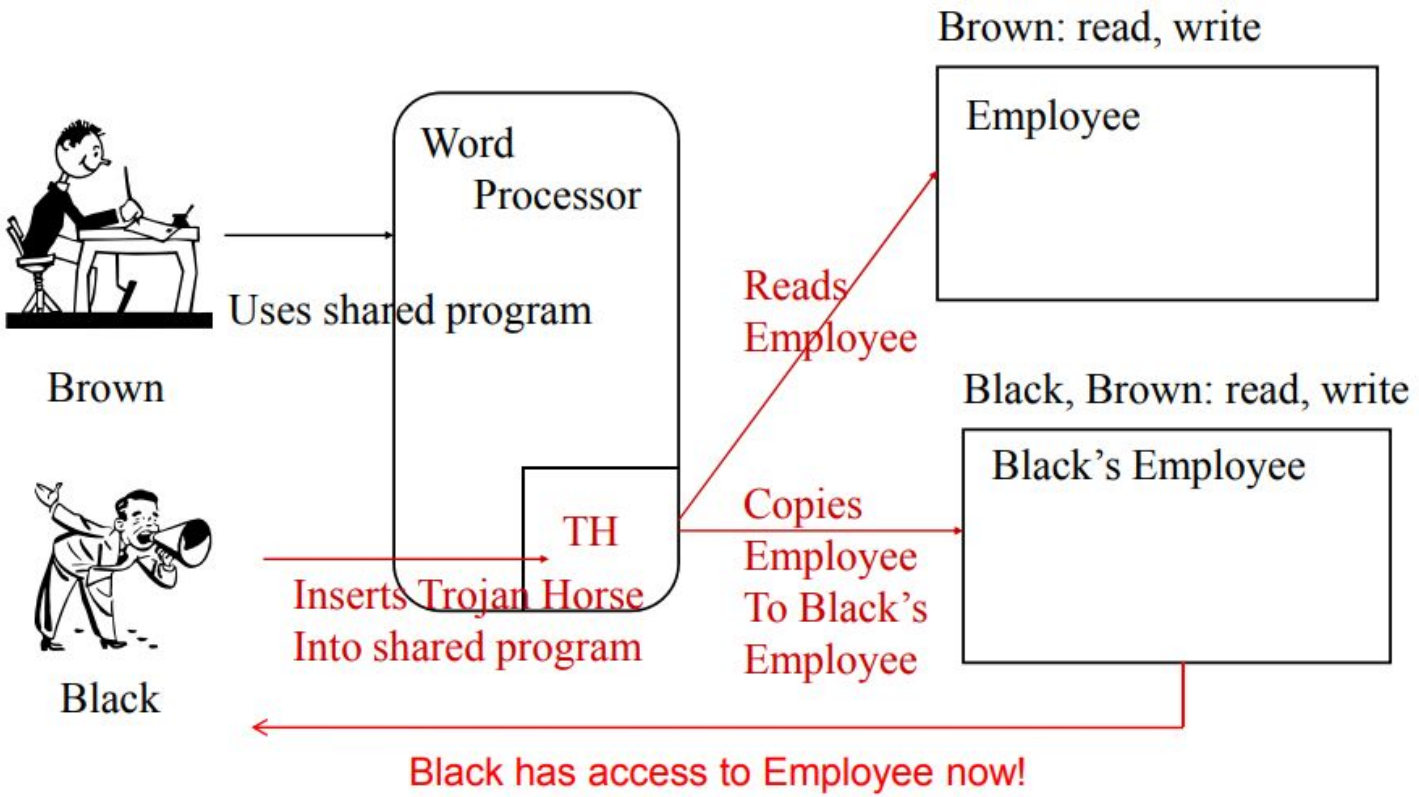
distributed databases scalability

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)

