Mandatory Security Policies: BLP

MAC vs DAC

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- Discretionary Access Control (DAC)
  - Access control is at the discretion of the user
  - Normal users can change access control state directly assuming they have appropriate permissions
  - E.g.: Access control implemented in standard OS's, e.g., Unix, Linux, Windows
- Mandatory Access Control (MAC)
  - Access decisions cannot be changed by normal users
  - Generally enforced by system wide set of rules
  - E.g.: SELinux, Windows Vista Integrity Levels
- "Strong" system security requires MAC
  - Normal users cannot be trusted

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 (BLP) basis for many, or most, of these

Bell-LaPadula: Basics

- Subject and objects are associated with a security level
- Security levels
  - Most basic example of security class
- The levels are completely ordered
  - Example: Top secret > secret > confidential > restricted > unclassified
- The subject's level is security clearance
- The object's level is security classification

Security Level Example

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Security Level	Subject	Object
Top Secret	Alice	Design for next generation iPhone
Secret	Bob	New pricing levels
Confidential	Carol	Current Financial Earnings
Unclassified	Dave	Current products list

BLP: Simple Security Property

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- No Read Up
- Subject can only read an object of less or equal security level.
- Level(0) <= Level(S)

BLP: *-Property

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- No Write Down

- A subject can only “append” (write-only) into an object of greater or equal security level.
  - Level(S) <= Level(O) for “append”

- A subject can only read+write into an object of same security level
  - Level(S) = Level(O) for “read+write”

BLP: ds-Property

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- A MAC system may also include a traditional discretionary access control check
  - DAC in MAC

- If *-property and simple security property checks pass, then also check the discretionary access rules

More Advanced Security Classes

- Simple linear ordering not adequate for larger systems

- Add set of categories to the security level to create a security label
  - E.g., top secret:{project1, project2}.
  - As clearance, subject is cleared to top secret only for project 1 and project 2 not project 3.

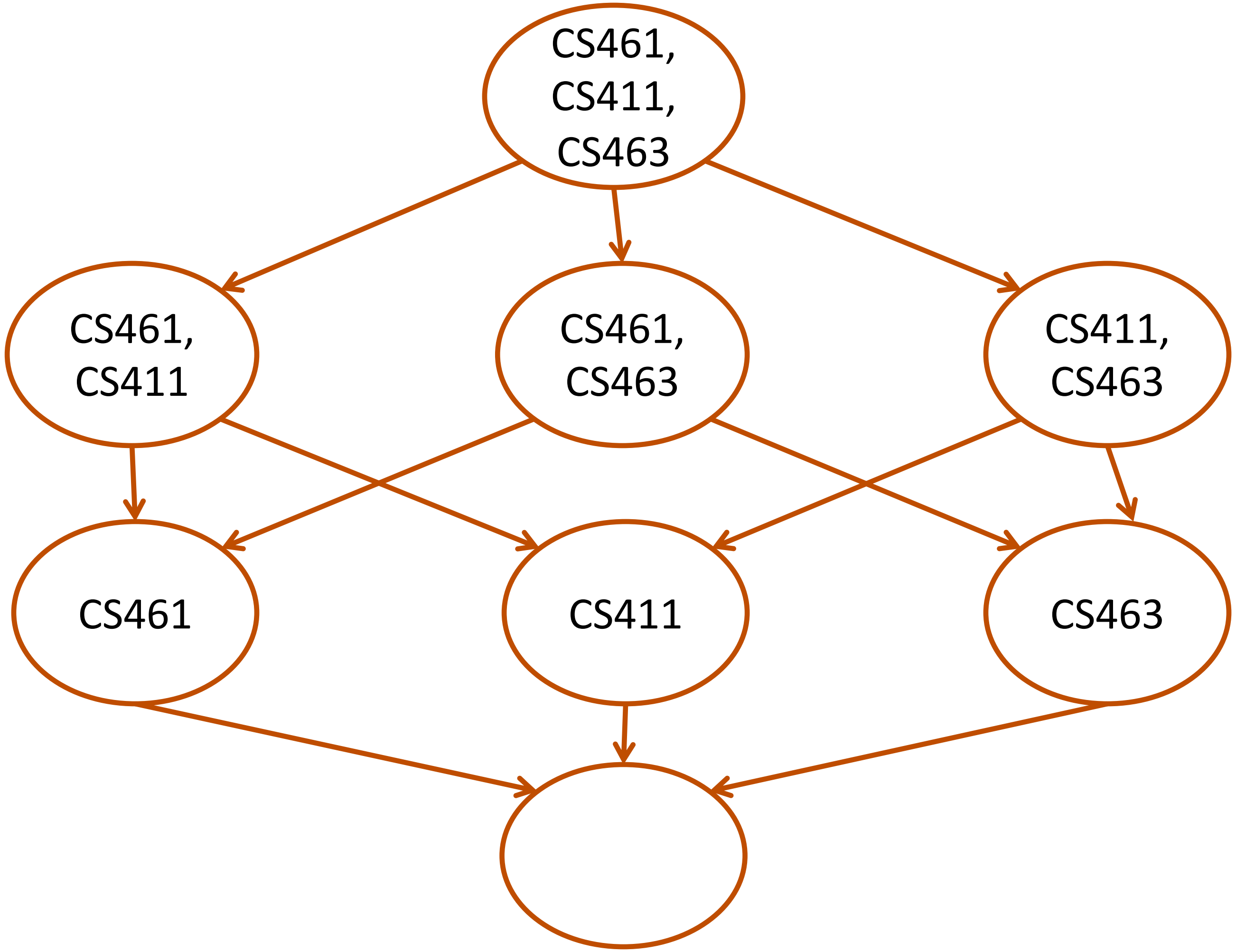
- Set of security labels forms a partial ordering or a lattice

Comparing Security Labels

- (A1, C1) "dominates" (A2, C2) iff A2 <= A1 and C2 subset of C1

- Replace "=>" with "dominates" and simple security condition and *-property hold
  - Simple Security Property: Subject s can only read an object o if Label(s) dominates Label (o)
  - *-Property: A subject s can append into an object o only if Label (o) "dominates" Label (s); A subject s can read+write into an object o only if Label (o) is same as Label (s)

Example Lattice of Categories



Security Label Comparisons

- Instructor Label = Secret:{461, 498}
- TA Label = Secret:{461}
- Student label = Confidential:{461}
- Instructor writes exam for CS461
  - What label should it have, so TA can help write?
    - A. Secret: {461}
    - B. Confidential:{461}
    - C. Public:{461}
    - D. Top Secret:{498}

Top secret > secret > confidential > restricted > unclassified

Security Label Comparisons

- Instructor Label = Secret:{461, 498}
- TA Label = Secret:{461}
- Student label = Confidential:{461}
- Instructor writes exam for 461
  - What label should it have for student to read exam?
    A. Secret:{461}
    B. Confidential:{461}
    C. Top Secret:{461}
    D. None of the above

Top secret > secret > confidential > restricted > unclassified

Adding Security Clearance Flexibility

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- Define maximum and current level for subjects
  - maxlevel(s) dominates curlevel(s)
  - In some systems, the min level is also defined

- How does this ease the previous example?

