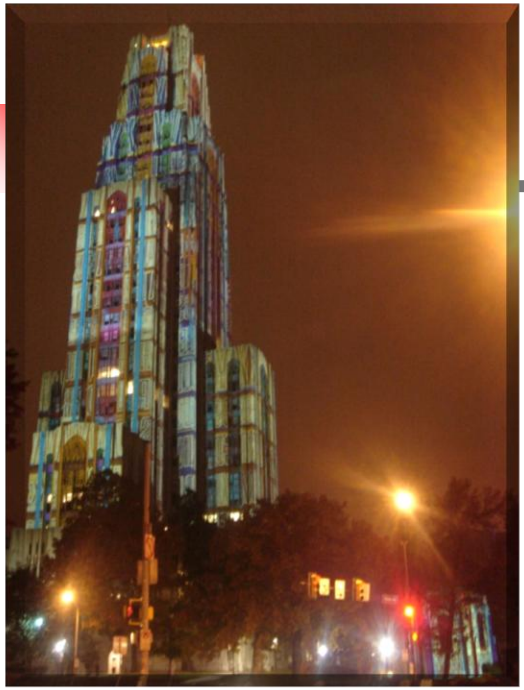
# IS 2150 / TEL 2810
# Information Security & Privacy



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Lecture 10
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Hybrid Models

Role based
Access Control

# Objective

- Define/Understand various Integrity models
  - Clark-Wilson
- Define/Understand
  - Chinese Wall Model
  - Role-based Access Control model
- Overview the secure interoperation issue

# Clark-Wilson Integrity Model

- Transactions as the basic operation
- 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: $D + YB - W$
- *Well-formed transaction*
  - A series of operations that move system from one consistent state to another
  - State before transaction consistent $\Rightarrow$ state after transaction consistent
- Issue: who examines, certifies transactions done correctly?
  - Separation of duty is crucial

# Clark/Wilson Model Entities

- **C**onstrained **D**ata **I**tems (CDI) : data subject to Integrity Control
  - Eg. Account balances
- **U**nconstrained **D**ata **I**tems (UDI): data not subject to IC
  - Eg. Gifts given to the account holders
- **I**ntegrity **V**erification **P**rocedures (IVP)
  - Test CDIs' conformance to integrity constraints at the time IVPs are run (checking that accounts balance)
- **T**ransformation **P**rocedures (TP);
  - Examples?

# Clark/Wilson: Certification/Enforcement Rules

- C1: When any IVP is run, it must ensure all CDIs are in valid state
- C2: A TP must transform a set of CDIs from a valid state to another valid state
  - TR must not be used on CDIs it is not certified for
- E1: System must maintain certified relations
  - TP/CDI sets enforced

# Clark-Wilson: Certification/Enforcement Rules

- E2: System must control users
  - (*user*, TP, {CDI}) mappings enforced
- C3: Relations between (*user*, TP, {CDI}) must support separation of duty
- E3: Users must be authenticated to execute TP
  - Note, unauthenticated users may manipulate UDIs

# Clark-Wilson: Certification/Enforcement Rules

- C4: All TPs must log undo information to append-only CDI (to reconstruct an operation)
- C5: A TP taking a UDI as input must either reject it or transform it to a CDI
- E4: Only certifier of a TP may change the list of entities associated with that TP; Certifier cannot execute
  - Enforces separation of duty (?)

# Clark-Wilson

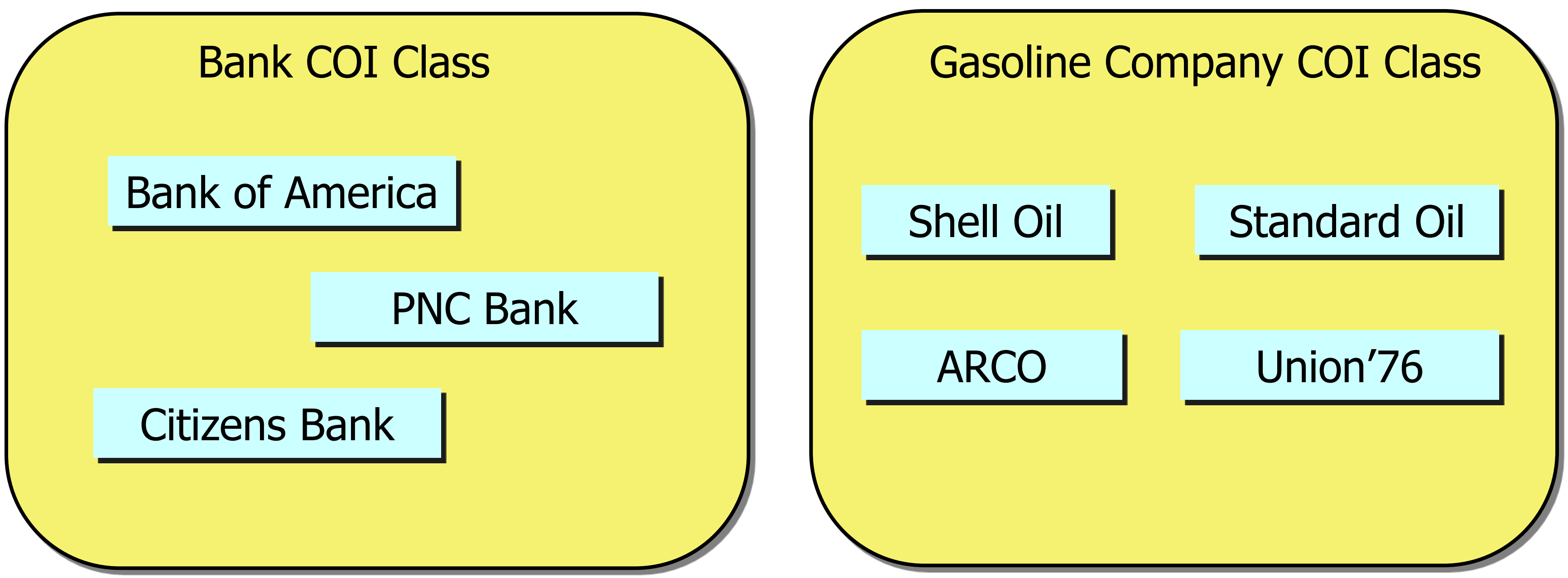
- Clark-Wilson introduced new ideas
  - Commercial firms do not classify data using multilevel scheme
  - they enforce separation of duty
  - Notion of certification is different from enforcement;
    - enforcement rules can be enforced,
    - certification rules need outside intervention, and
    - process of certification is complex and error prone

