CSE 410/565 Computer Security
Spring 2022

Lecture 9: Access Control II

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Review

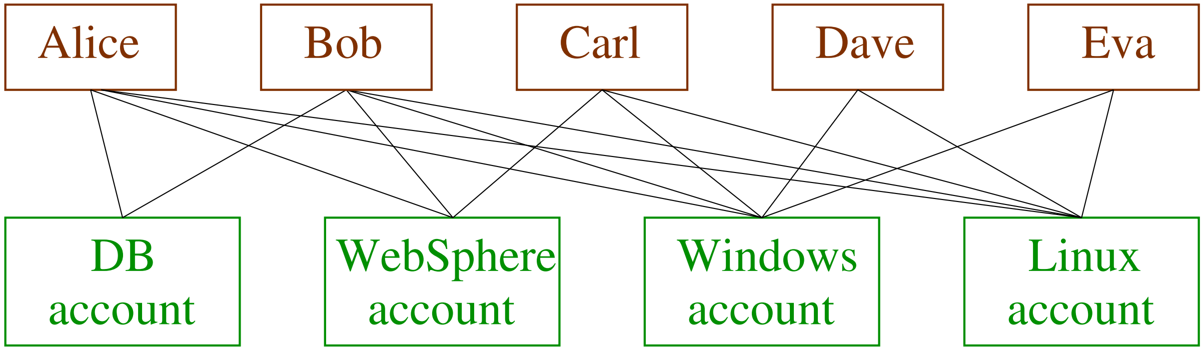
- Access control can be implemented in different ways
- Discretionary access control
  - lets subjects to grant privileges to other subjects at their discretion
- Mandatory access control
  - enforces system-wide policy
- Role-based access control
- Attribute-based access control

Role-Based Access Control

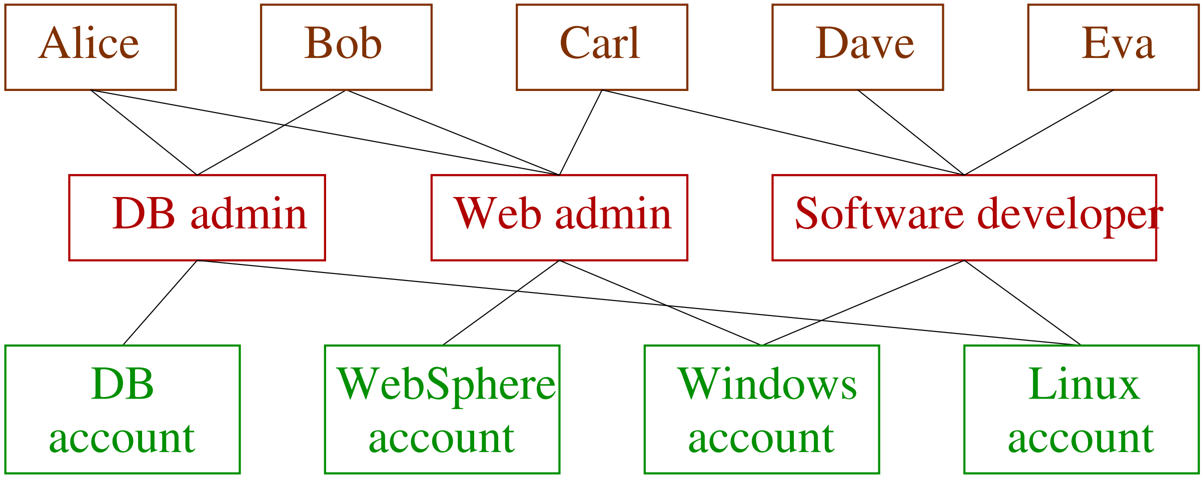
- In Role-Based Access Control (RBAC) models, subjects are combined into "roles" according to their privileges in the organization
  - often based on job function
- Permissions are assigned to roles rather than users
- A user can assume one or more roles within the organization according to their responsibilities
- RBAC fits operational model of an organization and is widely used

Role-Based Access Control

- Non-role-based AC



- Role-based AC



Role-Based Access Control

- Motivation for RBAC
  - problem: it is difficult to administer user–permission relation
  - roles are a level of indirection
    - “All problems in Computer Science can be solved by another level of indirection” B. Lampson
- RBAC is
  - multi-faceted
  - multi-dimensional
  - open ended
  - ranging from simple to sophisticated