Principle and Types of Tranquility

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- Strong tranquility
  - The clearances of subjects, and the classification of objects, do not change during the lifetime of the system

- Weak tranquility
  - The clearances of subjects and the classifications of the objects change in accordance with a specified policy.

Principle of Tranquility

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- Raising object's security level
  - Information once available to some subjects is no longer available
  - Usually assume information has already been accessed, so questionable protection
- Lowering object's security level
  - The declassification problem
  - Essentially, a write down, violates *-property

Summary

- Mandatory Security Policies
  - Designed by security expert
  - Can be awkward for users

- Different models address different goals
  - E.g., BLP is a confidentiality model

BIBA Integrity Model

Intuition for Integrity Levels

- The higher the level, the more confidence
  - E.g. - that a program will execute correctly
  - E.g. - that data is accurate and/or reliable
- Note relationship between integrity and trustworthiness
- Important point: *integrity levels are **not** security levels*
- Integrity models finding use in modern Operating Systems

Integrity Level Example

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Integrity Level	Subject	Object
Highly Trusted	Alice	System Software
Trusted	Bob	Software Signed by the OS Provider or other Trusted provider
Untrusted	Dave	Software downloaded from Internet

Strict Integrity Policy – Biba Model

- Simple Integrity Property
  - $s \in S$ can write to $o \in O$ iff $i(o) \leq i(s)$
  - No write up

- Integrity Confinement Property
  - $s \in S$ can read $o \in O$ iff $i(s) \leq i(o)$
  - No read down

- Invocation Property
  - $s_1 \in S$ can invoke $s_2 \in S$ iff $i(s_2) \leq i(s_1)$

- Dual of Bell-LaPadula model
  - Add compartments and discretionary controls to get full dual of Bell-LaPadula model

More Advanced Integrity Labels

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- Add set of categories to the integrity level to create integrity label
  - E.g., Trusted:{project1, project2}.
  - The information in object is trusted only for project 1 and project 2.
- Set of integrity labels forms a partial ordering or a lattice

Comparing Integrity Labels

- (A1, C1) “dominates” (A2, C2) iff A2 <= A1 and C2 subset of C1
- Replace “=>” with “dominates” in simple integrity, integrity confinement and invocation properties
  - Simple Integrity Property: Subject s can **write** to an object o only if Label(s) “**dominates”** Label (o)
  - Integrity Confinement Property: A subject s can **read** an object o only if Label (o) **“dominates”** Label (s)
  - Invocation Property: A subject s_1 can **invoke** a subject s_2 only if Label (s_1) **“dominates”** Label (s_2)

Integrity Models in Practice

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- Integrity Levels introduced in Windows Vista as Mandatory Integrity Control (MIC)

- Windows has 4 integrity levels:
  - Low < medium < high < system
  - Standard users – medium integrity level
  - System services – system integrity level
  - Object with no level associated are treated as “medium integrity level”

- Anything downloaded from the Internet is defaulted to “low” so that such software cannot corrupt medium, high and system files.
  - Note such software may still be able to read your data!

Summary

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- BIBA is a mandatory access control policy model focused on integrity
- It is a dual of Bell-LaPadula (BLP) that focuses on confidentiality
- Integrity levels are being used in modern operating systems to prevent corruption of system files

Chinese Wall Model

Chinese Wall Model

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- Addresses enforcing **conflict of interest** policies

- Example
  - Consultant knows sensitive information about Company A
  - Consultant's company also works with Company B, a competitor to Company A
  - Consultant shouldn't access information about Company B

- Other Examples:
  - between corporate advisors and brokers in investment banks
  - between editorial/news and advertising divisions
  - between lawyers representing the defendant and plaintiff from the same company/firm

