Policy Conflict Analysis Using Free Variable Tableaux for Access Control in Web Services Environments

10th May 2005

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Agenda

- Background
- Problem
  - Access Control Policy and Conflict
- Approach
  - Static Conflict Detection Method
- Conclusions and Future Work

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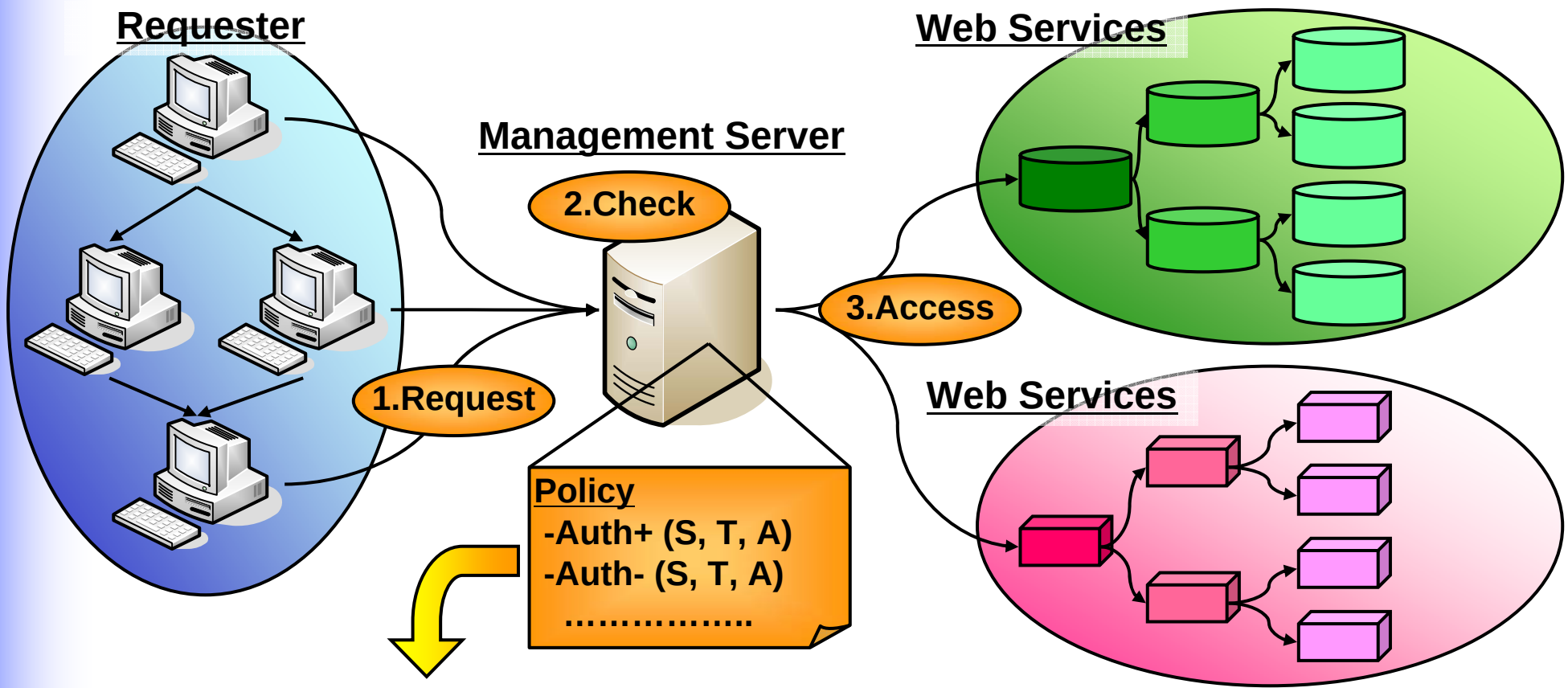
Web Services and Access Control Policy

- Aggregation Web Services Model
  - A management server integrates several Web Services and their resources and provides a common services interface for requesters.
  - Ex. Travel agency Web Services.



Problem : Access Control Policy may include conflicting policy.
Goal : Establish a static conflict detection method.