Role-Based Access Control

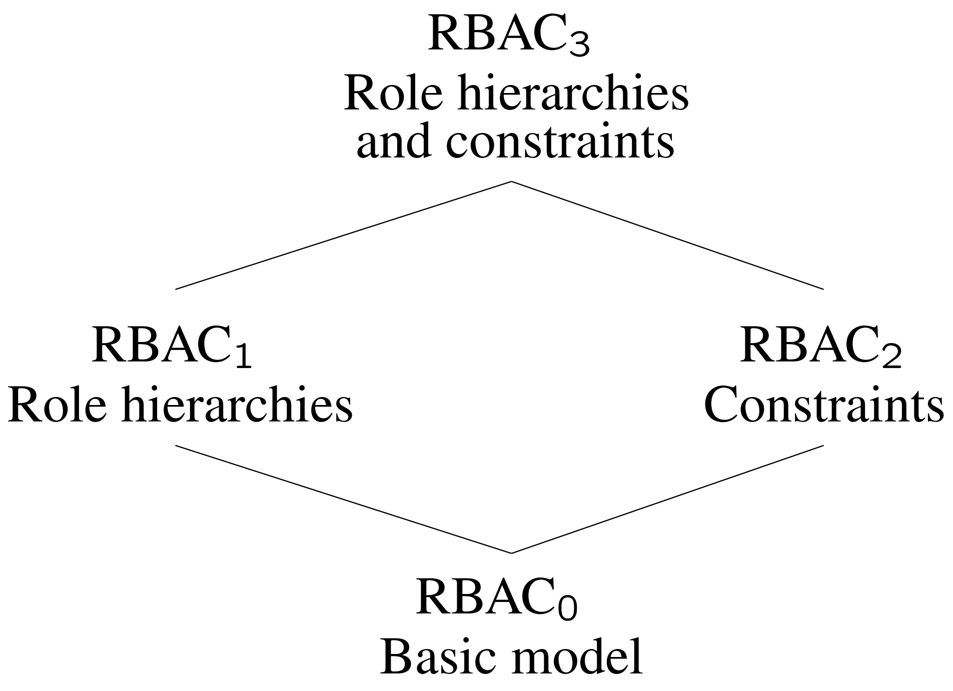
- Why use roles?
  - fewer relationships to manage
    - potential decrease from $O(mn)$ to $O(m+n)$, where m is the number of users and n is the number of permissions
    - there are often more users than roles and more objects than roles
  - roles are a useful level of abstraction
  - organizations operate based on roles
  - roles are likely to be more stable than the set of users and the set of resources
  - roles can effectively implement the principle of least privilege
    - finding the minimum set of necessary access rights is performed per role rather than per subject

Groups vs. Roles

- How are roles different from groups?
  - Answer 1:
  - Answer 2:
  - Answer 3:

RBAC Models

- The family of RBAC models proposed by Sandhu et al. (1996)



