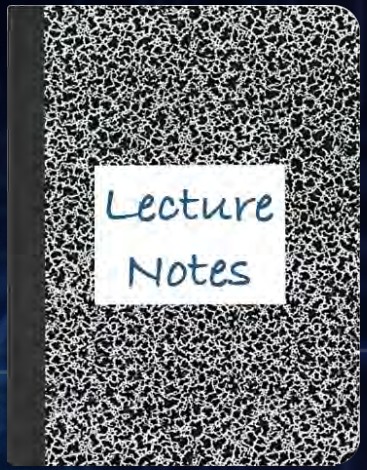
CS 419: Computer Security

Week 6: Part 3
Mandatory Access Control



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What's wrong with ACLs?

- **Users are in control**

```
chmod o+rw secret.docx
```

  - Now everyone can read and modify `secret.docx`
- **Doesn't work well in environments where management needs to define access permissions**
- **No ability to give time-based or location-based permissions**
- **Access is associated with objects**
  - **Hard to turn off access for a subject** - except by locking the user
  - Otherwise have to go through each object and remove user from the ACL

    … but you're still stuck with default access permissions and wondering how other users will set access rights in the future

Access Control Models: MAC vs. DAC

DAC: Discretionary Access Control

- A subject (domain) can pass information onto *any* other subject
- In some cases, access rights may be transferred
  e.g., *chown*
- ***Users are in charge of access permissions***
- *Most systems use this*

MAC: Mandatory Access Control

- Policy is centrally controlled
- Users cannot override the policy
- ***Administrators are in charge of access permissions***

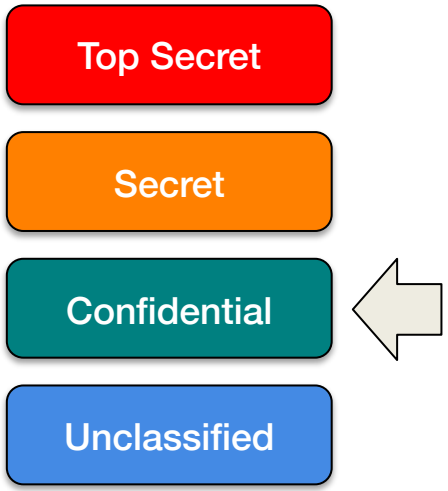
MLS: Multilevel Security Systems

Initially designed to address security concerns in the Air Force

Handle multiple levels of classified data in one system

Bell-LaPadula Model

- Designed for the military
- Based on U.S. military classification levels



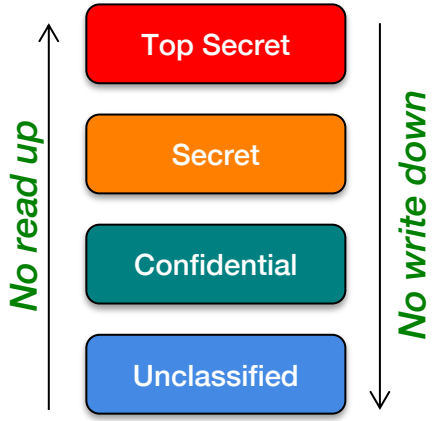
Motivation:
Preserve confidentiality. If one program gets hacked, it will not be able to access data at higher levels of classification

If you have confidential clearance:

- You can **access** confidential & unclassified data
- You can **create** confidential, secret, and top-secret data

Bell-LaPadula (BLP) Access Model

- **Objects are classified into a hierarchy of sensitivity levels**
  - Unclassified, Confidential, Secret, Top Secret
- **Each user is assigned a clearance**
- **"*No read up; no write down*"**
  - Cannot read from a higher clearance level
  - Cannot write to a lower clearance level
- **Assumes vulnerabilities exist and staff may be careless**
- **Need a "trusted subject" to declassify files**



Confidential cannot read Secret
Confidential cannot write Unclassified

Bell-LaPadula (BLP) Model Properties

Every subject & object gets a security label (e.g., confidential, secret)

1. **The Simple Security Property** – ***mandatory rules for reading***
   – No Read Up (NRU)
   A subject cannot read from a higher security level