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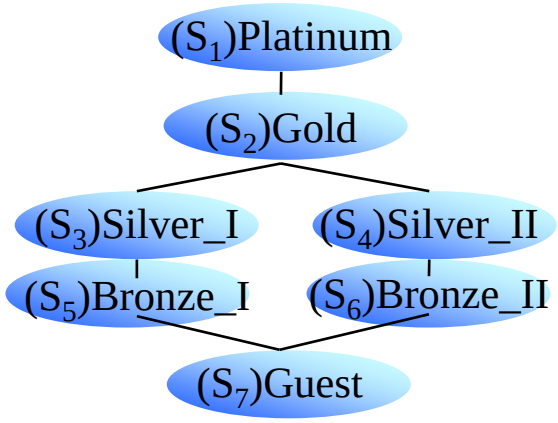
Access Control Policies and Roles

- **Policies** used for the Web Services
  - **Authorization Policy**
  - **Obligation Policy**

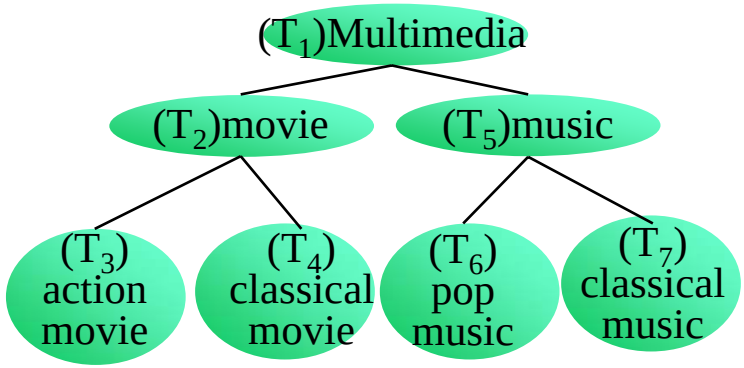
  Basic Policy
  - **Propagation Policy**

  Propagation Policy
  - **Action Composition Policy**
  - **Chinese Wall Policy**
  - **Separation of Duty Policy**
  - **Time Constraint Policy**

  Constraint Policy
- **Roles**
  - A role is a named collection of privileges.
  - Partial order relation is defined among roles.



(a) Subject Role Structure



(b) Target Role Structure

Basic Policy and Explicit Modality Conflict

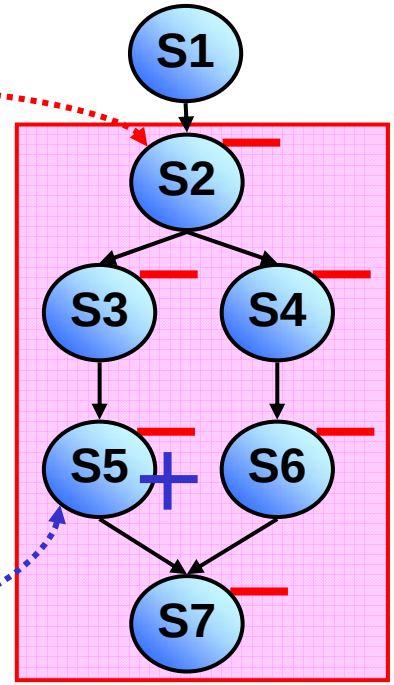
- **Authorization Policy**
  - `Auth+ (S, T, A) / Auth- (S, T, A)`
    - A positive/negative authorization policy defines the action "A" that a subject role "S" is permitted/prohibited to perform on a target role "T".
    - Ex. **`Auth+ (Bronze_I, movie, play)`**
    - Ex. **`Auth- (Gold, movie, play)`**
- **Obligation Policy**
  - `Obli+ (E, S, T, A) / Obli- (E, S, T, A)`
    - A positive/negative obligation policy defines the action "A" that a subject role "S" must/must not perform on a target role "T" when an event "E" occurs.
    - Ex. **`Obli+ (Play, Guest, fillout, questionnaire)`**
    - Ex. **`Obli- (Sunday, Guest, login, WebServices)`**

