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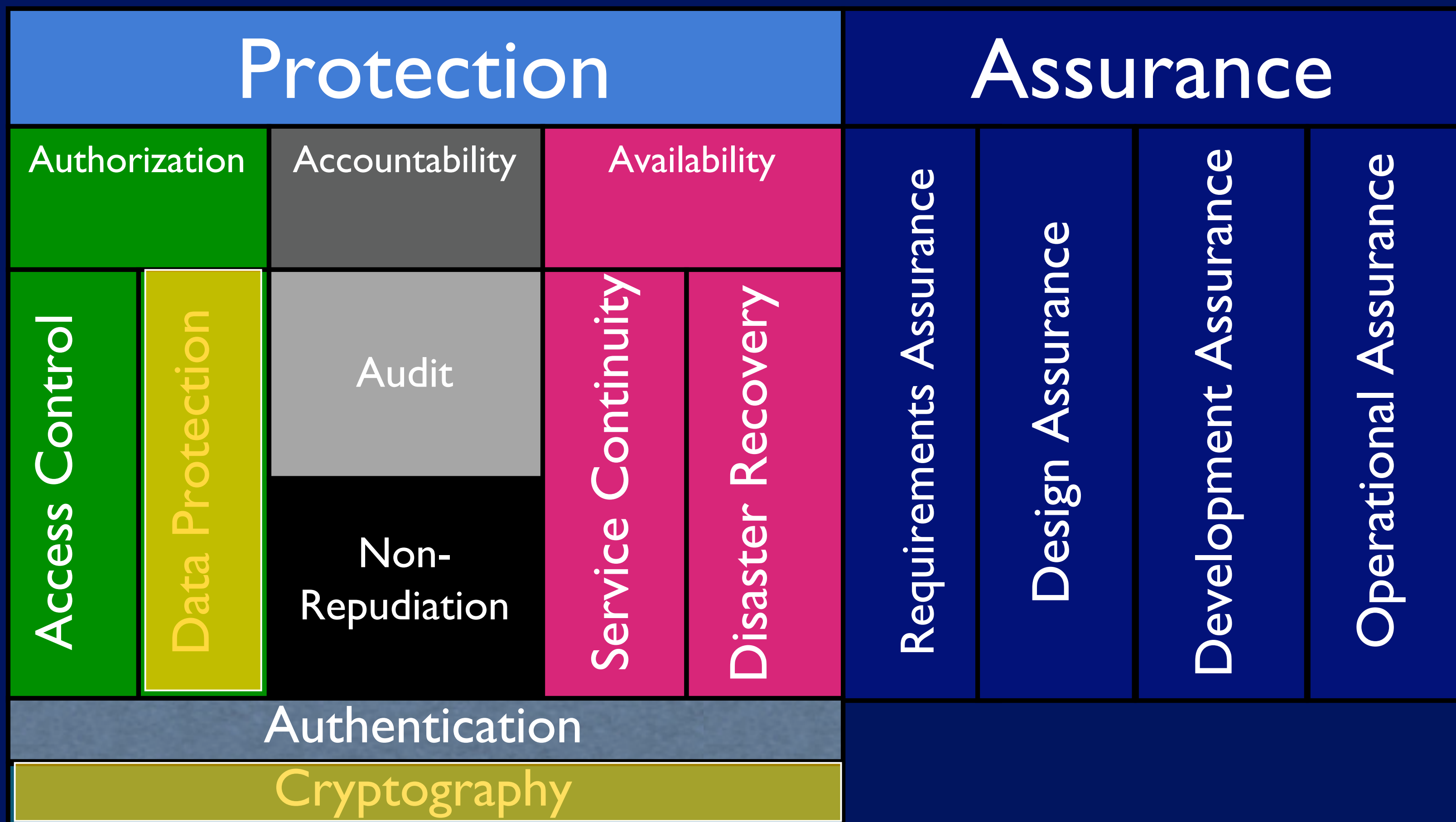
Security Policies

EECE 412

Outline

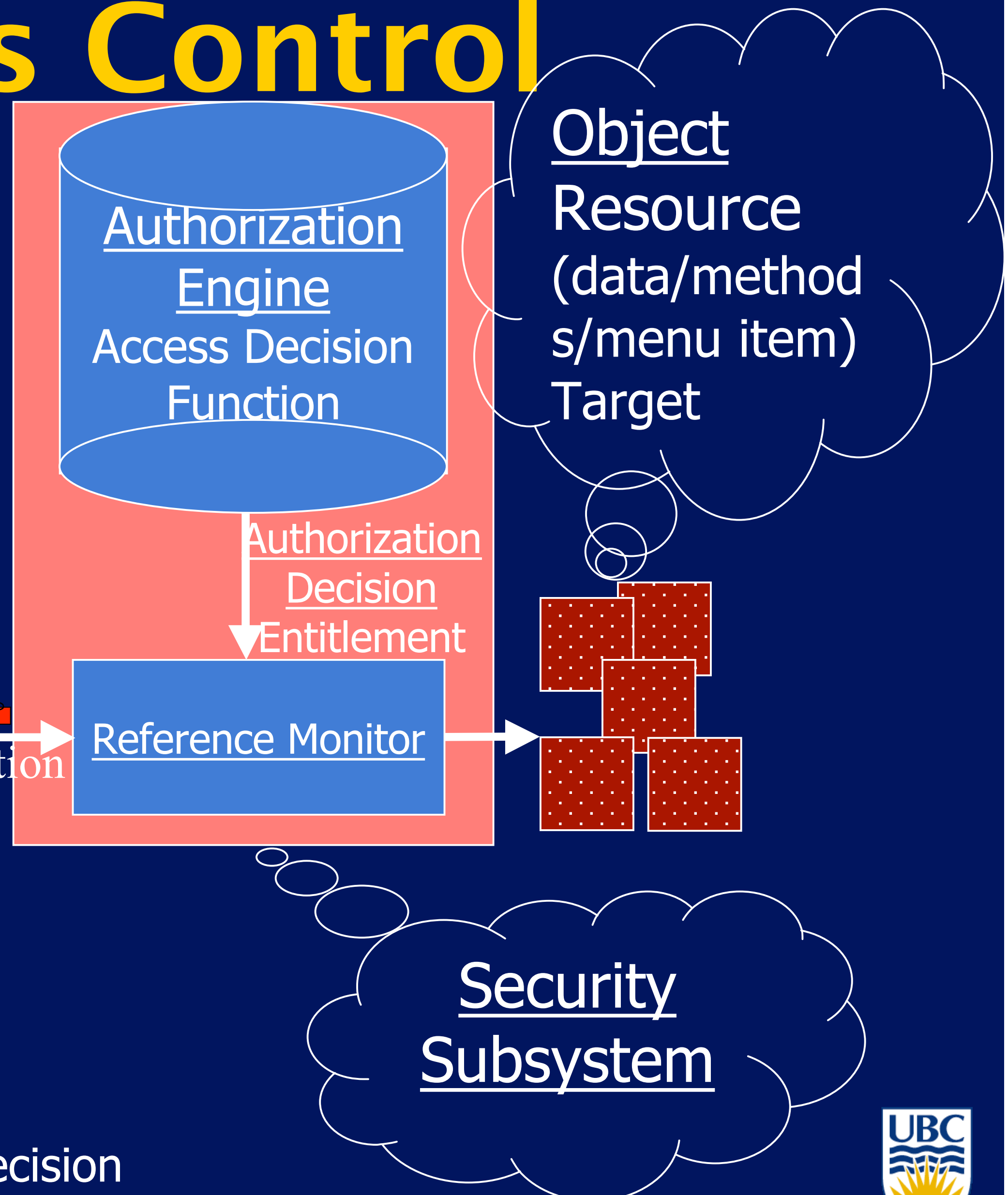
- Access control mechanisms
- Access Matrix (DAC)
- Security policies
  - Confidentiality policies
    - Bell LaPadula confidentiality model
  - Integrity policies
    - Biba integrity model
    - Clark-Wilson Integrity Model
  - Hybrid policies
    - RBAC