# Hybrid Policies

# Chinese Wall Model

- Supports confidentiality and integrity
  - Information flow between items in a Conflict of Interest set
  - Applicable to environment of stock exchange or investment house
- Models conflict of interest
  - *Objects*: items of information related to a company
  - *Company dataset* (CD): contains objects related to a single company
    - Written *CD*(*O*)
  - *Conflict of interest class* (COI): contains datasets of companies in competition
    - Written *COI*(*O*)
    - Assume: each object belongs to exactly one *COI* class

# Example


Bank COI Class
Bank of America
PNC Bank
Citizens Bank
Gasoline Company COI Class
Shell Oil
Standard Oil
ARCO
Union’76

# CW-Simple Security Property (Read rule)

- CW-Simple Security Property
  - *s* can read *o* *iff* any of the following holds
    - $\exists\, o' \in PR(s)$ such that $CD(o') = CD(o)$
    - $\forall\, o', o' \in PR(s) \Rightarrow COI(o') \neq COI(o)$, or
    - *o* has been "sanitized"

    ($o' \in PR(s)$ indicates $o'$ has been previously read by s)

- Public information may belong to a CD
    - no conflicts of interest arise
    - Sensitive data sanitized

# Writing

- Alice, Bob work in same trading house
- Alice can read BankOfAmercia's CD,
- Bob can read CitizensBanks's CD,
- Both can read ARCO's CD
- Alice could write to ARCO's CD,
  - what is a problem?

# CW-*-Property (Write rule)

- CW-*- Property
  - *s* can *write* *o* iff the following holds
    - The CW-simple security condition permits S to read O.
    - For all unsanitized objects o′, s can read o′ $\Rightarrow$ $CD(o') = CD(o)$
    - Alice can read both CDs
      - Is Condition 1 met?
    - She can read unsanitized objects of BankOfAmercia, hence condition 2 is false
      - Can Alice write to objects in ARCO's CD?