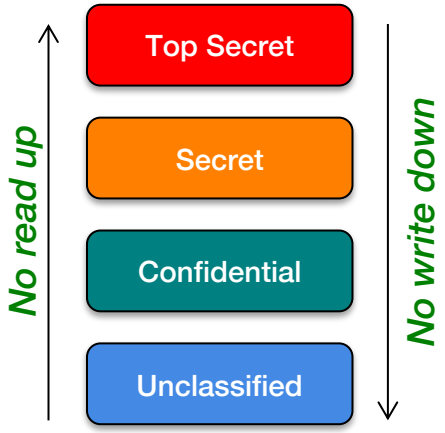
2. ***-Property** (star-property) – ***mandatory rules for writing***
   – No Write Down (NWD)
   A subject cannot write to a lower security level

3. **The Discretionary Security Property**
   – Discretionary access controls can be used for **DAC** *after* MAC is enforced

Multilateral Security:
Enhancing MLS to Control Access at the Same Security Levels

Basic Multilevel Security (MLS) Model

- Subjects and objects have assigned classification labels
- Rules control what you can read or write

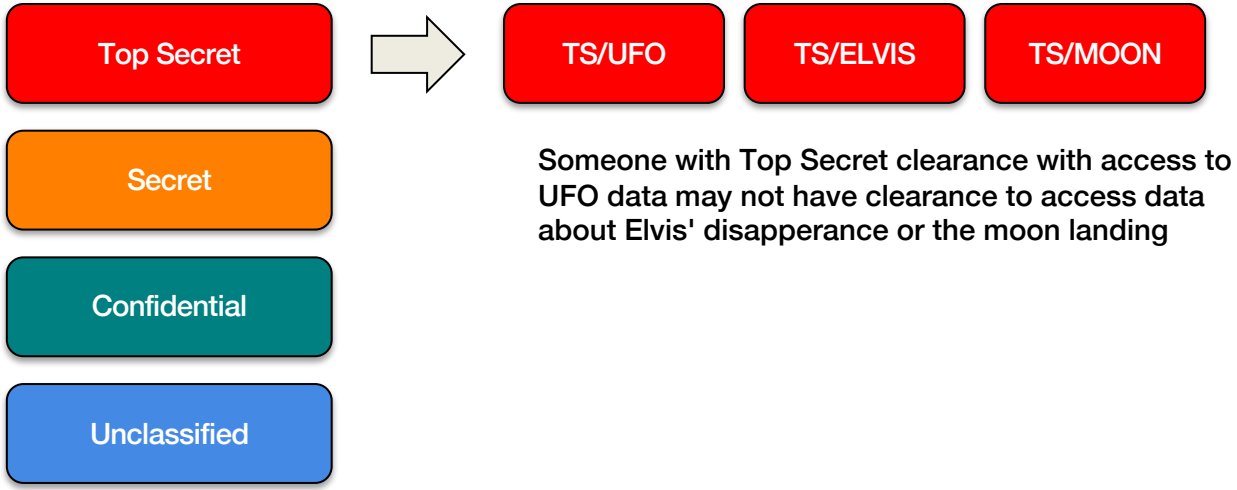


Bell-LaPadula

Multilateral Security – Further Restricting Access

Each security level may be divided into compartments

- Usually applied to the top-secret level
- TS/SCI = Top-Secret / Special Compartmentalized Intelligence
- You will be granted access to specific compartments
  - Formalized description of “need to know”