Where We Are


Protection
Assurance
Authorization
Accountability
Availability
Access Control
Data Protection
Audit
Non-Repudiation
Service Continuity
Disaster Recovery
Requirements Assurance
Design Assurance
Development Assurance
Operational Assurance
Authentication
Cryptography

Authorization Mechanisms: Access Control

Definition: **enforces the rules, when rule check is possible**



Mix of terms:

Authorization == Access Control Decision

Authorization Engine == Policy Engine

Policies and Mechanisms

- Policies describe what is allowed
- Mechanisms control how policies are enforced

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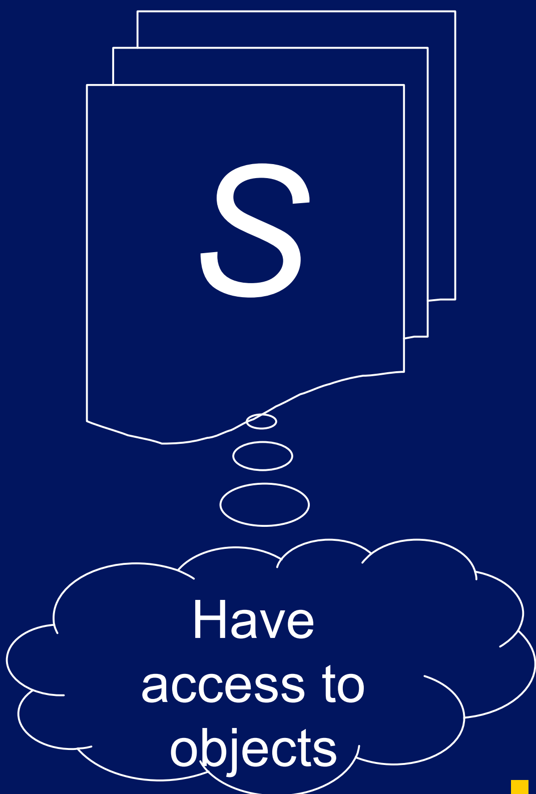
Access Matrix

Object System

Subjects



Objects

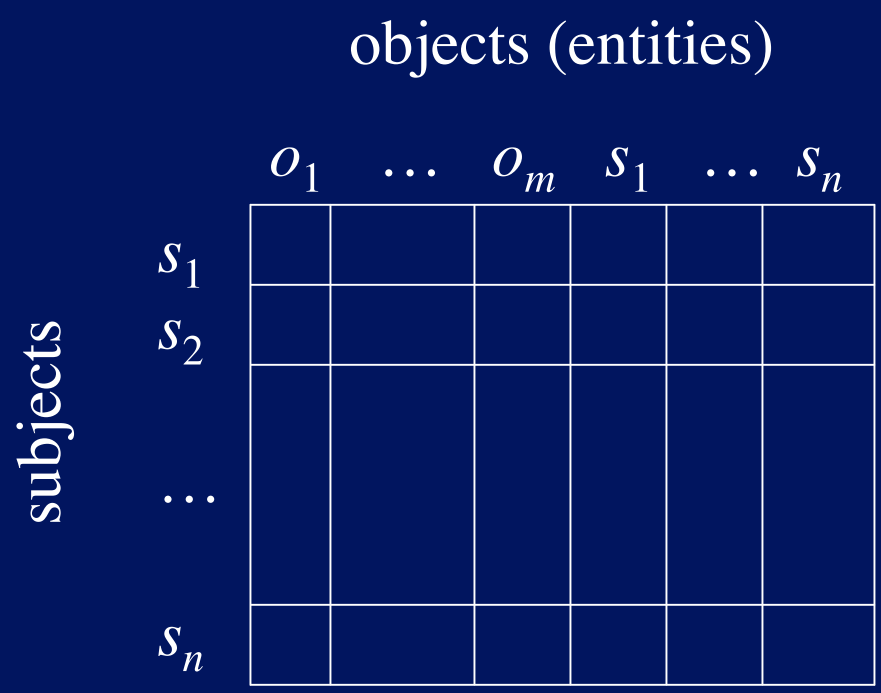
Access Matrix

A

	Subject 1	Subject 2	Subject 3	File 1	File 2	Process 1
Subject 1	*owner control	*owner control	*call	*owner *read *write		
Subject 2			call	*read	write	wakeup
Subject 3			owner control	read	*owner	

- Subjects are objects
- Objects are not subjects

Access Matrix Structure



- Subjects $S = \{ s_1,\ldots,s_n \}$
- Objects $O = \{ o_1,\ldots,o_m \}$
- Rights $R = \{ r_1,\ldots,r_k \}$
- Entries $A[s_i, o_j] \subseteq R$
- $A[s_i, o_j] = \{ r_x, \ldots, r_y \}$ means subject s_i has rights $r_x, \ldots, r_y$ over object o_j

Example

- Processes *p*, *q*
- Files *f*, *g*
- Rights *r*, *w*, *x*, *a*, *o*

	f	*g*	*p*	*q*
p	*rwo*	*r*	*rwxo*	*w*
q	*a*	*ro*	*r*	*rwxo*

Matrix Implementation Techniques

1. $T = \{<s,o,A_{d,x}>\}$ – impractical
   a) Only relevant parts of A need to be handy
   b) Could be very inefficient for some As (e.g. public files)
   c) List of objects to which d has access
2. Capability = $<o,A_{d,x}>$
   - C-lists
   - Attach C-list to subjects
   - Addresses (a), (c) and potentially (b)
3. attach the protection information to the object: $A_x(d)$
   - Access key – capability used for identification, (credential)
   - {<access key, {access attributes}>} – access control list (ACL)

Group Work

ACLs are good for revoking individual's access to a particular file.

