CS 419: Computer Security

Week 2: 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

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
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
   – Access control matrix can be used for DAC after MAC is enforced
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)
3. Multilevel Security (MLS) – the Bell-LaPadula Model
   - Multi-Category Security (MCS)
     • Extension of MLS to define categories within a security level

There 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 operations \}
  – 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

**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

**Motivation:**
**Preserve data integrity.**
If one program gets hacked, it will not be able to modify data at higher levels of integrity
An example of where Biba is useful

The Biba model fits certain real-world applications

• 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

• Calibration process can write data to lower levels
  • Calibration process can write to the user process – but cannot read user data

• 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** restriction
    – Did not end up protecting the system from users
MAC vs DAC Summary

- **DAC = Discretionary Access Control**
  - The user is in charge of setting file 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**
  - Works great when it’s ok to put the user in charge

- **Mandatory Access Control**
  - Needed when an organization needs to define policies
    - **Bell-LaPadula (BLP)**
      - Oldest & most widely studied model – synonymous with MLS
      - Designed to protect confidentiality
      - Doesn’t work well outside of the DoD … and is clunky within the DoD
    - **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**
    - Opposite of Bell-LaPadula: concerned with integrity, not confidentiality
Multilateral Security
Multilevel Security

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

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

Graph representing access rights of different labels & levels
Multilateral Security

• Data from two compartments ⇒ third compartment
  – Creates more isolation
  – Does not help with sharing

• One option
  – 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
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\}
**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 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
Program-Based 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