- **Explicit Modality Conflict**
  - Following three pairs of policies are defined as explicit modality conflict.
  - `Auth+ (S, T, A) / Auth- (S, T, A)`
  - `Obli+ (E, S, T, A) / Obli- (E, S, T, A)`
  - `Obli+ (E, S, T, A) / Auth- (S, T, A)`

Propagation Policy

- `Prop (Auth+|-, SRS|TRS, UP|DOWN)`
  A propagation policy defines how an authorization policy propagates in accordance with the partial order of the role structures.
- Examples
  - `Prop (Auth-, S ∈ SRS, DOWN)`
  - `Auth-(S2, T2, play)`

  These two policies derives following policies.
  - `Auth-(S3, T2, play) / Auth-(S4, T2, play)`
  - `Auth-(S5, T2, play) / Auth-(S6, T2, play)`
  - `Auth-(S7, T2, play)`



Subject Role Structure : S

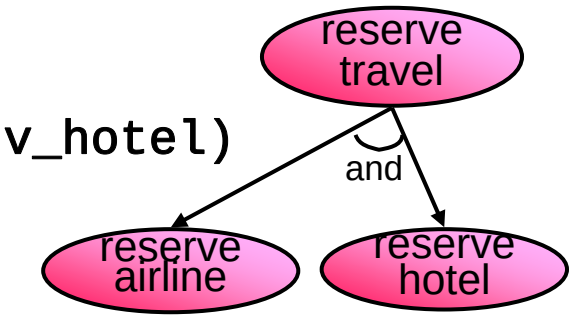
Implicit Modality Conflict

- Implicit Modality conflict is a modality conflict that occurs between the explicitly defined authorization policies and an authorization policies implicitly derived by the propagation policy.
- Examples:
  - `Prop (Auth-, S ∈ SRS, DOWN)`
  - `Auth-(S2, T2, play)`
  - `Auth+(S5, T2, play)`

Constraint Policy and Constraint Conflict (1/2)

- **Action Composition Policy**
  - Policies may be defined in terms of more than one action.
  - Example:
    `ac(reserv_travel = reserv_airline ∧ reserv_hotel)`
  - This action composition policy specifies that two actions `reserv_airline` and `reserv_hotel` are needed to complete the request `reserv_travel` .

- **Constraint Conflict**
  - An action composition policy may lead to constraint conflict.
  - Examples:
    - `ac(reserv_travel=reserv_airline∧reserv_hotel)`
    - `Auth+ (Guest, TR, reserve_travel)`
    - `Auth- (Guest, TR, reserve_hotel)`



Action composition policy

Constraint Policy and Constraint Conflict (2/2)

- **Chinese Wall Policy**
  - `CW (Subject, {T1, T2}, Action)`
    A Chinese wall policy defines two mutually exclusive target roles.
    Ex. **`CW (Guest, {Bank_A, Bank_B}, view_account)`**

- **Separation of Duty Policy**
  - `SoD (Subject, Target, {A1, A2})`
    A Separation of Duty policy defines two mutually exclusive actions.
    Ex. **`SoD (Guest, Auction, {sell, buy})`**

- **Constraint Conflict**
  - A Chinese wall policy and separation of duty policy may lead to constraint conflict.
  - Examples:
    - **`CW (Guest, {Bank_A, Bank_B}, view_account)`**
    - **`Auth+ (Guest, Bank_A, view_account)`**
    - **`Auth+ (Guest, Bank_B, view_account)`**