- How hard is it to revoke a user's access to a particular set of files, but not to all files, with ACLs?
- Compare and contrast this with the problem of revocation using capabilities.

Access Matrix Summary

- Object System
  - Subjects, objects, access matrix
  - Objects are shared
  - All subjects are objects
    - not all objects are subjects
- Matrix implementation
  - Capability lists
  - Access control lists

Security Policies

What's Security Policy?

- Policy partitions system states into:
  - Authorized (secure)
    - These are states the system can enter
  - Unauthorized (nonsecure)
    - If the system enters any of these states, it's a security violation
- Secure system
  - Starts in authorized state
  - Never enters unauthorized state
- Authorized state in respect to what?

What's Confidentiality?

- *X* set of entities, *I* information
- *I* has *confidentiality* property with respect to *X* if no $x \in X$ can obtain information from *I*
- *I* can be disclosed to others

- Example:
  - *X* set of students
  - *I* final exam answer key
  - *I* is confidential with respect to *X* if students cannot obtain final exam answer key

What's Integrity?

- X set of entities, I information
- I has *integrity* property with respect to X if all $x \in X$ trust information in I
- *Examples?*

Types of Access Control

- Discretionary Access Control (DAC, IBAC)
  - individual user sets access control mechanism to allow or deny access to an object
- Mandatory Access Control (MAC)
  - system mechanism controls access to object, and individual cannot alter that access
- Originator Controlled Access Control (ORCON)
  - originator (creator) of information controls who can access information

Question

- Policy disallows cheating
  - Includes copying homework, with or without permission
- A class has students do homework on computer
- Alice forgets to read-protect her homework file
- Bob copies it
- Who cheated?
  - Alice, Bob, or both?

Answer

- Bob cheated
  - Policy forbids copying homework assignment
  - Bob did it
  - System entered unauthorized state (Bob having a copy of Alice's assignment)
- If not explicit in computer security policy, certainly implicit
  - Not credible that a unit of the university allows something that the university as a whole forbids, unless the unit explicitly says so

Answer Part #2

- Alice didn’t protect her homework
  - Not required by security policy
- She didn’t breach security
- If policy said students had to read-protect homework files, then Alice did breach security
  - She didn’t do this

Key Points about Policies and Mechanisms

- Policies describe what is allowed
- Mechanisms control how policies are enforced

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Confidentiality Policies

What's Confidentiality Policy

- Goal: prevent the unauthorized disclosure of information
  - Deals with information flow
  - Integrity incidental
- Multi-level security models are best-known examples
  - Bell-LaPadula Model basis for many, or most, of these

Bell-LaPadula Model, Step 1

- Security levels arranged in linear ordering
- Example:
  - Top Secret: highest
  - Secret
  - Confidential
  - Unclassified: lowest
- Subjects have *security clearance* $L(s)$
- Objects have *security classification* $L(o)$

Example

security level	*subject*	*object*
Top Secret	Alice	Personnel Files
Secret	Bob	E-Mail Files
Confidential	Chiang	Activity Logs
Unclassified	Fred	Telephone Lists

- Alice can read all files
- Chiang cannot read Personnel or E-Mail Files
- Fred can only read Telephone Lists

Reading Information

- Information flows *up*, not *down*
  - "Reads up" disallowed, "reads down" allowed
- Simple Security Property
  - Subject *s* can read object *o* iff, $L(o) \leq L(s)$ and *s* has permission to read *o*
    - Note: combines mandatory control (relationship of security levels) and discretionary control (the required permission)
  - Sometimes called "no reads up" rule

Writing Information

- Information flows up, not down
  - "Writes up" allowed, "writes down" disallowed
- *-Property
  - Subject s can write object o iff $L(s) \le L(o)$ and s has permission to write o
    - Note: combines mandatory control (relationship of security levels) and discretionary control (the required permission)
  - Sometimes called "no writes down" rule

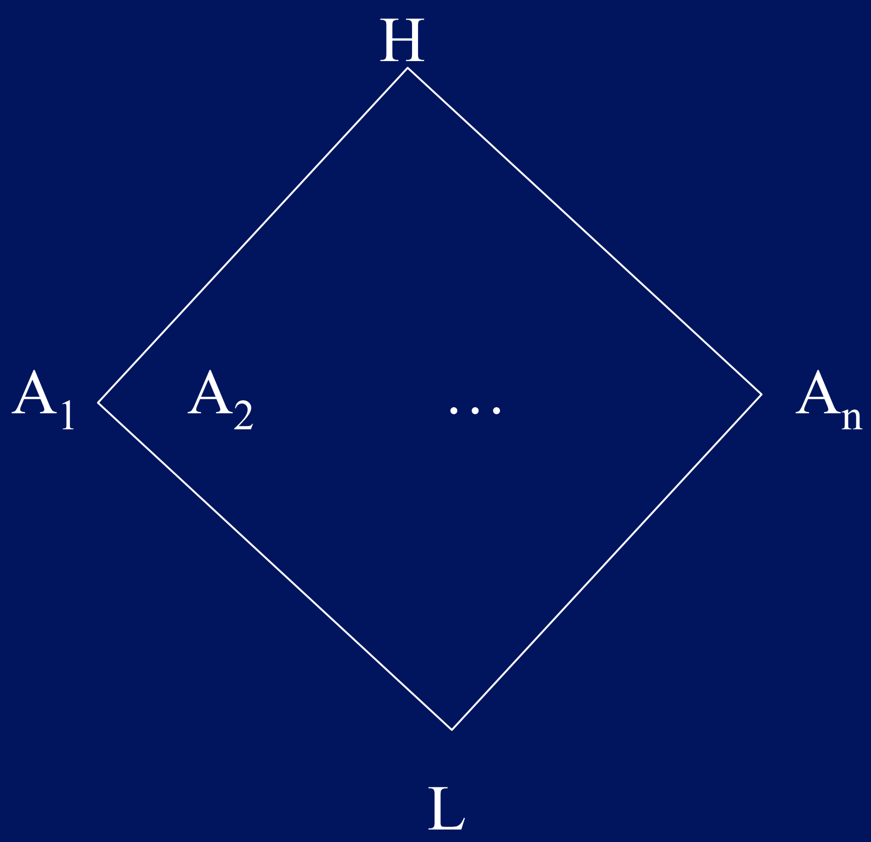
Bell-LaPadula Model, Step 2

- Expand notion of security level to include categories
- Security level is (*clearance*, *category set*)
- Examples
  - (Top Secret, { NUC, EUR, ASI })
  - (Confidential, { EUR, ASI })
  - (Secret, { NUC, ASI })