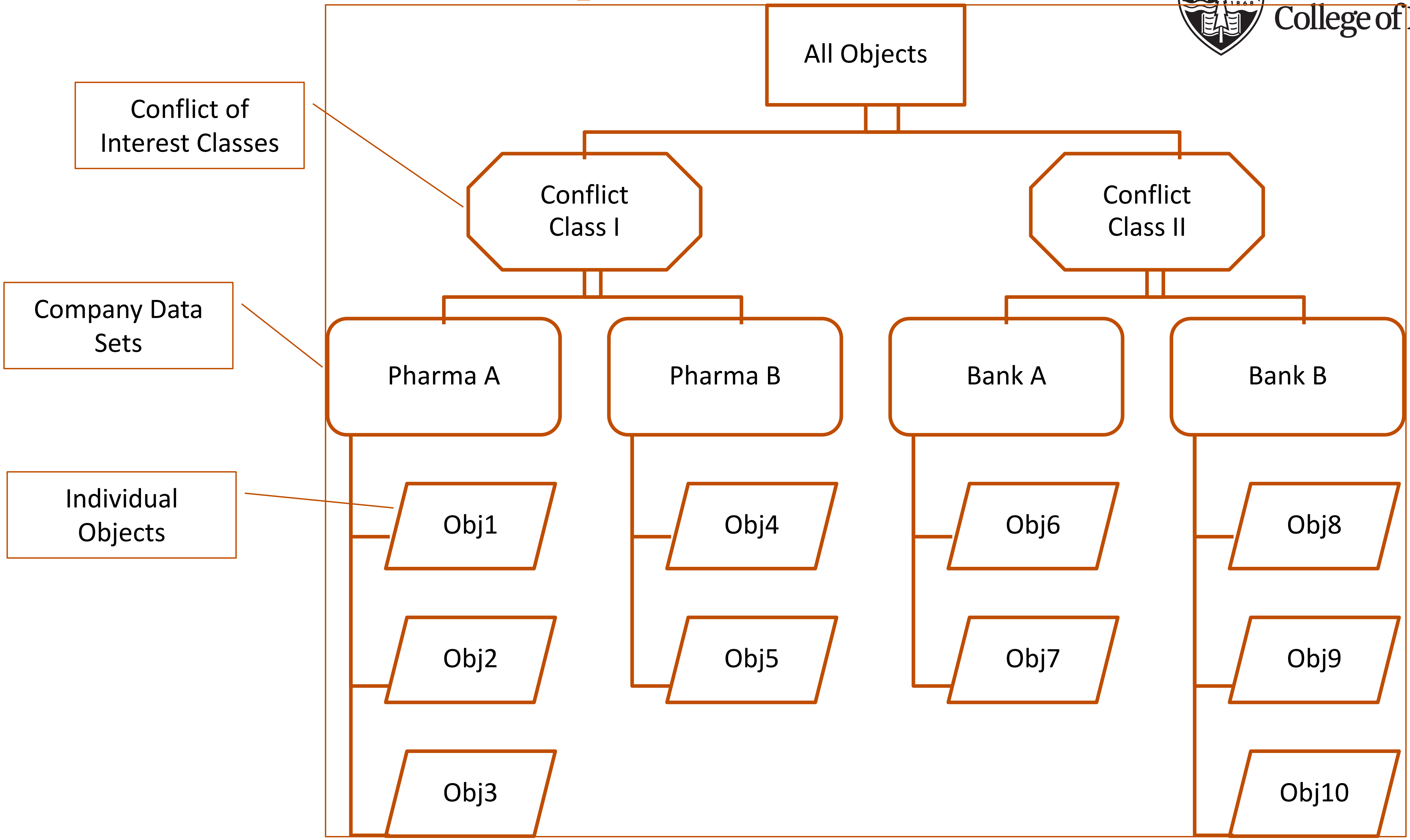
Definitions

- Subjects – Active entities

- Information
  - Objects – Individual items
  - Dataset (DS) – All objects that concern the same corporation
  - Conflict of interest (CI) class – All datasets whose corporations are in competition

- Access rules – rules for read and write access

Chinese Wall Example



Simple Security Rule

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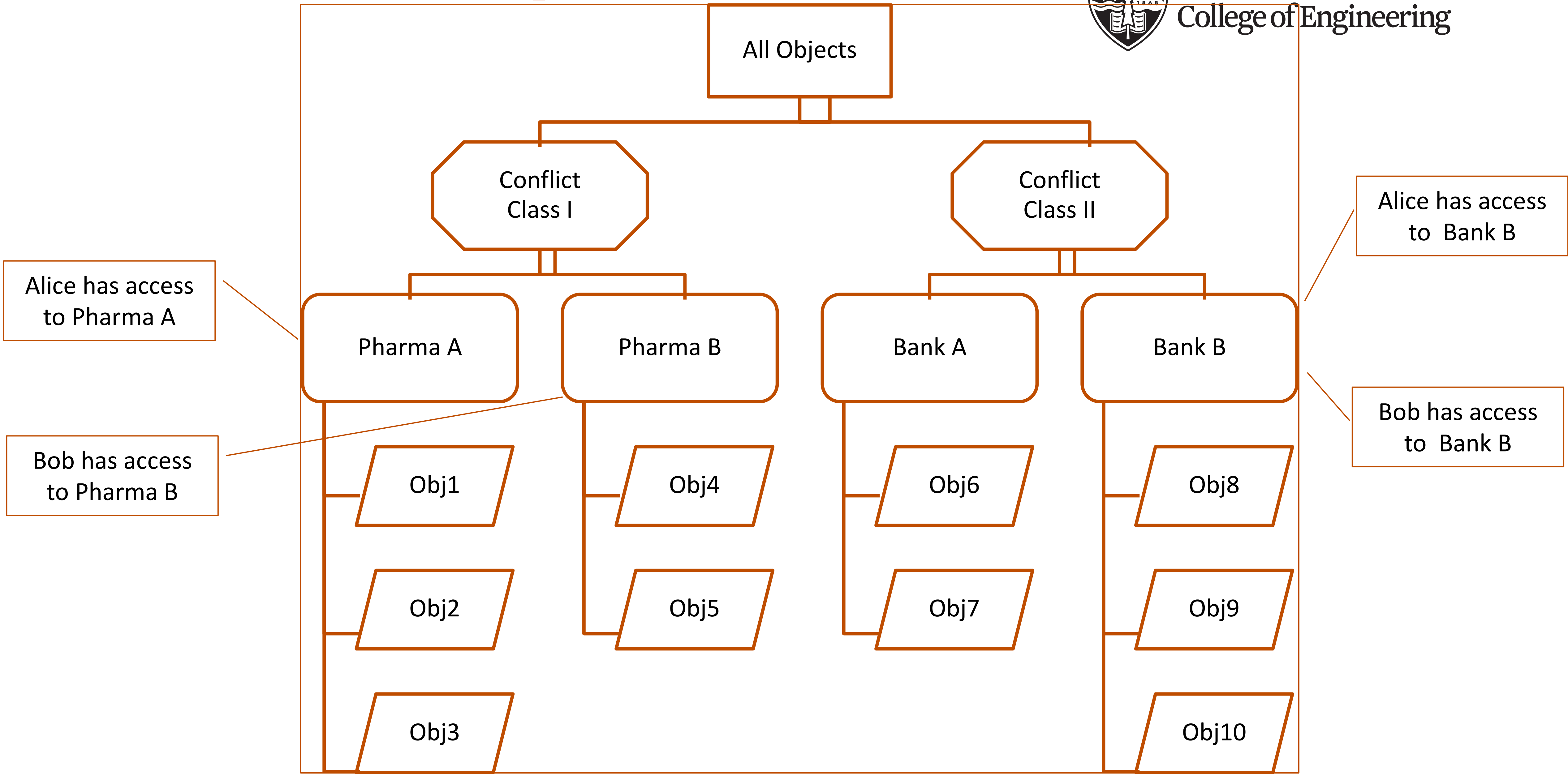
- Subject S can read an object O only if
  - O is in same DS as object already accessed by S or
  - O belongs to CI from which S has not yet accessed any information

