The *RCL2000* Language for Specifying Role-Based Authorization Constraints

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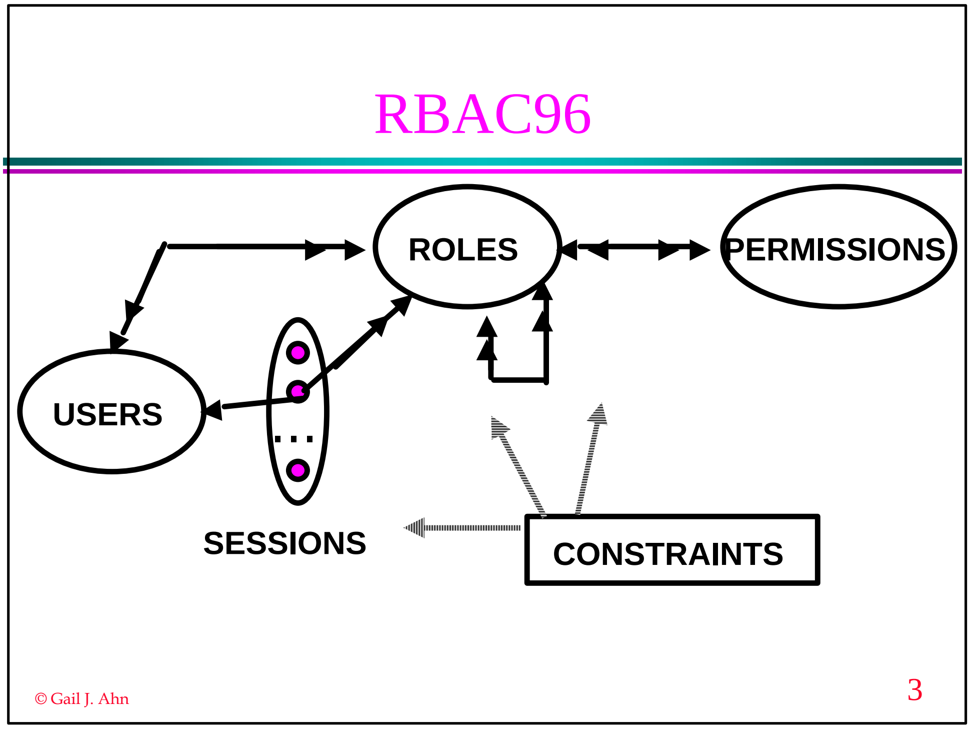
ABSTRACT

- **This presentation includes**
  - **The first formal (and intuitive) language for role-based authorization constraints**
  - **A formal semantics for this language**
  - **Demonstration of the expressive power of the language**
  - **Characterization of role-based constraints into prohibition and obligation constraints**



RBAC96

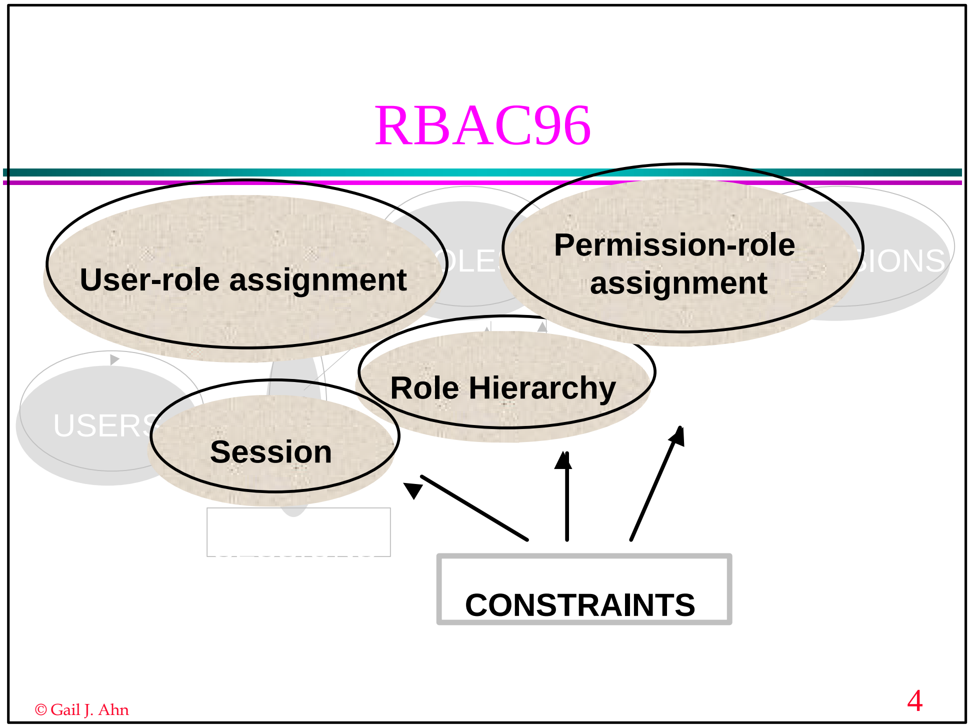
ROLES

PERMISSIONS

USERS

SESSIONS

CONSTRAINTS



RBAC96

User-role assignment

OLE

Permission-role assignment

IONS

Role Hierarchy

USERS

Session

CONSTRAINTS

SEPARATION OF DUTY (1)