RBAC$_3$
Role hierarchies
and constraints

RBAC$_1$
Role hierarchies

RBAC$_2$
Constraints

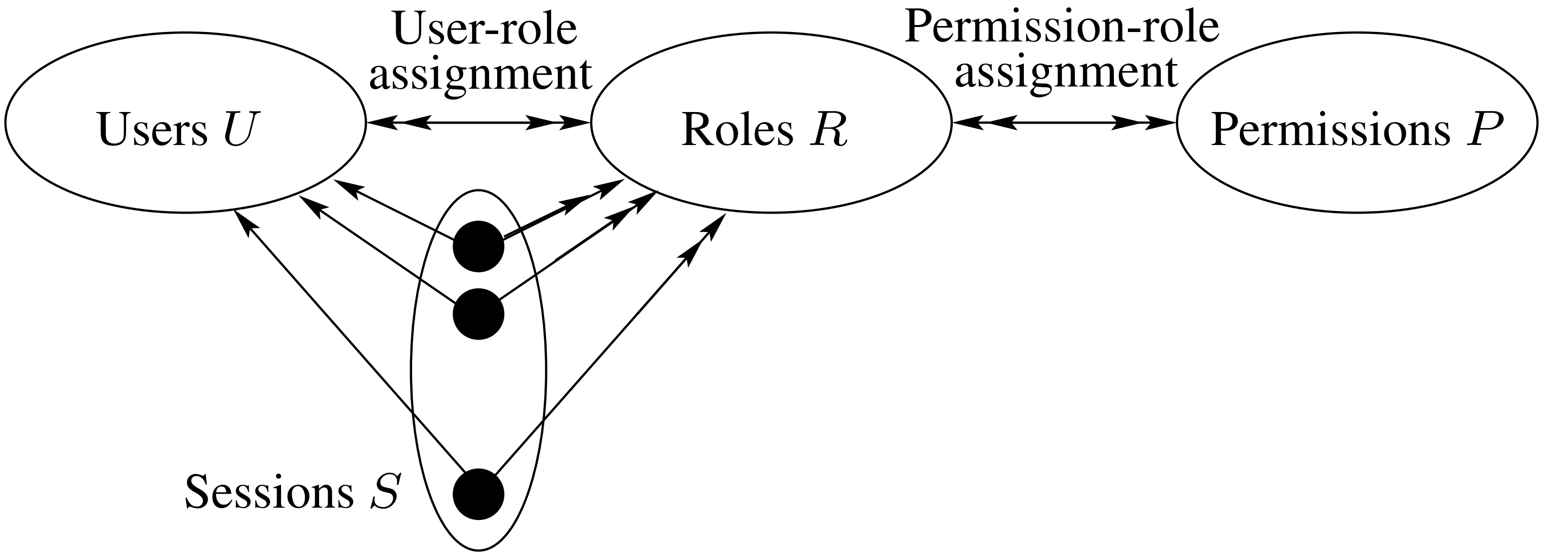
RBAC$_0$
Basic model

RBAC$_0$

- RBAC$_0$ contains four types of entities
  - users U
  - roles R
  - permissions P
  - sessions S
- User assignment is many-to-many $UA \subseteq U \times R$
- Permission assignment is many-to-many $PA \subseteq P \times R$
- Session activation
  - one-to-one for user: $S \to U$
  - one-to-many for roles: $S \to 2^R$