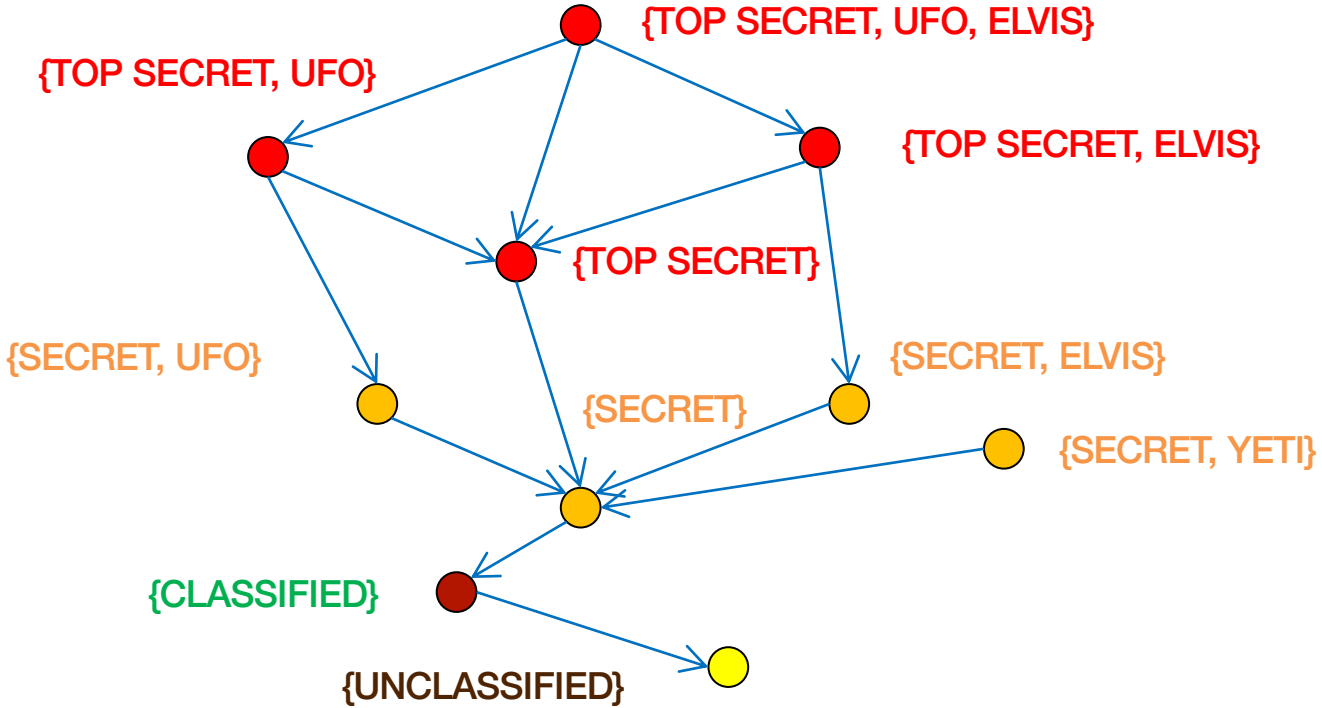


Compartmentalization

- **Subjects & objects get security labels (compartments) in addition to security classification labels**
- **If you do not have clearance for the label, you cannot access the data**
  - {TOP SECRET, UFO} cannot be read by someone with only {TOP SECRET} clearance
  - Neither can {SECRET, UFO}

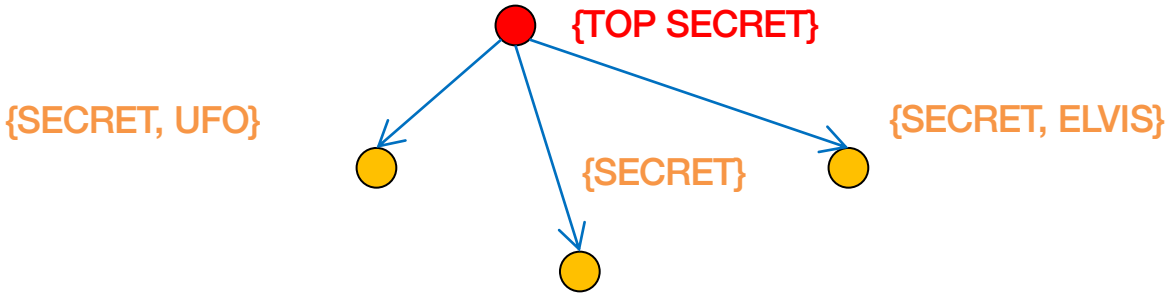
Lattice Model to Show Access

Graph representing access rights of different labels & levels



Problems with MLS + Compartments

- **Data shared by two compartments creates a third compartment**
  - Creates more isolation
  - Does not help with sharing
- **One option (which breaks the model)**
  - Allow multiple compartments at a lower level to be readable by a higher level