*-Property Rule

- A subject S can write to object O only if
  - S can read O according to the simple security rule AND
  - All objects that S can read are in the same DS as O

Chinese Wall Example



Summary

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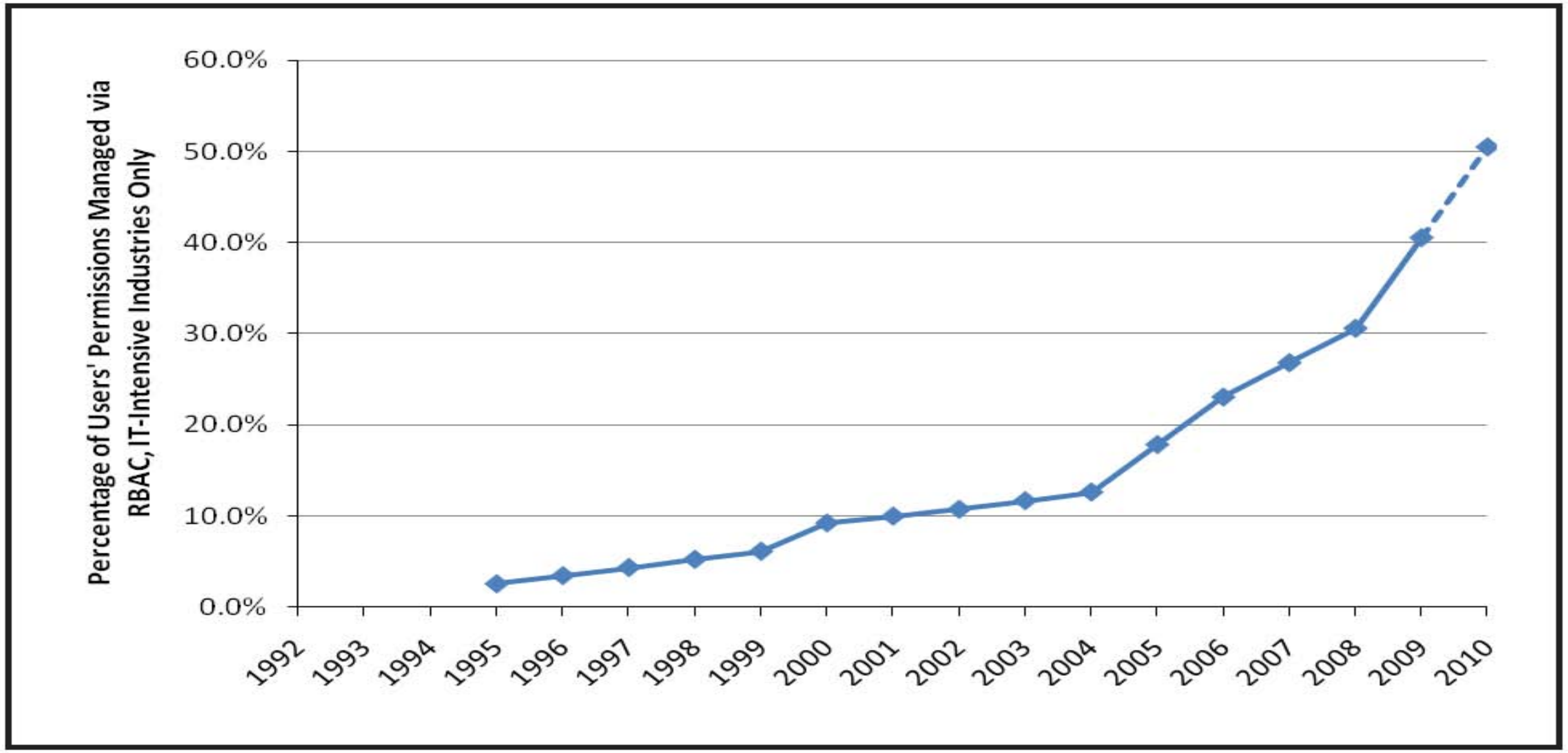
- Chinese Wall is a mandatory access control model that looks at multi-lateral security
  - focuses on conflict-of-interest
- It is used in law firms, consulting firms, accounting firms and in (semi) regulated industries like electricity generation and distribution

Role-Based Access Control (RBAC): Introduction

Role-Based Access Control (RBAC)

- RBAC is most widely used access control model in business world [NIST&RTI 2010]
  - introduced in early-nineties