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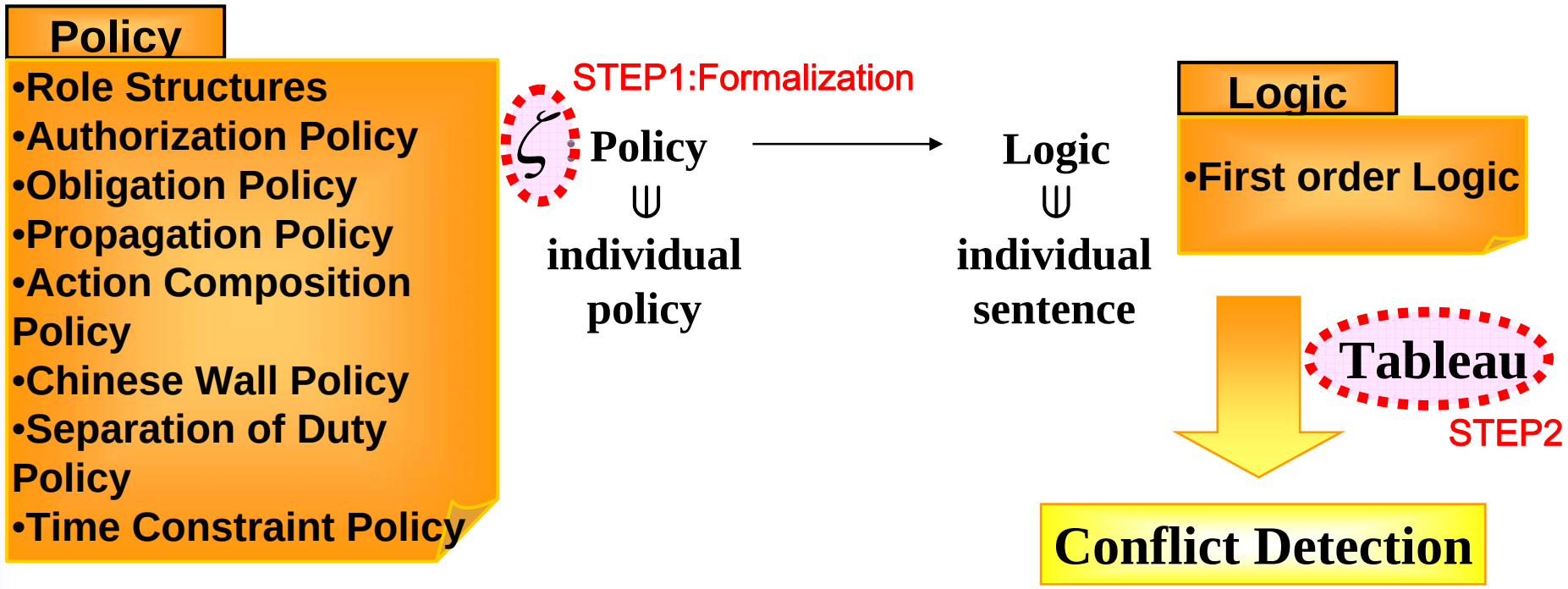
Formalization and the Free Variable Tableaux

- **Access Control Policy Formalization**



- **Free Variable Tableau**:
  - is the algorithm to detect an inconsistency of the set of sentences.
  - is sound and complete method.
  - has optimized implementations.
  - can abduce helpful information to resolve a conflict.

STEP1: Access Control Policy Formalization

- Authorization and Obligation Policy

$$
\begin{aligned}
\zeta(\texttt{Auth+}(S_1, T_1, A_1)) &:= \forall x(E_x \rightarrow P(S_1, T_1, A_1)) \\
\zeta(\texttt{Auth-}(S_1, T_1, A_1)) &:= \forall x(E_x \rightarrow \neg P(S_1, T_1, A_1)) \\
\zeta(\texttt{Obli+}(E_1, S_1, T_1, A_1)) &:= E_1 \rightarrow O(S_1, T_1, A_1) \\
\zeta(\texttt{Obli-}(E_1, S_1, T_1, A_1)) &:= E_1 \rightarrow R(S_1, T_1, A_1)
\end{aligned}
$$

  - “P” can be read as subject role S1 is permitted to carry out action A1 on target role T1.
  - “O” can be read as S1 must carry out action A1 on target role T1.
  - “R” can be read as S1 must not carry out action A1 on target role T1.
  - “Ex” can be read as an event Ex occurs.