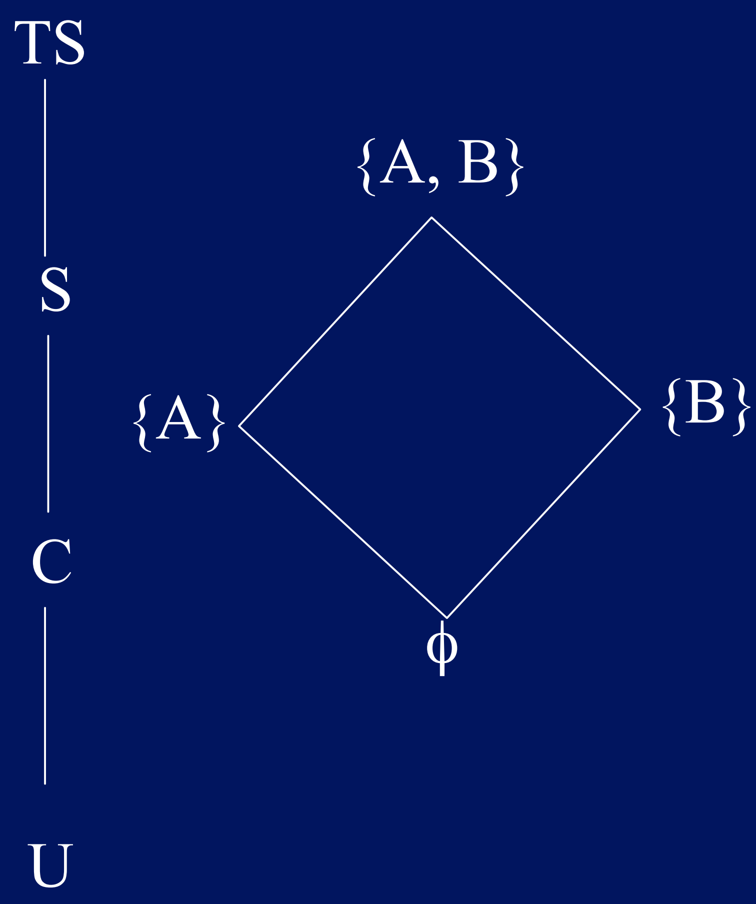
Levels and Lattices

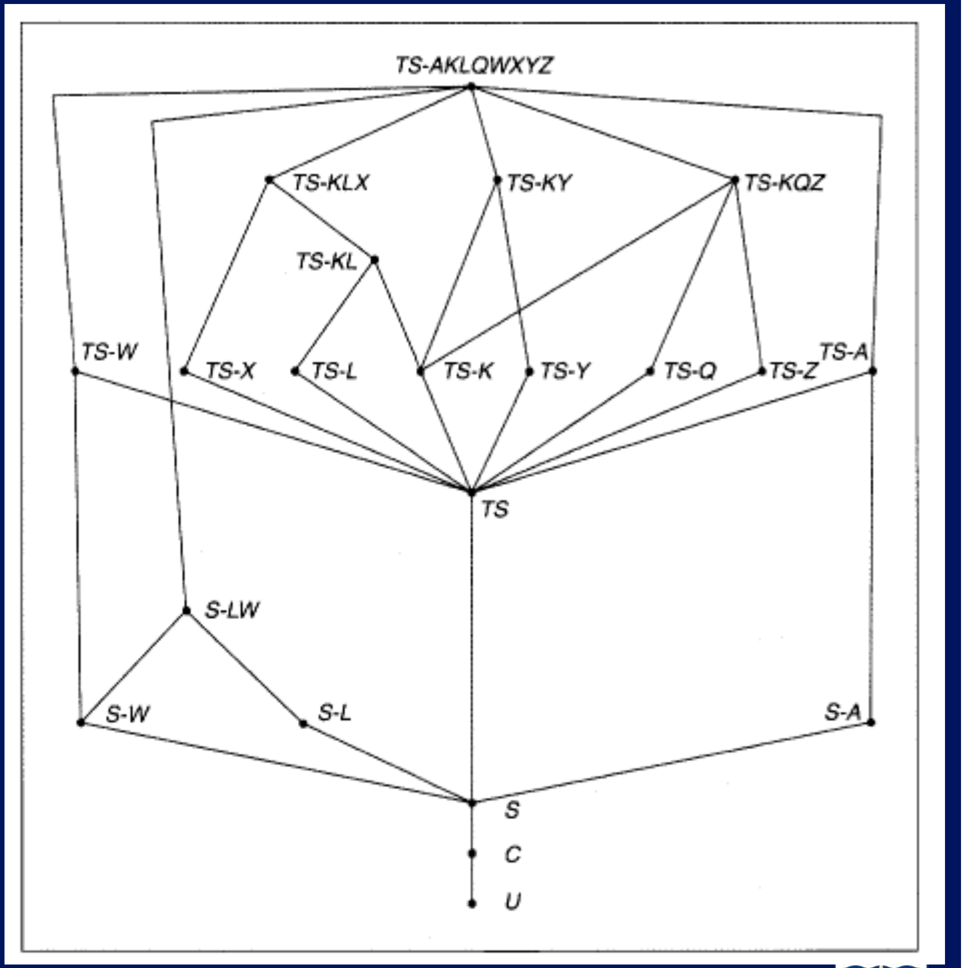
- (A, C) *dominates* (A', C') iff $A' \le A$ and $C' \subseteq C$
- Examples
  - (Top Secret, {NUC, ASI}) *dom* (Secret, {NUC})
  - (Secret, {NUC, EUR}) *dom* (Confidential,{NUC, EUR})
  - (Top Secret, {NUC}) ¬*dom* (Confidential, {EUR})
- Let C be set of classifications, K set of categories. Set of security levels $L = C \times K$, *dom* form lattice

Bounded Isolated Classes



The Military Lattice





Levels and Ordering

- Security levels partially ordered
  - Any pair of security levels may (or may not) be related by *dom* relation
- Note:
  - "dominates" serves the role of "greater than"
  - "greater than" is a total ordering, though

Reading Information

- Information flows *up*, not *down*
  - "Reads up" disallowed, "reads down" allowed
- Simple Security Property (Step 2)
  - Subject *s* can read object *o* iff *L*(*s*) *dom L*(*o*) and *s* has permission to read *o*
    - Note: combines mandatory control (relationship of security levels) and discretionary control (the required permission)
  - Sometimes called "no reads up" rule

Writing Information

- Information flows up, not down
  - "Writes up" allowed, "writes down" disallowed
- *-Property (Step 2)
  - Subject *s* can write object *o* iff *L*(*o*) *dom L*(*s*) and *s* has permission to write *o*
    - Note: combines mandatory control (relationship of security levels) and discretionary control (the required permission)
  - Sometimes called "no writes down" rule

Problem

- Colonel has (Secret, {NUC, EUR}) clearance
- Major has (Secret, {EUR}) clearance
- Major can talk to colonel ("write up" or "read down")
- Colonel cannot talk to major ("read up" or "write down")
- Clearly absurd!

