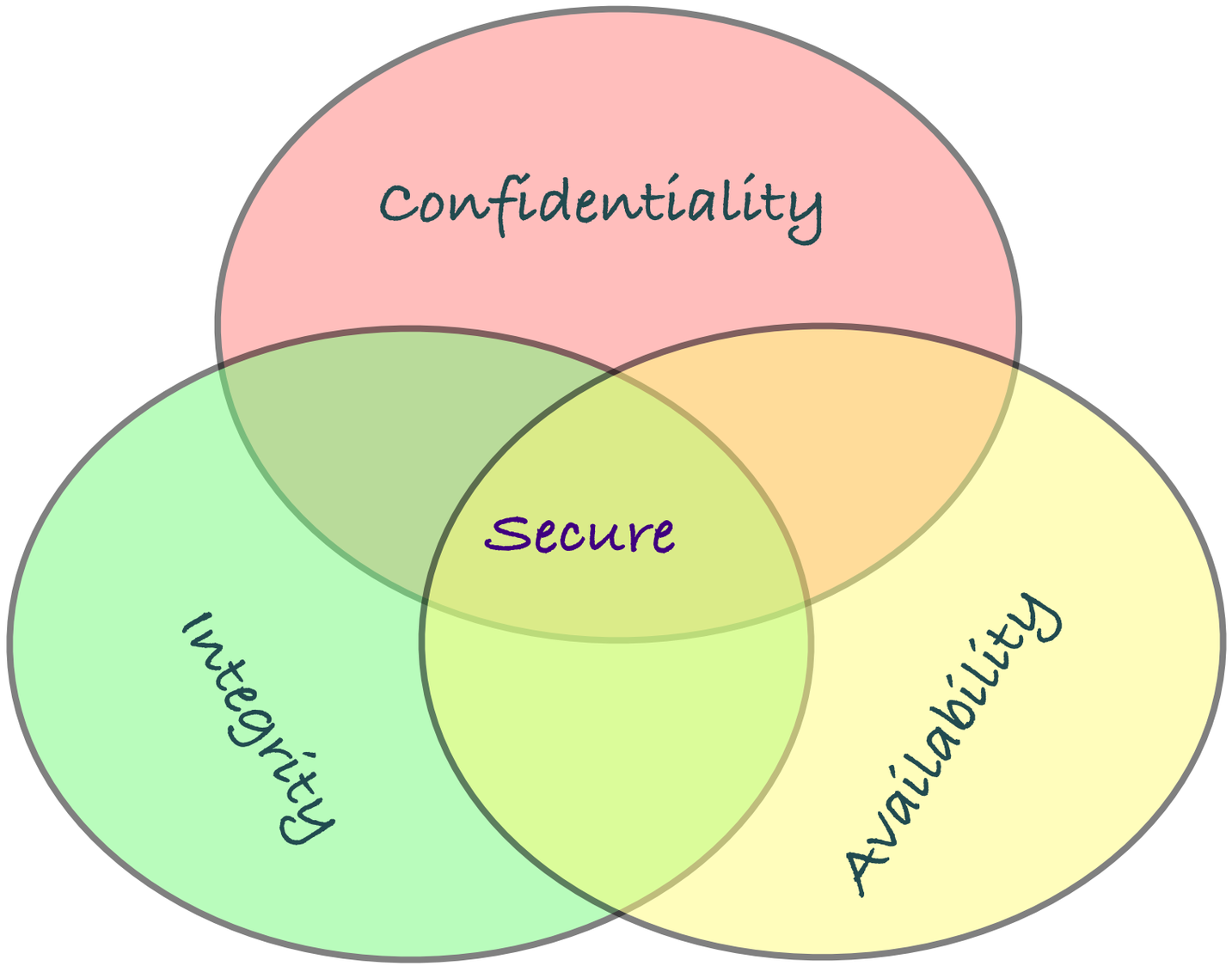
# Security Policies

# Security Targets




**Security:** find the right balance among these objectives

# Policies vs Models

- A *security policy* defines what is allowed
  - ✓ It characterizes the acceptable system's runs, or viceversa, those that are not acceptable
    - Analogous to a set of laws
    - It is defined in terms of high level rules and requirements that should be well defined, coherent and implementable

- A *security model* provides a formal representation of a set of IT systems, underlying the needed security features
  - ✓ It is an abstract description of system's behaviors and it is the formal base for designing policies

# Policies vs Models

- A system model describes what a user can do, not necessarily what it is authorized to do.

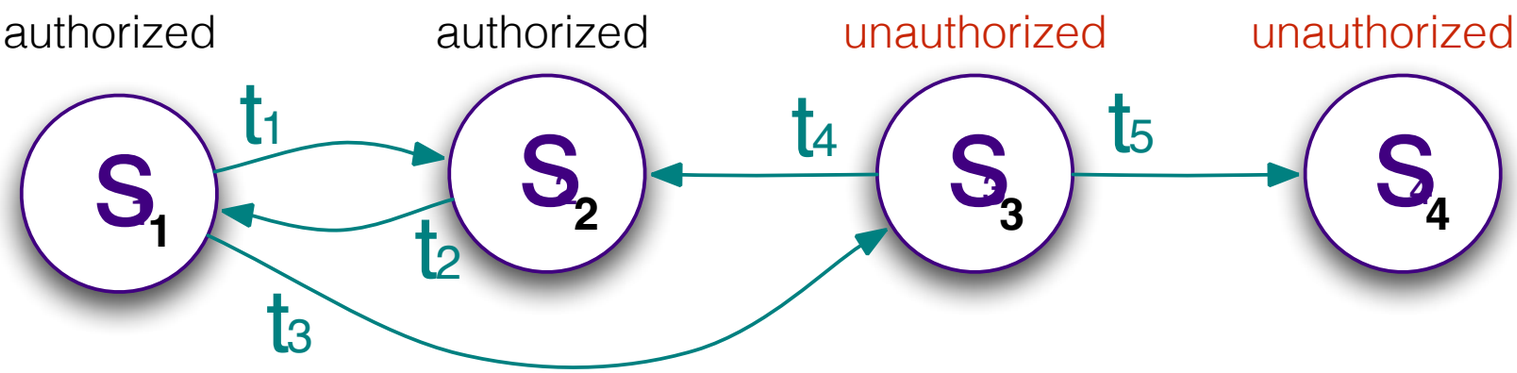
Soundness: The system satisfies the security properties (Are all reachable states authorized?)

- When a model is sufficiently formal, soundness is well defined:

$$\text{System} \models \text{Security property}$$

# Secure System

* *Secure system*: It is a system that starting from an authorized state can only enter in an authorized state



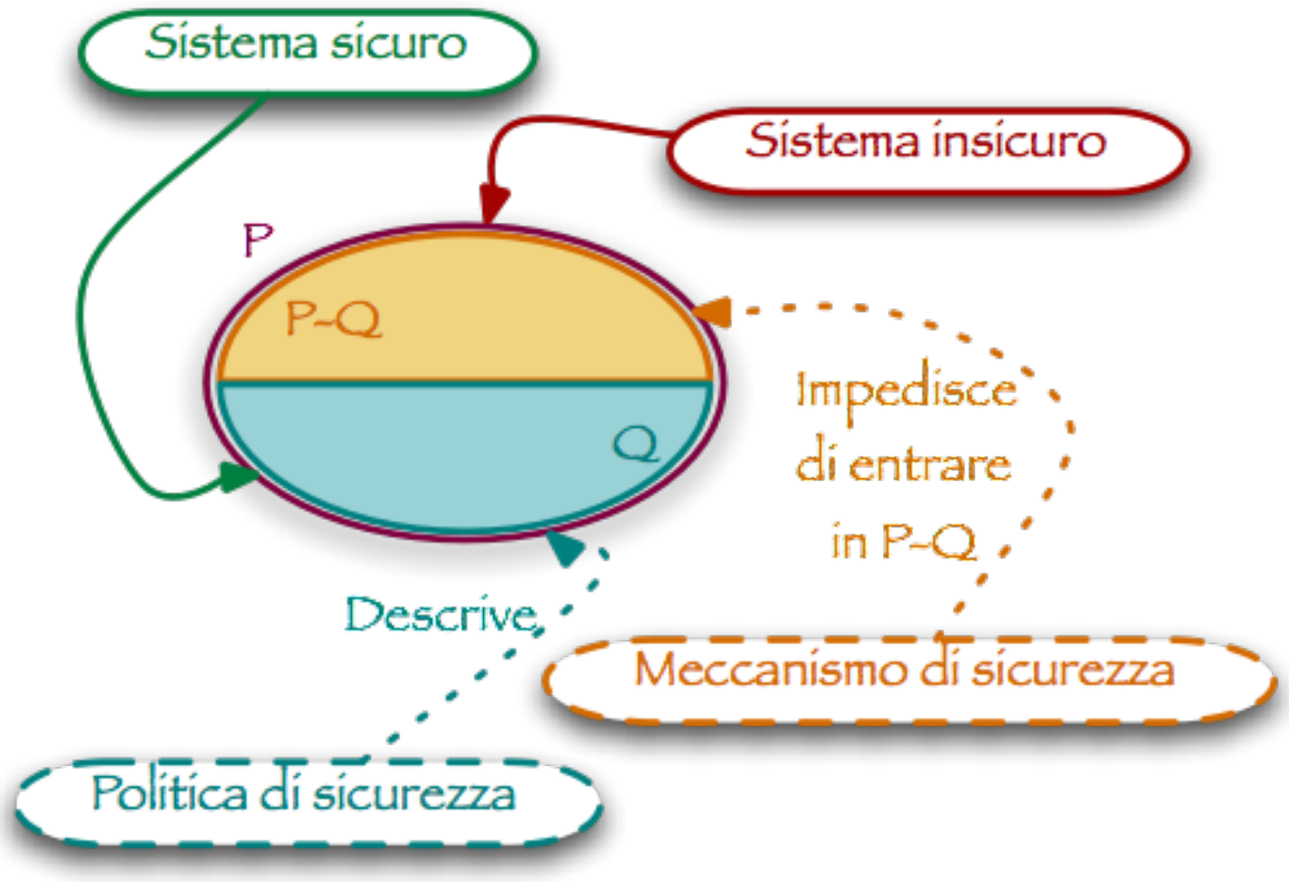

* *Security breach*: occurs when a system enters an unauthorized state.

# Secure System

- Policies and models are formalized in terms of *states* of the system
- A *state of a system* collects the current values stored in memory locations, registers and it provides a snapshot of the system in a certain instant of time
- The subset of information contained in a system state that regards protection is called *protection state:*
  - ✓ *File system*: portion of the system state that contains information on who is writing/reading a file, information on access control, etc…
  - ✓ *Program*: portion of the state system that provides a run-time image of program execution and contains information such as the value of the program counter, of the call stack, etc…
  - ✓ …
- *Abstraction*: A computer system is represented as a transition system!

# Secure System

- Let P be the state space of the system, and let Q ⊆ P be the set of authorized system states
  - ✓When the system is in a state in Q then the system is secure
  - ✓When the system is in a state in P ⧹ Q the system is not secure




- A security policy partitions the system states P in secure and insecure states
- A system is secure when starting from a secure state cannot enter an insecure state

# Secure System

- A policy is defined as a set of authorized/secure states
- Sometimes being authorized/secure may *depend on the history of computation* and therefore this cannot be decided by looking only at the current state
  - ✓ Example: a policy that does not allow to add an object that has been previously deleted
- To handle this kind of security requirements it is necessary to use a policy defined on system traces, thus a policy that defines the set of *authorized/secure traces:*

  $s_0\ s_1\ s_2\ s_3\ \ldots$

- A *system is secure* when every trace is authorized/secure

# Types of Security Policies

- It is important to identify the adeguate security policy for a system
- *Military security policy* (or *governmental* security policy) is a security policy developed primarily to provide *confidentiality* where information is classified as *non-classified, limited, classified, secret, top-secret.*
- *Commercial security policy* is a security policy developed primary to provide *integrity*
- *Confidentiality policy (Information-flow policy)* is a security policy dealing only with *confidentiality*
- *Integrity policy* is a security policy dealing only with *integrity*

# Examples of Policies

Security policy for e-banking

A client of the bank can see its balance and the transactions he/she has made. He/she can transfer money from his/her account to another account for amounts less or equal to 10.000 Euro. For bigger amounts the approval of a manager is needed….

Security policy for privacy

A user can access personal data only if this access is needed for accomplishing his/her current task and only if the user is allowed to execute such a task. Moreover, the goal of the current task has to correspond to the goals for which the personal data were originally collected, otherwise the user has to obtain an explicit permission.

