Consistency of Task-Based Authorization Constraints in Workflow System

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Introduction

- Workflow: consists a collection of tasks that are organized to facilitate some business process specification
  - Purchase order processing
  - Processing tax refunds

Introduction

- Security Challenge
  - Administration of security-relevant information
  - Specification of authorization policies and constraints
  - Solution
    - RBAC
    - Constraints

Introduction

- Constraints: restriction on the authorization
  - Separation of Duty
  - Binding of Duties
- Challenge for constraints in workflow system
  - Consistency

Goal

- Help workflow designers to define a sound constrained workflow authorization schema such that
  - each workflow instance can complete
  - each user or role authorized to perform a task will have an opportunity to perform that task in some workflow instance

Related Work

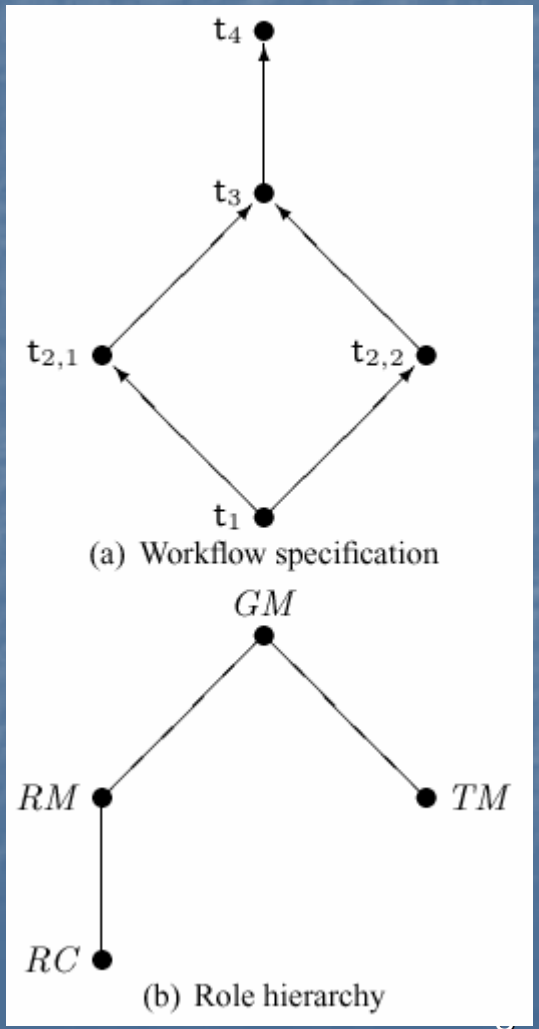
- E. Bertino, E. Ferrari, V. Atluri: TISS 99
  - Role planning and user planning
  - + Constraints are consistent
  - - Complicated
- J. Wainer, P. Barthelmess, A. Kumar: IJCIS 03
  - Override constraints when workflow can not be completed
  - + Completing workflow instance
  - - Weaken security

Our Contribution

- Give explicit definition of constraint workflow authorization schema
- Develop simple specification of authorization constraints
- Define consistency rules which can be checked efficiently