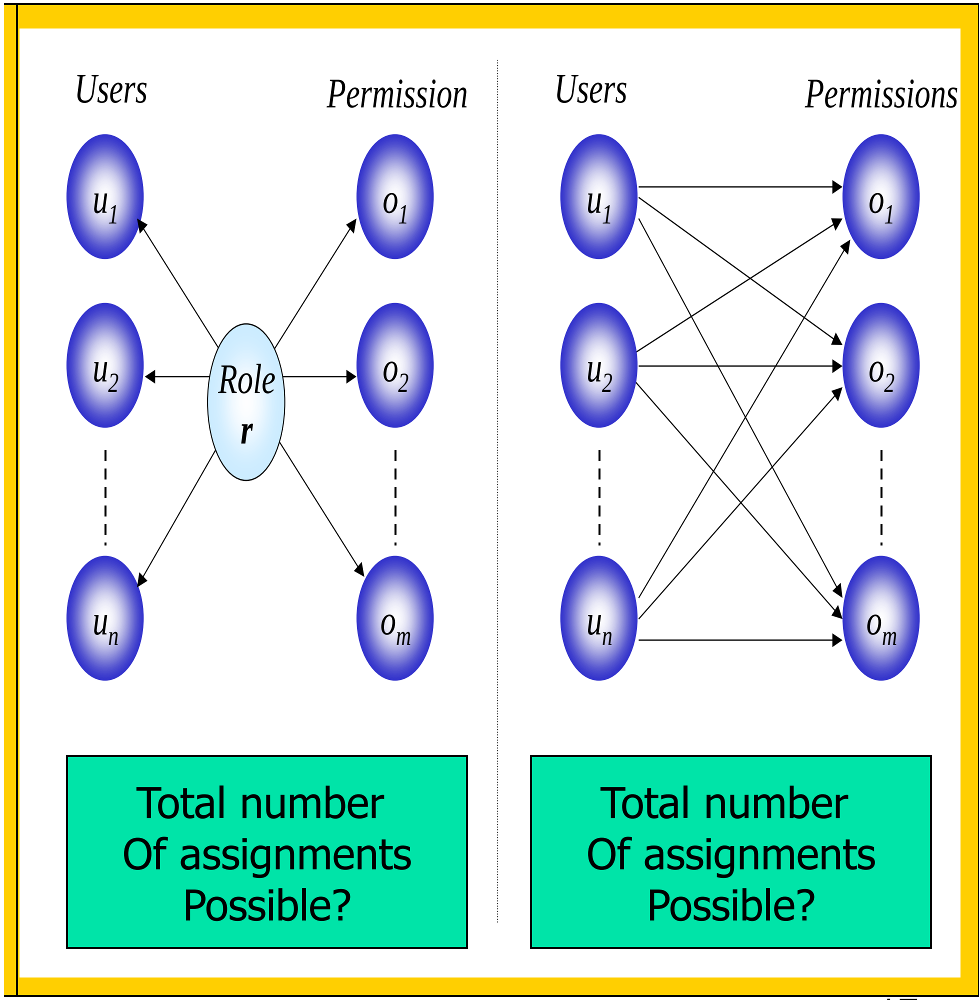
# Role-Based Access Control

# Role Based Access Control (RBAC)

- Access control in organizations is based on “roles that individual users take on as part of the organization”
  - Access depends on function, not identity
    - Example:

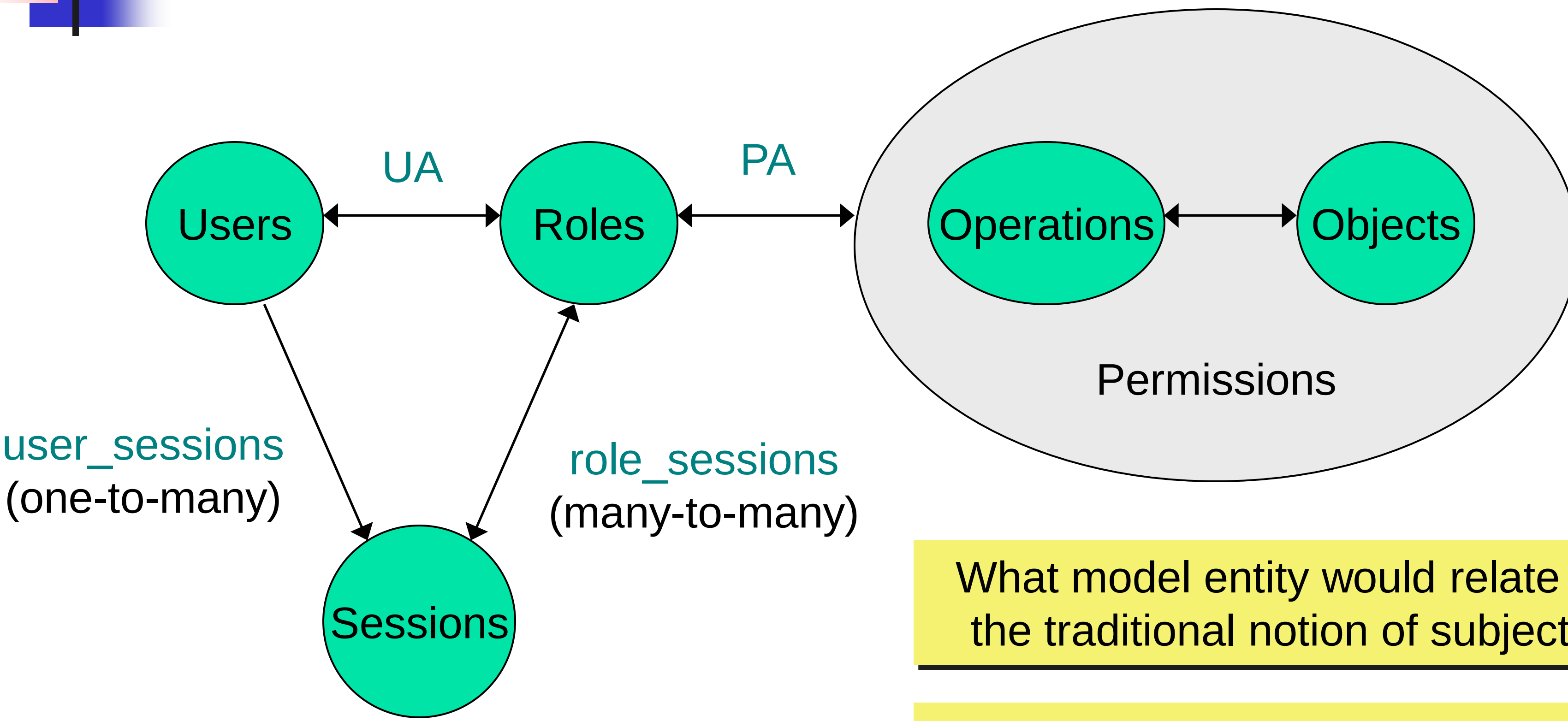
      Allison is bookkeeper for Math Dept. She has access to financial records. If she leaves and Betty is hired as the new bookkeeper, Betty now has access to those records. The role of “bookkeeper” dictates access, not the identity of the individual.
- A role is “is a collection of permissions”