It combines conditions with constraints on how data has to be used

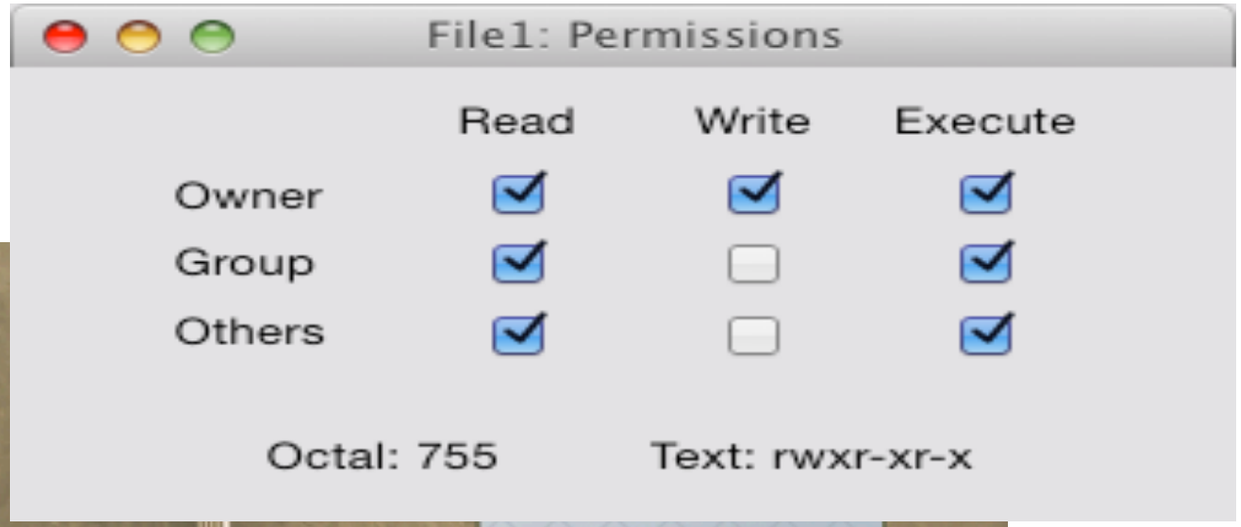
# Access Control

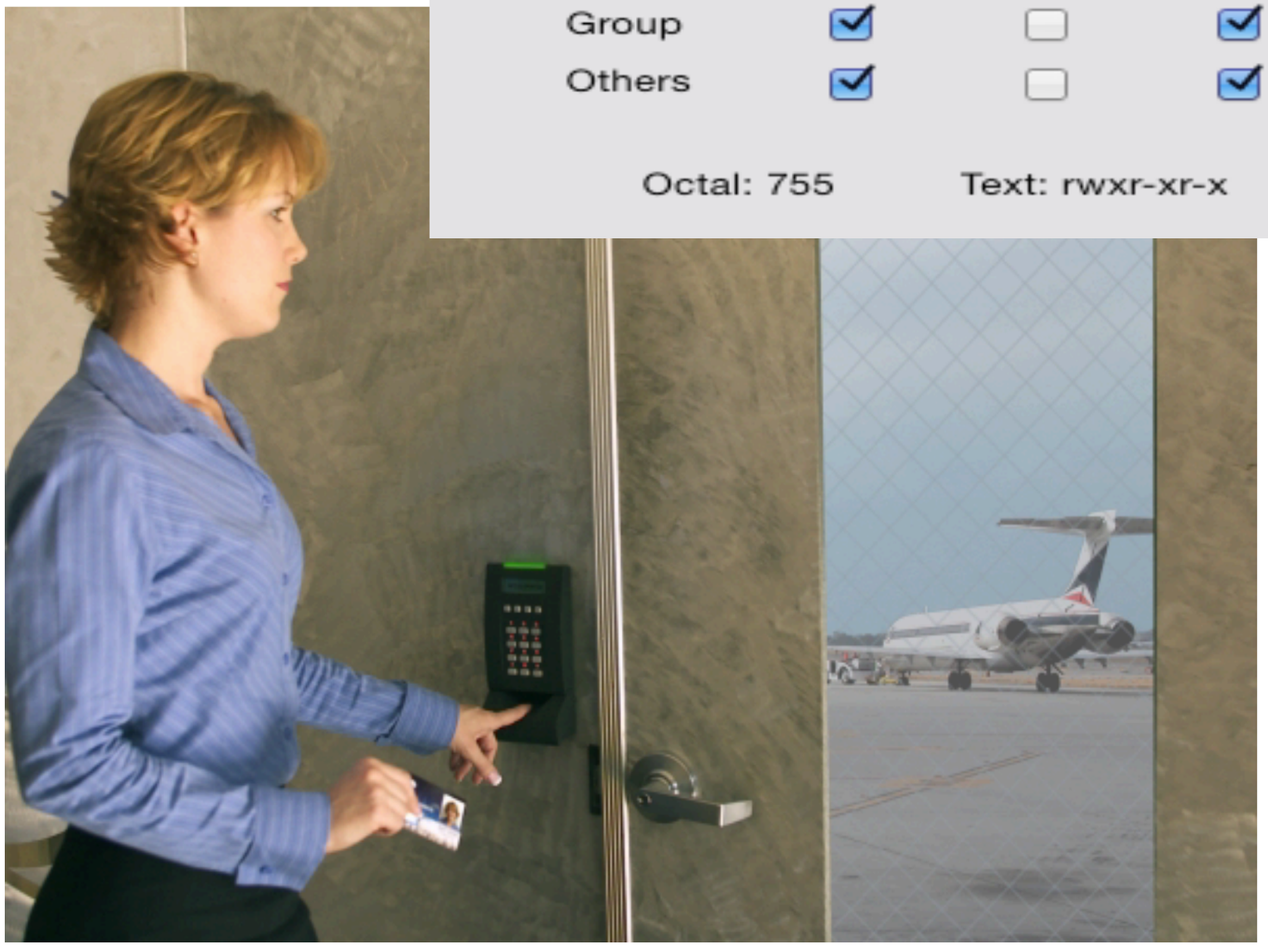
# What is access control?

- Central element of cyber security
- The prevention of unauthorized use of a resource, including the prevention of use of a resource in an unauthorized manner
- Involves users and groups
  - ✓authenticate to system
  - ✓assigned access rights to certain resources on system

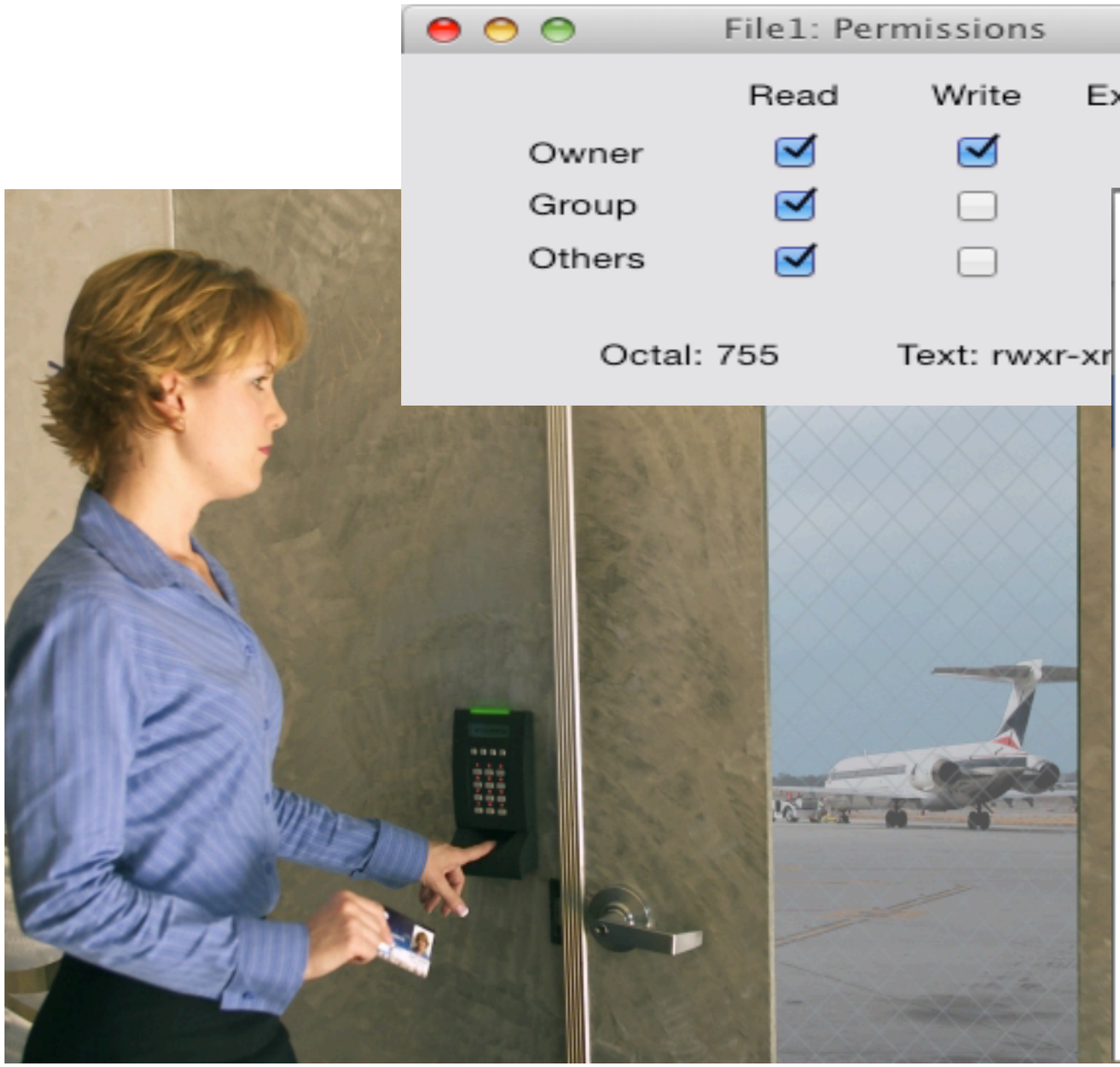
# Access control in use

# Access control in use

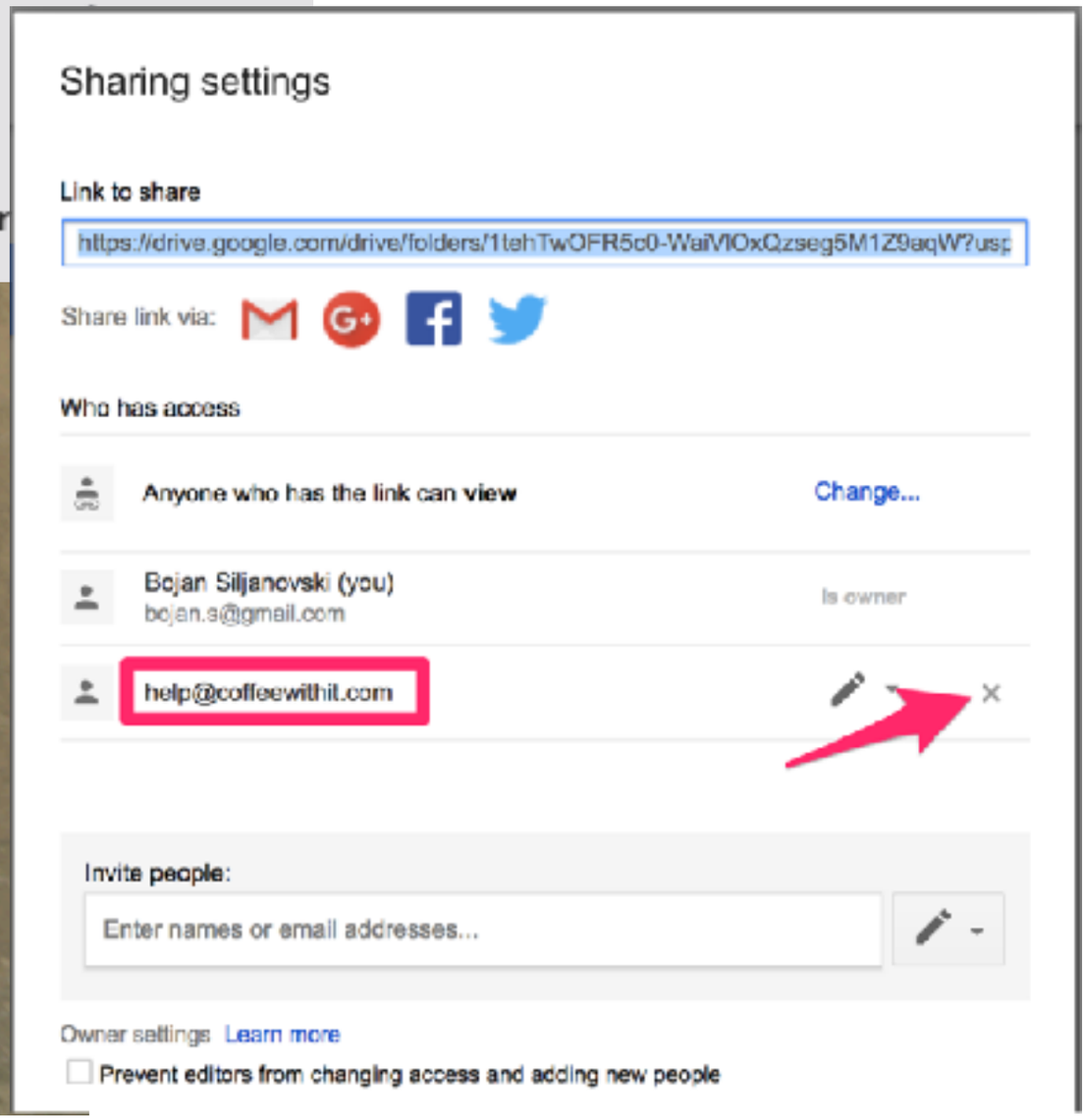


# Access control in use

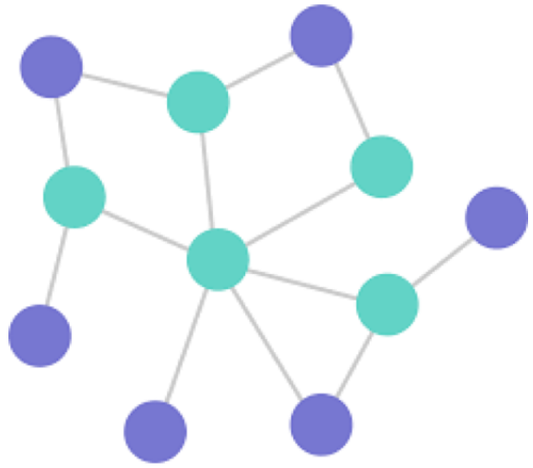




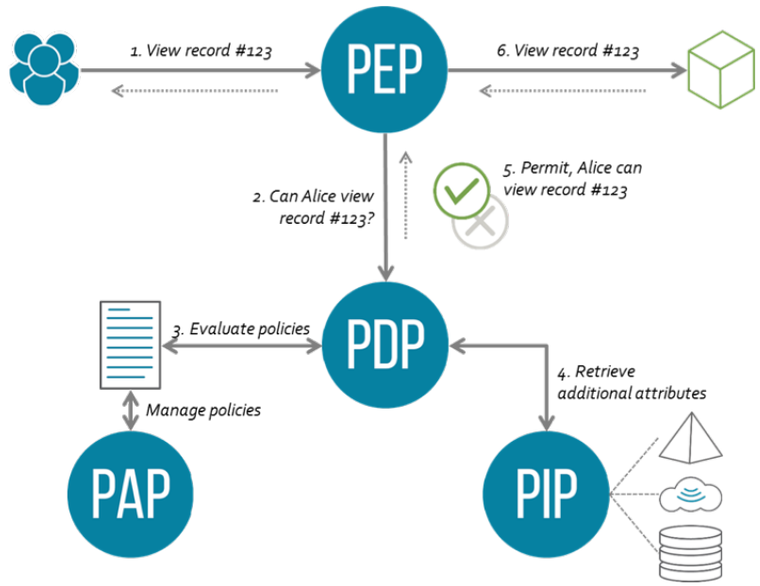



# Access Control system

**Access Control Policies**



**Access Control Model**




**Access Control Mechanism**

# Access Control

Access Control
- ✓Authentication
- ✓Authorization
- ✓Auditing

Security Manager


User

Authentication

Reference Monitor

Access Control


Resources

Audit

# Access control principles

* Authentication
  - ✓The verification an identity claimed by or for a system entity
* Authorization
  - ✓The granting of a right or permission to a system entity to access a system resource
* Audit
  - ✓The monitoring and processing of user accesses to system resources