Figure ES-2. RBAC Adoption, 1992–2010



A Mini Example of RBAC

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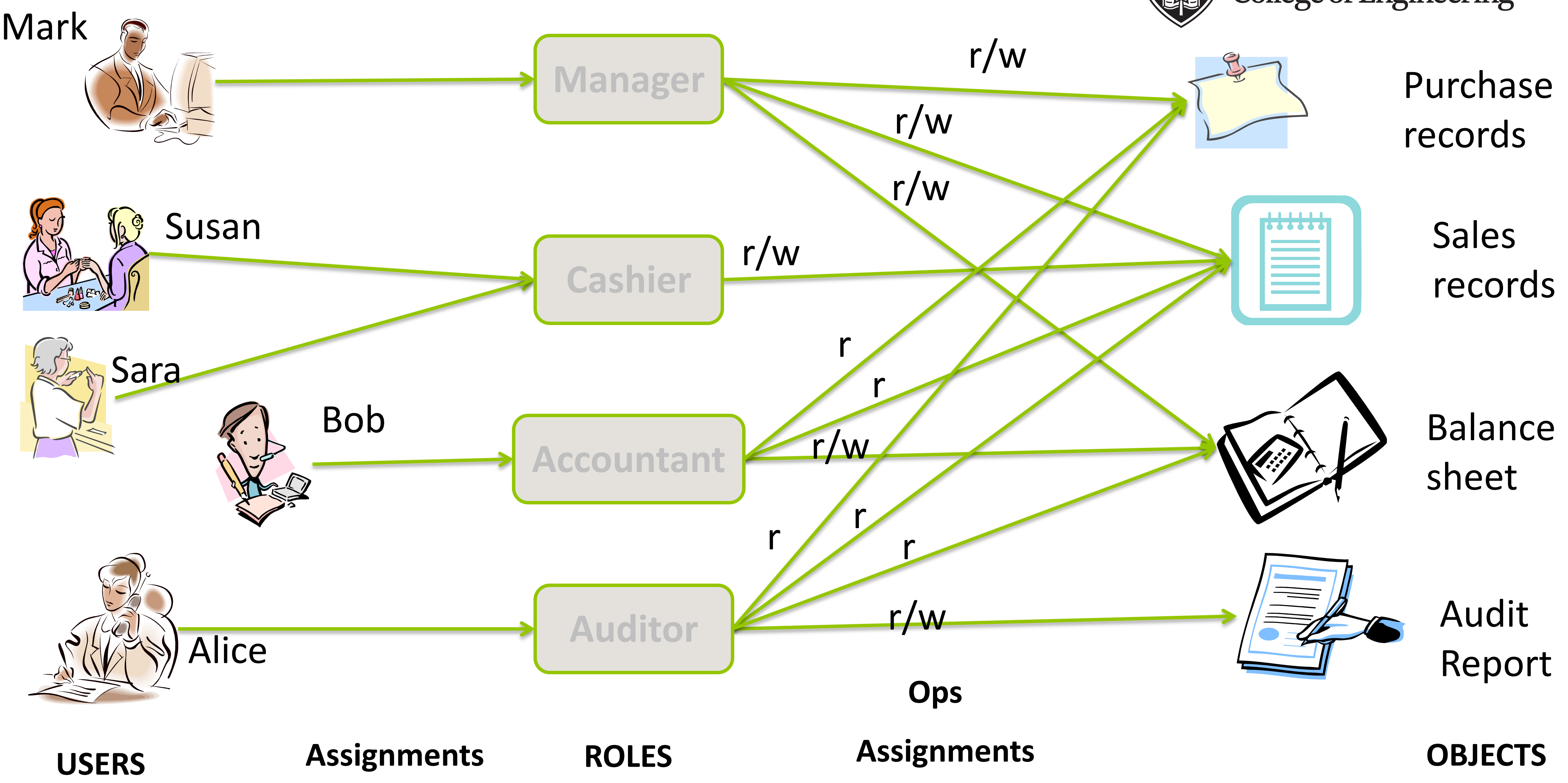


Role-Based Access Control

- Each role is defined by a set of permissions
  - created for job functions in an org.
  - represents competency, authority and responsibility
  - can be granted new permissions for new apps.
  - permissions can be revoked from a role

- Each user is assigned with one or more roles
  - based on the user's responsibility and qualification
  - can be reassigned with different roles

- Why RBAC?
  - User-permission associations are transitory
  - Role-permission associations are stable

Access Matrix Representation

	R1	R2	R3
U_1	X	X	
U_2	X		X
U_3		X	X
U_4			X
U_5	X	X	
…			
U_n	X		X

User-to-Role Mapping

	Roles			Files		Processes		Disks	
	R1	R2	R3	F1	F2	P1	P2	D1	D2
R1	control	owner	owner control	Read*	Read owner	wakeup	wakeup	seek	owner
R2		control		Write*	execute			owner	Seek*
R3			control		write	stop			

Role-to-Permission Mapping

- Similar to DAC ACM
- Roles can be Objects

DAC vs RBAC

- DAC
  - Users, Groups → Permissions
- RBAC
  - Roles → Permissions; Users → Roles
- Difference between groups and roles?
  - Group: collection of users
  - Role: collection of permissions, and possibly other roles [S96]
- Difference between DAC and RBAC
  - Different perspectives:
    - RBAC is from perspective of organization
  - Different right management: [Ferraiolo&Kuhn1992]
    - DAC: allows a user to grant access to the objects he owns;
    - RBAC: typically users cannot pass their rights to others

Summary

- Role-based access control is introduced in early 90s to simplify permission management

- In RBAC
  - Roles are assigned permissions (role is a collection of permissions)
  - Users are assigned roles

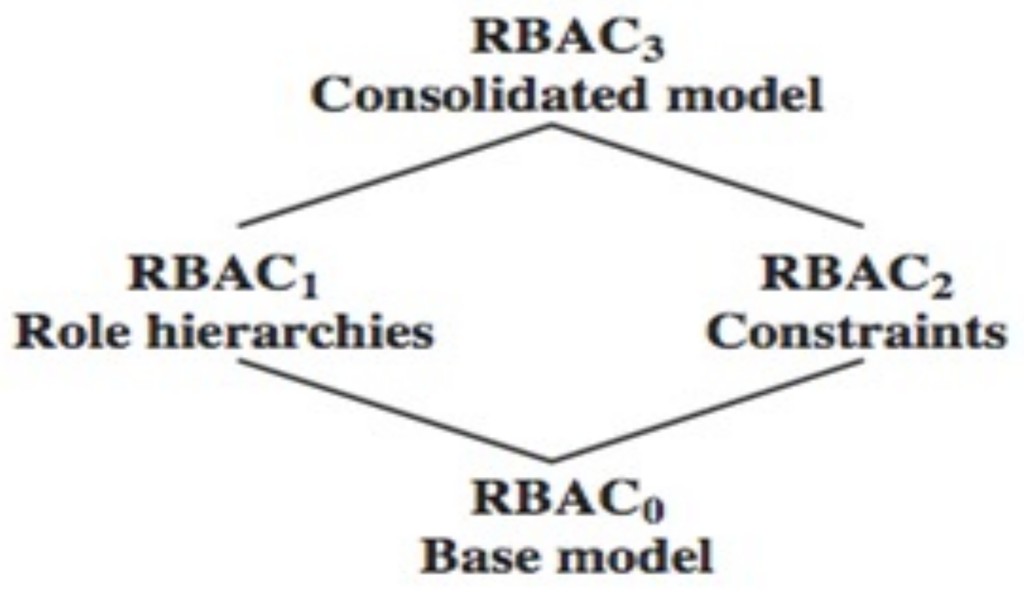
- Role-permission associations are relatively stable
  - Need to change less frequently

- User–role assignments change more often
  - Users change their role (promotions, lateral moves etc.)