# RBAC



Users
Permission
$u_1$
$u_2$
$u_n$
Role
r
$o_1$
$o_2$
$o_m$
Total number
Of assignments
Possible?
Users
Permissions
$u_1$
$u_2$
$u_n$
$o_1$
$o_2$
$o_m$
Total number
Of assignments
Possible?

# RBAC (NIST Standard)




What model entity would relate to the traditional notion of subject?

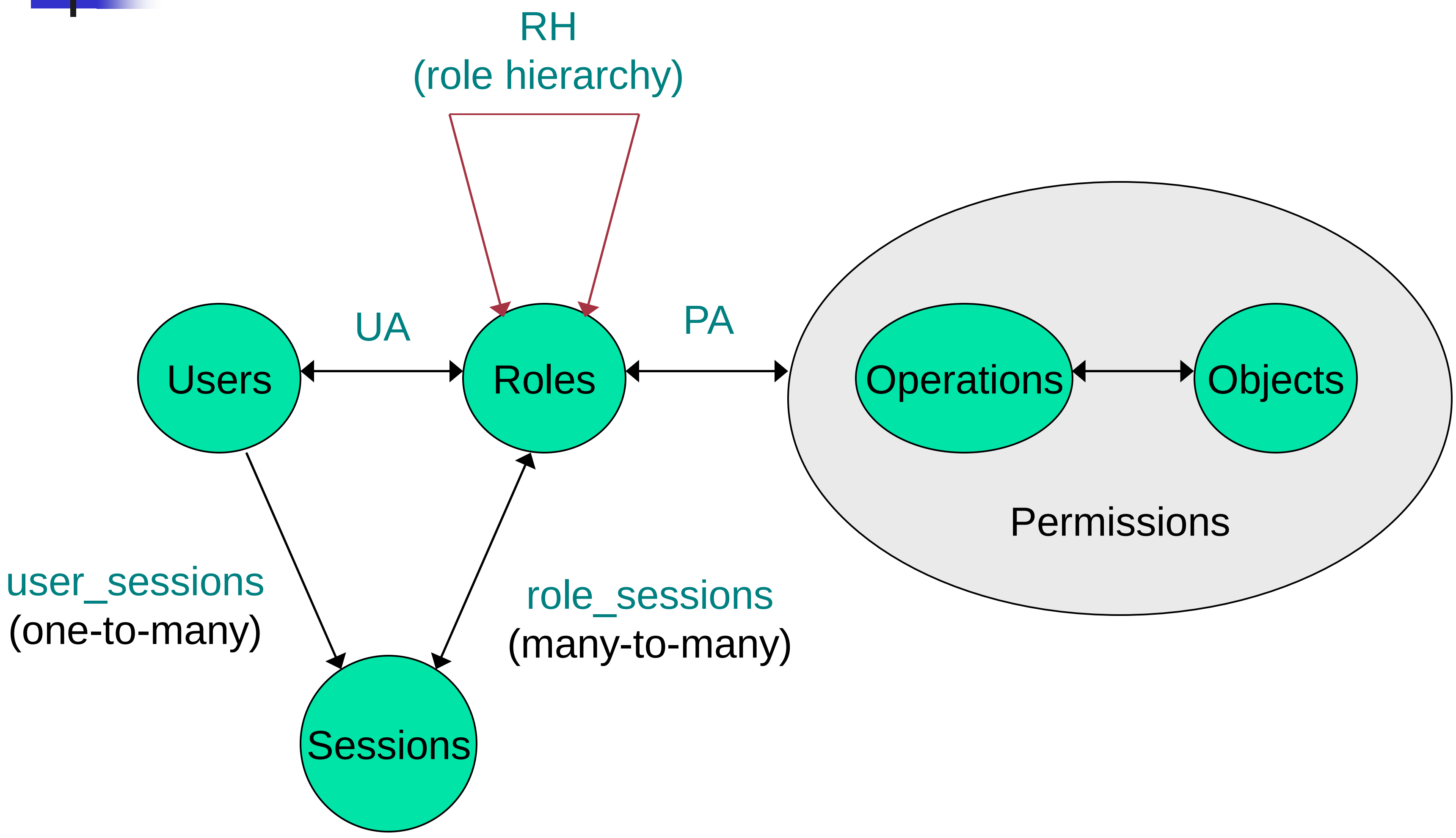
Total number of subjects possible?