- Axioms

$$
\begin{aligned}
\text{Ax1} &: \forall s, t, a(O(s, t, a) \rightarrow P(s, t, a)) \\
\text{Ax2} &: \forall s, t, a(\neg(O(s, t, a) \wedge R(s, t, a)))
\end{aligned}
$$

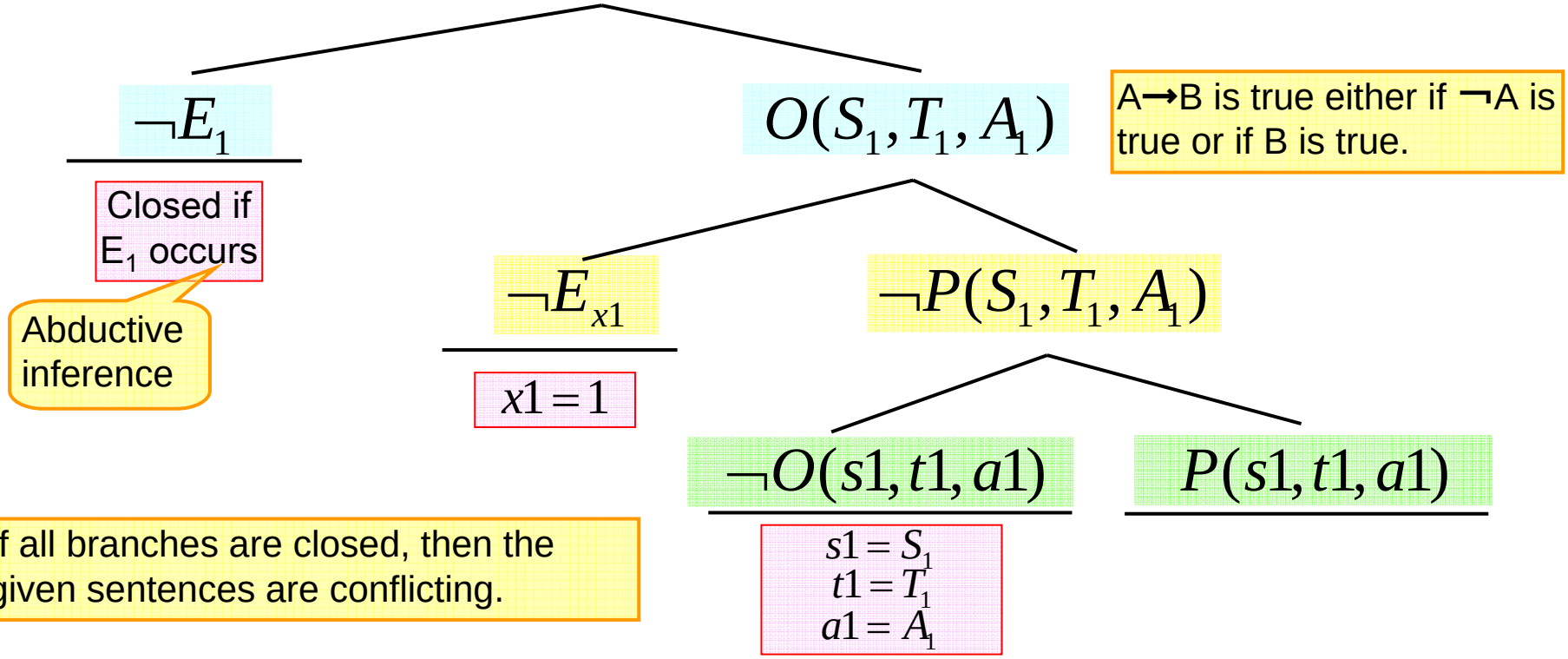
  - Ax1 is used to detect conflicts involving both authorization and obligation policies.
  - Ax2 is used to detect conflicts between positive and negative obligation policies.

STEP2: Explicit Modality Conflict Detection

`Obli+(E1,S1,T1,A1)` $\mapsto$ $E_1 \rightarrow O(S_1, T_1, A_1)$

`Auth-(S1,T1,A1)` $\mapsto$ $\forall x(E_x \rightarrow \neg P(S_1, T_1, A_1))$

`Ax1` $\mapsto$ $\forall s,t,a(O(s,t,a) \rightarrow P(s,t,a))$



This result shows that Obli+ policy and Auth- policy become a conflicting policy if event E_1 occurs.