# Auditing

- Two main components:
  - ✓ Collection and organization of data for verification
  - ✓ Analysis of the collected data to discover security violations
- Intrusion detection:
  - ✓ Passive: offline analysis to detect intrusions already happened
  - ✓ Active: real-time analysis for an immediate response for protection
- Problems
  - ✓ Decide what has to be monitored
  - ✓ How to automatically decide violations (offline or real-time)
- Solutions
  - ✓ Anomaly detection: exploit of vulnerabilities typically corresponds to unusual system behaviors
  - ✓ Detection of use of the system that is not allowed: rules that specify the allowed sequences of events of the system

# Access Control Requirements

- Reliable Input:
  - ✓ an access control system assumes that a user is *authentic*
- Support for fine and coarse specifications:
  - ✓ The access control system should support *fine-grained specifications*, allowing access to be regulated at the level of individual records in files. Moreover, each individual access should be controlled rather than a sequence of access requests.
- Least privilege (*Need-to-know*): each system entity is granted the minimum system resources and authorizations that the entity needs to do its work
  Separation of duty: dividing the steps in a system function among different individuals
- Open and close policies: specify what is allowed (close) or not allowed (open)
- Policy combination and conflict resolution
- Administrative policies: Specifies who can add, delete, modify the authorizations rules

# Access control policy elements: subjects

**Subject** is an entity capable of accessing an object.
Generally the concept of subject equates with that of process that actually accesses the object

- There are three different types of subjects
  - ✓ **Owner**: this may be the creator of a resource, i.e. a file
  - ✓ **Group**: a named group of users may be granted access rights. The membership to the group is enough to exercise access rights. A user may belong to multiple groups
  - ✓ **World**: the least amount of accesses and rights is granted to users that can access the system but that do not belong to the owners or to a group

# Access control policy elements: objects

**Object** is a resource to which access is controlled. It is an entity used to contain and/or receive information (records, pages, files, directories, mailboxes, messages, programs…)

- The number and types of objects to be protected by an access control system depends on the environment in which access control operates and the desired trade-off between
  - security
  - complexity
  - ease of use

# Access control policy elements: access rights

Access right describes the way in which a subject may access an object

* Examples of access rights
  - ✓ Read: subject may view, copy and print information
  - ✓ Write: subject may add, modify or delete data, it includes read access
  - ✓ Execute: subject may execute certain programs
  - ✓ Delete: subject may delete certain resources
  - ✓ Create: subject may creare certain resources
  - ✓ Concatenate: (append or blind write)
  - ✓ Search: subject may list or search a resource

# Access Control Policies

* **Discretionary Access Control (DAC):** access control based on the *identity of the requestor* and on access rules
* **Mandatory Access Control (MAC):** access control based on *comparison of security labels* that indicate how sensitive the resources are with security clearance that indicate the resources that an entity can access
* **Role-based access control (RBAC):** access control based on the *roles that users have* within the system and on rules stating what accesses are allowed to users in a given role
* **Attribute-based Access Control (ABAC):** access is based on identity attributes of the subject, the object, and the context

# Discretionary Access Control DAC

# Discretionary Access Control DAC

Users own resources and control the access to resources

- Access to data objects (files, directories, etc.) is permitted based on the *identity* of users.
- Owner controls the access rights of objects and of other users
- Discretionary: users can be given the ability of passing on their privileges to other users, where granting and revocation of privileges is regulated by an administrative policy
- Flexible mechanism prone to errors:
  - ✓it is necessary that all users understand the mechanism and respect the security policy
  - ✓there is no control on the flow of information
- often provided using an access matrix

# Access Control Matrix

- Provides the relations among objects (passive entities) and subjects (active entities) in terms of access rights. The two dimensions of the matrix represent:
  - Identified subjects that may attempt to access resources
  - Objects that may be accessed

objects

| subjects | news.doc | photo.png | fun.com |
|---|---|---|---|
| alice | read | view<br>edit | view |
| bob | read<br>write | view<br>edit | view<br>modify |
| charlie | | | |
| dave | | view | |

# Access Control List

news.doc

| | |
|---|---|
| bob | read<br>write |
| alice | read |

photo.png

| | |
|---|---|
| alice | view, edit |
| bob | view, edit |
| dave | view |

fun.com

| | |
|---|---|
| alice | view |
| bob | view<br>modify |

# Capability List

Alice's capability

| news.doc | photo.png | tun.com |
|---|---|---|
| read | view, edit | view |

Bob's capability

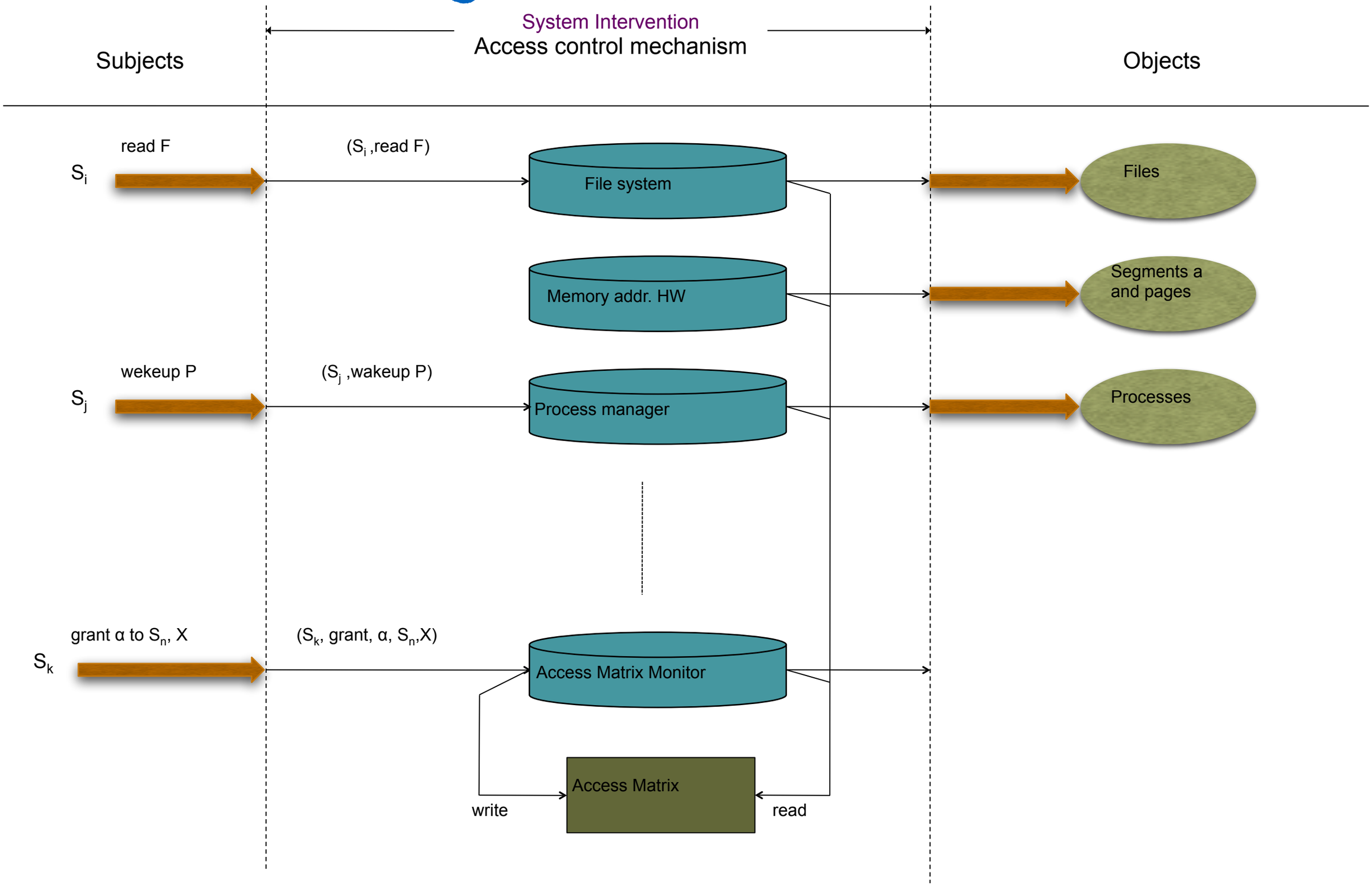
| news.doc | photo.png | fun.com |
|---|---|---|
| read<br>write | view, edit | view<br>edit |

Charlie's capability

Dave's capability

| photo.png |
|---|
| view |

# Verify the protection state



# Examples of DAC policies

- Graham-Denning Model (1972)
- Harrison-Ruzzo-Ullman Model (HRU)
- Take-Grant Model

# Graham-Denning Model (1972)

- DAC access control mechanism based on protection rules
- subjects S, objects O, rights R, matrix M
- Objects have owners with special privileges and subjects have controllers with special privileges
- There are 8 protection rights:
  - ✓create/delete objects
  - ✓create/delete subjects
  - ✓Read access rights
  - ✓Grant access rights
  - ✓Delete access rights
  - ✓Transfer access rights

# Graham-Denning Model: RULES

| Rule | Command (from $s_0$) | Condition | Operation |
|---|---|---|---|
| R1 | create o | -- | add column for o in M;<br>insert 'owner' in $M[s_0,o]$ |
| R2 | delete o | 'owner' in $M[s_0,o]$ | deletes column for o in M |
| R3 | create s | -- | add a row for s in M;<br>insert 'control' in $M[s_0,s]$ |
| R4 | delete s | 'control' in $M[s_0,s]$ | delete row for s in M |
| R5 | read the access right of s on o | 'control' in $M[s_0,s]$ or 'owner' in $M[s_0,o]$ | copy M[s,o] in $s_0$ |
| R6 | grant r [r*] for s on o | 'owner' in $M[s_0,o]$ | add r [r*] in M[s,o] |
| R7 | delete r from s on o | 'control' in $M[s_0,s]$ or 'owner' in $M[s_0,o]$ | remove r in M[s,o] |
| R8 | transfer r[r*] for s on o | 'r*' in $M[s_0,o]$ | add r[r*] in M[s,o] |

# Harrison-Ruzzo-Ullman Model (HRU)

## S will access O?

- Access control model based on commands, where every command involves conditions and primitive operations
- *commands* determine the transition from one state to another one when specific conditions are satisfied
- Let $\mathbf{X_0=(S_0,O_0,M_0)}$ be the **initial state** of a system, where **M** is the access matrix
- The set of *state transitions* is represented as a set of operations $\mathbf{t_1,t_2,t_3,}$ and successive states are represented as $\mathbf{X_1, X_2}$… where the notation

$$\mathbf{X_i \vdash_{t(i+1)} X_{i+1}}$$

  means that the *state transition* $\mathbf{t_{i+1}}$ moves the system from state $\mathbf{X_i}$ to $\mathbf{X_{i+1}}$

- $\vdash^*$ denotes the transitive closure of $\vdash$
- Every *command* corresponds to a <u>sequence of transition operations</u>

# HRU: Primitive Operations

- We define a set of primitive commands that alter the access control matrix **M**
  - ✓ **create (subject) s**
  - ✓ **create (object) o**
  - ✓ **destroy (subject) s**
  - ✓ **destroy (object) o**
  - ✓ **enter (right) r into M[s,o]**
  - ✓ **delete (right) r from M[s,o]**

# Transitions

State transitions are modeled by command execution, where S, O and M are the subjects objects and access matrix before execution and S', O' and M' are the subjects objects and access matrix after execution

| Operation | Conditions | New State |
|---|---|---|
| **enter r into M**[s,o] | $s \in S$, $o \in O$ | $S'=S$<br>$O'=O$<br>$M'[s,o]=M[s,o] \cup \{r\}$<br>$M'[s_1,o_1]=M[s_1,o_1]\ \forall (s_1,o_1) \neq (s,o)$ |
| **delete r from M**[s,o] | $s \in S$, $o \in O$ | $S'=S$<br>$O'=O$<br>$M'[s,o]=M[s,o] \setminus \{r\}$<br>$M'[s_1,o_1]=M[s_1,o_1]\ \forall (s_1,o_1) \neq (s,o)$ |
| if $s \notin S$ or $o \notin O$ | then | $(S',O',P')=(S,O,P)$ and the request fails |

# Transitions

Assumption: all subjects are objects $S \subseteq O$

| Operation | Condition | New State |
|---|---|---|
| **create (subject)** s' | $s' \notin O$ | $S'=S \cup \{s'\}$<br>$O'=O \cup \{s'\}$<br>$M'[s,o]=M[s,o]\ \forall s \in S, o \in O$<br>$M'[s',o]= \varnothing$ per $o \in O$<br>$M'[s,s'] = \varnothing$ per $s \in S$ |
| **create (object)** o' | $o' \notin O$ | $S'=S$<br>$O'=O \cup \{o'\}$<br>$M'[s,o]=M[s,o]\ \forall s \in S, o \in O$<br>$M'[s,o']= \varnothing$ per $s \in S$ |

# Transitions

Assumption: all subjects are objects $S \subseteq O$

| Operation | Condition | New State |
|---|---|---|
| **destroy (subject)** s' | $s' \in S$ | $S'=S \setminus \{s'\}$<br>$O'=O \setminus \{s'\}$<br>$M'[s,o]=M[s,o]\ \forall s \in S', o \in O'$ |
| **destroy (object)** o' | $o' \in O$<br>$o' \notin S$ | $S'=S$<br>$O'=O \setminus \{o'\}$<br>$M'[s,o]=M[s,o]\ \forall s \in S', o \in O'$ |

If the conditions are not satisfied then (S,O,M) = (S',O',M') and the request fails

# Commands

- A command is structured as follows:

**command** name ($o_1$,$o_2$,...$o_k$)
  **if** $r_1$ in M[$s_1$,$o_1$]
    $r_2$ in M[$s_2$,$o_2$]
    ...
    $r_m$ in M[$s_m$,$o_m$]
  **then**
    $op_1$
    $op_2$
    ...
    $op_n$
**end**

r = right
op = primitive operation

# HRU: Example

```
command create_file (s,f)
        create f
        enter 'owner' in M[s,f]
        enter 'read' in M[s,f]
        enter 'write' in M[s,f]
end
```

✓ When **s** creates a file **f**, **s** is the owner of **f** with read and write access on the file

```
command grant_read (s,p,f)
    if    'owner' in M[s,f]
    then
        enter 'read' in M[p,f]
end
```