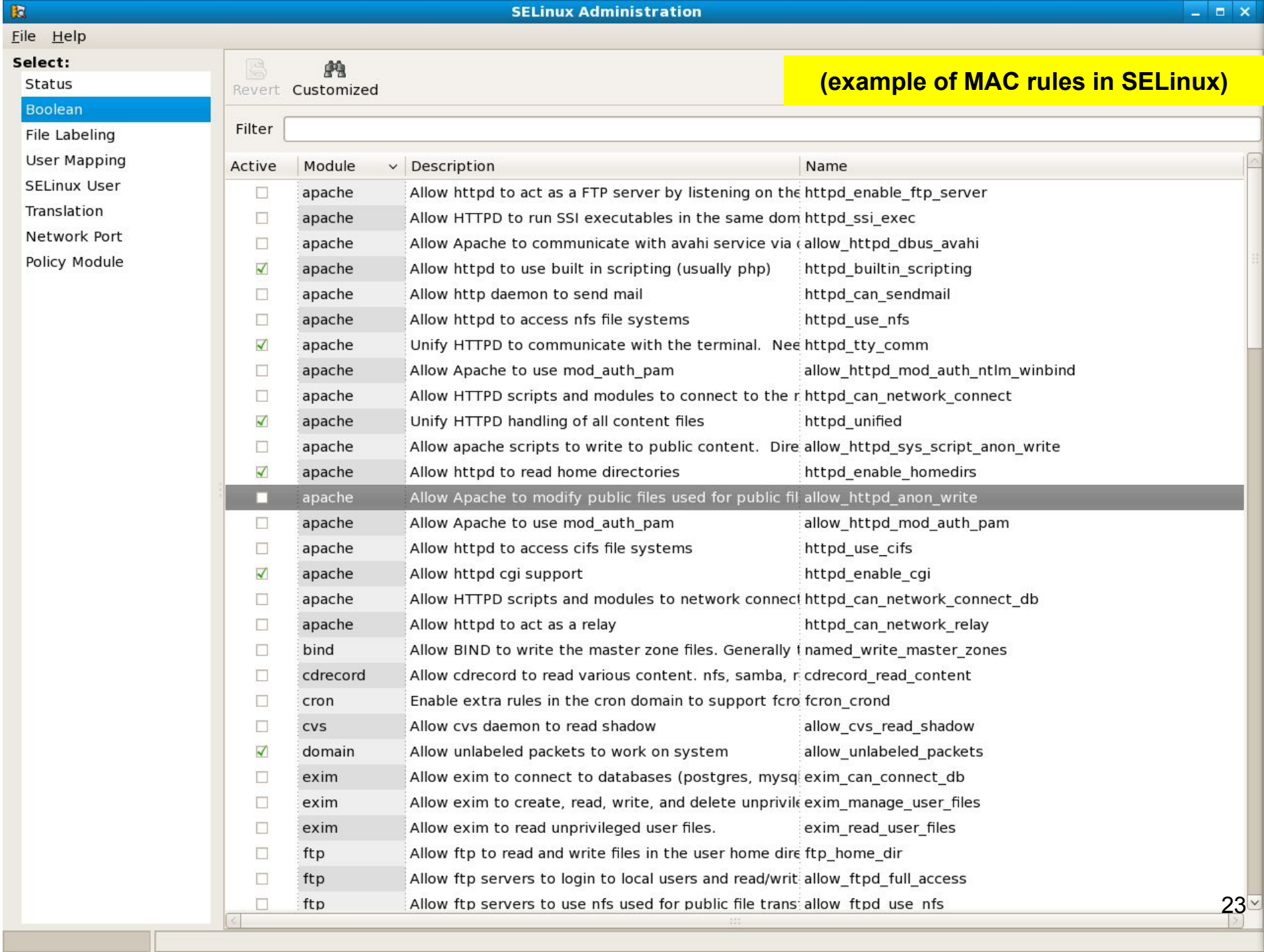
Idea: do not let owners assign privileges.

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
Select:
Status
Boolean
File Labeling
User Mapping
SELinux User
Translation
Network Port
Policy Module
Revert
Customized
(example of MAC rules in SELinux)
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 t 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 (no foreign parties)

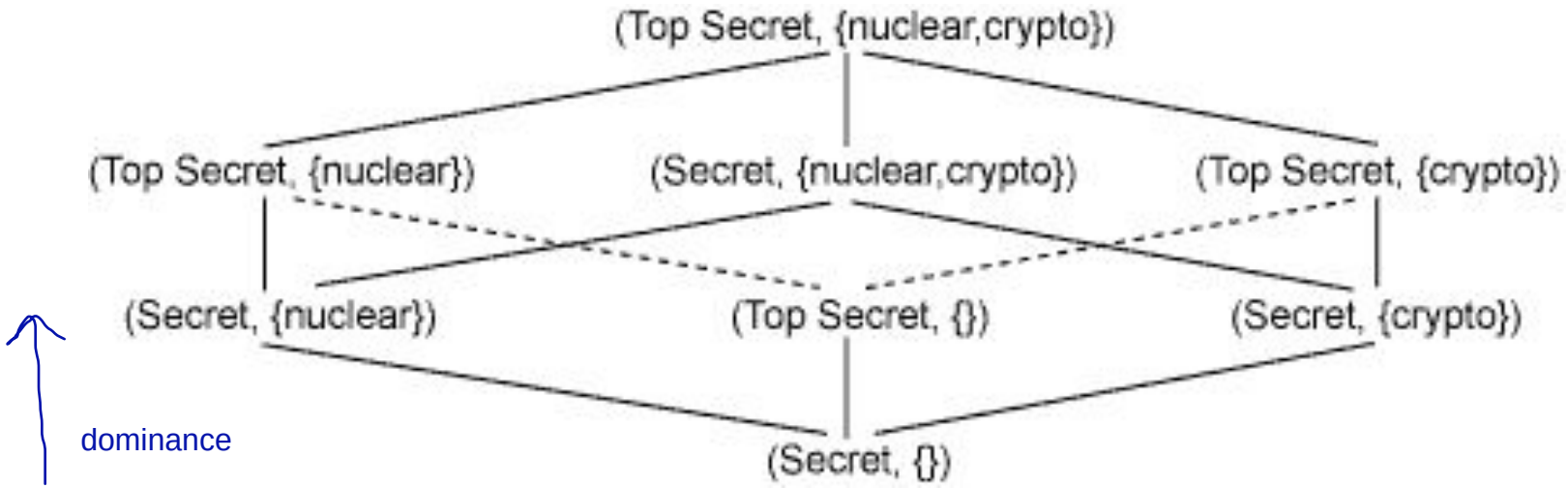
Labels are orthogonal to the classification