Multilevel & Multilateral Security Models

- **Do not help downgrading data**
  - Need special roles to re-label or declassify data
- **Handing searches across compartments is difficult**
  - No single entity will likely have rights to everything

Type Enforcement Model (TE)

Secondary Access Control Matrix that gives MAC priority over DAC

- **Domains and Types**
  - Assigns subjects to **domains**
  - Assigns objects to **types**
  - Matrix defines permitted **domain-domain** and **domain-type** interactions

Role-Based Access Control (RBAC)

- **More general than Bell-LaPadula**
- **Designed to allow enforcement of both MAC & DAC properties**
- **Access decisions do not depend on user IDs but on roles**
  - Administrators define roles for various job functions
  - Each role contains permissions to perform certain operations
  - Users are assigned one or more roles
- **Roles are *job functions*, not *permissions***
  - "update customer information" is a role
  - "write to the database" is not a role
- **Enables fine-grained access**
  - Roles may be defined in application specific ways (e.g., "move funds")

RBAC Rules

- **Role assignment**
  - A subject can execute an operation only if the subject has been assigned a role
- **Role authorization**
  - A subject's active role must be authorized for that subject
  - Ensures that users can only take on roles for which they have been authorized
- **Transaction authorization**
  - A subject can execute a transaction only if the transaction is authorized through the subject's role membership

RBAC is essential to database security

Aren’t roles == groups?

- **Group = collection of users**
  - Does not enable management of user-permission relationships
- **Role = collection of permissions**
  - Permissions can be associated with users and groups
- **Roles have a session**
  - Users can activate a role

RBAC Benefits

- **RBAC is hugely popular in large companies**
  - Driven by regulations such as HIPAA and Sarbanes-Oxley
- **Makes it easy to manage movement of employees**
- **Makes it easy to manage "separation of duty" requirements**
- **Can manage complex relationships**
  - Doctor X wants to view records of Patient Y
  - Doctor needs roles of "Doctor" and "attending doctor with respect to Y"
  - Roles allow specification of *only if*, *not if* or *if and only if* relations
- **RBAC can simulate MAC and DAC**

See http://csrc.nist.gov/groups/SNS/rbac/faq.html

SELinux (Security Enhanced Linux)

SELinux = Security-Enhanced Linux

Originally a kernel patch created by the NSA to add MAC to Linux

Supports three MAC models:

1. **Type Enforcement** (**TE**)
2. **Role-Based Access Controls** (**RBAC**) – built on top of TE
3. **Multilevel Security** (**MLS**) – the Bell-LaPadula Model
   - **Multicategory Security** (**MCS**)
     - Support for categories but without a security hierarchy (no levels)

There are other security models and implementations available in other distributions

Type Enforcement (TE) on SELinux

- **Subjects are grouped into domains**
  - Processes are subjects – they run with the privileges of a user
  - Each subject is assigned a label identifies its domain
- **Objects are grouped into types**
  - A label assigned to an object (file) identifies its **type**
- **Domains & types are managed in the same way**
  - Each has a security context, represented by a **security ID** (**SID**)
- **An Access Control Matrix defines subject-object permissions**
- **Each process has a security ID (SID), user ID, and group ID**

Type Enforcement (TE) on SELinux

Access control rules

The security administrator defines
what access a **domain** (subject) can perform on a **type** (object)

```
allow userdomain bin_t:file: execute;
allow user2domain bin_t:file: read;
```

- **Allows users with the label "`userdomain`" execute rights for files with the label "`bin_t`"**
- **Allows users with the label "`user2domain`" read rights for those files**

RBAC in SELinux

- **RBAC is built on top of TE (type enforcement)**
  - Users mapped to roles at login time
  - Roles are authorized for domains
  - Domains are given permissions to access object types
- **Role-based access is specified in terms of TE**
  - Role = { groups, users, file operatons }
  - Goal is to simplify labeling

Note:
This does not allow fine-grained roles, such as "*access employee names*" or "*transfer funds*"

Biba Integrity Model

- **Bell-LaPadula was designed to address confidentiality**
- **Biba is designed to ensure data integrity**