Role vs Group?

# Core RBAC (relations)

- Permissions = $2^{\text{Operations x Objects}}$
- UA $\subseteq$ Users x Roles
- PA $\subseteq$ Permissions x Roles
- *assigned_users*: Roles $\rightarrow 2^{\text{Users}}$
- *assigned_permissions*: Roles $\rightarrow 2^{\text{Permissions}}$
- *Op*(p): set of operations associated with permission p
- *Ob*(p): set of objects associated with permission p
- *user_sessions*: Users $\rightarrow 2^{\text{Sessions}}$
- *session_user*: Sessions $\rightarrow$ Users
- *session_roles*: Sessions $\rightarrow 2^{\text{Roles}}$
  *session_roles*($s$) = $\{r \mid (\text{session\_user}(s), r) \in \text{UA}\}$
- *avail_session_perms*: Sessions $\rightarrow 2^{\text{Permissions}}$

# RBAC with Role Hierarchy



# RBAC with General Role Hierarchy

- *authorized_users*: Roles$\rightarrow 2^{\text{Users}}$

  $authorized\_users(r) = \{u \mid r' \geq r \,\&\, (r', u) \in UA\}$
- *authorized_permissions*: Roles$\rightarrow 2^{\text{Permissions}}$

  $authorized\_permissions(\mathrm{r}) = \{p \mid r \geq r' \,\&\, (p, r') \in PA\}$

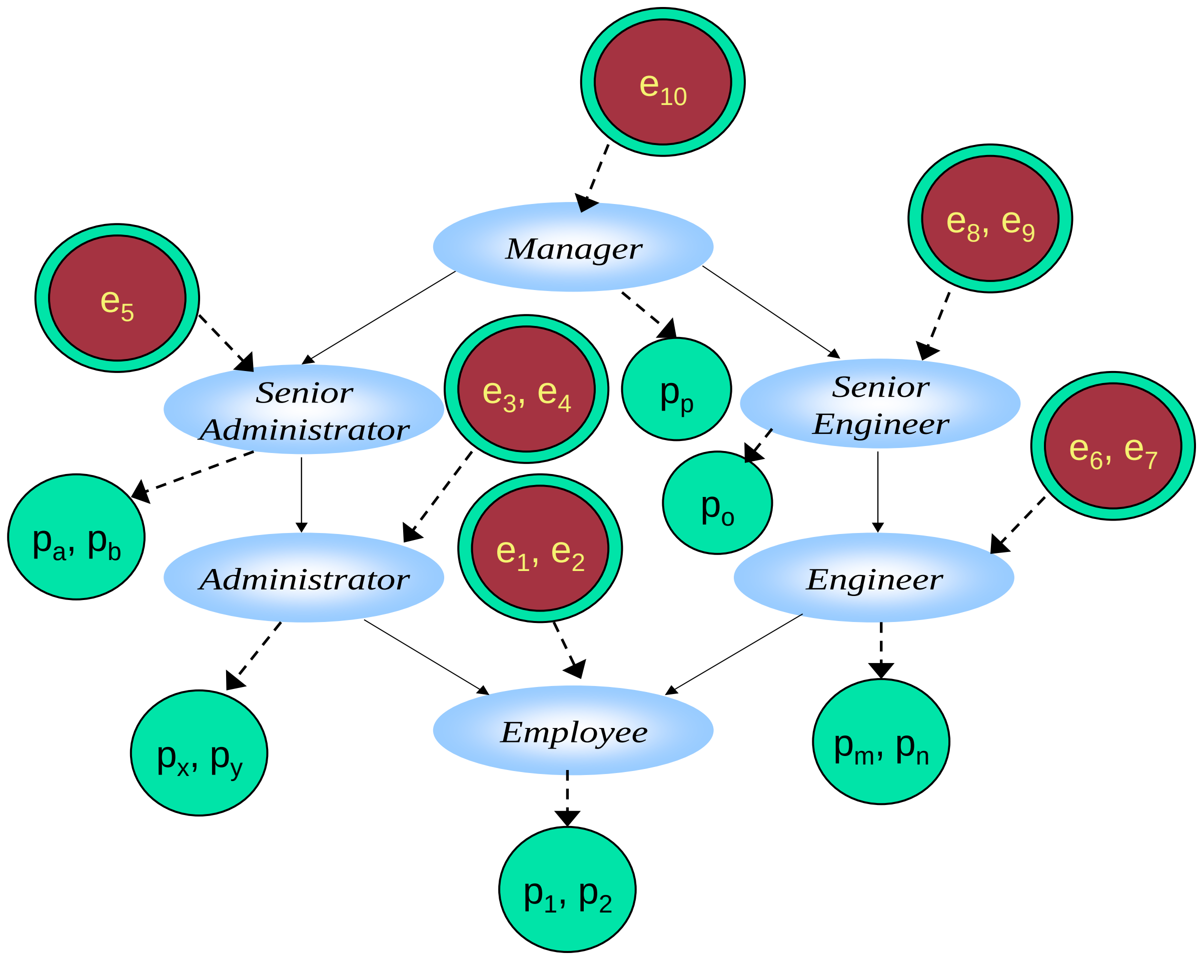
- RH $\subseteq$ Roles x Roles is a partial order
  - called the inheritance relation
  - written as $\geq$.