✓ The owner **s** of the file can grant read access to another subject **p**

# HRU: Definitions

- An authorization system is defined by a *set of commands* and by its state, captured by the *access matrix*
- The effect of a command is recorded as a *change* to the access matrix
- The HRU model can capture security policies regulating the allocation of access rights
- To **verify** that a system complies with such a policy, you have to check that there exists **no way for undesirable access rights to be granted**

# Take-Grant Systems

## Can the safety of a particular system, with specific rules, be established?

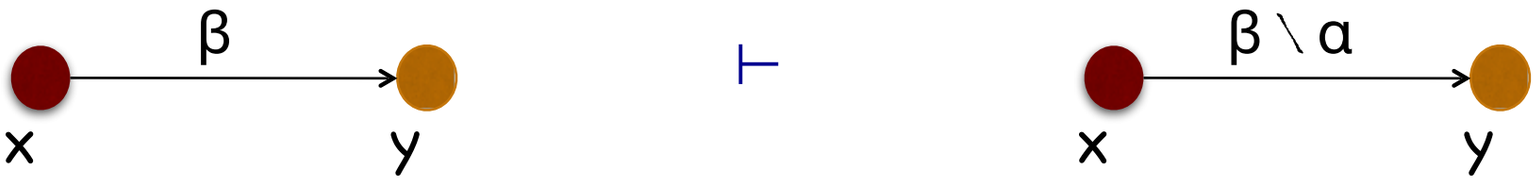
- Consider the protection models Take-Grant
- Four primitive operations:
  - ✓ **create**
  - ✓ **remove**
  - ✓ **take (t)**
  - ✓ **grant(g)**

- Subjects **S** (denoted ● ), objects **O** (denoted ● ), rights **R**
- Graph: Nodes = **S**∪**O** (the nodes that can be both objects and subjects are denoted as ● ), Edges = **S×O**, label**(s,o) = M[s,o]**

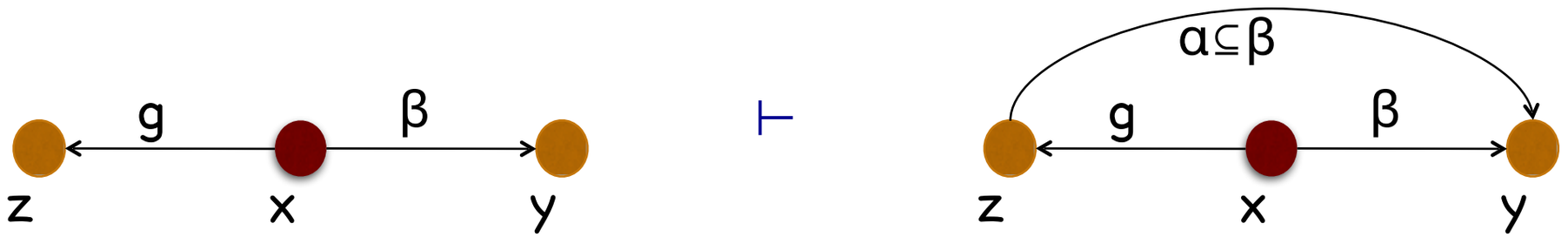
# Operations

Creation of a subject/object : create(y,α)

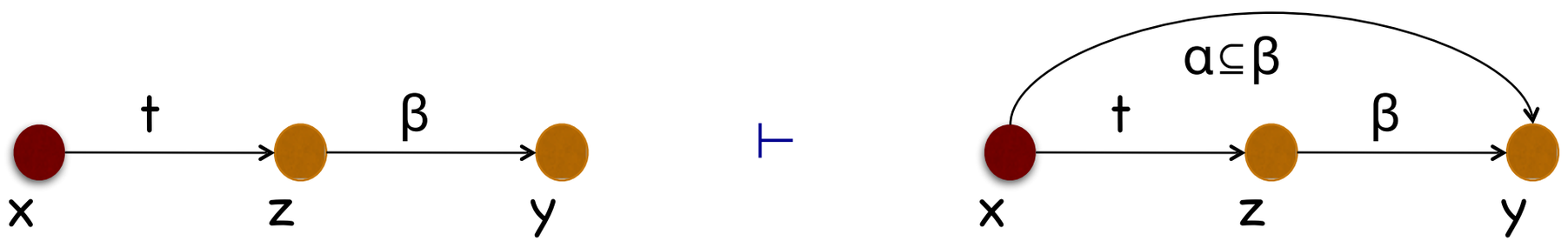

Remove access rights: remove(y,α)




Grant access rights: grant(z,y,α)




Take access rights: take(z,y,α)



# Decidability

- Let us define the predicate **can◦share**

- **can◦share (α,x,y,$G_0$) = true** iff exists a sequence of protection graphs $G_1,\ldots,G_n$ such that $G_0 \vdash^* G_n$ using only the 4 rules of the take-grant model, and in $G_n$ there is an edge from **x** to **y** with label **α**.

**Theorem**

There exists an algorithm of complexity **O(|V|+|E|)** that verifies the predicate **can◦share**, where **V** is the set of nodes and **E** the set of edges of $G_0$.

- This means that it is possible to decide if:
  - **s** can share **o** with **s'**
  - **s** can take the access to **o** from **s'**

# Limits of DAC

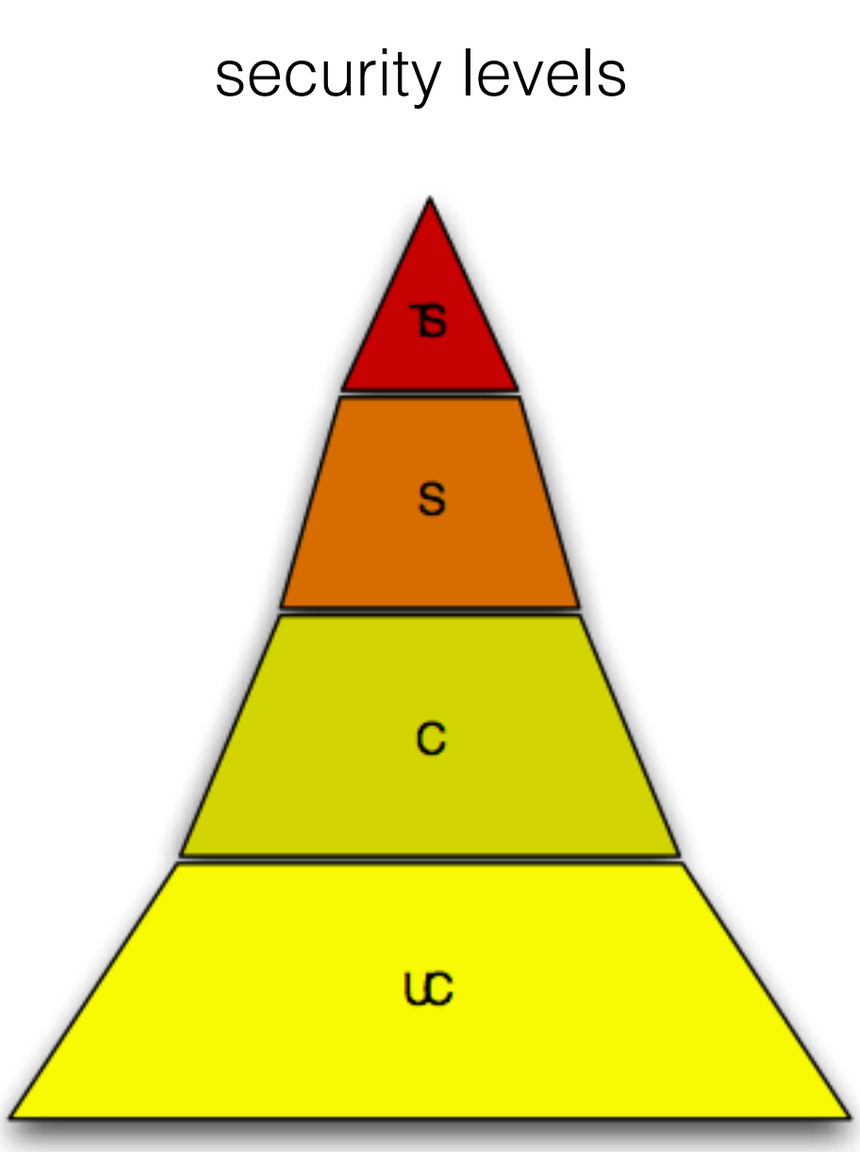
- Managing a policy is a complex task in a large system
- Set of subjects or objects is large
- Set of subjects or objects change frequently
- Flexible mechanism prone to errors:
  - ✓ it is necessary that all users understand the mechanism and respect the security policy
  - ✓ there is no control on the flow of information

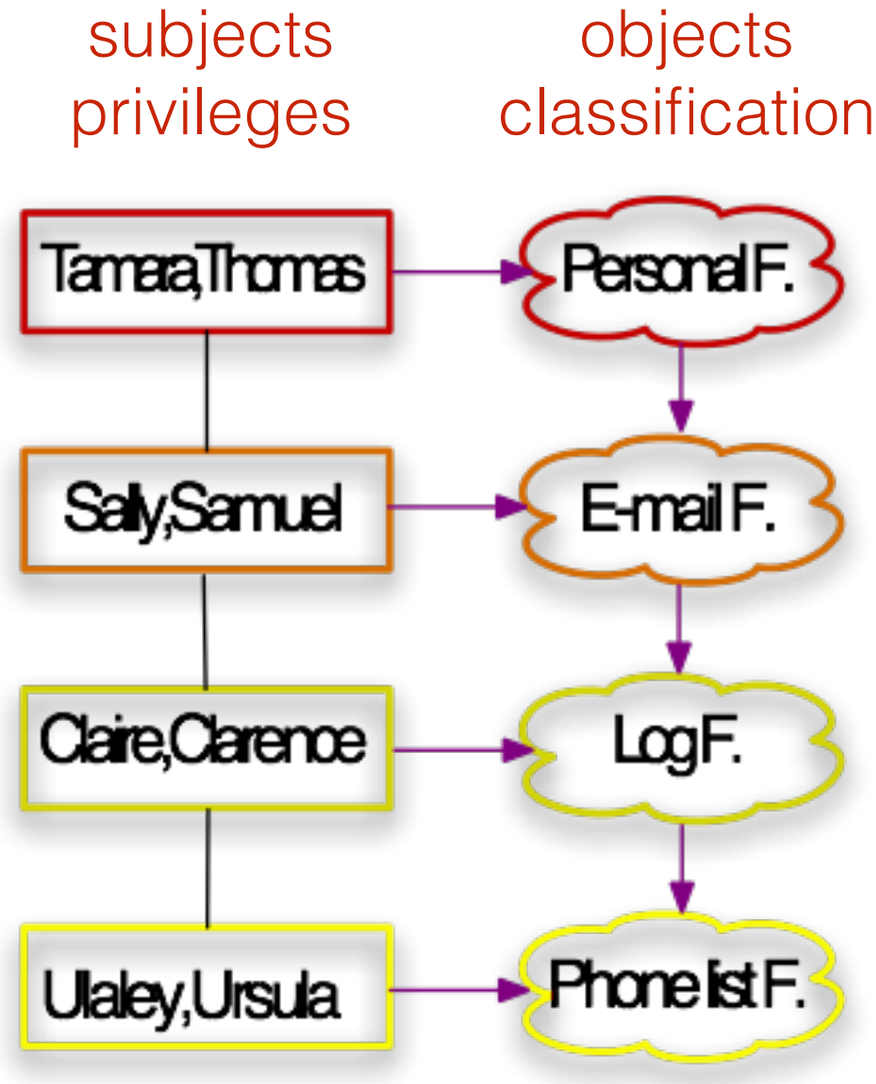
# Mandatory Access Control: MAC

# Mandatory Access Control: MAC

- Decision on access control are made based on the labels of objects that represent how critical the objects are and on the levels of authorizations of the subjects
- MAC is often identified with multi-level security
- Access rights to objects are established by a central authority and not by the owner
  - ✓the access control is mandatory
  - ✓moves the control from the users to the system
- Less flexible than DAC but more secure