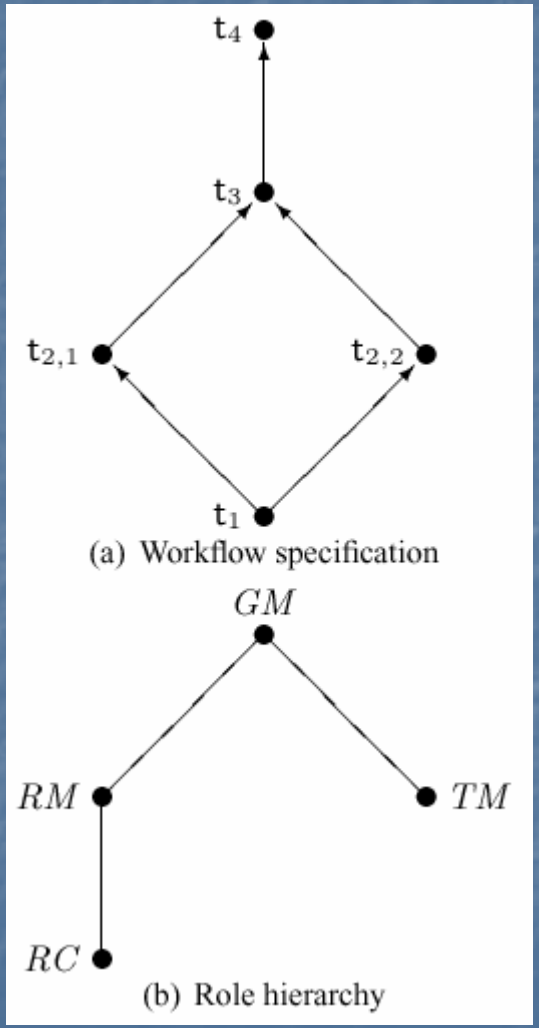
Workflow Example

- Producing payments for tax refunds
  - t_1: a clerk prepares a check for a tax refund
  - t_2: the check is approved or denied by two different managers
  - t_3: A third manager makes a final decision based on the decisions made in t_2
  - t_4: a clerk issues or voids the check based on the decision of t_3



Constraints

- c_1: The two instances of t_2 should be performed by different users
- c_2: t_2 and t_3 should be performed by different users
- c_3: t_1 and t_4 should be performed by different users
- c_4: t_2 must be performed by a role that is more senior than the role that performed t_1 unless t_1 and t_2 are performed by GM
- c_5: t_1 and t_2 must be performed by different users
- c_6: At least three roles should perform the workflow instance



Constraint Workflow Authorization Scheme

- $(T, \leq, \rho)$, where T is a (partially ordered) set of tasks and ρ is a function from T to the set of natural numbers indicating the number of occurrences of each task in the workflow
- Role hierarchy: $(R, \leq)$
- User-role association: $UA \subseteq U \times R$
- Task-role association: $PA \subseteq T \times R$
- Constraint-task association: $PC \subseteq C \times T$
- $R(t)=\{r' \in R: \exists (t, r) \in PA, r' \geqslant r\}$
- $U(t)=\{u \in U: (u, r) \in UA, r \in R(t)\}$
- Task instance: (t_i, u_i, r_i)
- Workflow instance: $[(t_1, u_1, r_1),\ldots, (t_n, u_n, r_n)]$

Task	Role
t_1	RC
t_2	RM
t_3	RM
t_4	RC

(c) Task-role assignment relation PA

User	Role
Alice	RC
Bob	RM
Carol	RM
Dave	RC
Eve	GM
Fred	TM

(d) User-role assignment relation UA

Constraint-Task assignment PC

- $PC \subseteq C \times T$ where $C=\{c_1, c_2, c_3, c_4, c_5, c_6\}$
  - c_2: t_2 and t_3 should be performed by different users
    - $(c_2, t_3) \in PC$
  - c_1: The two instances of t_2 should be performed by different users
    - $(c_1, t_2) \in PC$
  - c_6: At least three roles should perform the workflow instance
    - $(c_6, t_1) \in PC$, $(c_6, t_2) \in PC$, $(c_6, t_3) \in PC$, $(c_6, t_4) \in PC$

Constraints Specification

- Entailment constraints
  - Execution of t is constrained by the execution of t′ where t′ < t
  - Entailed task of t′ : t
  - (*ur*, t′, *E*, *pred*)
    - $ur \in \{u, r\}$
    - $E \subseteq U(t')$ if $ur = u$ or $E \subseteq R(t')$ if $ur = r$
    - $pred \in \{=, \neq, <, >, \leqslant, \geqslant\}$
    - $pred(u_{t'}, u_t)$=true if $ur = u$ or $pred(r_{t'}, r_t)$=true if $ur = r$
  - **c_2:** t_2 and t_3 should be performed by different users
    - $c_2 = (u, t_2, U(t_2), \neq)$

Cardinality Constraints

- Local cardinality constraints
  - Impose restrictions on the number of users to execute a task
    - **c_1:** The two instances of t2 should be performed by different users
    - $c_1=(2,2)$
- Global cardinality constraints
  - Impose restrictions on the number of roles to execute a set of tasks
    - **c_6:** At least three roles should perform the workflow instance
    - $c_6=(T,3)$

Consistency

- A constrained authorization schema ((T,≤,ρ),PA,PC) is sound if
  - All (c,t) ∈ PC is well-formed
    - A constraint-task pair is well-formed *if*
      - E.g., (*ur*, t′, *E*, *pred*)
        - *ur* = *u* or *r*
        - t′< t
        - $E \subseteq U(t')$ if *ur* = *u* or $E \subseteq R(t')$ if *ur* = *r*
        - *pred* ∈ {=, ≠, <, >, ≤, ≥}
  - For all $u \in U(t)$ and all $r \in R(t)$, there is a successful workflow instance in which t is executed by *u* or *r*

