Traditional Access Control and Fundamentals

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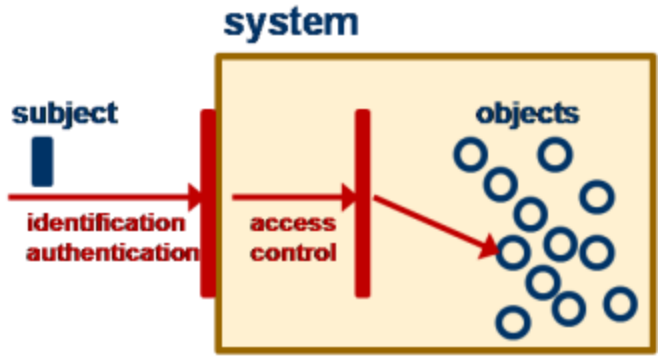
- Introduction to Mandatory Access Control
- The Bell-La Padula Model

The Biba Model

Access to the System

- **A system can protect itself in two ways:**
  - It can limit **who can access** the system
    - This requires the system to implement a two-step process of
      - **identification (asking you who you are)** and
      - **authentication (asking you to prove it).**
  - It can limit **what user can do** after they have accessed the system.
    - This requires the system to implement **access control** mechanisms.



Access Control: Notion

The primary purpose of security mechanisms in a system is to control access to resources

Resources: Files, memory areas, processor time, devices, database records.

Some history

- ✓Early systems had no internal access control.
  - Any user could access any file simply by knowing its name.
- ✓Access control became a more serious issue with the emergence of disk storage, on which files of many users could be stored (before the days of network and interactive computing).
- ✓Controlling access to disk files was probably the first widespread computer security concern.

  For the first time the system, rather than the operator, was required to enforce access control.

Access Control: Definition

Access control (AC)

is the process of **mediating every request** to resources and data maintained by a system, and **determining** whether the request should be granted or denied.