RBAC Models

RBAC Models

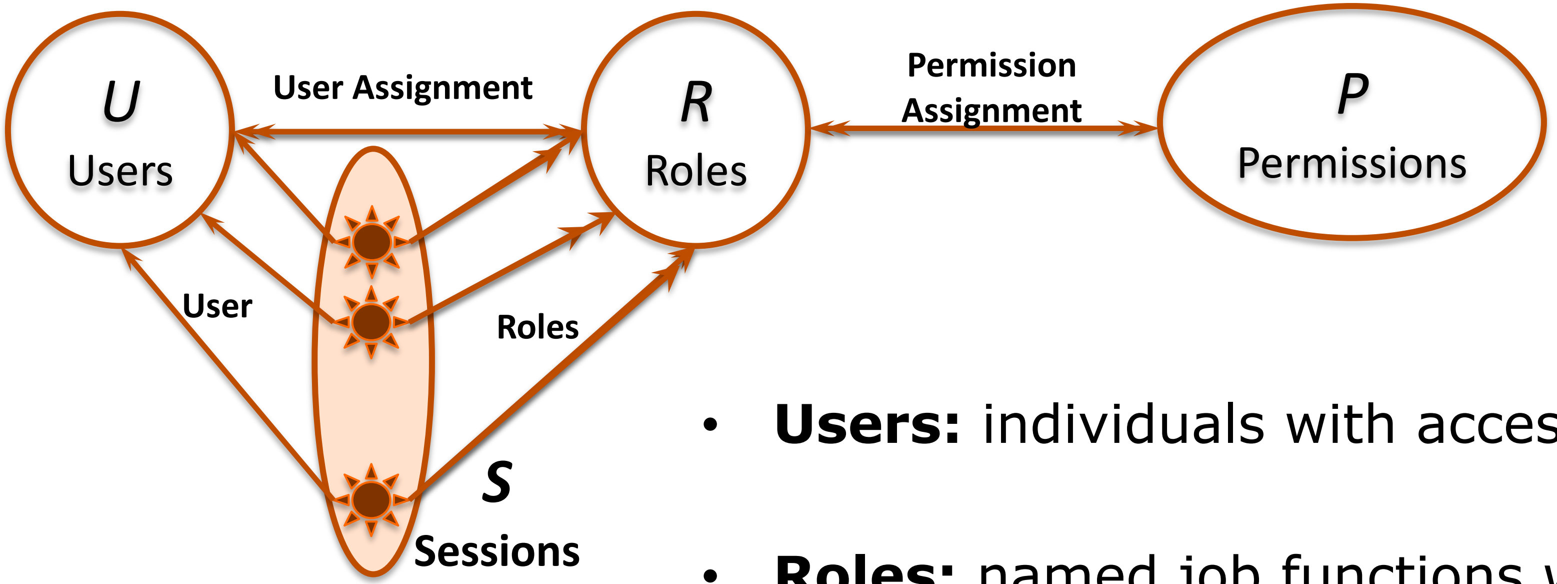
- $RBAC_0$
  - Minimum functionality
- $RBAC_1$
  - $RBAC_0$ + Role hierarchies
- $RBAC_2$
  - $RBAC_0$ + Constraints
- $RBAC_3$
  - $RBAC_0$ + $RBAC_1$ + $RBAC_2$



(a) Relationship among RBAC models

Figure Credit: Sandhu et al, Role-Based Access Control Models, IEEE Computer, Volume 29, Number 2, February 1996, pages 38-47.

$RBAC_0$ – Base



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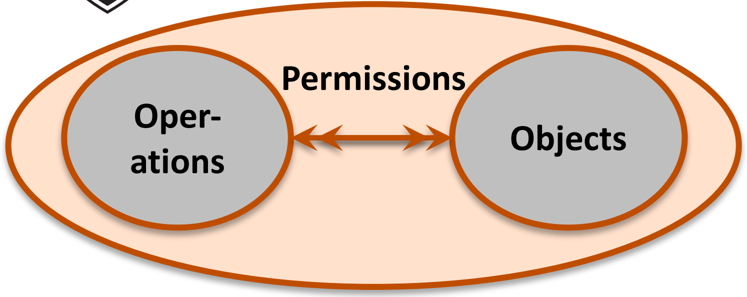

- **Users:** individuals with access to the system
- **Roles:** named job functions within the org
- **Permission:** approval to perform an *operation* on *object(s)* (a particular mode of access to objects)
  - Object: any resource
  - Operation: executable image of a program / action on object(s)
- **Session:** a mapping between a user and a subset of roles
  - allows selective activation and deactivation of roles assigned

$RBAC_1$ – – $RBAC_0$ + Role Hierarchies

- Reflect hierarchical structure of roles in org
- Mathematically, partial order (reflexive, transitive, anti-symmetric)
- Help reduce permission management further

$RBAC_1$ – – $RBAC_0$ + Role Hierarchies

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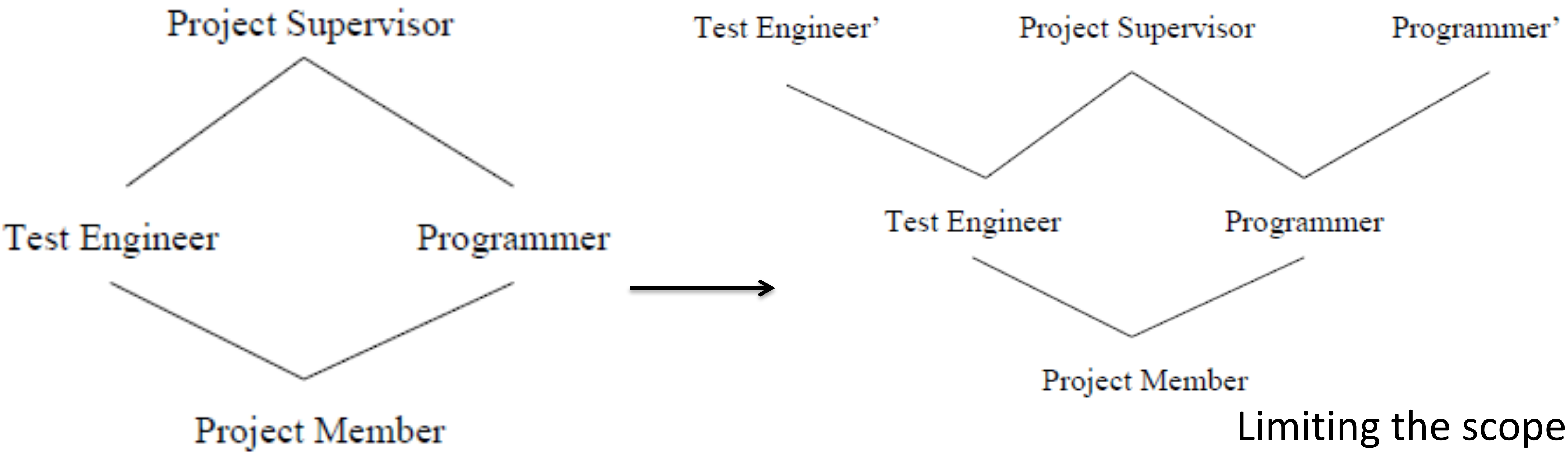
Higher -> More rights, line from lower to higher means inheritance of rights