Confidentiality = constraints on who can *read* data

Integrity = constraints on who can *write* data

Motivation:
Preserve data integrity.
If one program gets hacked, it will not be able to modify data at higher levels of integrity

Biba model properties

- **Simple Security Property** = A subject cannot read an object from a lower integrity level
  Subjects may not be corrupted by objects from a lower level
  No read down
- **Star property** = A subject cannot write to an object at a higher integrity level
  Subjects may not corrupt objects at a higher level than the subject
  No write up
- A process cannot request higher access

Example Use Case for the Biba Integrity Model

Protect system software from untrusted users

- **Simple Integrity Property ("No Read Down")**
  - A high-integrity subject cannot read a lower-integrity object
  - Prevents trusted processes (e.g., kernel, system daemons) from being corrupted by untrusted sources
- **Star Property (“No Write Up”)**
  - A low-integrity subject cannot write to a higher-integrity object
  - Ensures that untrusted users or processes cannot modify critical system files

Example Use Case for the Biba Integrity Model (2)

Junior accountants can input data, but only senior accountants can approve or modify final financial reports

Standard permissions are insufficient

- **If senior accountants own reports, they may still use unverified data**
- **If files are group writable, junior accountants can modify final reports**

Discretionary Access Control (DAC) Cannot Differentiate Between Trust Levels

Example Use Case for the Biba Integrity Model (2)

Junior accountants can input data, but only senior accountants can approve or modify final financial reports

Junior accountants (low integrity)

- Can write new transaction records (low integrity data)
- Cannot modify approved financial reports (high integrity data)

- **Senior accountants (high integrity)**
  - Can modify approved financial reports
  - Cannot use unverified (low-integrity) data to update final reports (*No Read Down Rule*).

Example Use Case for the Biba Integrity Model (3)

A doctor (high-integrity subject) is trusted to modify patient records (high-integrity objects)

– But cannot write to low-integrity objects (e.g., patient-submitted forms) because that would violate the "no write down" rule.
This prevents the doctor from lowering the integrity of the high-integrity medical records.

- **A nurse (medium-integrity subject) can update working notes (medium-integrity objects)**

– But cannot directly modify the official medical records (high-integrity objects) due to the "no write up" rule.
This ensures the official records are only modified by high integrity subjects.

- **A patient (low-integrity subject) can submit forms (low-integrity objects)**

– But cannot update their own medical records (high-integrity objects) due to the "no write up" rule.
This prevents the patient from corrupting the official medical records with unverified information.

Example Use Case for the Biba Integrity Model (4)

ECG device:

- Runs a calibration process, which stores a calibration file = *high integrity*
- Runs user processes, that run ECG tests = *lower integrity*

- **Normal users cannot write the calibration file but can read it**
  - Can read data at higher levels (calibration = higher data level)
    - User process can read calibration data – but cannot modify it
- **The calibration process can write data to lower levels**
    - Calibration process can write to the user process – but cannot read user data

This model works well when you need to get data from a trusted device

Biba Problems

Like Bell-LaPadula, it doesn't always fit the real world

- **Microsoft offers Mandatory Integrity Control (Biba model)**
  - User's access token gets assigned an integrity level
  - File objects have an Access Control Entry (ACE) to hold an integrity level:
    - ***System***: Critical files
    - ***Medium***: Regular users and objects
    - ***High***: Elevated users
    - ***Low***: Internet Explorer, Adobe Reader, etc.
    - New process gets the *minimum* of the user integrity level and the file integrity level
  - Default policy = *NoWriteUp*
    - Goal: Apps downloaded with IE can read files but cannot write them – limit damage done by malware
    - Trusted subjects would have to overwrite the security model
      - Users get used to the pop-up dialog boxes asking for permission!
  - Microsoft dropped the *NoReadDown r*estriction
    - Did not end up protecting the system from users

Chinese Wall model

Chinese wall = rules designed to prevent conflicts of interest

- Common in financial industry
  - E.g., separate corporate advisory & brokerage groups
- Also in law firms and advertising agencies

- **Separation of duty**
  - A user can perform transaction *A* or *B* but not both

- **Three layers of abstraction**
  - **Objects**: files that contain resources about some company
  - **Company groups** = set of files relating to one company
  - **Conflict classes**: groups of competing company groups:

    Class 1 = `{Coca-Cola, PepsiCo, Keurig Dr. Pepper}`

    Class 2 = `{Alaska Airlines, American Airlines, United, Delta, JetBlue }`

Chinese Wall model

Basic rule

A subject can access objects from a company **only** if it never accessed objects from competing companies.