Solution

- Define maximum, current levels for subjects
  - *maxlevel*(*s*) *dom curlevel*(*s*)
- Example
  - Treat Major as an object (Colonel is writing to him/her)
  - Colonel has *maxlevel* (Secret, { NUC, EUR })
  - Colonel sets *curlevel* to (Secret, { EUR })
  - Now *L*(Major) *dom curlevel*(Colonel)
    - Colonel can write to Major without violating "no writes down"

Key Points Regarding Confidentiality Policies

- Confidentiality policies restrict flow of information
- Bell-LaPadula model supports multilevel security
  - Cornerstone of much work in computer security

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Integrity Policies

Biba Integrity Model (1977)

- Set of subjects S, objects O, integrity levels I, relation $\leq \subseteq I \times I$ holding when second dominates first or same
- *min*: $I \times I \rightarrow I$ returns lesser of integrity levels
- *i*: $S \cup O \rightarrow I$ gives integrity level of entity
- r: $S \times O$ means $s \in S$ can read $o \in O$
- w: $S \times O$ means $s \in S$ can write $o \in O$
- x: $S \times O$ means $s \in S$ can execute $o \in O$

What does a higher integrity level of an object mean?

Intuition for Integrity Levels

- The higher the level, the more confidence
  - That a program will execute correctly
  - That data is accurate and/or reliable
- Note relationship between integrity and trustworthiness
- Important point: *integrity levels are **not** security levels*

Low-Water-Mark Policy

- Idea: when s reads o, $i'(s) = min(i(s), i(o))$; s can only write objects at lower levels
- Rules
  1. $s \in S$ can write to $o \in O$ if and only if (iff) $i(o) \leq i(s)$.
  2. If $s \in S$ reads $o \in O$, then $i'(s) = min(i(s), i(o))$, where $i'(s)$ is the subject's integrity level after the read.
  3. $s_1 \in S$ can execute $s_2 \in S$ if and only if $i(s_2) \leq i(s_1)$.
- When can s read o according to the Low-Water-Mark policy?

Problems

- Subjects' integrity levels decrease as system runs
  - Soon no subject will be able to access objects at high integrity levels
- What could be a solution?
- Alternative: change object levels rather than subject levels
  - Soon all objects will be at the lowest integrity level

Ring Policy

- Idea: subject integrity levels static
- Rules
  1. $s \in S$ can write to $o \in O$ if and only if $i(o) \leq i(s)$.
  2. Any subject can read any object.
  3. $s_1 \in S$ can execute $s_2 \in S$ if and only if $i(s_2) \leq i(s_1)$.
- Eliminates indirect modification problem

Strict Integrity Policy (a.k.a., “Biba’s Model”)

- Similar to Bell-LaPadula model
  1. $s \in S$ can read $o \in O$ iff $i(s) \leq i(o)$
  2. $s \in S$ can write to $o \in O$ iff $i(o) \leq i(s)$
  3. $s_1 \in S$ can execute $s_2 \in S$ iff $i(s_2) \leq i(s_1)$
- Add compartments and discretionary controls to get full dual of Bell-LaPadula model

Example: LOCUS and Biba

- Goal: prevent untrusted software from altering data or other software
- Approach: make levels of trust explicit
  - *credibility rating* based on estimate of software's trustworthiness (0 untrusted, *n* highly trusted)
  - *trusted file systems* contain software with a single credibility level
  - Process has *risk level* or highest credibility level at which process can execute
  - Must use *run-untrusted* command to run software at lower credibility level

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Clark-Wilson Integrity Model

Model

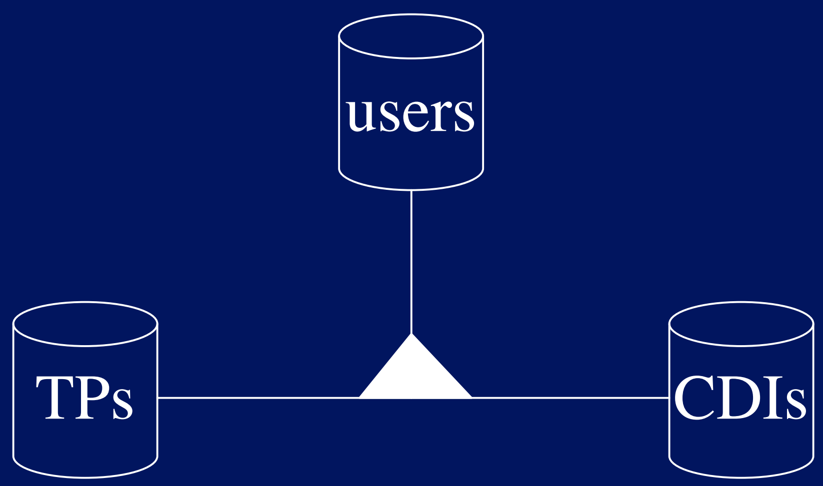
- Integrity defined by a set of constraints
  - Data in a *consistent* or valid state when it satisfies these
- Example: Bank
  - *D* today's deposits, *W* withdrawals, *YB* yesterday's balance, *TB* today's balance
  - Integrity constraint: $YB + D - W = TB$
- *Well-formed transaction* move system from one consistent state to another
- Issue: who examines, certifies transactions done correctly?
  - The principle of separation of duty

Entities in the Model

- CDIs: constrained data items
  - Data subject to integrity controls
- UDIs: unconstrained data items
  - Data not subject to integrity controls
- IVPs: integrity verification procedures
  - Procedures that test the CDIs conform to the integrity constraints
- TPs: transaction procedures
  - Procedures that take the system from one valid state to another

The Idea

Constrain who can do what by defining authorized triples: (user, TP, {CDI})




Chinese Wall Model

What's Chinese Wall Model

Problem:

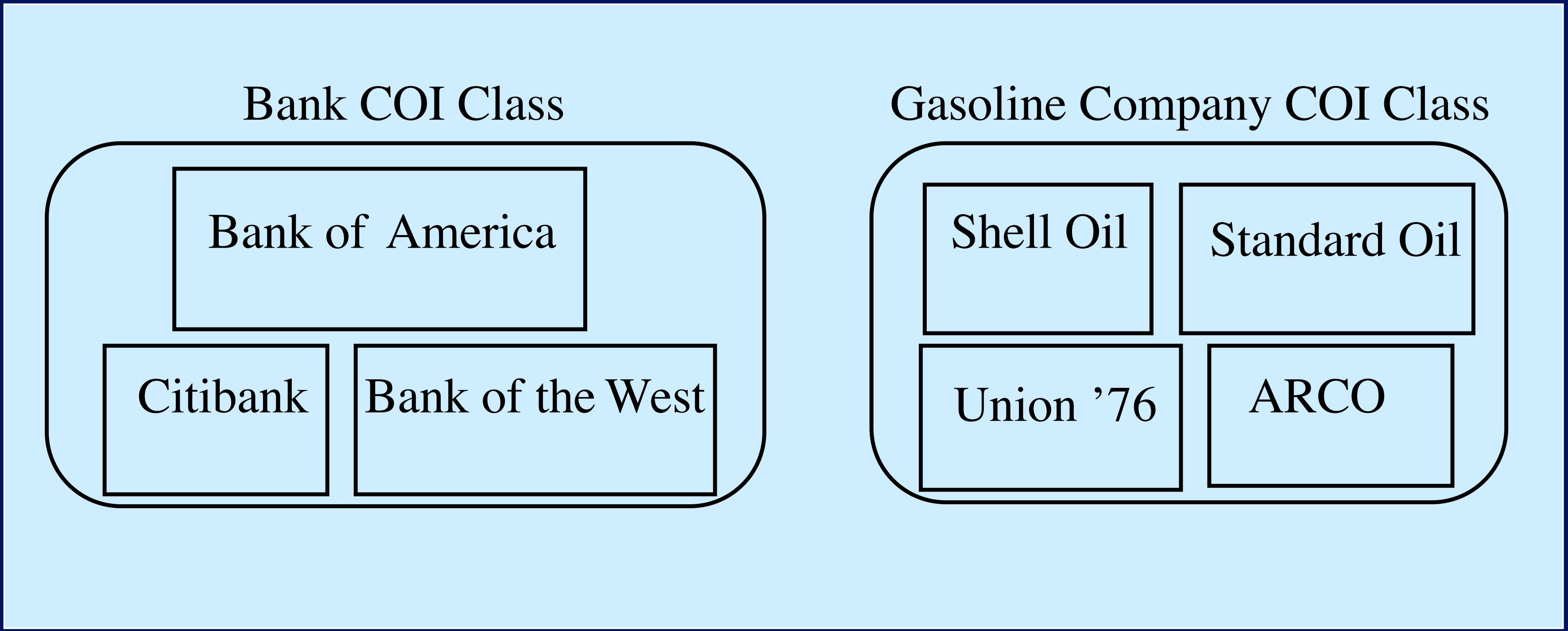
- Tony advises American Bank about investments
- He is asked to advise Toyland Bank about investments

- Conflict of interest to accept, because his advice for either bank would affect his advice to the other bank

Organization

- Organize entities into "conflict of interest" classes
- Control subject accesses to each class
- Control writing to all classes to ensure information is not passed along in violation of rules
- Allow sanitized data to be viewed by everyone

Example



- If Anthony reads any *Company dataset* (CD) in a conflict of interest (COI), he can *never* read another CD in that COI
  - Possible that information learned earlier may allow him to make decisions later

CW-Simple Security Condition

- s can read o iff either condition holds:
  1. There is an o' such that s has accessed o' and $CD(o') = CD(o)$
     - Meaning s has read something in o's dataset
  2. For all $o' \in O$, $o' \in PR(s) \Rightarrow COI(o') \neq COI(o)$
     - Meaning s has not read any objects in o's conflict of interest class
- Ignores sanitized data (see below)
- Initially, $PR(s) = \varnothing$, so initial read request granted

Writing

- Anthony, Susan work in same trading house
- Anthony can read Bank 1's CD, Gas' CD
- Susan can read Bank 2's CD, Gas' CD
- If Anthony could write to Gas' CD, Susan can read it
  - Hence, indirectly, she can read information from Bank 1's CD, a clear conflict of interest

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ORCON Model

What’s the problem ORCON solves?

Problem: organization creating document wants to control its dissemination

- Example: Secretary of Agriculture writes a memo for distribution to her immediate subordinates, and she must give permission for it to be disseminated further. This is “originator controlled” (here, the “originator” is a person).

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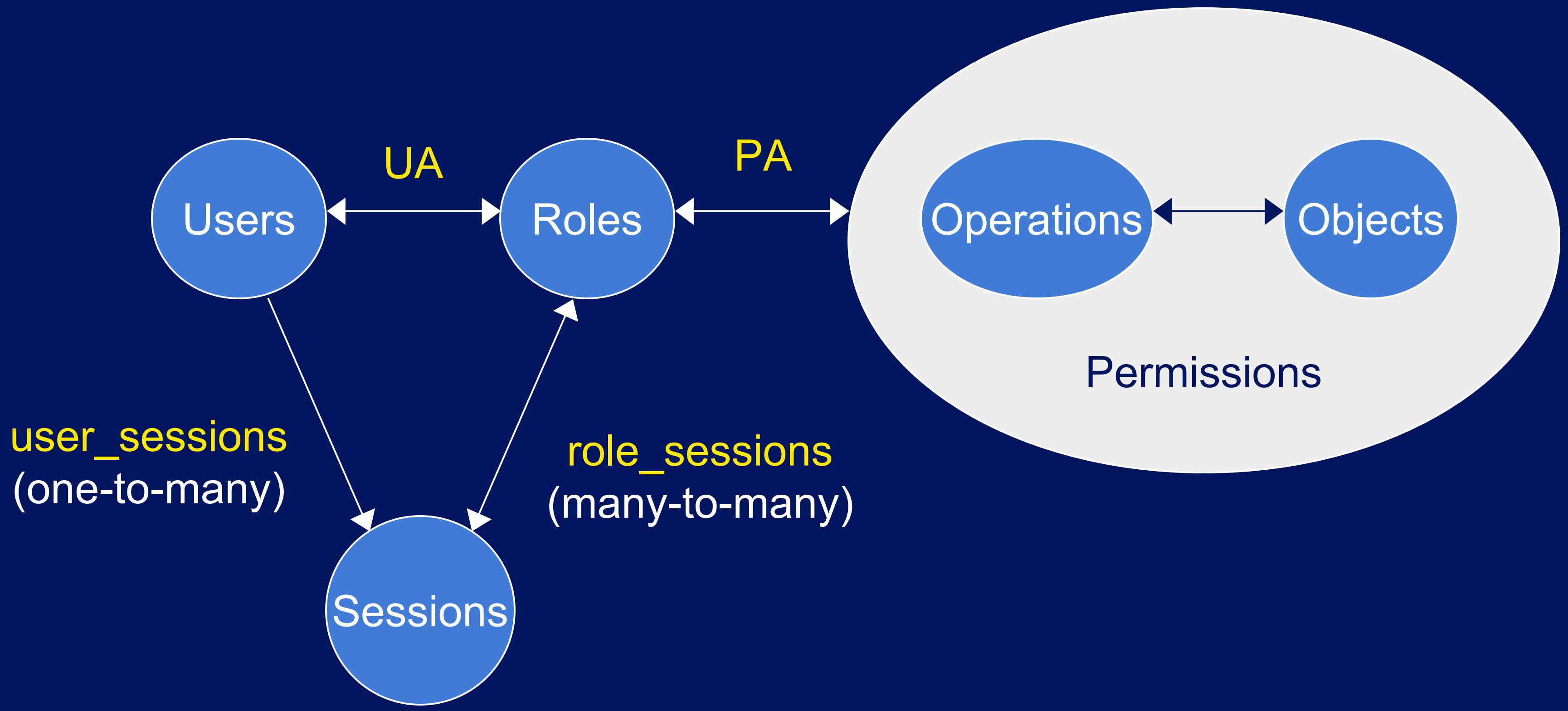
Role-based Access Control (RBAC)