  $(r_1 \geq r_2) \rightarrow authorized\_users(r_1) \subseteq authorized\_users(r_2)$ & $authorized\_permisssions(r_2) \subseteq authorized\_permisssions(r_1)$

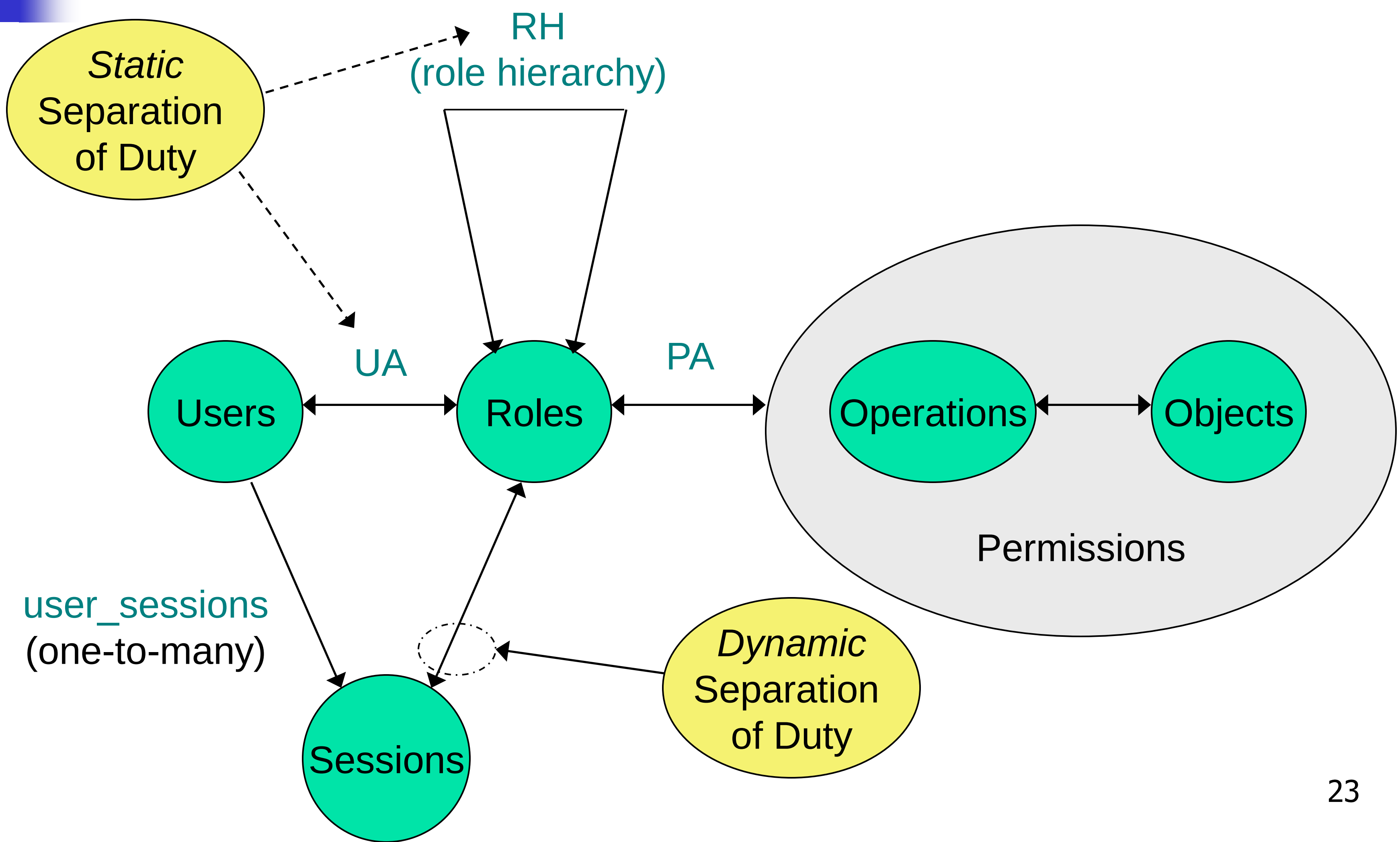
*What do these mean?*

# Example

authorized_users(Employee)?
authorized_users(Administrator)?
authorized_permissions(Employee)?
authorized_permissions(Administrator)?



# Constrained RBAC



# Static Separation of Duty

- $SSD \subseteq 2^{Roles} \times N$
- In absence of hierarchy
  - Collection of pairs $(RS, n)$ where $RS$ is a role set, $n \geq 2$
    $for\ all\ (RS, n) \in SSD,\ for\ all\ t \subseteq RS$:
    $|t| \geq n \rightarrow \bigcap_{r \in t} assigned\_users(r) = \emptyset$

Describe!