Simple Security property

- A subject ***s*** can be granted access to an object ***o*** only if the object
  - Is in the same company group as objects already accessed by ***s***

or

  - ***o*** belongs to a different conflict class

*-property

- Write access is allowed ***only*** if
  - Access is permitted by the simple security property

and

  - No object was read which is in a different company dataset than the one for which write access is requested *and* contains **unsanitized** information
    - ***Sanitization*** = disguising a company's identify
    - This means that you could read data across the wall ***only*** if it's anonymized

MAC vs DAC Summary

- **DAC = Discretionary Access Control**
  - User are in charge of setting access permissions
  - If you own a file, you can set any access permissions you want on it … and even give it away
  - The root user (user ID 0) has the power to change any permissions
- **MAC = Mandatory Access Control**
  - System owner (administrator) defines security policies
  - Users cannot override them, regardless of their privilege level

MAC takes priority over DAC

Access Models: Summary

- **Discretionary Access Control: Puts the user in charge of access**
- **Mandatory Access Control: Needed when an organization needs to define policies**
  - Multi-Level Security (MLS) and Bell-LaPadula (BLP)
    - Oldest & most widely studied model – synonymous with Multi-Level Security (MLS)
    - Designed to protect confidentiality
    - Doesn't work well outside of the DoD … and is clunky within the DoD
  - Multi-Lateral Security and Multi-Compartment Security: e
    - Extends BLP to support compartments within each security level
  - Type Enforcement (TE)
    - Simple MAC model to override DAC
  - Role-Based Access Control (RBAC)
    - Identifies roles and assigns users to roles
    - Made popular by business needs
    - Most actively used MAC model
  - Biba Model
    - Conceptually the opposite of Bell-LaPadula: concerned with integrity, not confidentiality
  - Chinese Wall Model
    - Identifies conflict classes and prevents users from accessing across them

MAC can reduce the need for root

- **Traditionally the *root* user has supreme power**
  - You need supreme power to do *any* administrative task
  - Example: a network administrator can read – and modify – any files on the system
- **Models such as TE and RBAC allow you to define classes of users that can perform only certain operations and access certain files**
  - E.g., you can define a **network administrator** who can modify network configuration files and run network commands ... but not create user accounts or reboot the system

Security Risks

- **Even if the mechanisms work perfectly, policies may fail**
  - DAC: you're trusting the users or a sysadmin to set everything up correctly
  - MAC
    - User or role assignment may be incorrect
    - Collaboration needs to be considered
    - Models like Bell-LaPadula and Biba require overrides to function well
- **Corruption**
  - Attacks may change the definition of roles or the mapping of users to roles
  - This is an attack on the Trusted Computing Base
- **Users**
  - Most malware is installed willingly
  - Users thus give it privileges of – at least – normal applications
  - As far as the operating system is concerned, it is enforcing defined policy

Security Risks

- **Even administrators should not be able to read all files**
  - Many security systems enforce this
  - Edward Snowden should not have been able to copy sensitive documents onto a thumb drive … even if NSA policy banned thumb drives
- **General assumption has been that programs are trusted and run with the user's privileges**
- **Worked well for system programs**
- **Do you trust the game you installed on your phone?**
- **Need to consider better application isolation**
  - Android turned Linux into a single-user system
  - User IDs are used on a per-application bases

Network Services & Program-Based Access Control

- **A lot of access decisions must be handled by programs, not the OS**
  - Database users and the access each user has within the database
  - Microsoft Exchange & Active Directory administrators
  - Mail readers
  - Web services: users are unlikely to have accounts on the system
  - Movement of data over a network
    - How do you send access permissions to another system?
    - Digital rights management = requires trusted players

- **Programs may implement RBAC (e.g., Exchange) or other mechanisms**
  - But the OS does not help

The End