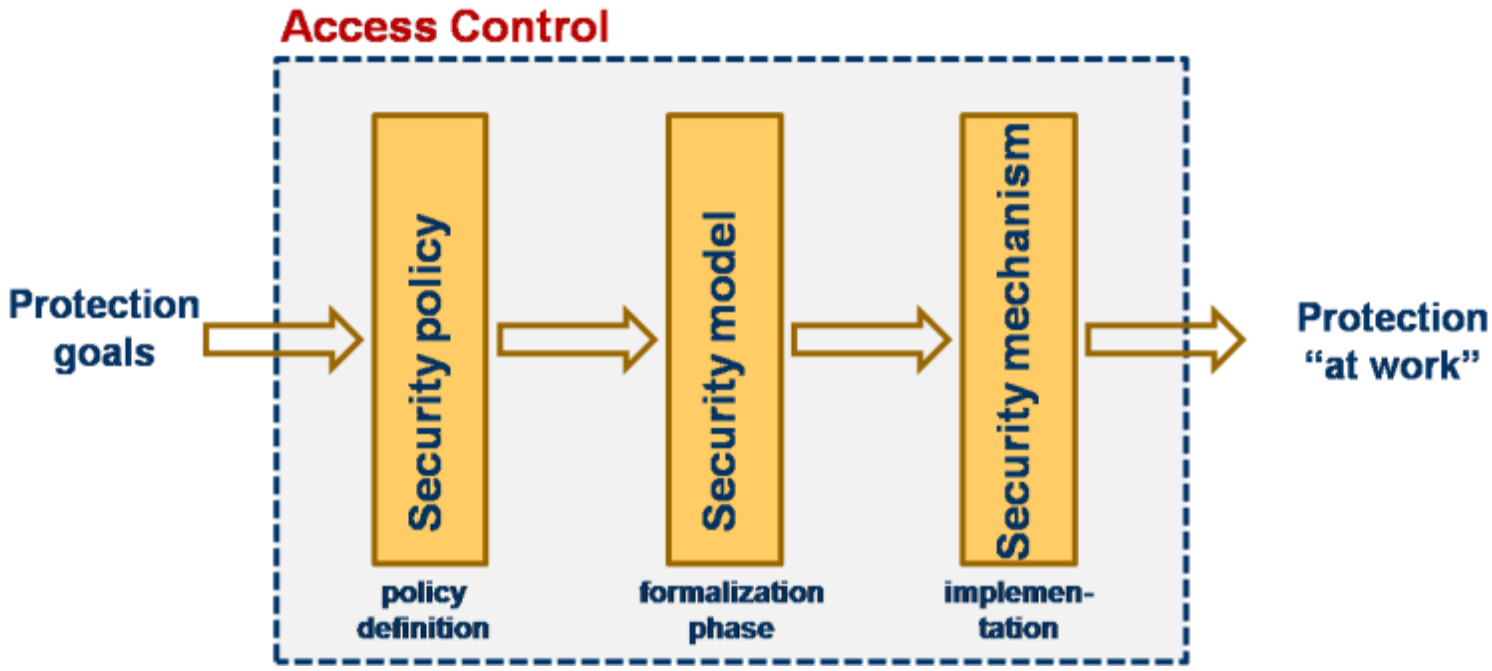
The development of an AC system

requires **definition of regulations** according to which access is to be controlled, and their **implementation** as functions executable by a computer system.

Important question: Who defines the regulations?

E.g., the system, some user, administrator, owner of some resources.

Multi-phase Approach for Design of AC



The formalization phase allows the definition of a formal model making it possible to **define and prove security properties** that systems enforcing the models will enjoy

Therefore, by proving that

- **the model is "secure"**, and
- that the mechanism **correctly implements the model**

we can argue that **the system is "secure"**.

Classes of Access Control Policies

Access control policies can be grouped into three main classes

Discretionary (or authorization-based) policies

Users, on their discretion, can specify to the system who can access their objects (e.g., files).

Mandatory policies

The system controls access based on mandated regulations determined by a central authority.

Role-based policies

Access to some resource depends on the role that a user have within the system and on rules stating what access are allowed to users in given roles.

Administrative policies

Define **who** can specify authorization/rules governing access control Usually coupled with (or included in) discretionary and role-based policies.

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Discretionary Access Control (DAC)

Discretionary Access Control (DAC) implements discretionary policies

- DAC base access on the identity of the subject and identity of the object involved.
  - ✓Access control is left to the discretion of the owner.
  - ✓The owner of the object constrains **who** and **how** (read, write, execute) can access it.
- DAC centers around the concept of users having control over system resources.
- Each system resource is assigned ownership by one or more entities.
- DAC is also called **identity-based access control** (IBAC) or **authorization-based access control.**

Discretionary Access Control (cntd.)

Advantages

Simplicity, flexibility and ease of implementation.

Drawback

There is no formal assurance concerning the flow of information, Trojan horse threads.

Examples for DAC

Passwords for file

Access Capability list

Owner/Group/Other

Access control lists (ACL)

Example for DAC: Passwords for File Access

A password-based access scheme is used to protect files by assigning to each file a password by its owner.

- Only users who know the password are able to access the file.
  - Note: This password has nothing to do with any password the user might need to log into the system.
  - Usually there must exist two passwords for each file: one for controlling reading, and one for controlling writing.
- In a system with thousand of files password-based access schemes are unsuitable.
- This was one of the primary protection mechanisms in the early systems.

Problems with the Passwords for File Access

Management problem

- In a large organization where users come and go daily, a password-based protection scheme for all files becomes impossible to manage.

Revocation problem

- There is no way to revoke one users access to the file (by changing the password) without revoking every ones access.

Tracking problem

- There is no way for the system to keep track of who has access to the file, since passwords are distributed manually without systems knowledge.