- In presence of hierarchy
  - Collection of pairs (RS, n) where RS is a role set, n ≥ 2;
    $for\ all\ (RS, n) \in SSD,\ for\ all\ t \subseteq RS$:
    $|t| \geq n \rightarrow \bigcap_{r \in t} authorized\_uers(r) = \emptyset$

Describe!

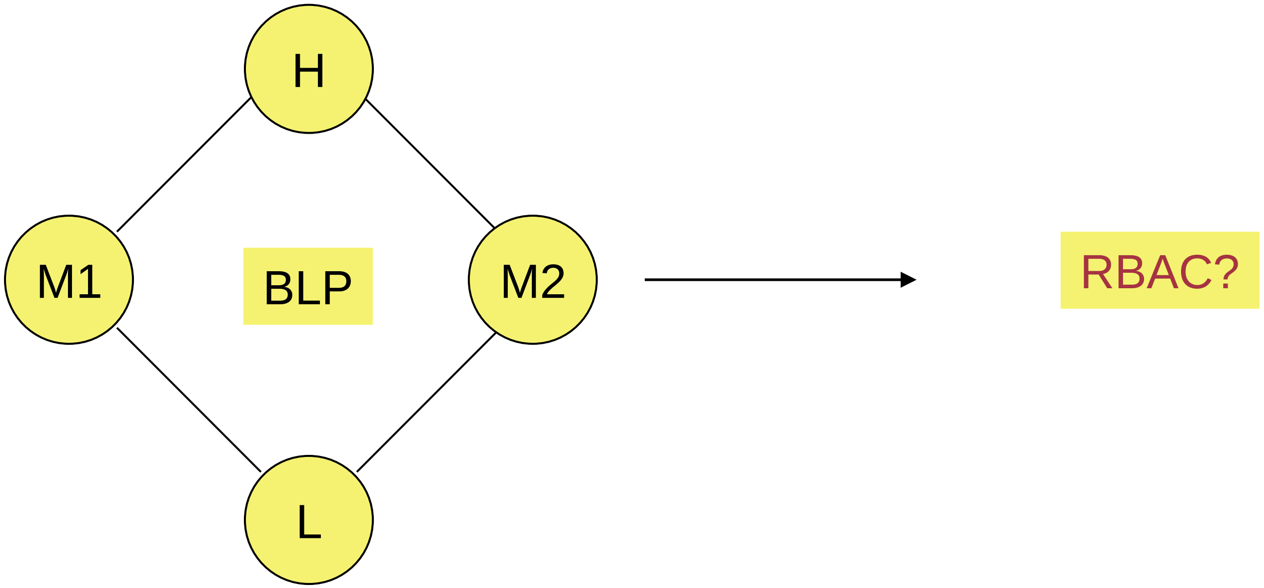
# Dynamic Separation of Duty

- $DSD \subseteq 2^{\text{Roles}} \times N$
  - Collection of pairs ($RS$, $n$) where $RS$ is a role set, $n \geq 2$;
    - A user cannot activate $n$ or more roles from RS
  - What is the difference between SSD or DSD containing:

    ($RS$, $n$)?

    - Consider ($RS$, $n$) = ($\{r_1, r_2, r_3\}$, 2)?
    - If SSD – can $r_1$, $r_2$ *and* $r_3$ be assigned to $u$?
    - If DSD – can $r_1$, $r_2$ *and* $r_3$ be assigned to $u$?

# Can we represent BLP using RBAC?



# Advantages of RBAC

- Allows Efficient Security Management
  - Administrative roles, Role hierarchy
- Principle of least privilege allows minimizing damage
- Separation of Duty constraints to prevent fraud
- Allows grouping of objects / users
- Policy-neutral - Provides generality
- Encompasses DAC and MAC policies

# RBAC's Benefits

TABLE 1: ESTIMATED TIME (IN MINUTES) REQUIRED FOR ACCESS ADMINISTRATIVE TASKS

| TASK | RBAC | NON-RBAC | DIFFERENCE |
|---|---|---|---|
| Assign existing privileges to new users | 6.14 | 11.39 | 5.25 |
| Change existing users' privileges | 9.29 | 10.24 | 0.95 |
| Establish new privileges for existing users | 8.86 | 9.26 | 0.40 |
| Termination of privileges | 0.81 | 1.32 | 0.51 |

# Cost Benefits

- Saves about 7.01 minutes per employee, per year in administrative functions
  - Average IT admin salary - $59.27 per hour
  - The annual cost saving is:
    - $6,924/1000;
    - $692,471/100,000

How do we get this?

# Policy Composition

# Problem: *Consistent* Policies

- Policies defined by different organizations
  - Different needs
  - But sometimes subjects/objects overlap
- Can all policies be met?
  - Different categories
    - Build lattice combining them
  - Different security levels
    - Need to be *levels* – thus must be able to order
  - What if different DAC and MAC policies need to be integrated?