Example of Role Hierarchy

Limiting the scope of inheritance:
Role Hierarchy with *private roles*

Figure Credit: Sandhu et al, Role-Based Access Control Models, IEEE Computer, Volume 29, Number 2, February 1996, pages 38-47.

$RBAC_2$ – $RBAC_0$+Constraints

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- Constraints: Reflect higher-level organizational policy
- Example constraint types
  - **Mutually exclusive roles** (U → R and R → P)
    - User to only one role in set, permission to only one role
    - Implication – users with different roles have no shared permissions
    - E.g.: A user cannot be both the Accountant and Auditor
  - **Cardinality** – maximum number users assigned to role, maximum number of roles permitted a user (static or dynamic), maximum number of permissions to a role
    - E.g.: Role of CEO of a company can only have one user assigned to it

$RBAC_2$ – $RBAC_0$+Constraints

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- Example constraint types
  - **Prerequisite** – can assign role only if already assigned prerequisite role
    - Idea is to support least privilege…if role R1 inherits from R2 and R3, then if only R2 or R3 rights are needed, those roles can be used
    - Remember, no hierarchies in $RBAC_2$

Static Separation of Duty (SSD)

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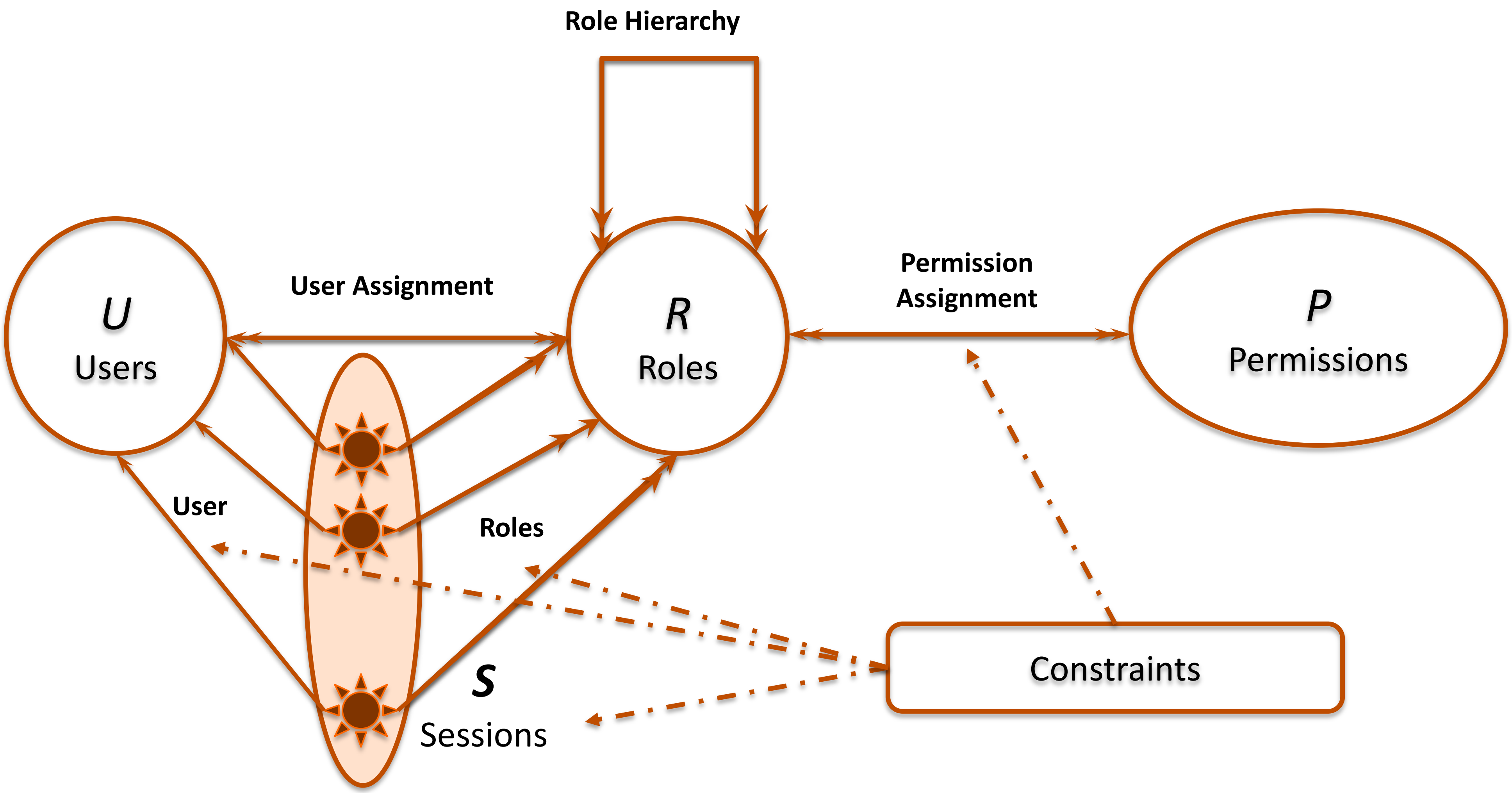
- Prevents conflict of interest
- Cardinality constraint on a set of roles
  - SSD := (*rs*, *n*) where no user is assigned to *n* or more roles from the *role set rs, i.e.*
- Mutual exclusive roles as a special case:
  - SSD := $(\{r_1, r_2\}, 2)$

Dynamic Separation of Duty (DSD)

- Similar to SSD, but activated within sessions
- Typically for temporal conflicts of interest
- Definition
  - DSD := (*role set*, *n*) ($n \geq 2$) no user session may activate $\geq n$ roles from *role set*
- Example: Author and PC member (conference)

RBAC$_3$ – Consolidated Model



RBAC and Security Principles

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- RBAC supports well-known security principles:
  - Least Privilege
  - Separation of duties

- Least Privilege : RBAC can be configured so only those permissions required for a job function are assigned to a role representing that function.