Possibility of unauthorized use

- Passwords for file access tend to be embedded as character strings within programs that need to use the files; so one users program can be run by another person who does not necessarily knows the passwords for all the files the program needs.

Remembering problem

- Requiring the user to remember a separate password for each file is an unreasonable burden.

Example for DAC: Capability List

Notion of capability

A capability list (or a **capability**, for short) is like a access-key to a specific object, along with the mode of access (read, write, execute). A subject possessing a capability may access the object in the specified mode.

Access control with capabilities

At the highest level in the system, where we are concerned with users and files, the **system holds a capability list for every subject** (e.g., user)

User cannot add capabilities to this list.
Exception: If a user creates a new file, the capability for this file will be added in the list.
User might be allowed to give access to files by passing copies of their own capabilities to other users.
Users might be able to revoke access to their own files by taking away capabilities from others (revocation can be difficult to implement).

Disadvantages and Advantages of Capabilities

Disadvantage: Management problem

The system must maintain a list for each user that may contain hundreds or thousands of entries.

When a file is deleted, then the system has to update every capability list (for each user).

Answering a simple question as a ”who has access to this file?” requires the system to undergo a long search through every users capability list.

Successful use of capabilities

At lower levels in the system, where capabilities provide the underlying protection mechanism and not the user-visible access control scheme.

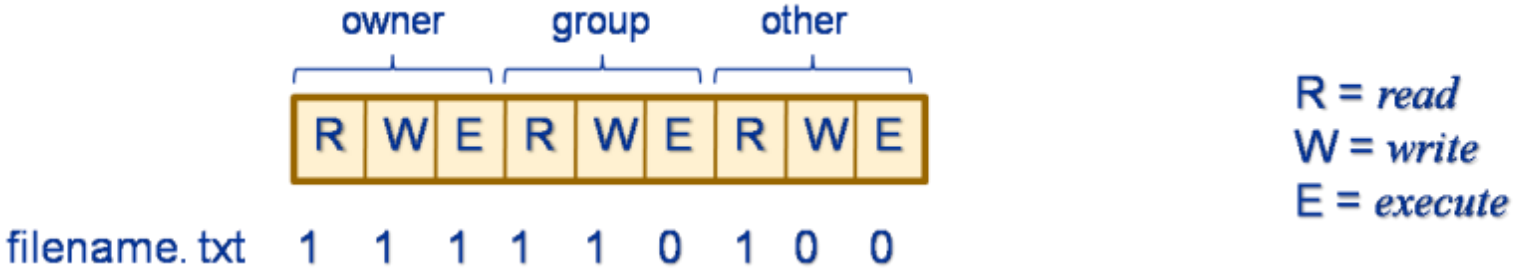
- Low-level use of capabilities used by hardware.
- Low-level use of capabilities used by software.

Example for DAC: Owner/Group/Other Technique

Few bits of access control information are attached to each file. These bits specify the access modes for different classes of users.

Usually there are no more than four classes of users (owner of the file, users belonging to the owners group or project, special system users, and the rest of the world).

In a large system, where users are grouped by project or department, most access control needs are satisfied by this technique.



Advantages and Disadvantages of Owner/Group/Other Technique

Advantages

Effective, simple and very common discretionary access control scheme.

Implemented in Unix, DECs, RSX and VMS, and many other systems.

Disadvantages/Problems

The technique fails apart when access across specific groups are required. Inability of the technique to specify access rights for an individual user.

There is no way for user *X* to specify that ONLY user *Y*, and nobody else, should have access to the file, unless there is a group defined in the system to which only *X* and *Y* belong.