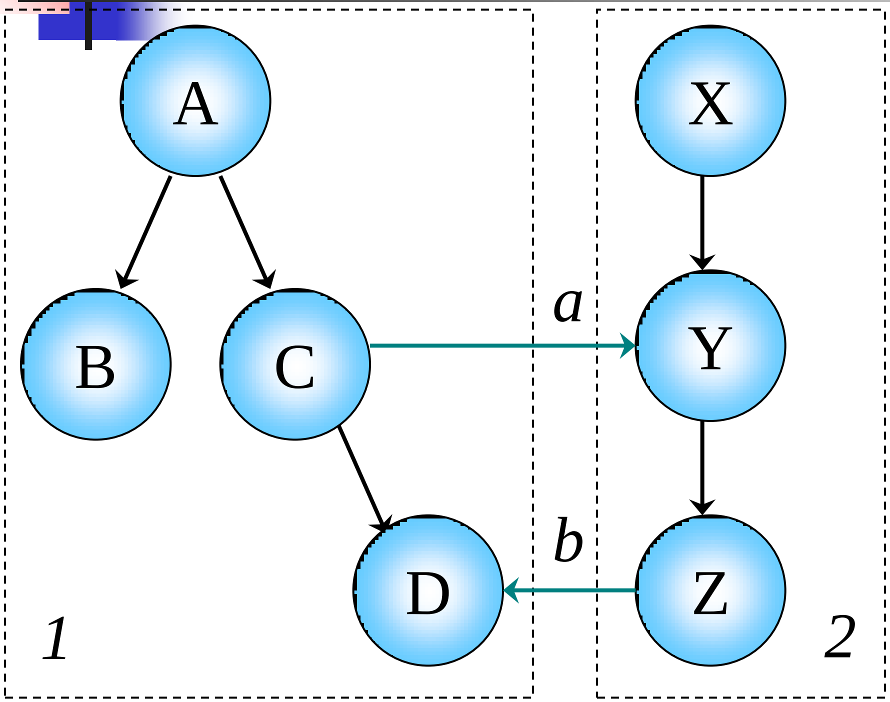
# Secure Interoperability

- Principles of secure interoperation [Gong, 96]

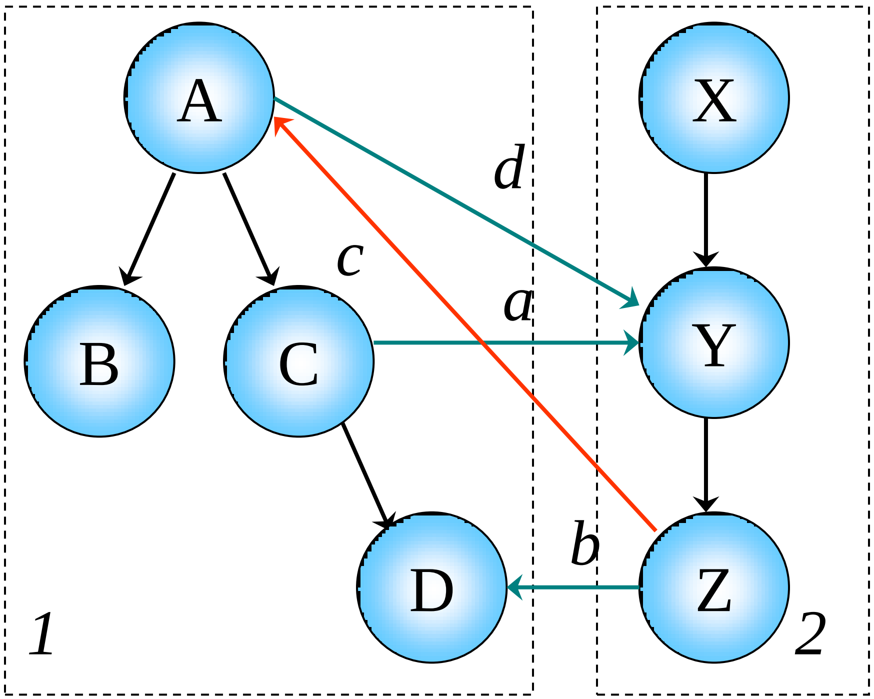
  *Principle of autonomy*
  - If an access is permitted within an individual system, it must also be permitted under secure interoperation

  *Principle of security*
  - If an access is not permitted within an individual system, it must not be permitted under secure interoperation
- Interoperation of secure systems can create new security breaches

# Secure Interoperability (Example)




$F_{12}$ = {a, b}




$F_{12}$ = {a, b, c, d}

$F_{12}$ - permitted access between systems 1 and 2

(1) $F_{12}$ = {a, b, d}
Direct access

(2) $F_{12}$ = {c}
Indirect access

# Summary

- Integrity polices
  - Level based and non-level based
- Chinese wall is a dynamic policy
  - Conflict classes
- RBAC – several advantages
  - based on duty/responsibility/function
  - Economic benefits as well as diversified