- SOD is fundamental technique for preventing fraud and errors

- Related Work
  - Enumerate several forms of SOD
  - Little work on specifying SOD in a comprehensive way

SEPARATION OF DUTY (2)

PURCHASING MANAGER

ACCOUNTING PAYABLE MANAGER

PROHIBITION

- Separation of Duty constraints

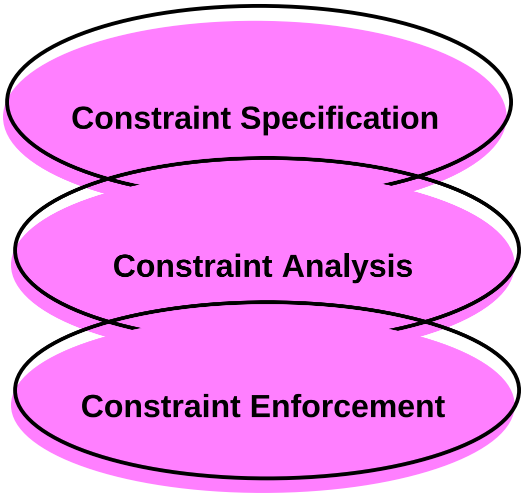
OBLIGATION

- Every faculty member must be assigned to at least one departmental committee

RESEARCH PLAN

- Need to specify these constraints
  - Language
- Show the meaning of expression
  - Formal semantics
- Expressive power of the language
  - Well-known constraints and simulations
- Analysis of the work
  - Characterization

BIG PICTURE



Constraint Specification

Constraint Analysis

Constraint Enforcement

WHO IS THE USER

- Security Researcher
- Security Policy Designer
- Security Architect

RCL 2000

- RCL 2000 (Role-based Constraints Language 2000)
- Specification Language
  - to formally express constraints in role-based systems
- Most components are built upon RBAC96

BASIC ELEMENT (from RBAC96)

- U : a set of users
- R : a set of roles
  - RH Í R ´ R : role hierarchy
- OBJ : a set of objects
- OP : a set of operations
- P = OP ´ OBJ : a set of permissions
- S : a set of sessions

BASIC ELEMENT (from RBAC96)

- UA : a many-to-many user-to-role assignment relation
- PA : a many-to-many permissions-to-role assignment relation

SYSTEM FUNCTIONS (from RBAC96)

- user : R ® 2^U
- roles, roles* : U È P È S ® 2^R
- sessions : U ® 2^S
- permissions, permissions* :
  R ® 2^P
- operations : R ´ OBJ ® 2^{OP}
- object : P ® 2^{OBJ}

BASIC ELEMENT (beyond RBAC96)

- CR : all conflicting role sets
- CU : all conflicting user sets
- CP : all conflicting permission sets

BASIC ELEMENT
(beyond RBAC96)

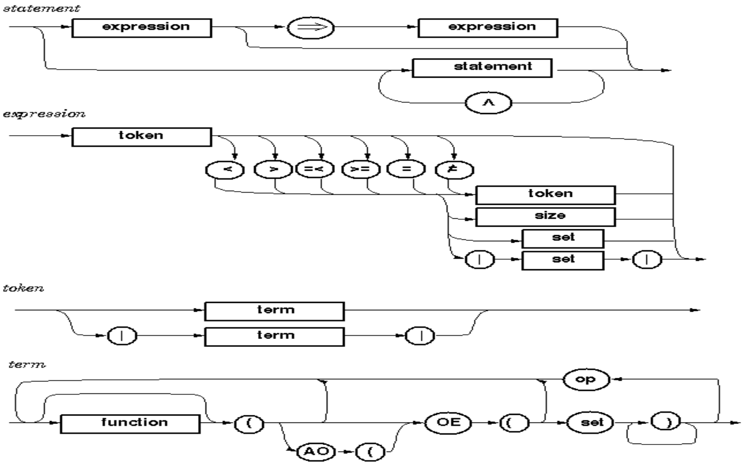
- CR1 : all conflicting role sets
- CR2 : all conflicting role sets
- CR3 : all conflicting role sets
- …..