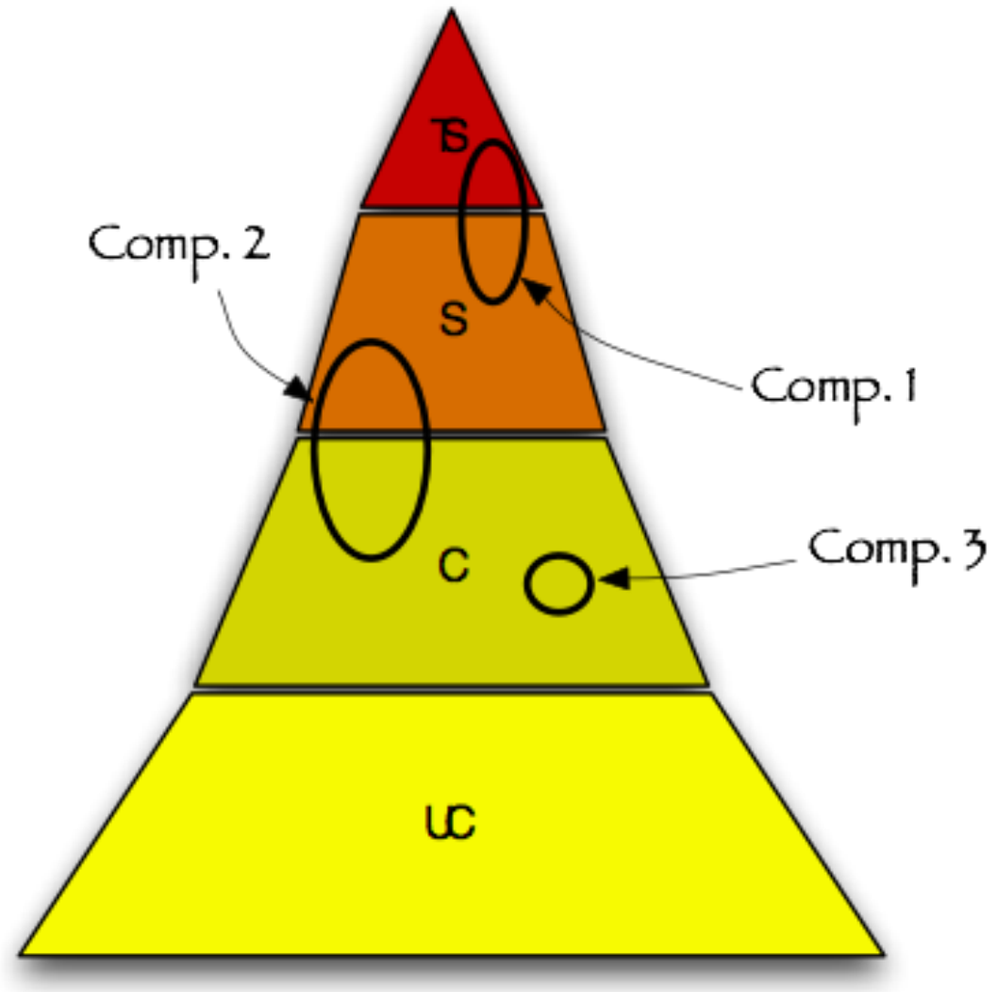
# Multi-level Security



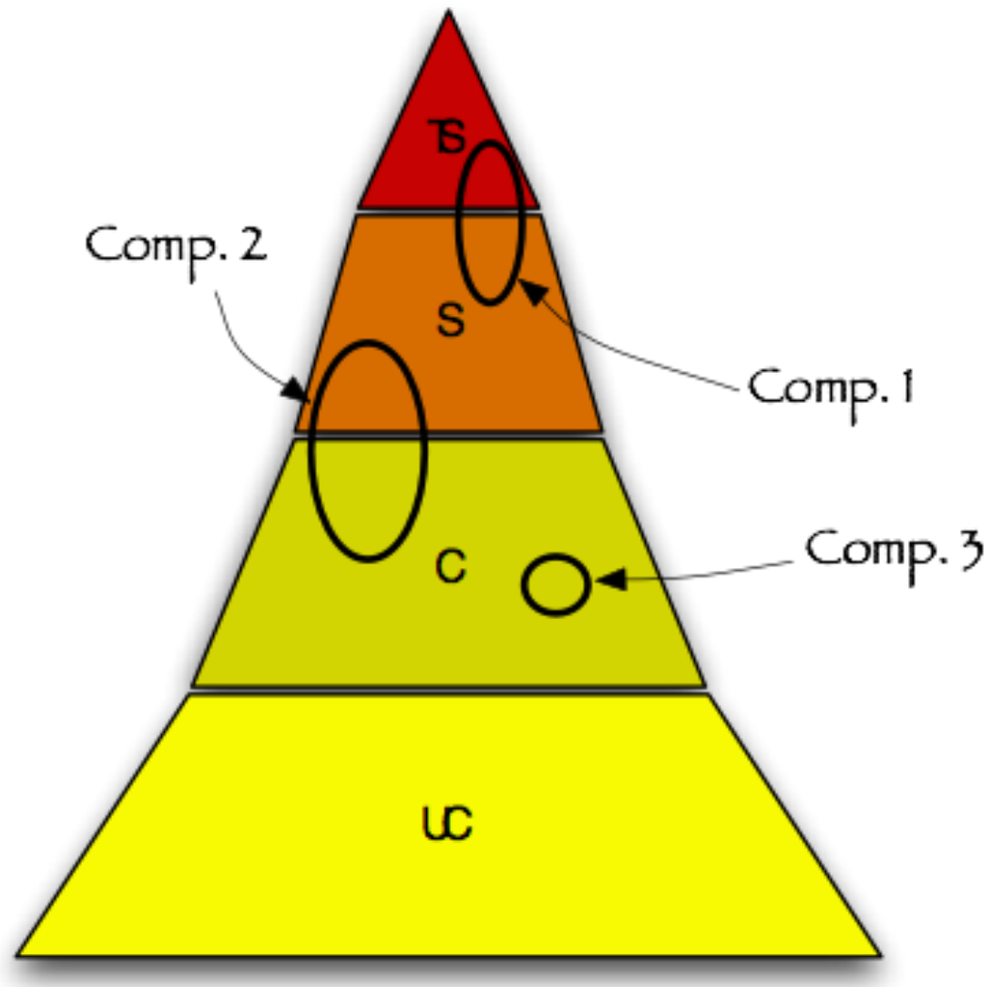
# Military Policy

- Access to information is based on the need-to-know principle
- Classified information is associated to one or more compartments that describe the subjects
  - ✓ we could have two projects A and B that need to access secret information but their access to secret information is limited
- Compartments can include information at different levels in the classification
- A single element can belong to more than one compartment



# Military Policy

- Class = (level,compartment) defines the sensitivity of the information.
- Access has to be authorized
- Rights = (level,compartments)
- Used to limit access, **s** read **o** iff:
  - ✓ the security level of **s** is at least the one of **o**
  - ✓ **s** needs to know all compartments to which **o** belongs



# Lattice and Security Levels

In a policy where a subject may access object only if the subject's security level is higher than the object's security level, we wish to have *unique answer* to the following questions:

* Given two objects at different security levels, what is the minimal security level a subject must have to be allowed to read both objects?
* Given two subjects at different security levels, what is the maximal security level an object can have so that it still can be read by both subjects?
* *Lattice of security levels*
  - ✓ greatest lower bound
  - ✓ least upper bound

# Lattice and Security Levels

Indeed, with linear ordering you can only express a limited set of security policies. In order to limit the access to the information of a secret project X only to people working on X we need the following security lattice:

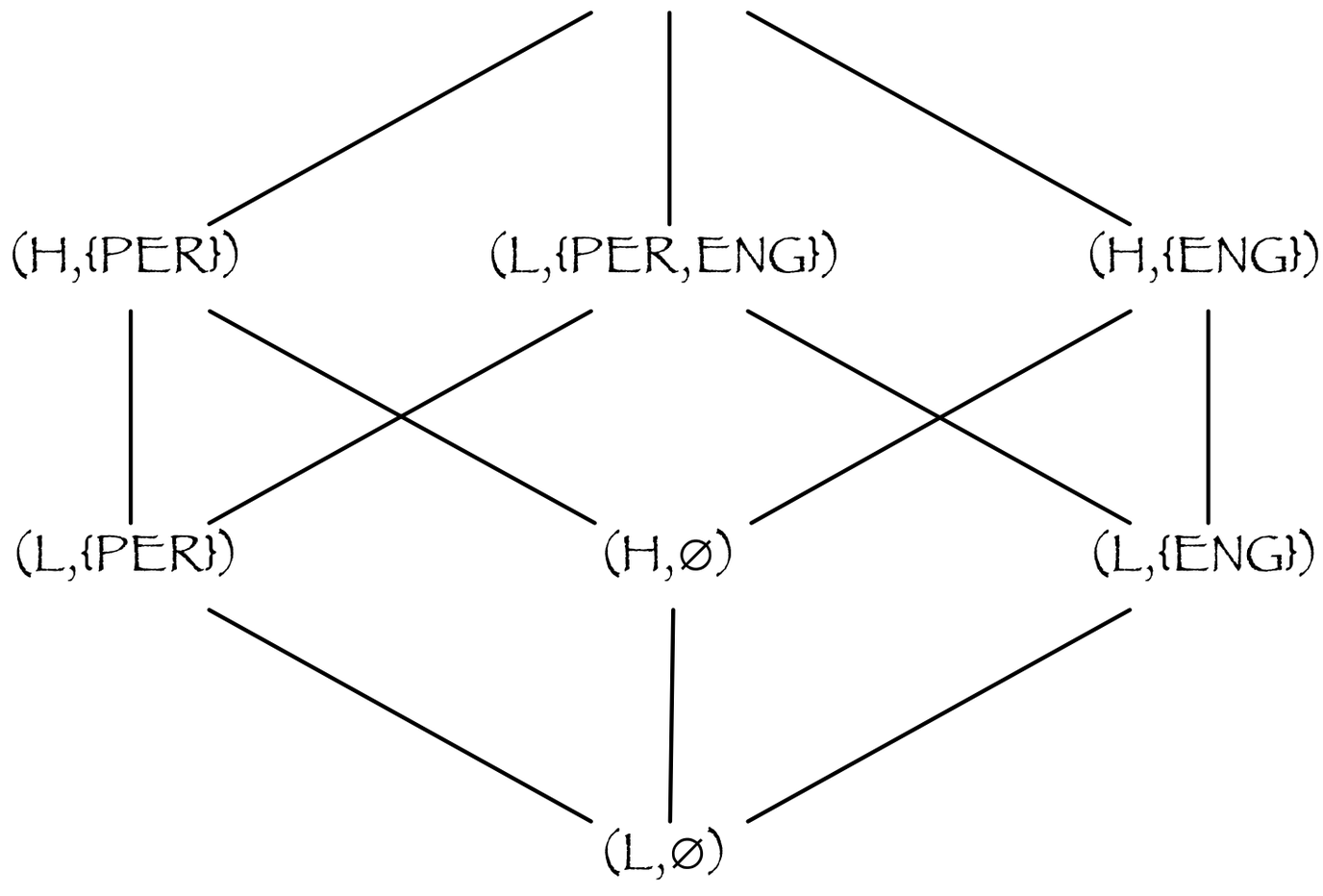
- Let **H** be a set of security levels with hierarchical ordering $\leq_H$;
- Let **C** be a set of compartments (project names, company division, academic departments,…)
- A security label is a pair **(h,c)** with $h \in H$ and $c \subseteq C$
- We define a partial order over security labels as follows:

$$(h_1,c_1) \leq (h_2,c_2) \quad \text{iff} \quad h_1 \leq_H h_2 \quad \text{and} \quad c_1 \subseteq c_2$$

# Example of Lattice of Security Labels

- Security levels: public (L), private (H)
- Compartments: personell (PER), engineering (ENG)
- Ordering relations:

(L,{PER}) ≤ (H,{PER}), (L,{PER}) ≤ (L,{PER,ENG}), (L,{PER}) (H,{ENG})



# Access Control Models

- Access control models can be classified according to different features:
- The capture confidentiality policies (**Bell-LaPadula**), integrity policies (**Biba**, Clark-Wilson) or both (Chinise Wall)
- There are models that can be applied to environments with static policies (Bell-LaPadula), and others that allow dynamic changes in the access rights (Chinise Wall)
- Some models apply to military environments (Bell-LaPadula) others to commercial environments (Clark-Wilson, Chinise Wall)
- Security models can be informal (Clark-Wilson) or formal (Bell-LaPadula, Harrison-Ruzzo-Ullman).

# The Bell-LaPadula Model

- Typical MAC model based on multilevel security .
  - ✓ Security clearance of subjects
  - ✓ Security classification of objects
  - ✓ Control access matrix

GOAL

prevent read access to objects with security classification higher than the subject's clearance

*Information cannot flow from high to low*

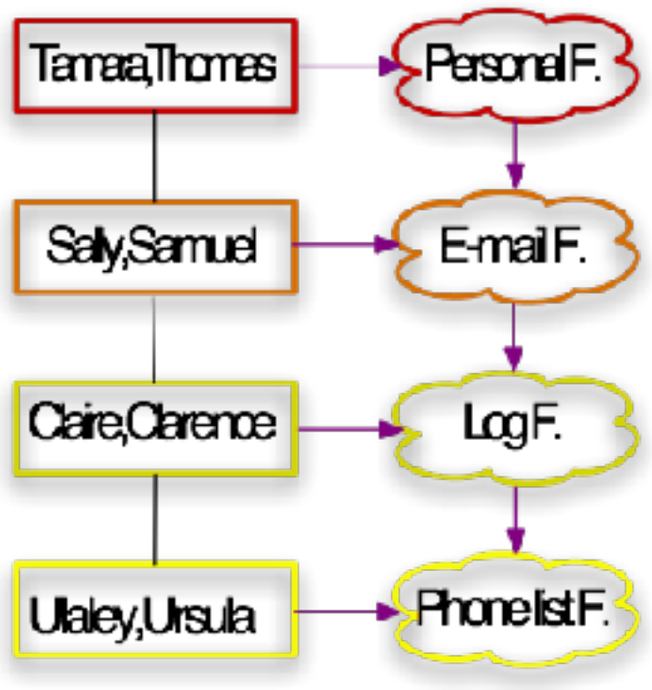
- Discretionary vs Mandatory: BLP combines mandatory and discretionary access controls. MAC is defined based on security levels of the objects and clearance of the subjects. Moreover, a subject may grant another subject access to an object constrained by the MAC rules.

# BLP: Simple Security Property

Simple Security Property (no reads up)

**S** can read **O** iff $\mathbf{h_o \leq h_s}$ and **S** has read DAC on **O**

- Ex: Claire and Clarence cannot read personal files
- Es: Tamara and Sally can read log files

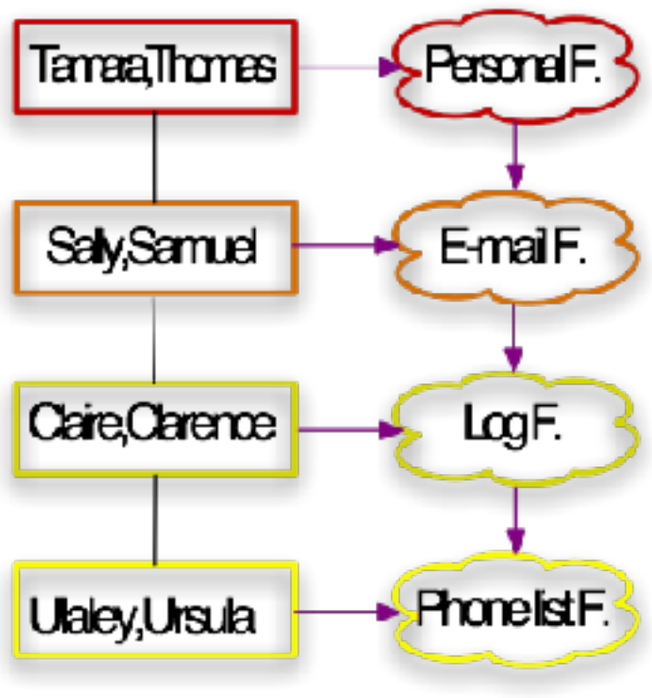



- Problem: Tamara could copy the content of personal file into log files, thus allowing Claire to access personal data!

# BLP Star-Property

Star-Property, Preliminary Version (no write down)
**S** can write **O** iff $h_s \leq h_o$ and **S** has write DAC on **O**

Ex: Tamara cannot write on log files since
$h_{Tamara} > h_{Log\ F.}$




*Secure system* A system is secure if both ss-property and star-property hold.

*State* representation of of subjects that have current access to objects and the current access rights

Basic Security Theorem, Preliminary Version: If a system has a secure initial state and every possible state transition preserves the ss-property and the star-property preliminary version, then every possible state of the system is secure.