- Separation of duties : by ensuring that mutually exclusive roles must be invoked to complete a sensitive task.

NIST RBAC Standard

- Standards
  - **ANSI INCITS 359-2012** replaces 359-2004.
  - **ANSI INCITS 494-2012** supplements 359-2012 with enhanced constraints, which can include attributes.
  - **ANSI INCITS 459-2011** provides guidance in RBAC system implementation and interoperability.

- RBAC Reference Models:
  - Core RBAC
  - Hierarchical RBAC
    - General Hierarchies
    - Limited Hierarchies
  - Constrained RBAC
    - RBAC with Static Separation of Duty Relations
      - With and Without Hierarchies
    - RBAC with Dynamic Separation of Duty Relations
    - **RBAC with general constraints on attributes of users/objects/environment** (**new** in **ANSI INCITS 359-2012**)

NIST Model

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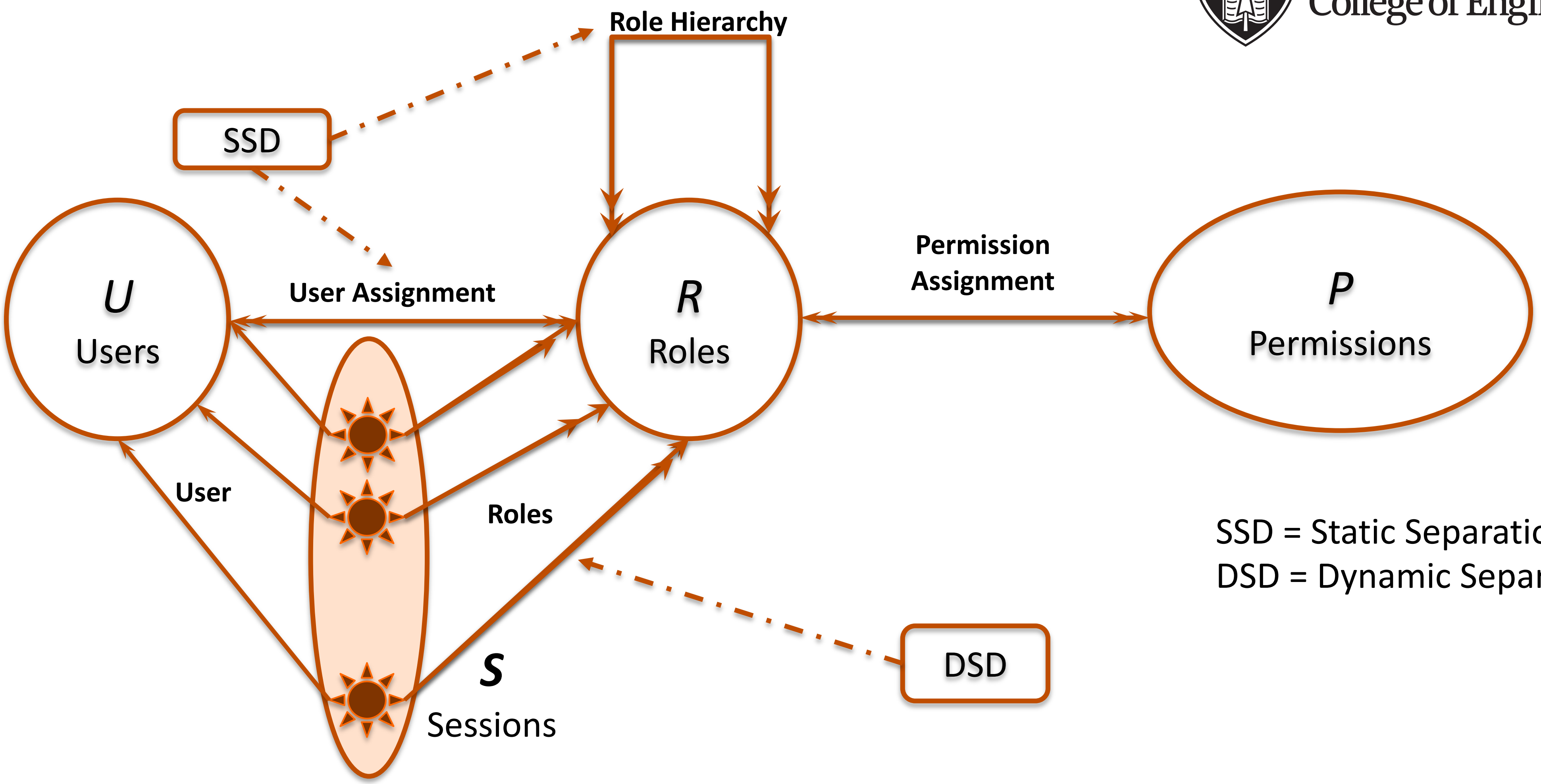

SSD = Static Separation of Duty
DSD = Dynamic Separation of Duty

NIST RBAC Model

Unspecified by NIST RBAC

- Scalability
- Authentication
- Negative permissions
- Nature of permissions
- Discretionary role activation
- Role engineering
- RBAC administration
- Role revocation

Summary

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- Many variations of RBAC models exist
- First paper introduced 4 models
  - $RBAC_0$
  - $RBAC_1 = RBAC_0$ + Role Hierarchies
  - $RBAC_2 = RBAC_0$ + Constraints
  - $RBAC_3 = RBAC_0$ + Role Hierarchies + Constraints
- NIST Standardized variations of the original models
  - Core RBAC, Hierarchical RBAC and Constrained RBAC
- RBAC is suitable for supporting well-known security principles
  - Least Privilege, Separation-of-duty