NON-DETERMINISTIC
FUNCTIONS (beyond RBAC96)

- introduced by Chen and Sandhu (1995)
- oneelement   (OE)
  - oneelement(X) = x_i, where x_i Î X
- allother (AO)
  - allother(X) = X - {OE(X)}

    = X - {x_i}
    - should occur along with OE function

SYNTAX



EXAMPLES OF CONSTRAINT EXPRESSION

Conflicting roles cannot have common users

- **|roles(OE(U)) Ç OE(CR)| £1**

Conflicting users cannot have common roles

- **roles(OE(OE(CU))) Ç roles(AO(OE(CU))) = f**

Users cannot activate two conflicting roles

- **|roles(sessions(OE(U))) Ç OE(CR)| £1**

Users cannot activate two conflicting roles in a single session

- **| roles(OE(sessions(OE(U)))) Ç OE(CR)| £1**

FORMAL SEMANTICS

- **Reduction Algorithm**
  - **to convert a constraint expression to a restricted form of first order predicate logic (RFOPL)**
- **Construction Algorithm**
  - **to construct a constraint expression from RFOPL**

REDUCTION ALGORITHM

OE(OE(CR)) Î roles(OE(U)) Þ AO(OE(CR)) Ç roles(OE(U)) =Æ

1. **OE(OE(CR)) Î roles(OE(U)) Þ (OE(CR) - {OE(OE(CR))}) Ç roles(OE(U)) = Æ**

2. **" cr Î CR : OE(cr) Î roles(OE(U)) Þ (cr - {OE(cr)}) Ç roles(OE(U)) = Æ**

3. **" cr Î CR, " r Î cr : r Î roles(OE(U)) Þ (cr - {r}) Ç roles(OE(U)) = Æ**

4. **" cr Î CR, " r Î cr, " u Î U : r Î roles(u) Þ (cr - {r}) Ç roles(u) = Æ**

RFOPL STRUCTURE

- sequence part : predicate
- " r Î R, " u Î U : r Î roles(u)
- " x_2 Î x_1, " x_3 Î x_2, " x_4 Î x_3 : predicate

CONSTRUCTION ALGORITHM

" cr Î CR, " r Î cr, " u Î U : r Î roles(u) Þ (cr - {r}) Ç roles(u) = Æ

1. " cr Î CR, " r Î cr : r Î roles(OE(U)) Þ (cr - {r}) Ç roles(OE(U)) = Æ
2. " cr Î CR : OE(cr) Î roles(OE(U)) Þ (cr - {OE(cr)}) Ç roles(OE(U)) = Æ
3. OE(OE(CR)) Î roles(OE(U)) Þ (OE(CR) - {OE(OE(CR))})
   Ç roles(OE(U)) = Æ
4. OE(OE(CR)) Î roles(OE(U)) Þ AO(OE(CR)) Ç roles(OE(U)) =Æ

SOUNDNESS AND COMPLETENESS

- **Theorem 1** *Given RCL2000 expression* a, a *can be translated into RFOPL expression* b. *Also* a *can be reconstructed from* b.

  C(R(a**)) =** a

- **Theorem 2** *Given RFOPL expression* b, b *can be translated into RCL2000 expression* a. *Also* b´ *which is logically equivalent to* b *can be reconstructed from* a.

  R(C(b**)) =**b´

SEPARATION OF DUTY CONSTRAINTS

- **Specification of SOD constraints identified by Simon and Zurko (1997) and formulated by Virgil et al (1998)**
- **Identify new SOD properties**
  - **Role-centric**
  - **User-centric**
  - **Permission-centric**

ROLE-CENTRIC SOD CONSTRAINT EXPRESSION

- **Static SOD**
  - : **Conflicting roles cannot have common users**

    U = $\{u_1,u_2,\ldots u_n\}$, R = $\{r_1,r_2,\ldots r_n\}$,
    CR = $\{cr_1,cr_2\}$: $cr_1 = \{r_1,r_2,r_3\}$, $cr_2 = \{r_a,r_b,r_c\}$

  - ➢ **|roles(OE(U)) Ç OE(CR)| £1**

PERMISSION-CENTRIC SOD CONSTRAINT EXPRESSION

- **SSOD-CP**
  - ➢ **|permissions(roles(OE(U))) Ç OE(CP)| £1**

- **Variations of SSOD-CP**
  - ➢ **SSOD-CP Ù**
    |permissions(OE(R)) Ç OE(CP)| £1