# BLP ds-property

- DAC:  subjects that can access an object can transfer the access rights of that objects to other subjects
- In BLP this is expressed by the ds-property

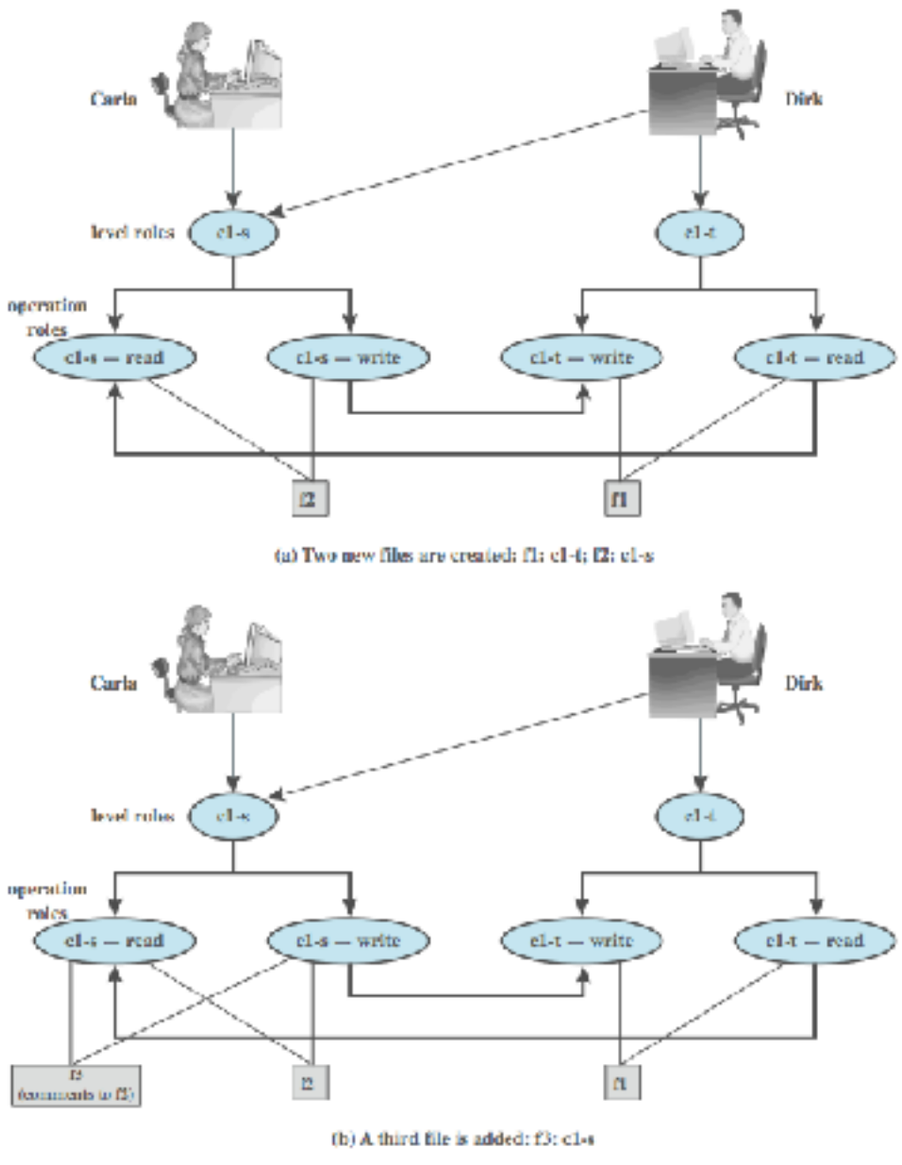
**ds-property**

A subject may grant to another subject access to an object (on the owner's discretion), constrained by the MAC rules. Thus, a subject can exercise only accesses for which it has the necessary authorization and which satisfy the MAC rules.

A system is *secure* if it satisfies the ss-property, the star-property and the ds-property.

# BLP: Example

Carla reads and writes f2, Dirk reads and writes f1 and reads f2 if Carla allows him, but he cannot write f2 for the *-property



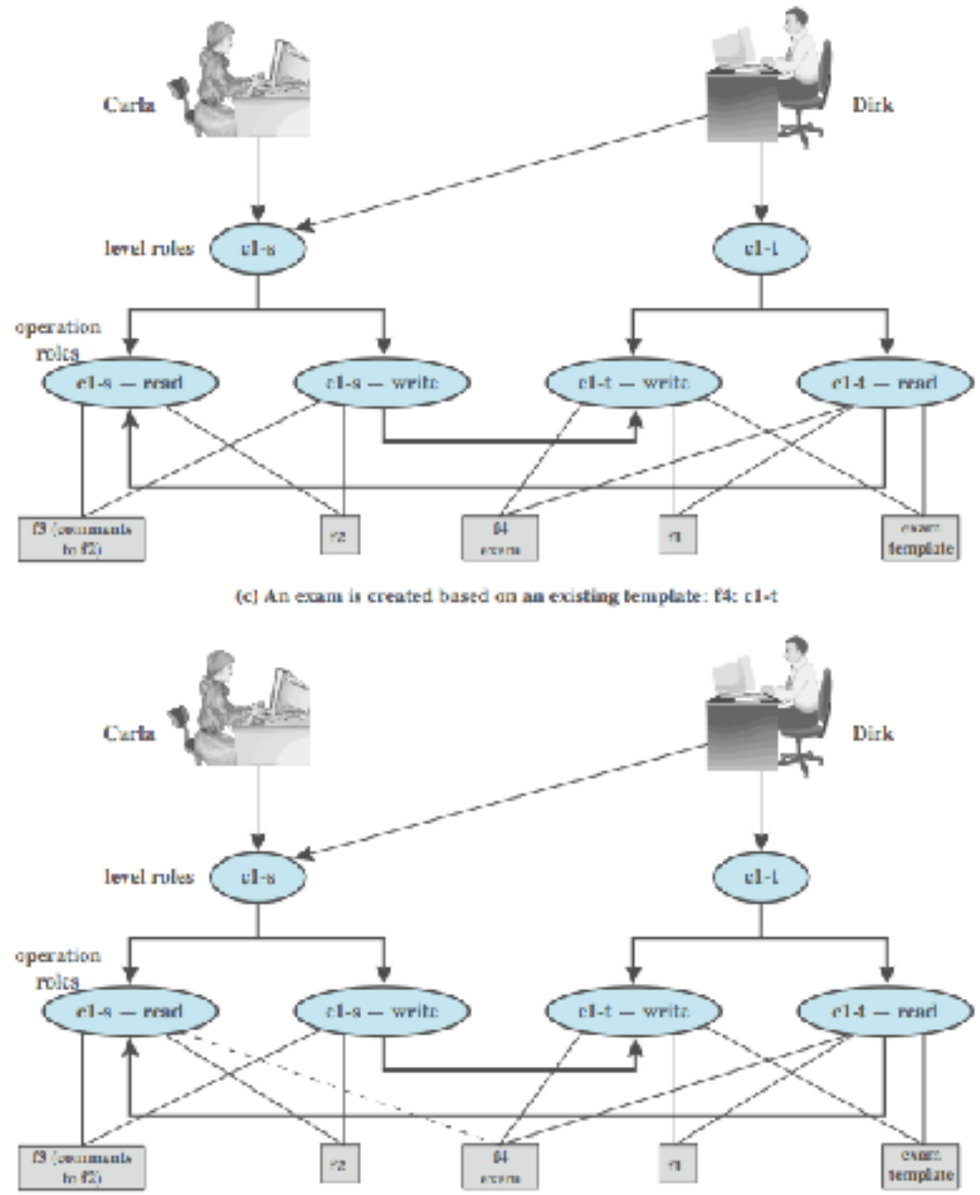

(a) Two new files are created: f1: cl-t; f2: cl-s

(b) A third file is added: f3: cl-s

**Figure 10.2 Example of Use of BLP Concepts** (page 1 of 3)

Dirk reads f2 and wants to create a file with the comments for Carla Dirk logs as a student and creates f3 so that Carla can read it

Dirk writes an exam f4 based on the exam templates, so he has to do it as a teacher

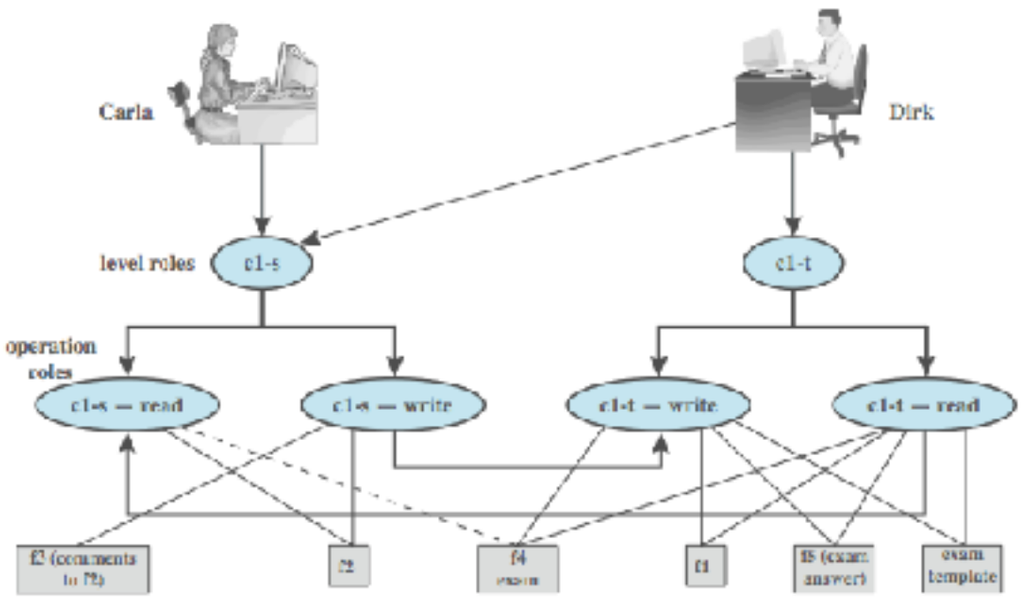



(c) An exam is created based on an existing template: f4: cl-t

(d) Carla, as student, is permitted acess to the exam: f4: cl-s

Carla cannot read the exam f4 because this violates the ss-property. Dirk has to **declassify** f4 so that Carla can read it. The system administrator should do this downgrade

# BLP: Example




(e) The answers given by Carla are only accessible for the teacher: f5: c1-t

**Figure 10.2 Example of Use of BLP Concepts** (page 3 of 3)

Carla writes the results of the exam in f5, she has to do it at the teacher level so that only Dirk can read it. This is allowed since BLP allows writing up.

# BLP: Advantages and limitations

- BLP is a very significant security model
  - ✓ Descriptive capabilities: the BLP state describes the current access operations and all current access permissions
  - ✓ The security policies are based on security levels and access control matrix. It is easy to change structures for new policies.
  - ✓ By changing the properties we can handle integrity (Biba model)
- BLP does not cover all aspects of security
  - ✓ It only deals with confidentiality (no integrity)
  - ✓ It does not address the management of access control
  - ✓ It contains *covert channels*
    - ✓ A low-level subject creates an object dummy.obj at its own level
    - ✓ Its high-level accomplice (or trojan horse) upgrades the security level of dummy.obj to high or leaves it unchanged
    - ✓ Later the low-level subject tries to read dummy.obj. Success or failure of this request reveals the action of the high level subject. One bit of information has been transmitted from high to low.

# Modello di Biba (1977)

Biba studied the *integrity* of systems and he proposed three policies, one of which is the mathematical dual of the Bell-LaPadula Model

* Subjects **S**, objects **O** and integrity levels **I** ordered (≤)
* **i: S** ∪ **O** → **I** returns the integrity level of subjects and objects
  - ✓ Data at higher level is *more accurate* or reliable (with respect to some metrics) than data at a lower level
  - ✓ Integrity labels *inhibit data manipulation*
* Three relations:
  - ✓ **r** ⊆ **S x O,** **s** reads **o**
  - ✓ **w** ⊆ **S x O**, **s** writes/modifies **o**
  - ✓ **x** ⊆ **S x S** , **s** invokes **s'**

# Biba: Integrity Policy

- Integrity ≠ security
  - ✓ Security labels primarily limits the flow of information
  - ✓ Integrity labels primarily inhibit the modification of information

- This policy is the dual of the BLP, and it prevents that trusted objects and subjects are corrupted by untrusted information

  1. Simple integrity property (no write up) **s** ∈ **S** can write **o** ∈ **O** iff **i(o)≤ i(s)**

- This first rule forbids write up
  - ✓ If a subject can alter an object with an higher degree of trust, he/she could inject false or corrupted data

# Biba: Integrity Policy

* This policy is the dual of the BLP, and it prevents that trusted objects and subjects are corrupted by untrusted information

1. Simple integrity property (no write up) **s** ∈ **S** can write **o** ∈ **O** iff **i(o)≤ i(s)**
2. Integrity star-property (no read-down) **s** ∈ **S** can read **o** ∈ **O** iff **i(s)≤ i(o)**

* The second rule forbids to read down

  ✓ it requires that a subject can read only objects of higher integrity in order to disallow a subject to contaminare a higher object with data from a lower object

* These rules implies that a subject **s** can read and write an object **o** iff **i(s) = i(o)**.

# Biba: Integrity Policy

* This policy is the dual of the BLP, and it prevents that trusted objects and subjects are corrupted by untrusted information

1. Simple integrity property (no write up) **s** ∈ **S** can write **o** ∈ **O** iff **i(o) ≤ i(s)**
2. Integrity star-property (no read-down) **s** ∈ **S** can read **o** ∈ **O** iff **i(s) ≤ i(o)**
3. Invoke property $\mathbf{s_1} \in \mathbf{S}$ can invoke $\mathbf{s_2} \in \mathbf{S}$ iff $\mathbf{i(s_2) \leq i(s_1)}$

* The third rule forbids to a subject to invoke a subject of higher integrity level, otherwise he/she would control more reliable subjects

# Biba: Low-watermark policy dynamic integrity levels

* The following integrity rules *automatically adjust* the integrity level of an entity if it comes into contact with dirty information.