Example for DAC: Access Control Lists (ACLs)

- **An access control list (ACL) is placed on each file.**
- **The ACL identifies the individual users or groups who may access the file.**

ACL for file F1

Stefan.Crypto	rew
* . Crypto	re
Marcel . *	n
.	r

ACL for file F2

Sadeghi . *	rew
Palacios . *	r
.	n

ACL for file F3

Hans.Trust	rew
Marcel. Trust	rew
* . Trust	r
* . Crypto	r

n = no access
Marcel has no access to F1 unless he is in the crypto group

Advantages and Disadvantages of ACLs

Advantages

Because all access control information for a file is stored in one place and is clearly associated with the file.

Identifying who has access to a file can be done very efficiently adding or deleting names to the list can be done very efficiently

Disadvantages/Problems

Performance

The ACL has to be scanned each time any user wants to access the file (impact on systems where large number of files are opened in relatively short time).

Storage management

Maintaining a variable-length list for each file results in either a complex directory structure or wasted space for unused entries.

Problem only for systems having huge number of very small files (e.g., Unix).

Modeling Discretionary Access Control

Different DAC policies and models have been proposed in the literature.

The most popular discretionary model is the **Access Matrix Model**

Core of the Access Matrix Model is the **Access Control Matrix (ACM)**

- Rows: Set of subjects *S* in the system
- Columns: Set of objects *O* in the system
- Matrix entry *ACM*[*i* , *j*]: The rights that a subject s_i has on object o_j. This is a subset of the set of rights *R* that is defined in the system E.g., *R* = {read, write, execute}.

The Access Control Matrix can be

- **Static** (entries do not change in the course of time)
- **Dynamic** (entries change in the course of time)

Example for an Access Control Matrix

S = {Process1,Process2}
O = {File1, File2, Process1, Process2}
R = {*read, write, execute, append, own*}

Note: *S* ⊆*O* *!!!*

- *own*: The subject that has this right can grant or take rights to the other subjects (and to itself)
- *append*: Subject is allowed to attach some data (or a file) to the object (integrity concern!)
- *execute*: Subject is allowed to execute the object
- *write*: Subject is allowed to write into the object i.e., alter the object (integrity concern!)
- *read*: Subject is allowed to read the object (confidentiality concern!)

The Access Control Matrix could be:

	File1	File2	Process1	Process2
Process1	***read, write, own***	***read***	***read, write, own, execute***	***write***
Process2	***append***	***read, write, own***	***read***	***read, write, own, execute***

ACM Example: Description

File entitlements

- Process1 can read or write to File1 and can only read File2.
- Process2 can append data to File1 and can read or write to File2.

Process entitlements

- Process1 can communicate with Process2 by writing to it.
- Process2 can read from Process1.

Note: The "**own" right** gives the creator of an object special rights (i.e., grant new rights to another subject or remove existing rights and delete rights)

- Process 1 owns File1 and itself ⇒ can change the rights on them!
- Process 2 owns File2 and itself ⇒ can change the rights on them!

DAC Advantages

- An individual user can set an access control mechanism to allow or deny access to an object.
- Relies on the object owner to control access.
- DAC is widely implemented in most operating systems, and we are quite familiar with it.
- Strength of DAC:

  Flexibility: a key reason why it is widely known and implemented in mainstream operating systems.

DAC Disadvantages

- **Global policy:** DAC let users to decide the access control policies on their data, regardless of whether those policies are consistent with the global policies. Therefore, if there is a global policy, DAC has trouble to ensure consistency.
- **Information flow:** Information can be copied from one object to another, so access to a copy is possible even if the owner of the original does not provide access to the original copy. This has been a major concern for military.
- **Malicious software:** DAC policies can be easily changed by owner, so a malicious program (e.g., a downloaded untrustworthy program) running by the owner can change DAC policies on behalf of the owner.
- **Flawed software:** Similar to the previous item, flawed software can be "instructed" by attackers to change its DAC policies.

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Mandatory Access Control (MAC)

Idea of MAC: A system mechanism (e.g., the operating system) controls access to an object and an individual user cannot alter that access.

Neither the subject nor the owner of the object can determine whether access is granted.