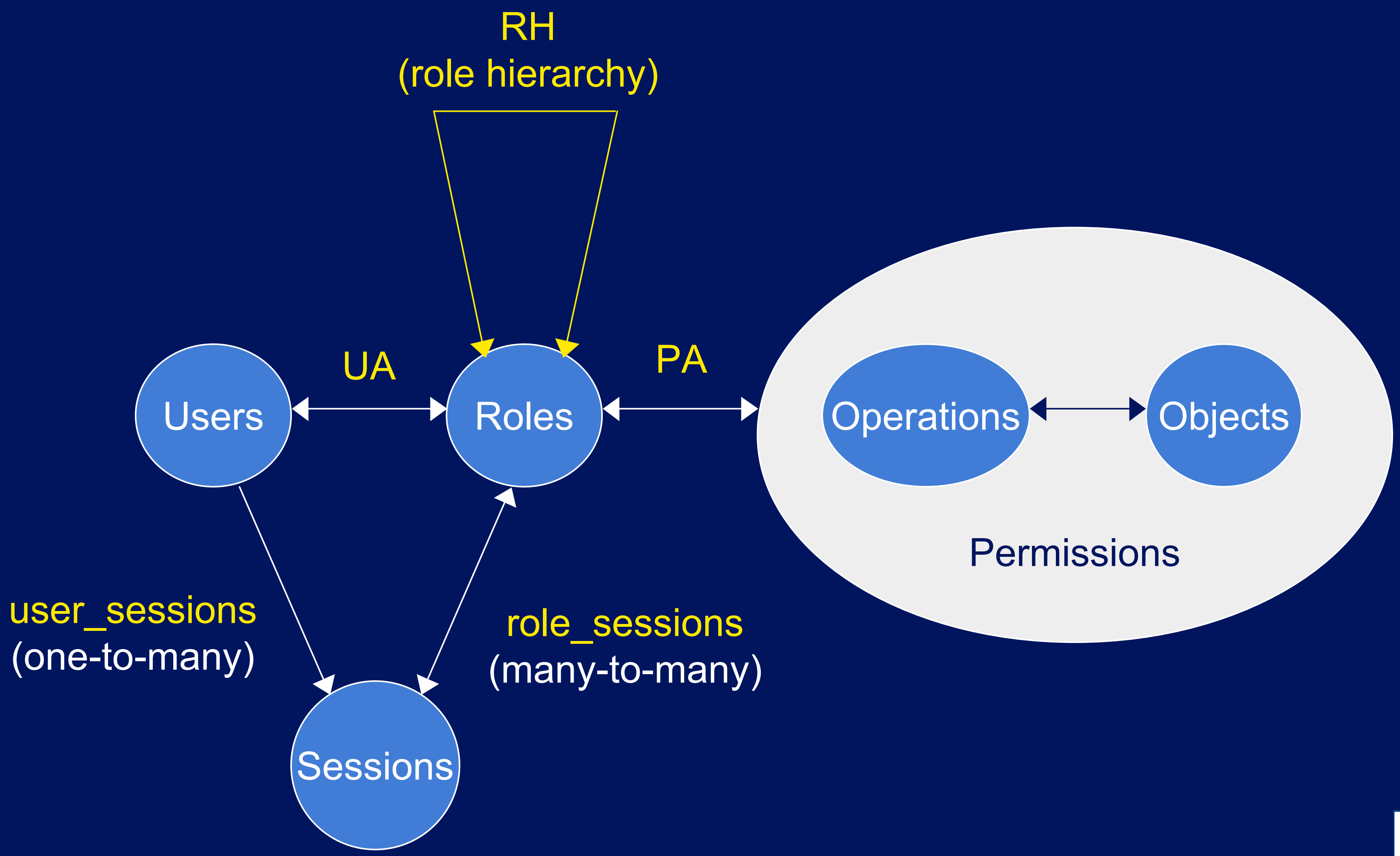
RBAC

- Access depends on role, not identity or label
  - Example:
    - Allison, administrator for a department, has access to financial records.
    - She leaves.
    - Betty hired as the new administrator, so she now has access to those records
  - The role of "administrator" dictates access, not the identity of the individual.