1. Simple integrity property: **s** ∈ **S** can write **o**∈**O** iff **i(o) ≤ i(s)**
2. Subject low watermark property: A subject **s** can read objects at any integrity level. If **s** ∈ **S** reads **o** ∈ **O** then **i'(s) = min(i(s),i(o))**
3. Invoke property: $\mathbf{s_1} \in \mathbf{S}$ can invoke $\mathbf{s_2} \in \mathbf{S}$ iff $\mathbf{i(s_2) \leq i(s_1)}$

* The second rules lowers the integrity level of a subject to the one of the objects that he/she reads
  - ✓ The subjects accesses data that are less reliable than what he/she is

# Robe based Access Control: RBAC

# DAC do not scale

objects

| subjects | news.doc | photo.png | fun.com |
|---|---|---|---|
| alice | read | view<br>edit | view |
| bob | read<br>write | view<br>edit | view<br>modify |
| charlie | | | |
| dave | | view | |

- Access control matrix

| | news.doc | photo.png | fun.com |
|---|---|---|---|
| bob | read<br>write | | |
| alice | read | | |
| alice | | view, edit | |
| bob | | view, edit | |
| dave | | view | |
| alice | | | view |
| bob | | | view<br>modify |

- Access control list

- Capability list

Alice's capability

| news.doc | photo.png | tun.com |
|---|---|---|
| read | view, edit | view |

Bob's capability

| news.doc | photo.png | fun.com |
|---|---|---|
| read<br>write | view, edit | view<br>edit |

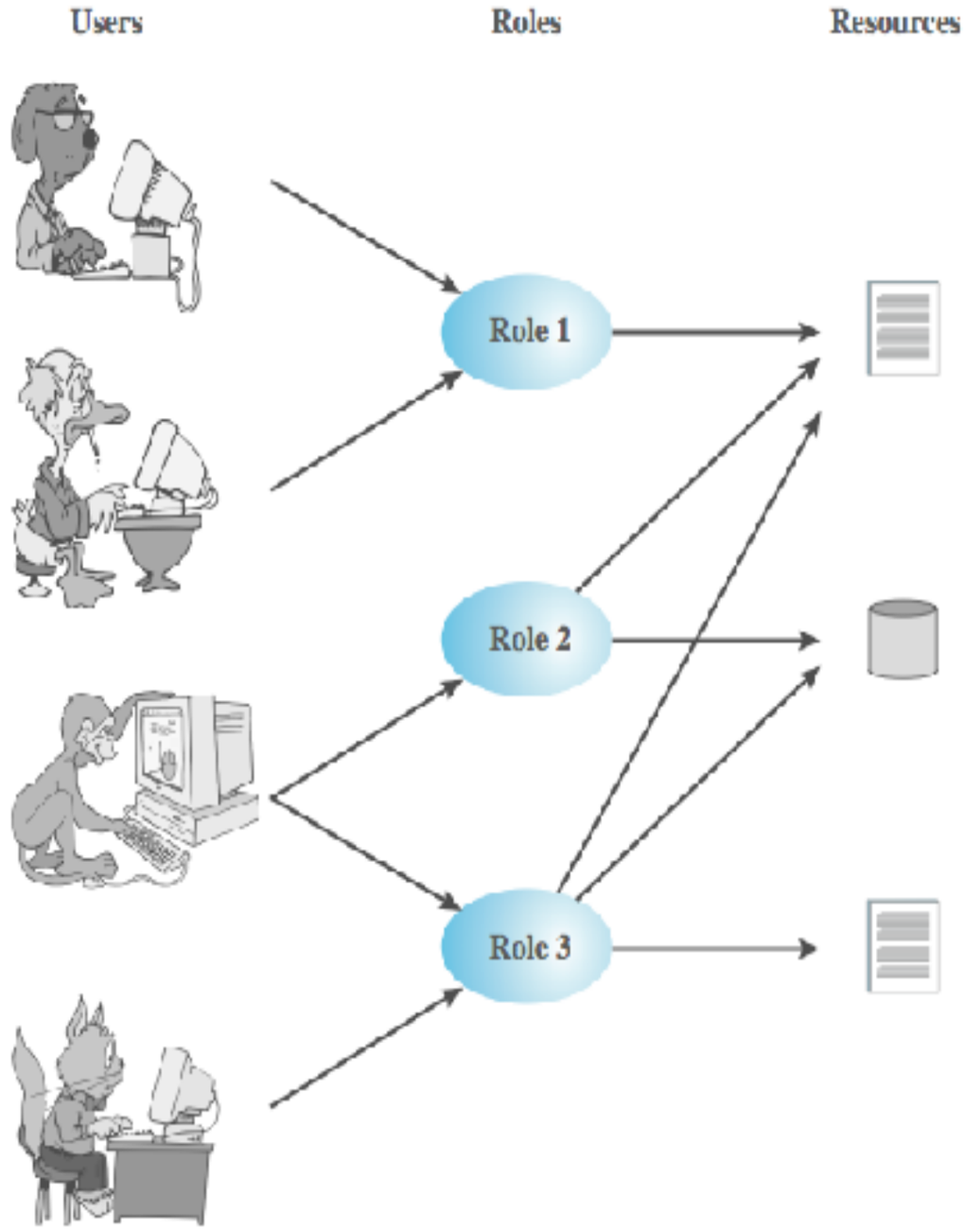
Charlie's capability

Dave's capability

| photo.png |
|---|
| view |

# RBAC

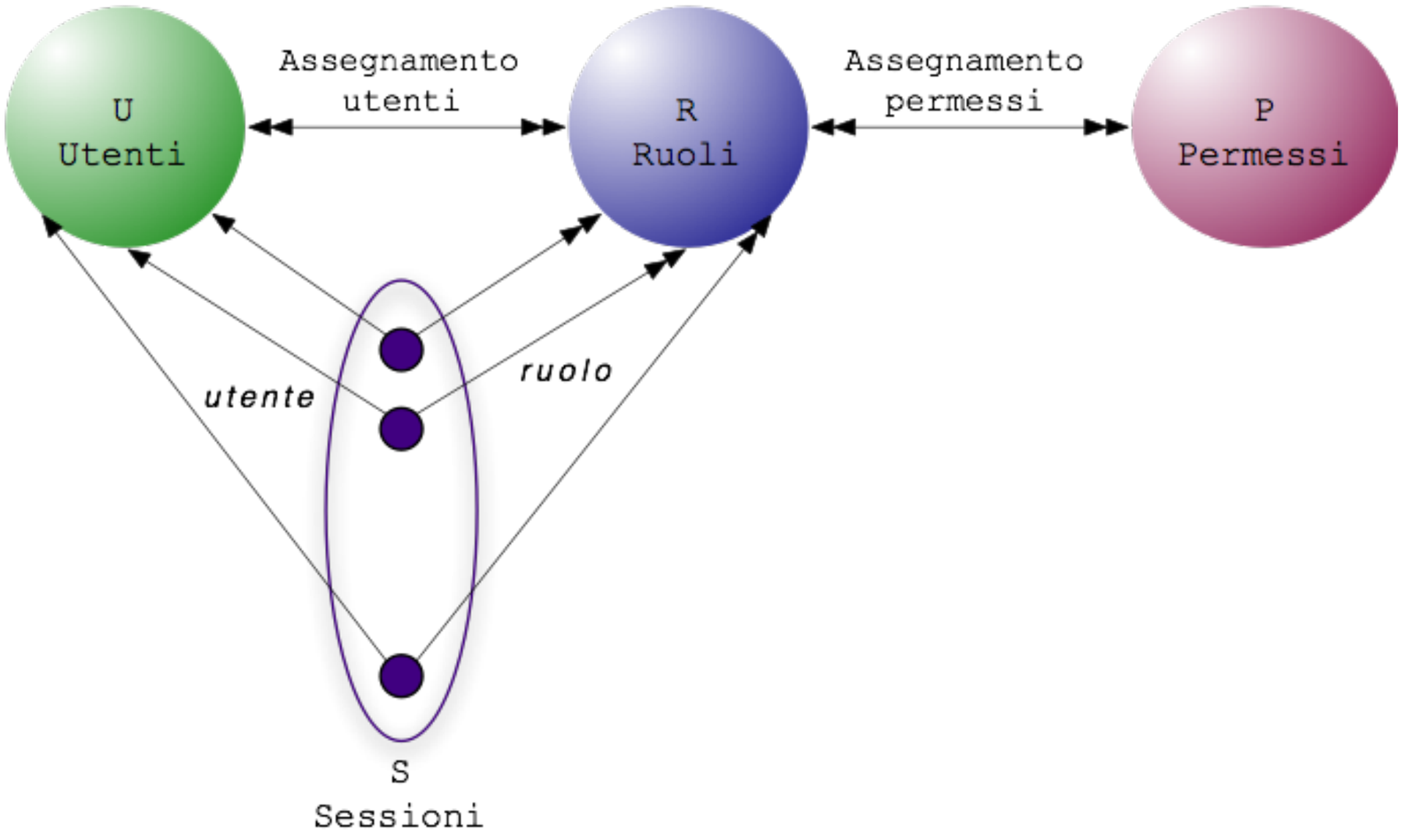
- DAC systems define the access rights of individual users and groups of users
- RBAC systems assign access rights to roles instead of individual users. Users are assigned to different roles, either *statically* or *dynamically*.
- Least privilege / need to know



# RBAC Family

- Defined by Ravi Sandhu in 1996
- ANSI standard since 2004
- **RBAC0**: Core model: users, roles, permissions, sessions
- **RBAC1**: RBAC0 + Role Hierarchies
- **RBAC2**: RBAC1 + Constraints