The system mechanism will check information associated with both the subject and the object to determine whether the subject should access the object.

Rules describe the conditions under which access is allowed Mandatory policies are also called rule-based policies.

Example

Sometimes, the law allows the fiscal authorities to have access on your bank account record.

Mandatory Access Control (MAC) (cntd.)

Goal of MAC:

Preserve confidentiality and integrity of information.

Prevent some types of Trojan horse attacks that can change security attributes.

Types of mandatory policies

Secrecy policies: controls the direct and indirect flow of information to the purpose of preventing leakages to unauthorized subjects.

Integrity policies: controls the direct and indirect flow of information to the purpose of preventing unauthorized altering of objects.

Mandatory control can be used in conjunction with discretionary control

Serve as an additional and stronger restriction on access.

MAC and Multilevel Security (MLS)

Many different MAC schemes have been defined

Nearly all are variants of the U.S. Department of Defences **multilevel security policy.**

It is difficult to discuss mandatory controls apart from multilevel security.

Idea of multilevel security (MLS)

Each **object** in the system (e.g., a file) possesses a **classification.**

Each **subject** in the system (e.g., a user) possesses a **clearance.**

In order to determine whether a subject is allowed to access an object, the subjects clearance is compared to the objects classification.

Both classification and clearance are sometimes denoted as **access classes.**

Notions in Multilevel Security

Both classification and clearance are made up of two components:

A **security level** that is an element of linearly ordered set.

E.g., *Unclassified* < *Confidential* < *Secret* < *TopSecret*

A set of one or more **categories** (also called compartments), consisting of names of the thematic areas to which an object may belong.

E.g.,*{Nato, Nuclear, Navy}* or *{Administration, Laboratory, Surgery}*

Categories are independent of each other and are not ordered.

Category describes a kind of information.

Objects placed in multiple categories have the kinds of information in all of those categories.

Example

An object o_i could have a classification (*Confidential*, *{Nato}*).

A subject s_j could have a clearance (*Secret*, *{Nato, Navy}*)

Multilevel Security

"Need to Know" Principle: States that no subject is granted an access unless the access is necessary to perform its functions.

- The set of categories to which a subject may have access is simply the power set of the set of categories.

Example: If the categories are NUC, EUR, and US. A subject can have access to any of the following sets of categories: Φ, {NUC}, {EUR}, {US}, {NUC, EUR}, {NUC, US}, {EUR, US}, and {NUC, EUR, US}.

- These sets of categories form a lattice under the operation ⊆ (subset of).
- Any set, default, is a subset of itself, and empty set is a subset of any set.

Mathematical Relationships

When categories and levels are combined, four relationships are possible between two access classes

1 **The security level (L, C) dominates the security level (L', C') if and only if L' ≤ L and C' ⊆ C.**

The first access class dominates (dom) the second

That is, the level of the first is greater than the level of the second, and the category set of the first contains all the categories of the second .

2 Example: AC_1 = (*Secret, {Nato, Navy}*), AC_2 = (*Confidential, {Nato}*) ⇒ AC_1 dom AC_2
because *Secret* ≥ *Confidential* and *{Nato}* ⊆ *{Nato, Navy}*

3 **The second access class dominates the first**

The access classes are equal

Special case where both 1. and 2. are true
Example: AC_1 = (*Secret, {Nato, Navy}*), AC_2 = (*Secret, {Nato, Navy}*)
4 ⇒ AC_1 = AC_2 because AC_1 dom AC_2 and AC_2 dom AC_1

The access classes are disjoint and cannot be compared

The first contains a category not in the second, and the second contains a category not in the first
Example: AC_1 = (*Secret, {Nato, Navy}*) and AC_1 = (*Secret, {Nuclear , Navy}*) are disjoint classes

Mathematical Models for Multilevel Security

Protection of confidentiality of information: Bell La Padula Model (BLP)

Addresses the confidentiality problem by mathematically describing the ”read” and ”write” restrictions based on **confidentiality (secrecy) access classes.**

Protection of integrity of information: Biba Model

Addresses the modification problem by mathematically describing read and write restrictions based on **integrity access classes.**

The Bell-La Padula (BLP) Model

First mathematical model of a multilevel secure computer system

Developed and formalized by David Bell and Leonard La Padula.