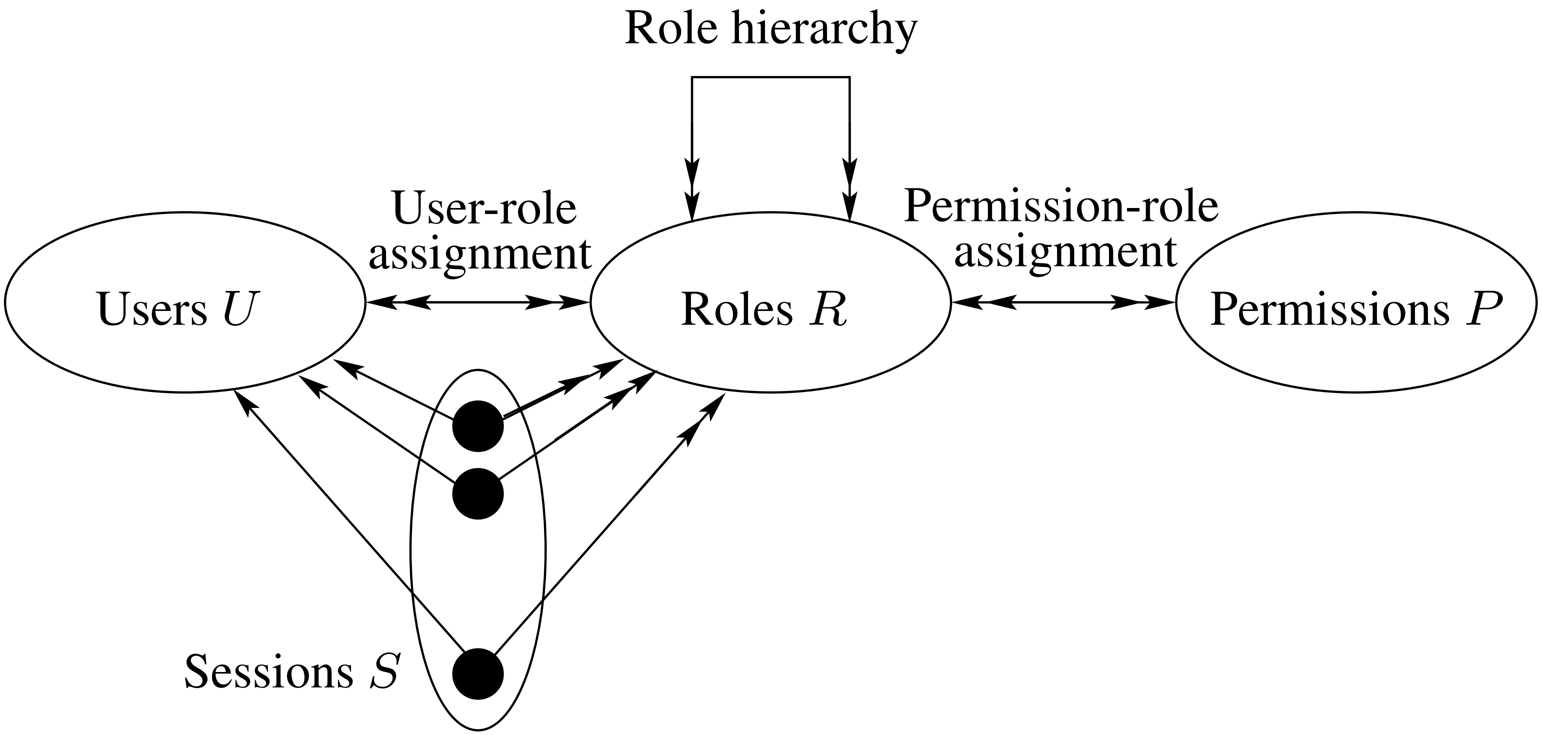
RBAC$_0$

- A session s must comply with UA and PA assignments
  - $roles(s) \subseteq \{r \mid (user(s), r) \in UA\}$
  - permissions of session s are $\bigcup_{r \in roles(s)} \{p \mid (p, r) \in PA\}$



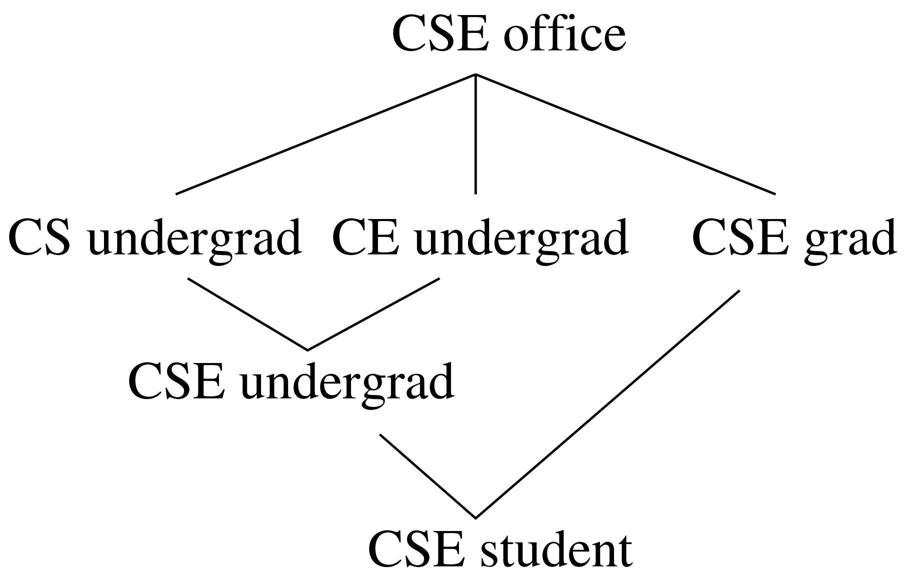
RBAC_1

- RBAC_1 enhances RBAC_0 with role hierarchies



RBAC$_1$

- Role hierarchies are based on the idea that subordinate job functions may have a subset of access rights of a superior job function
  - a role inherits access rights of its descendant roles
- Example of a role hierarchy