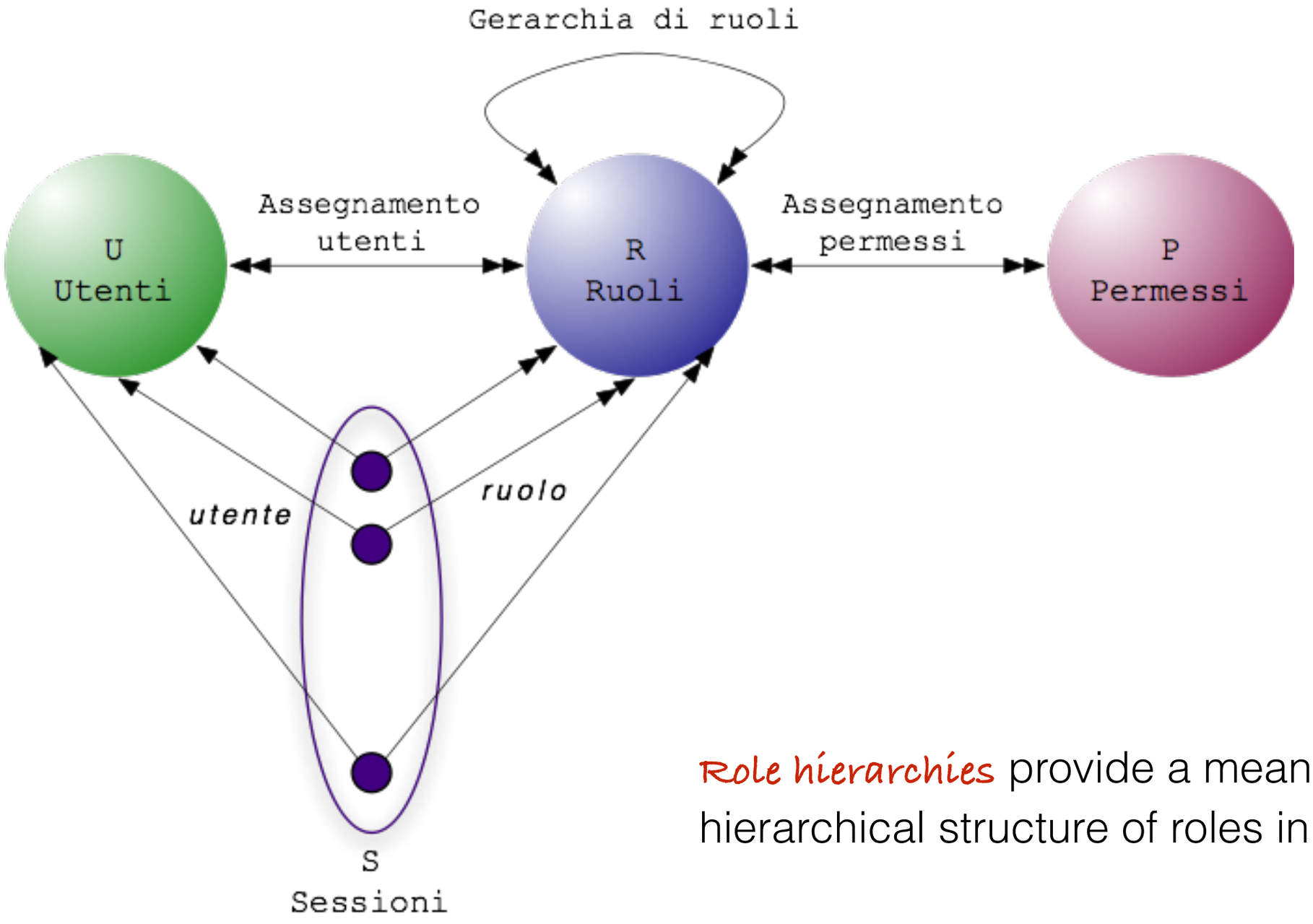
# Base Model - $RBAC_0$



# Example of roles

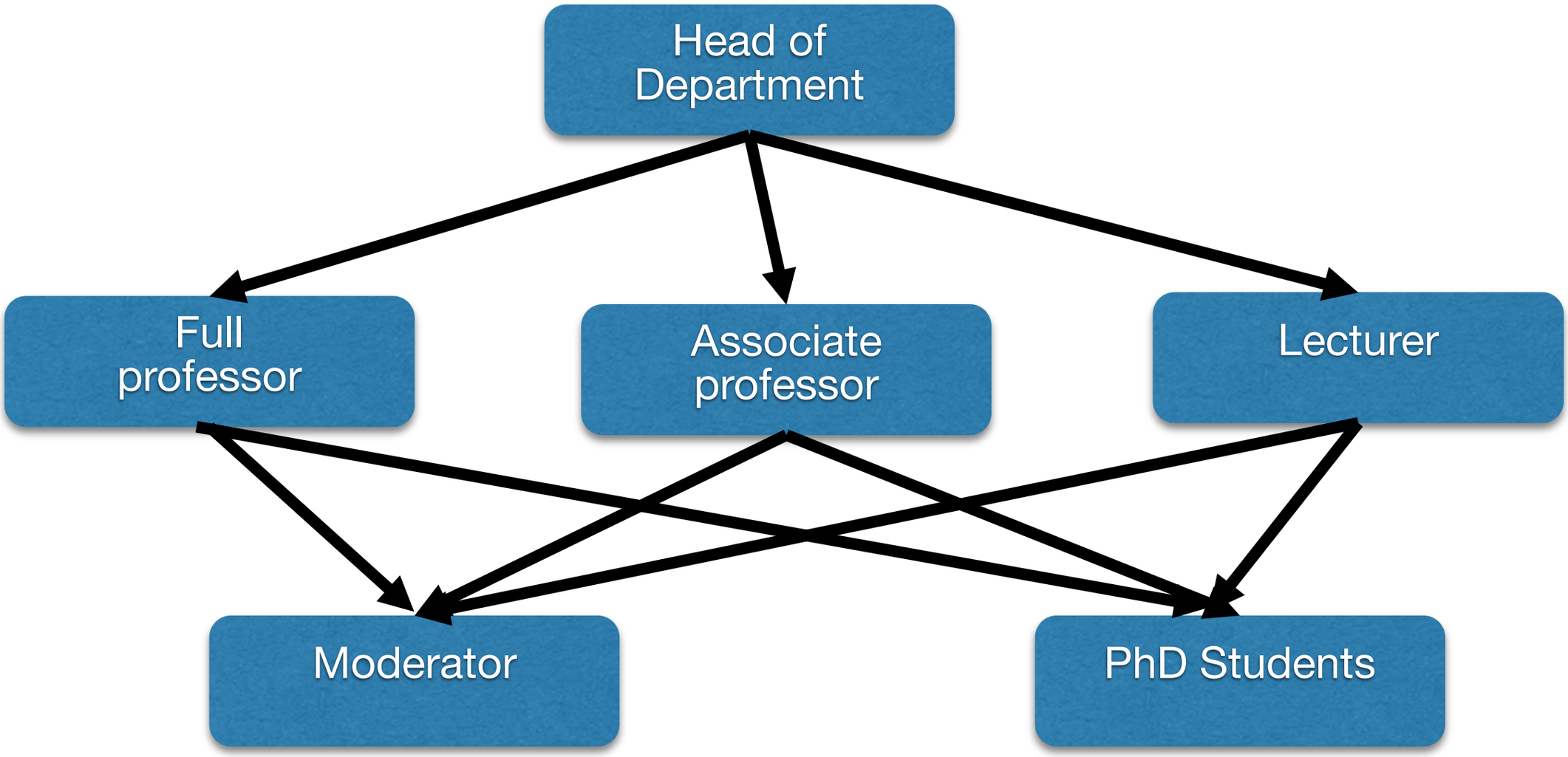
- **Roles**
  - ✓ Lecturer
  - ✓ PhD student
  - ✓ Associate Professor
  - ✓ Full Professor
  - ✓ Head of Department
- **Objects**
  - ✓ Exam paper
  - ✓ Coursework
  - ✓ Module Marks

# Role Hierarchies - $RBAC_1$

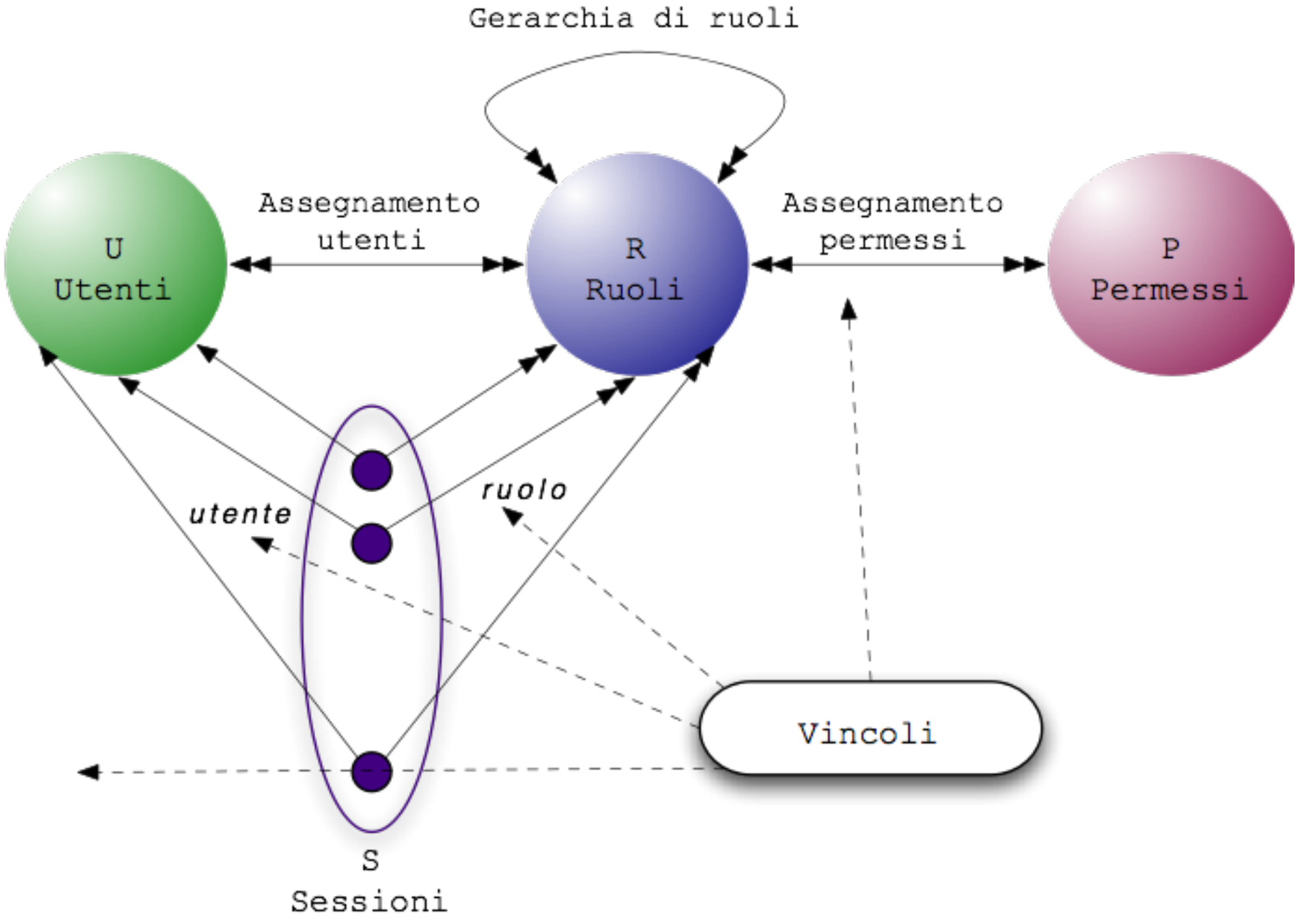



Role hierarchies provide a means of reflecting the hierarchical structure of roles in an organization.

# Role Hierarchies - $RBAC_1$



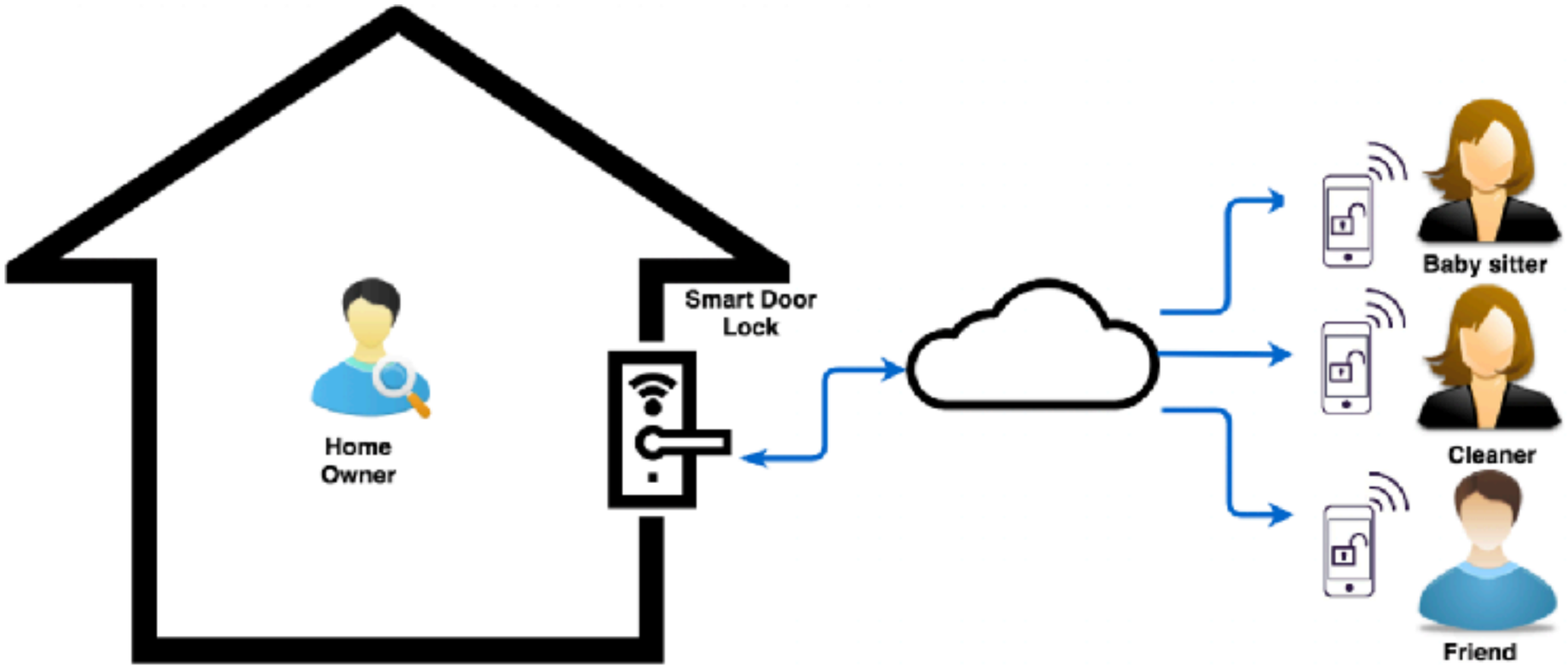
# Consolidated $RBAC_2$



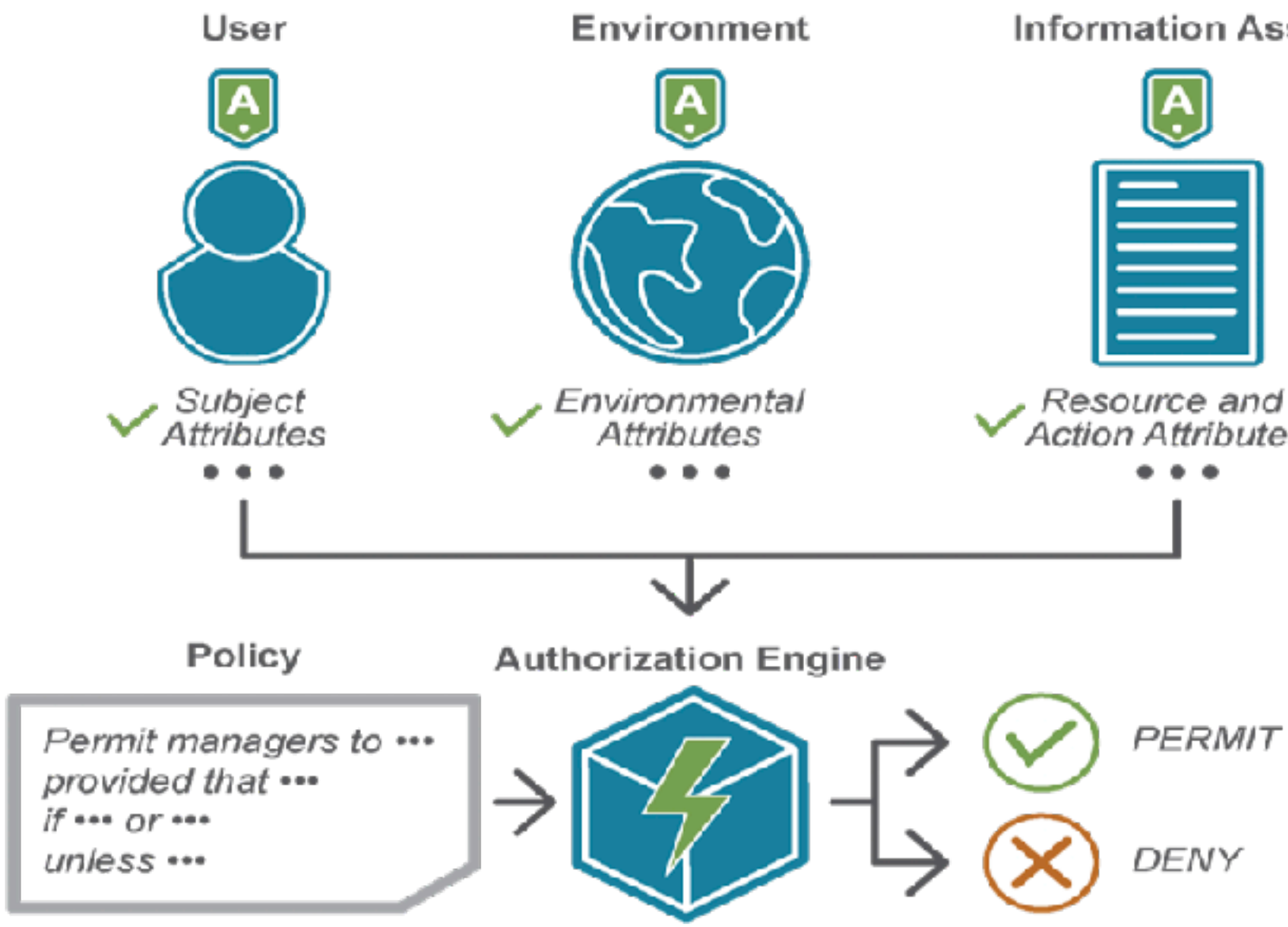
# RBAC: Advantages

- Roles are abstractions of the function present in an organization (it can be seen as collection of procedures)
  - ✓Roles are different from groups
  - ✓Roles are more related to responsibility  and access rights associated to responsibilities
- Abstraction makes access control policies more tractable
- When the number of roles is low there is a big advantage in the amount of information that needs to be stored wrt the standard access control matrix
- Efficient administering and monitoring of permissions
- No need to manually assign users to permissions
- Automatically done by assigning users to roles
- Used in: healthcare (NHS-GB), Banks and insurance policies, commercial products, cloud platforms

# Attribute based access control ABAC



# Attribute based access control ABAC



# Summary

- Access control specifies who or what may have access to a system resource and the type of access that is permitted
- Four types of access control policies
  - ✓ Discretionary
  - ✓ Mandatory
  - ✓ Role-based
  - ✓ Attribute-based
- Access control is very hard to implement correctly
  - ✓ Employees are often over-entitled