Published in 1973.

It has influenced the development of many other models.

It has strongly influenced the development of computer security technologies (e.g., UNIX, Multics).

Controls the information flow

The flow model in BLP is motivated by the **confidentiality** of information.

A confidentiality policy prevents the unauthorized disclosure of information; unauthorized alternation of information is secondary.

Suited for modeling strong hierarchical systems

It was designed for the military in USA.

Basic Security Theorem of the BLP Model

- **BLP Basic Security Theorem (rules of the model)**

Simple security property (”no-read-up”-principle):[1]

A subject *s* is allowed a ”read” access to an object *o* only if the access class of the subject dominates the access class of the object, i.e., *AC* (*s*) dom *AC* (*o*), and *s* has discretionary read access to *o*

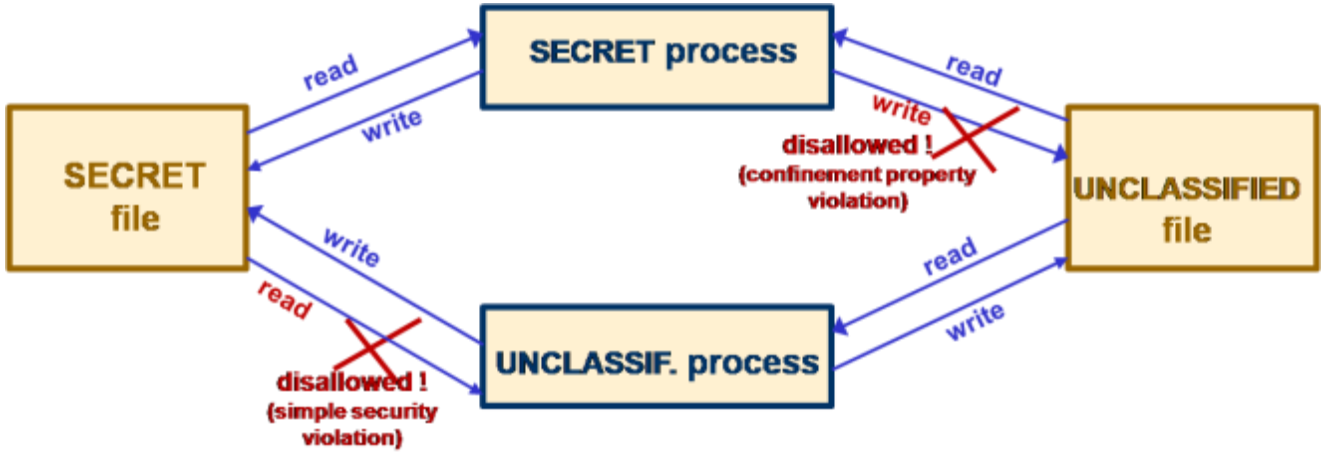
Confinement property (or *-property) (”no-write-down”-principle):[2]

A subject *s* is allowed a ”write” access to an object *o* only if the access class of the subject is dominated by the access class of the object, i.e., *AC* (*o*) dom *ACs*, and *s* has discretionary write access to *o*

*-property

- It was driven by the fear that a user with “Secret” clearance might be “tricked” by attackers (e.g., through Trojan horse programs or software vulnerabilities) to copy down the information to a ”Unclassified” area where the attackers can read.