Constraint Interaction

- Two constraint-task pairs interplay if
  - The constraints are assigned to the same task
    - E.g., ((2,2), t_2), ((r, t_1, R(t_1), <),t_2)
  - The constraints are assigned to a task and its entailed task
    - E.g., ((*u*, t', *U* (t'),≠), t) and ((2, 2), t') where t is an entailed task of t'
  - The constraints are assigned to a set of restricted tasks in T'
    - E.g., for global cardinality constraint (T', n_r), ((T', n_r),t) and ((T', n_r),t') where t, t' ∈ T'

Interplaying Sets CT

- Affected tasks in CT
  - $((2,2), t_2), ((r, t_1, R(t_1), <), t_2): \{t_2\}$
  - $((u, t', U(t'), \neq), t), ((2, 2), t'): \{t\}$
- Non-interplay set SC
  - any (c,t) in SC does not belong to any CT or they are in some CT but t is not an affected task of that CT
- Any $(c,t) \in$ SC should be self-consistent
- Any CT should be inter-play-consistent

Interplay consistency

- Self-consistent or inter-play consistent
  - Consistency rules for different constraint-task pairs
    - E.g., for c=(*u*, t′, *E*, *pred*) ∈ SC and (c,t) ∈ PC , then for any α ∈ *E* , U(t|t′, α, c) ≠ ∅ and $\bigcup_{\alpha \in U(t')}$ U(t|t′, α, c)=U(t)
    - Computations required
      - Set computation

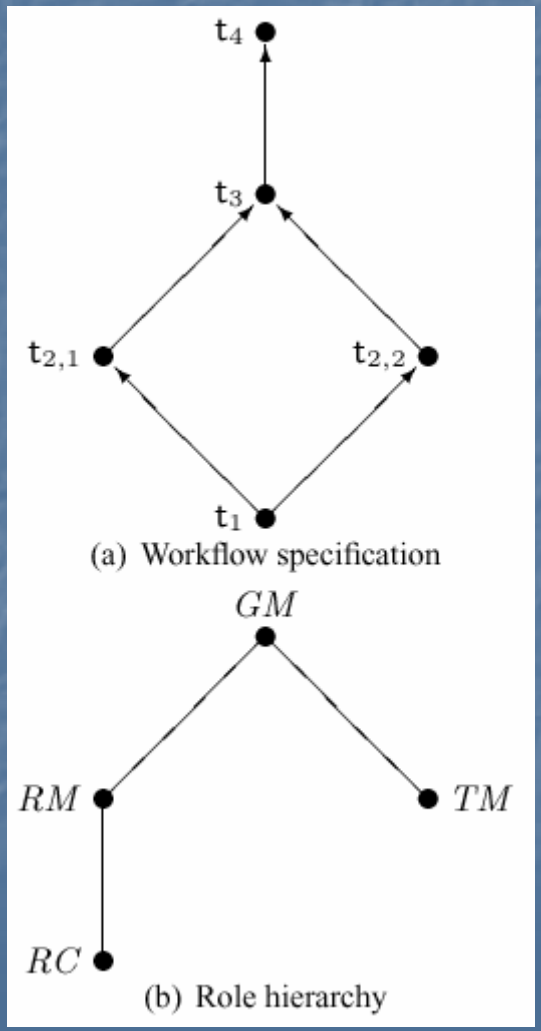
Main Result

- **Theorem:** a constrained workflow authorization schema ((T, ≤, ρ), PA, PC) is sound if and only if all constraint-task pairs in SC are self-consistent and all the inter-play sets are inter-play-consistent

Example

- Constraint Inconsistency of our example
  - E.g. CT={(c_4, t_2), (c_1, t_2)} inter-play
    - c_1: the two instances of t_2 should be performed by different users
      - c_1 =(2, 2)
    - c_4: t_2 must be performed by a role that is more senior than the role that performed t_1 unless t_1 and t_2 are performed by GM
      - c'_4 =(*r*, t_1, R(t_1), <), c''_4 =(*r*, t_1, GM, =)
    - If Bob or Carol executes t_1, then the workflow instance cannot complete at t_2

Example



(a) Workflow specification

(b) Role hierarchy

Task	Role
t_1	RC
t_2	RM
t_3	RM
t_4	RC

(c) Task-role assignment relation PA

User	Role
`Alice`	RC
`Bob`	RM
`Carol`	RM
`Dave`	RC
`Eve`	GM
`Fred`	TM

(d) User-role assignment relation UA

Conclusion

- Give explicit definition of constraint workflow authorization schema
- Give a solution to constraints consistency problem in workflow system
  - Simple constraints specification
  - Efficient consistency rules checking