USER-CENTRIC SOD CONSTRAINT EXPRESSION

- SSOD-CU (User-centric)
  - SSOD-CR Ù |user(OE(CR)) Ç OE(CU)| £1

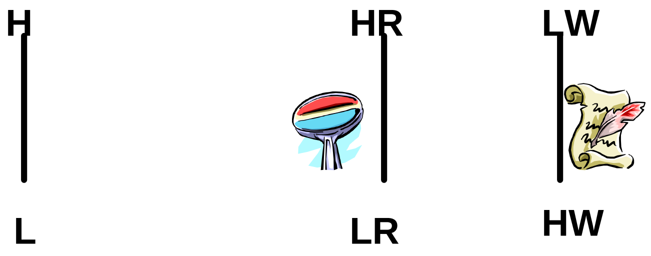
DYNAMIC SOD

- User-based DSOD
  - |roles(sessions(OE(U))) Ç OE(CR)| £1
- User-based DSOD with CU
  - |roles(sessions(OE(OE(CU)))) Ç OE(CR)| £1
- Session-based DSOD
  - |roles(OE(sessions(OE(U)))) Ç OE(CR)| £1
- Session-based DSOD with CU
  - |roles(OE(sessions(OE(OE(CU))))) Ç OE(CR)| £1

CASE STUDIES

- Lattice-based access control
  - Ravi Sandhu (1993, 1996)
- Chinese Wall policy
  - Ravi Sandhu (1992)
- Discretionary access control
  - Sandhu and Munawer (1998)

LATTICE-BASED ACCESS CONTROL



- Subject *s* can write object *o* only if l(*s*) £ l(*o*)
- Subject *s* can read object *o* only if l(*o*) £ l(*s*)

Constraints on UA: *Each user is assigned to exactly two roles xR and LW*

LATTICE-BASED ACCESS CONTROL

- AR = {ar1, ar2}
  - ar1={HR, HW}, ar2={LR, LW}
- ASR = {asr1, asr2}
  - asr1={HR, LW}, asr2={LR, LW}

- Constraint on UA:
  - roles(OE(U)) = OE(ASR)
- Constraint on sessions:
  - roles(OE(sessions(OE(U)))) = OE(AR)

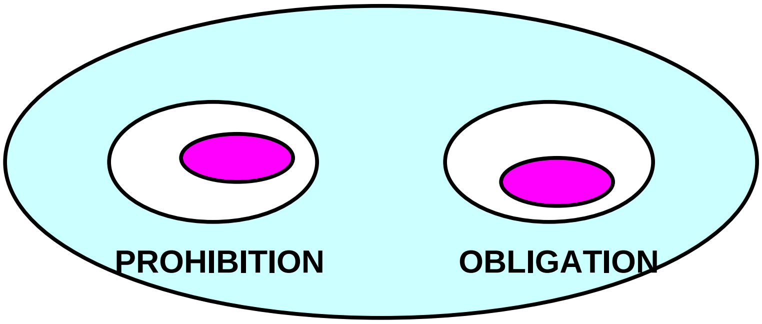
PROHIBITION CONSTRAINTS

- Forbid the RBAC component from doing (or being) something which is not allowed to do (or be)
  - Separation of duty constraints

OBLIGATION CONSTRAINTS

- Force the RBAC component to do (or be) something
  - LBAC-RBAC, Chinese Wall-RBAC simulation

CONSTRAINTS CHARACTERIZATION



CONSTRAINTS

SIMPLE PROHIBITION CONSTRAINTS

- Type 1
  - ½*expr* ½£ 1
- Type 2
  - *expr* = f or ½*expr*½= 0
- Type 3
  - ½*expr1*½<½*expr2*½

SIMPLE OBLIGATION CONSTRAINTS

- Type 1
  - *expr* ¹ 0 or ½*expr*½> 0
- Type 2
  - Set X = Set Y
- Type 3
  - obligation constraints Þ obligation constraints
- Type 4
  - ½*expr* ½ = 1
    - ½*expr* ½ = 1 ° ½*expr* ½£ 1 Ù ½*expr*½> 0

CONTRIBUTIONS

- Developed the first formal and intuitive language for role-based authorization constraints
- Provided a formal semantics for this language
- Demonstrated the expressive power of the language by
  - specifying well-known separation of duty constraints
  - identifying new role-based SOD constraints
  - showing how to specify constraints identified in the simulations of other policies in RBAC
- Characterized role-based constraints into prohibition and obligation constraints

FUTURE WORK

- Extension of RCL 2000
  - Applying it the formalization of some realistic security policies
- Implementation Issue
  - Tool for checking syntax and semantic as well as visualization of specification
- Enforcement of constraints