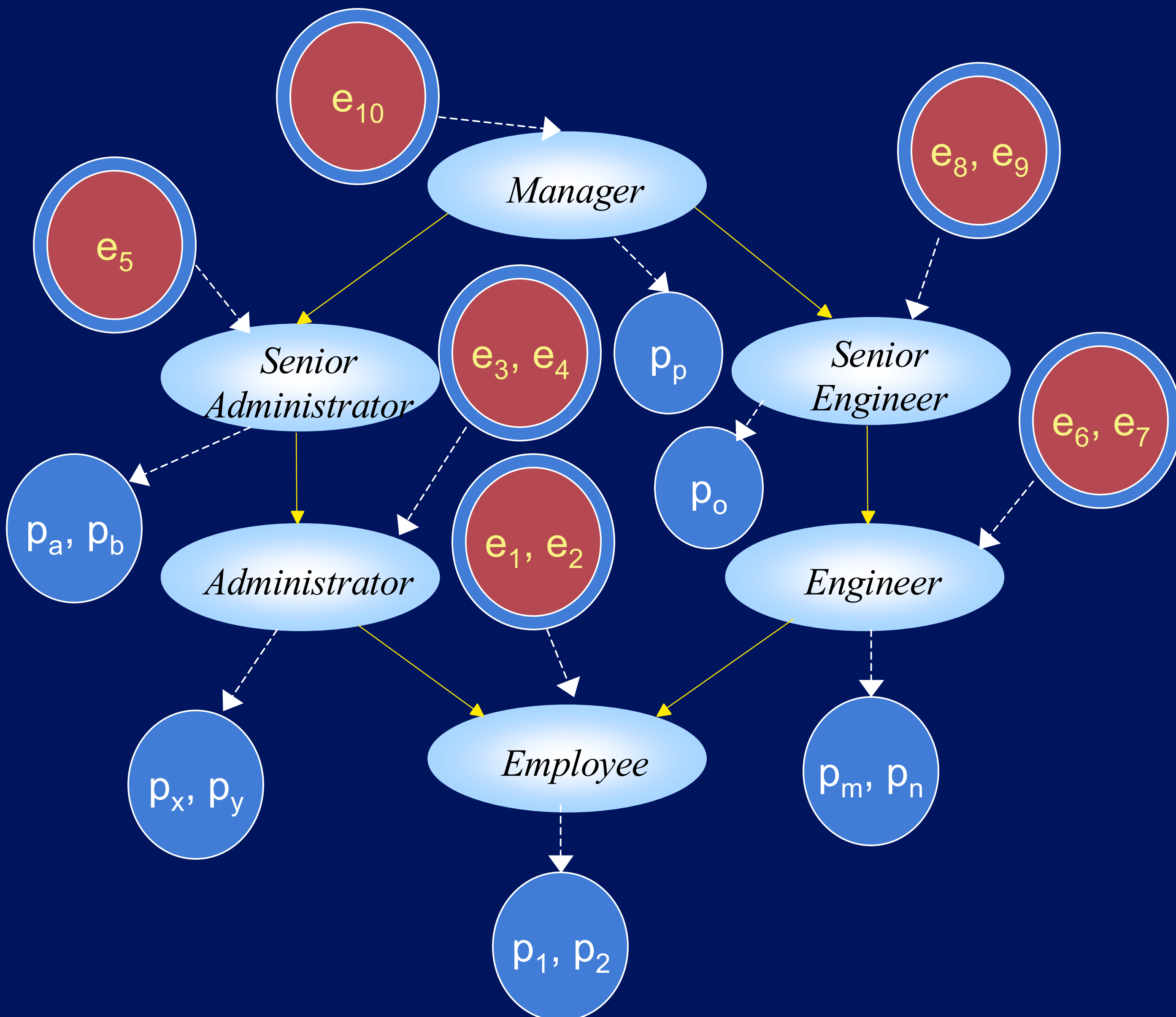
RBAC (NIST Standard)



RBAC with General Role Hierarchy

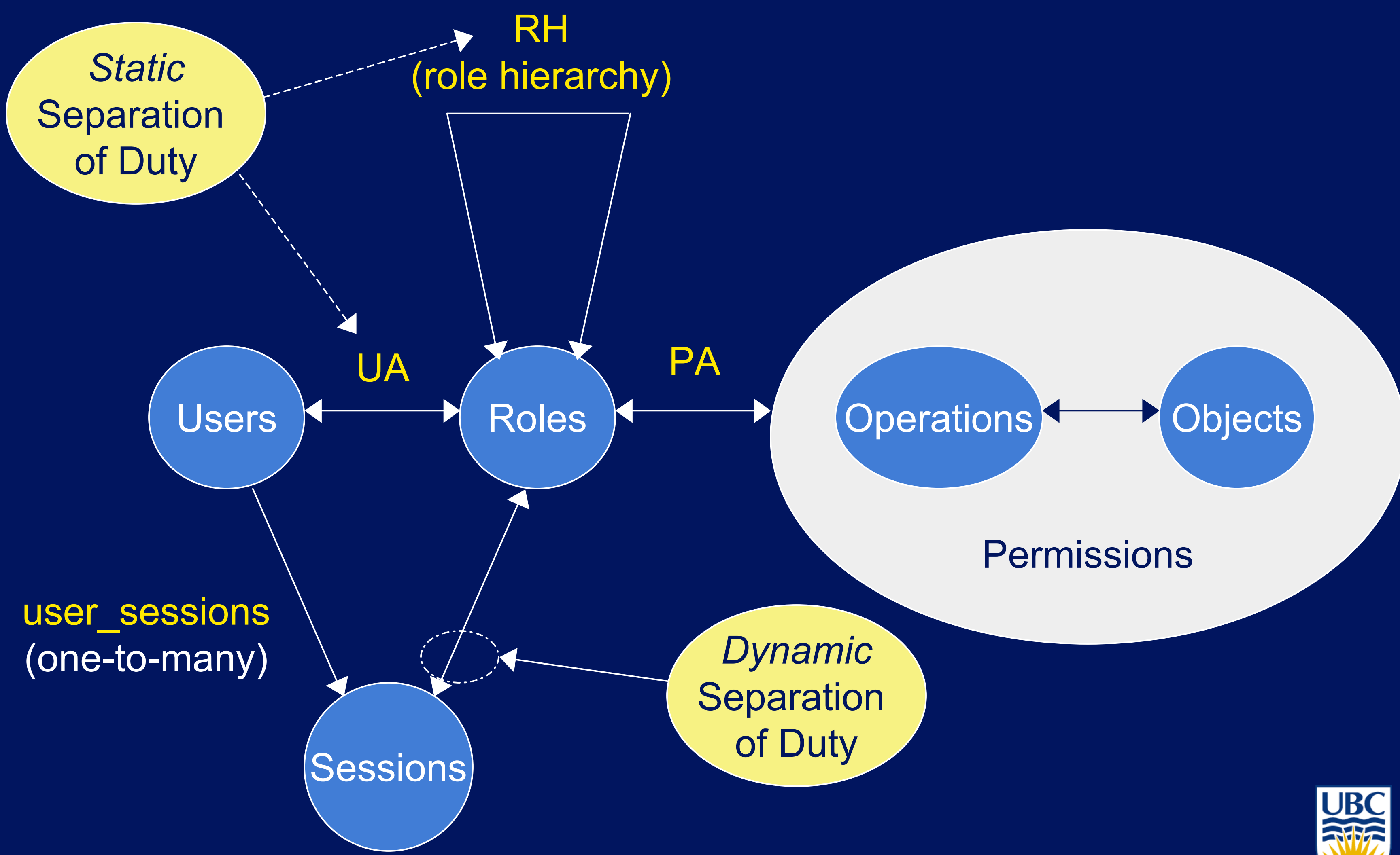


Example



e10
Manager
e8, e9
e5
Senior Administrator
e3, e4
pp
Senior Engineer
e6, e7
pa, pb
po
Administrator
e1, e2
Engineer
px, py
Employee
pm, pn
p1, p2

Constrained RBAC



Key Points

- Integrity policies
  - deal with trust
    - As trust is hard to quantify, these policies are hard to evaluate completely
    - Look for assumptions and trusted users to find possible weak points in their implementation
  - Biba based on multilevel integrity
  - Clark-Wilson focuses on separation of duty and transactions
- Hybrid policies
  - deal with both confidentiality and integrity
  - Different combinations of these
  - ORCON model neither MAC nor DAC
    - Actually, a combination
  - RBAC model controls access based on subject’s role(s)