CSE office

CS undergrad

CE undergrad

CSE grad

CSE undergrad

CSE student

RBAC$_1$

- Formal model:
  - U, P, R, S, PA, UA are unchanged from RBAC$_0$
  - role hierarchy $RH \subseteq R \times R$ is a partial order on R whiten as $\geq$
    - $r_1 \geq r_2$ means that r_1 is an ancestor of r_2
    - partial order means that relationship between any two roles can be undefined
  - requirements on session activation change
    - $roles(s) \subseteq \{r \mid \exists r' \text{ s.t. } [(r' \geq r) \;\&\; (user(s), r') \in UA]\}$
    - session s has permissions $\bigcup_{r \in roles(s)} \{p \mid \exists r' \text{ s.t. } [(r \geq r') \;\&\; (p, r') \in PA]\}$

RBAC$_2$

- No formal model is specified for RBAC$_2$ that adds constraints to RBAC$_0$

- A constraint is a condition related to roles or a relationship defined on roles

- Types of constraints (Sandhu et al. 96)
  - mutually exclusive roles
  - cardinality constraints
  - prerequisite constraints

Constraints in RBAC

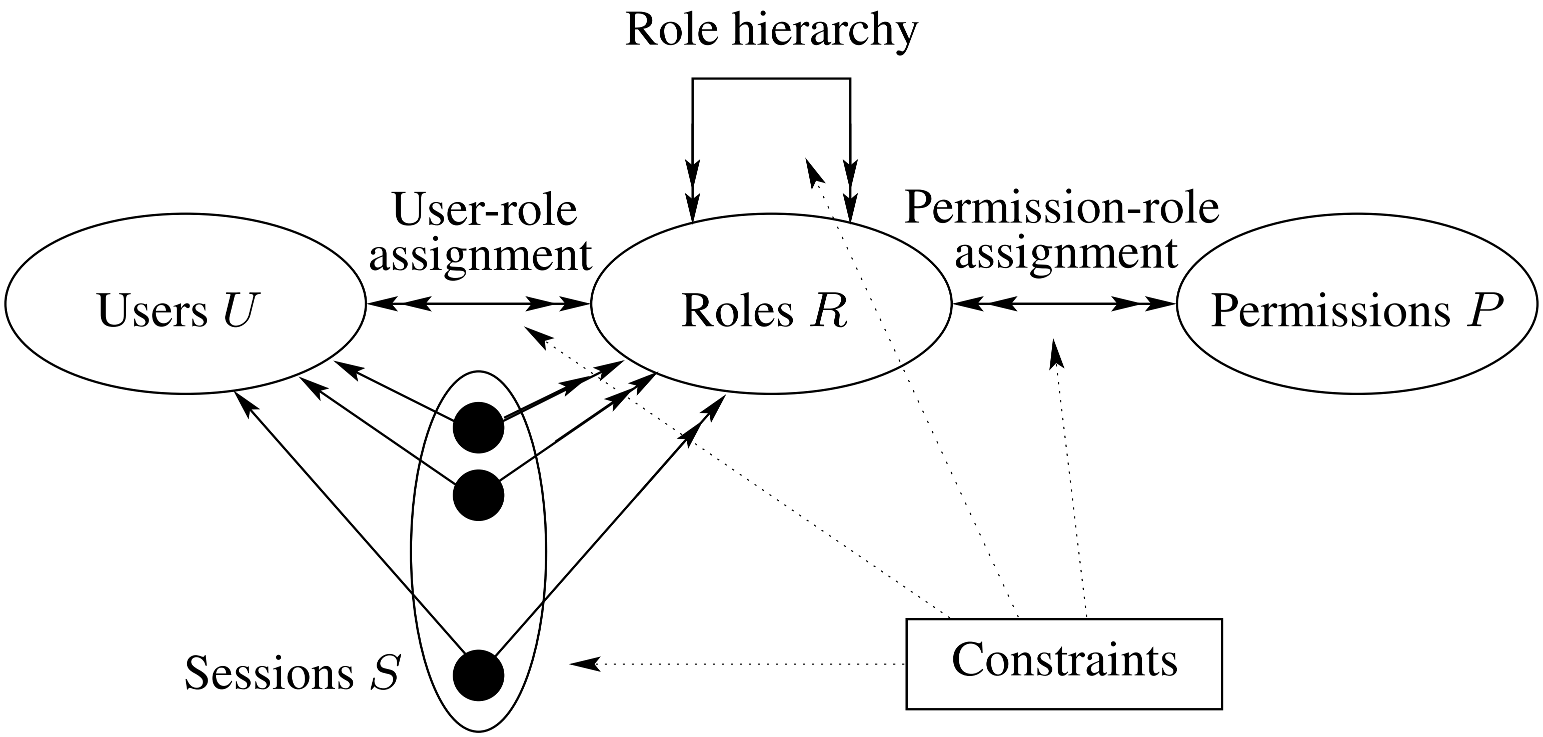
- Mutually exclusive roles: a user can be assigned to only one role from a particular set of roles
  - static exclusion:
  - dynamic exclusion:
  - such constraints support the separation of duties principle
- Prerequisite (or precondition) constraints: the prerequisite must be true before a user can be assigned to a particular role
  - a user can be assigned to role r_1 only if it is already assigned to another role r_2