Bell-LaPadula Model: An Example



- **Simple example:** In a system two security levels has been defined *{Unclassified, Secret}* with *Secret* > *Unclassified*. No categories has been defined.
  - Subjects and objects in the system: two processes (subjects) and two files (objects)
    - One file and one process are *Unclassified*
    - Other file and other process are SECRET

The information flow is in the picture above is represented as an arrow →

Examples

Q. A colonel with (SECRET, { NUC, EUR }) clearance needs to send a message to a major with (SECRET, { EUR }) clearance.

Ans. The colonel must write a document that has at most the (SECRET, {EUR}) classification. But this violates the *-property, because (SECRET, { NUC, EUR }) *dom* (SECRET, { EUR }).

- This model through a relationship between maximum security level and current security level allows this type of communication.

maximum security level *dom* current security level

Colonel's maximum security level is (SECRET, { NUC, EUR }) and changes to current security level to (SECRET, { EUR }). This is valid, then create the document at the major's clearance level and send it to him.

Biba Model for Integrity

Goal of the model: Protection of integrity of information

- ✓ Developed 1977 by Kenneth Biba.
- ✓ Addresses the modification problem by mathematically describing ”read” and ”write” restrictions based on **integrity access classes.**

✓ Deal with integrity alone and ignores confidentiality entirely.

✓ Biba model covers integrity levels, which are analogous to sensitivity levels in Bell-LaPadula.

✓ Integrity levels cover inappropriate modification of data.

✓ Prevents unauthorized users from making modifications (1st goal of integrity).

Biba Model

All concepts of multilevel security (MLS) are used

- An integrity access class is a pair consisting of integrity level and set of categories.
  - Integrity levels are defined as an ordered set,

    e.g., *Unclassified* < *Inter Sensitive* < *High Integrity*
  - Categories are unordered set of thematic areas.
- The ”Dominance” relation *dom* is the same as in other MLS models Remind:
  - For subjects, the access class is called ”classification” for objects, the access class is called ”clearance”.

Basic Security Theorem of the Biba Model

- **Biba Basic Security Theorem (rules of the model)**

1. **Simple integrity** (”no-write-up”-principle):

   A subject *s* is allowed a ”write” access to an object *o* only if the integrity access class of the subject dominates the integrity access class of the object, i.e., $AC(s)$ dom $AC(o)$, and *s* has discretionary read access to *o*

2. **Integrity confinement (or *-property)** (”no-read-down”-principle):

   A subject *s* is allowed a ”read” access to an object *o* only if the integrity access class of the subject is dominated by the integrity access class of the object, i.e., $AC(o)$ dom ACs, and *s* has discretionary write access to *o.*

Biba Model: An Example

Simple example:

In a system two integrity levels has been defined.
{High integrity, Low integrity} with *High integrity* > *Low integrity*. No categories has been defined.

Subjects and objects in the system: two processes (subjects) and two files (objects)

- One file and one process are *High integrity*
- Other file and other process are *Low integrity*

The information flow is in the picture above is represented as an arrow →

Some Remarks on Integrity Control

Mandatory integrity control mechanisms are very important in operating systems.

The primary application has been to avoid modification of some certain system programs and system databases that are important to the operation of the system and yet do not involve information with any secrecy content.

For example, the list of user allowed to access the system might not be secret, but it must be protected from modification by untrusted software.
This protection must be stronger that the discretionary protection provided for user files (mandatory integrity mechanisms provide that type of protection!).

Mandatory integrity control mechanisms are also very important in commercial systems.

E.g., who is allowed to change records in an Aircompany-database with flights?

Literature

[HRU] M. A. Harrison, W. L. Ruzzo and J. D. Ullman: **”Protection in Operating Systems”** Communications of ACM. 19(8):461–471, August 1976.

[BLP] David Bell and Leonard LaPadula: **”Secure Computer Systems: Mathematical Foundations and Models”** Technical Report MTR-2547 v2, MITRE, 1973.

[Biba] K. J. Biba: **”Integrity Considerations for Secure Computer Systems”** Technical Report MTR-3153, MITRE, 1977.