Secrecy Levels + Labels = Lattice (LBAC)

Classification = *partial order relationship*.

Dominance in a lattice is defined as:

$\{C1,L1\} \geq \{C2,L2\} \Leftrightarrow C1 \geq C2$ and $L2 \subseteq L1$



(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

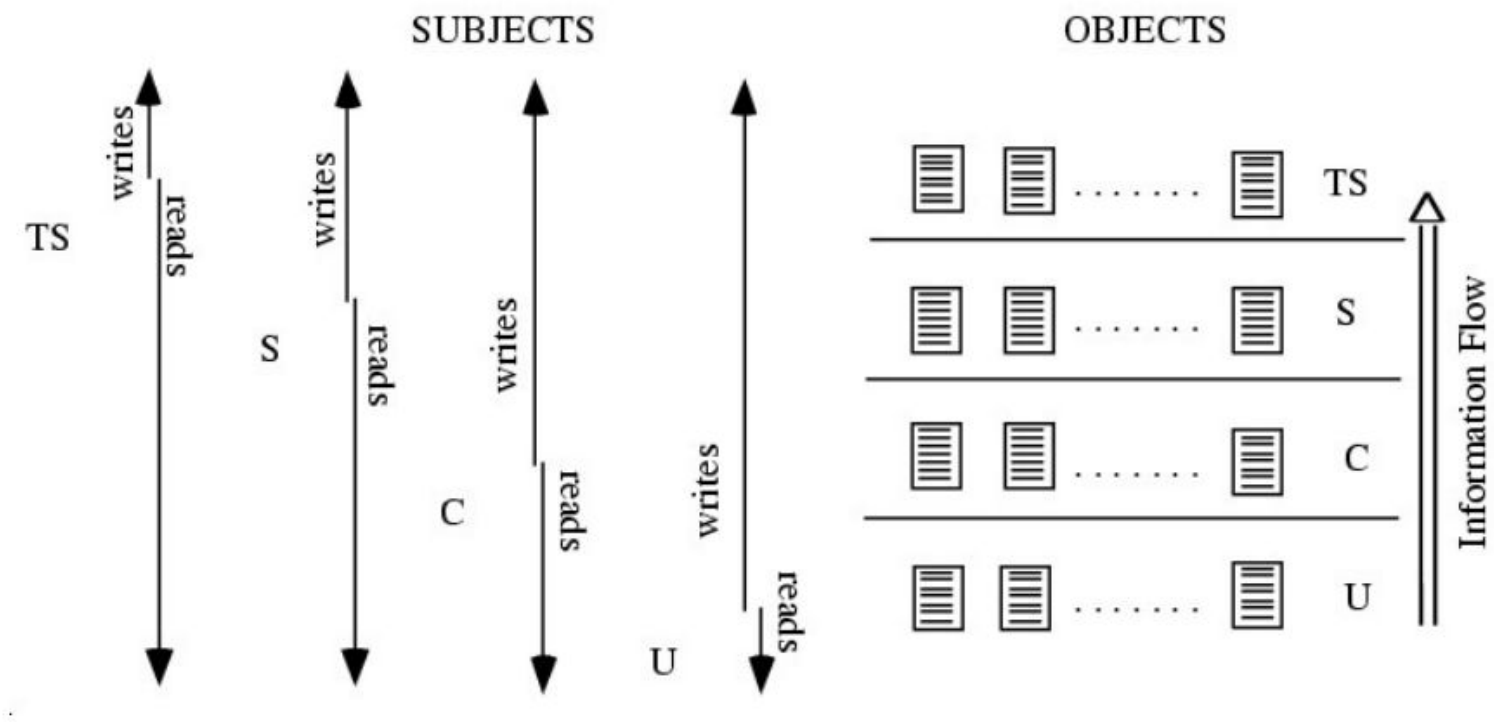
Tranquility property: secrecy levels of objects cannot change dynamically.

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

Bell-LaPadula Model (BLP) Information Flow



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

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.