Constraints in RBAC

- Cardinality constraints: setting restrictions on the number of roles
  - user-role assignment
    - at most k users can be assigned to the role
    - a user can be assigned to at most m roles
  - role-permission assignment
  - role activation
- Why should we bother to specify constraints?
  -
  -
  -

RBAC$_3$

- RBAC$_3$: features of RBAC$_0$, RBAC$_1$, and RBAC$_2$



- Now role constraints can be based on the role hierarchy

RBAC in Use

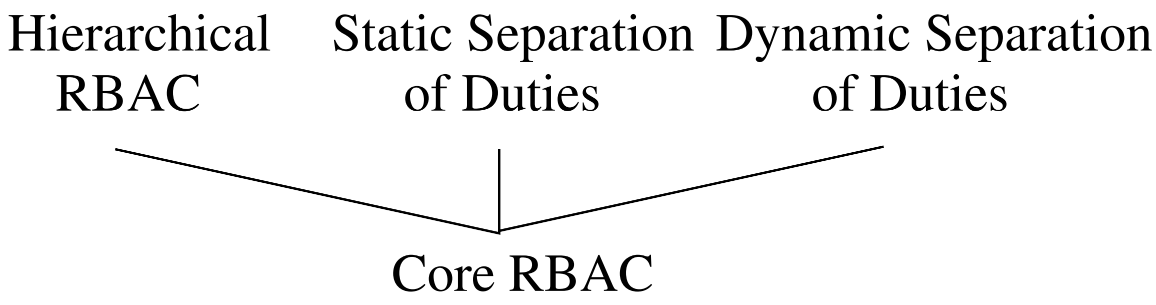
- Products that use RBAC
  - database management systems (e.g., Oracle)
  - enterprise security management (e.g., IBM Tivoli Identity Manager)
  - operating systems (e.g., Solaris OS, AIX)
- RBAC economic impact study (2002)
  - was conducted by the Research Triangle Institute (RTI) based on interviews with software developers and companies that use RBAC
  - it estimated by 2006 30–50% of employees in service sector would be managed by RBAC systems (10–25% for non-service sectors)
  - it conservatively estimated the economic benefits of this degree of penetration through 2006 to be $671 million

RBAC in Use

- Another analysis was performed in 2010
  - RBAC use rose to 41% in 2009 and was estimated to be just over 50% in 2010
  - over 80% of respondents reported that using roles improved efficiency of maintaining their organization's access control policy
  - economic benefits of RBAC adoption between 1994 and 2009 were estimated at $6 billion

The RBAC Standard

- In 2001 RBAC was proposed to become a NIST standard
- It was adopted as ANSI (American National Standards Institute) standard 359 in 2004
- The standard has the following structure



The RBAC Standard

- The ANSI standard has been criticized by Li et al. (2007)
  - there are many errors
  - there are other limitations and design flaws
  - the publication proposes several changes to the standard
- It was republished as 359-2012 and since reaffirmed as 359-2017 (R2017)
  - the current version consists of two parts: the RBAC reference model and the RBAC system and administrative functional specification

RBAC Extensions

- RBAC has been extensively studied
  - many extensions exist (temporal, geo-spatial, privacy-aware)
  - administration of RBAC
  - constraints, workflow, role engineering, . . .

Attribute-Based Access Control

- Attribute-based access control (ABAC) is a rather recent mechanism for specifying and enforcing access control
  - properties are specified in the form of attributes
  - authorizations involve evaluating predicates on attributes
  - conditions on properties of both the subject and resource can be enforced

Attribute-Based Access Control

- ABAC provides a lot of flexibility in specifying rules and supports fine-grained access control
  - it is capable of enforcing DAC, MAC, and RBAC concepts
- This comes at a performance cost
  - it has seen the most success for web services and cloud computing where there is already a response delay
- There are three key elements in an ABAC model
  - attributes
  - policies
  - architecture

Attribute-Based Access Control

- ABAC attributes are characteristics of subjects, objects, environment, and operations preassigned by an authority

- An ABAC model can have three types of attributes
  - subject attributes
    - e.g., name, ID, job function, etc.
  - object attributes
    - e.g., name/title, creation time, ownership information, etc.
  - environment attributes
    - e.g., current date and time, network's security level, etc.

Attribute-Based Access Control

- ABAC architecture specifies how access control is enforced
- When a user submits an access request, the authorization decision is governed by
  - access control policies
  - subject attributes
  - object attributes
  - environmental attributes
- Contrast the above with ACLs in DAC
- ABAC systems are thus significantly more complex

Attribute-Based Access Control

- ABAC policies rules implement authorizations using subject-object-environment information (s, o, e)
  - there may not be explicit roles or groups and authorization decisions are instead made based on attributes
  - e.g., consider access to a database of movies
    - everyone can access movies rated as G
    - users of age $\geq$ 13 can access moved rated as PG-13
    - users of age $\geq$ 17 can access movies rated as R
    - a policy might be written as $P_1(s, o, e)$:
      return (Age$(s) \geq 17 \wedge$ Rating$(o) \in \{$R, PG-13, G$\}) \vee$
      $(13 \leq$ Age$(s) < 17 \wedge$ Rating$(o) \in \{$PG-13, G$\}) \vee$
      (Age$(s) < 13 \wedge$ Rating$(o) \in \{$G$\})$

Attribute-Based Access Control

- ABAC policies can be combined into more complex rules
  - e.g., limit access to new releases to premium membership
    - $P_2(s, o, e)$: return $(\text{MemberType}(s) = \text{Premium}) \vee (\text{MemberType}(s) = \text{Regular} \wedge \text{MovieType}(o) = \text{OldRelease})$
  - grant access if both rules are met
    - $P_3(s, o, e)$: return $P_1(s, o, e) \wedge P_2(s, o, e)$
  - the environment (e.g., the date) can be used for policies such as promotions

Identity Management

- Identity management is related, but not identical to access control
  - it refers to maintaining identity independent of one’s job title, job duties, access privileges, location, etc.
  - contrast this with accounts to login into applications, networks, etc.
- A digital identity is typically established based on a set of attributes
  - the attributes together comprise a unique user within a system or enterprise
  - credentials get associated with an identity
  - access is based on credentials that an identity possesses

Identity Management

- Can you use identities maintained by one organization to access systems maintained by other organizations?
  - identity federation refers to the technology, policies and processes to enable this functionality
  - it answers this question via trust
- When disclosing an identity's attributes and credentials to external parties, we generally want to follow the need-to-know principle
- Traditionally identities were maintained by identity service providers which relying parties can use
- More recently, trust network providers regulate interactions between identity service providers and relying parties

Identity Management

- OpenID is an open standard that allows users to be authenticated by relying parties using third party OpenID identity providers

- Open Identity Trust Framework (OITF) is a standardized specification of a trust framework for identity and attribute exchange
    - it was developed by the community and nonprofit organizations

- Attribute Exchange Network (AXN) is an online gateway for identity service providers and relying parties to access verified identity attributes

Summary

- The choice of an access control model depends on the context
  - system requirements, security policies, etc.
  - can use DAC, MAC, RBAC, attribute-based AC, or other solutions
  - have to consider costs of implementation, maintenance, and rule enforcement
- Federated identity allows for identity credentials to be used across different organizations