STEP1: Access Control Policy Formalization

- **Propagation Policy**
  - There are 8 types of propagation policies.

prop1 : prop(Auth+,R∈SRS,UP)
prop2 : prop(Auth-,R∈SRS,DOWN)
prop3 : prop(Auth+,R∈SRS,DOWN)
prop4 : prop(Auth-,R∈SRS,UP)
prop5 : prop(Auth+,R∈TRS,UP)
prop6 : prop(Auth-,R∈TRS,DOWN)
prop7 : prop(Auth+,R∈TRS,DOWN)
prop8 : prop(Auth-,R∈TRS,UP)

$$\zeta(\mathrm{prop1}) = \zeta(\mathrm{prop2}) := \forall x, y, z, a(P(x, y, a) \wedge H_{\mathcal{R}}(z, x) \rightarrow P(z, y, a))$$
$$\zeta(\mathrm{prop3}) = \zeta(\mathrm{prop4}) := \forall x, y, z, a(P(x, y, a) \wedge H_{\mathcal{R}}(x, z) \rightarrow P(z, y, a))$$
$$\zeta(\mathrm{prop5}) = \zeta(\mathrm{prop6}) := \forall x, y, z, a(P(x, y, a) \wedge H_{\mathcal{R}}(y, z) \rightarrow P(x, z, a))$$
$$\zeta(\mathrm{prop7}) = \zeta(\mathrm{prop8}) := \forall x, y, z, a(P(x, y, a) \wedge H_{\mathcal{R}}(z, y) \rightarrow P(x, z, a))$$

where, $H_R(x,y)$ means that x is a senior role of y.

STEP2: Implicit Modality Conflict Detection

Arbitrary event $\mapsto E_1$

Subject Role Structure $\mapsto H_R(S_2, S_3), H_R(S_3, S_5), \cdots$

Auth+(S5,T2,A1) $\mapsto \forall x(E_x \rightarrow P(S_5, T_2, A_1))$

Auth-(S2,T2,A1) $\mapsto \forall x(E_x \rightarrow \neg P(S_2, T_2, A_1))$

Propagation Policy $\mapsto \forall x, y, z, a(P(x, y, a) \wedge H_R(z, x) \rightarrow P(z, y, a))$

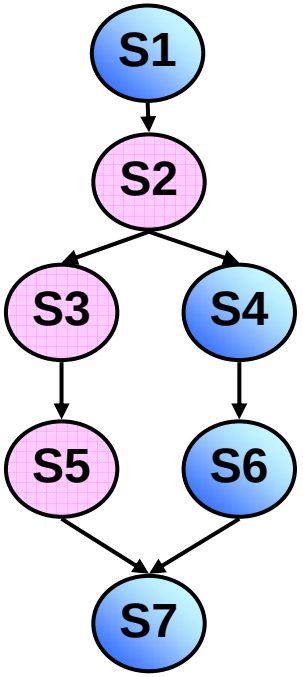
$$\frac{\neg P(x1, y1, a1) \vee H_R(z1, x1) \qquad P(z1, y1, a1)}{x1 = S_5 \quad z1 = S_3 \quad y1 = T_2 \quad a1 = A_1}$$

Abductive inference

$P(S_3, T_2, A_1)$

$$\frac{\neg P(x2, y2, a2) \vee H_R(z2, x2) \qquad P(S_2, T_2, A_1)}{x2 = S_3 \quad z2 = S_2 \quad y2 = T_2 \quad a2 = A_1}$$

Abductive inference



This result indicates that conflict is caused by the propagation {S2→S3→S5}

STEP1: Access Control Policy Formalization

- Action composition Policy

$$\zeta(A_1 = \Gamma(A_2, \cdots, A_n)) := \forall x, y(P(x, y, A_1) \leftrightarrow \Gamma(P(x, y, A_2), \cdots, P(x, y, A_n)))$$

–Examples:
A1=A2∧A3 is translated into
∀x,y (P(x,y,A1) ↔P(x,y,A2) ∧ P(x,y,A3)

- Chinese Wall Policy

$$\zeta(\mathrm{cw1}) := \forall x, y \neg(P(x, T_1, y) \wedge P(x, T_2, y))$$

- Separation of Duty Policy

$$\zeta(\mathrm{sod1}) := \forall x, y(\neg(P(x, y, A_1) \wedge P(x, y, A_2)))$$

STEP2: Constraint Conflict Detection

Arbitrary event $\mapsto E_1$

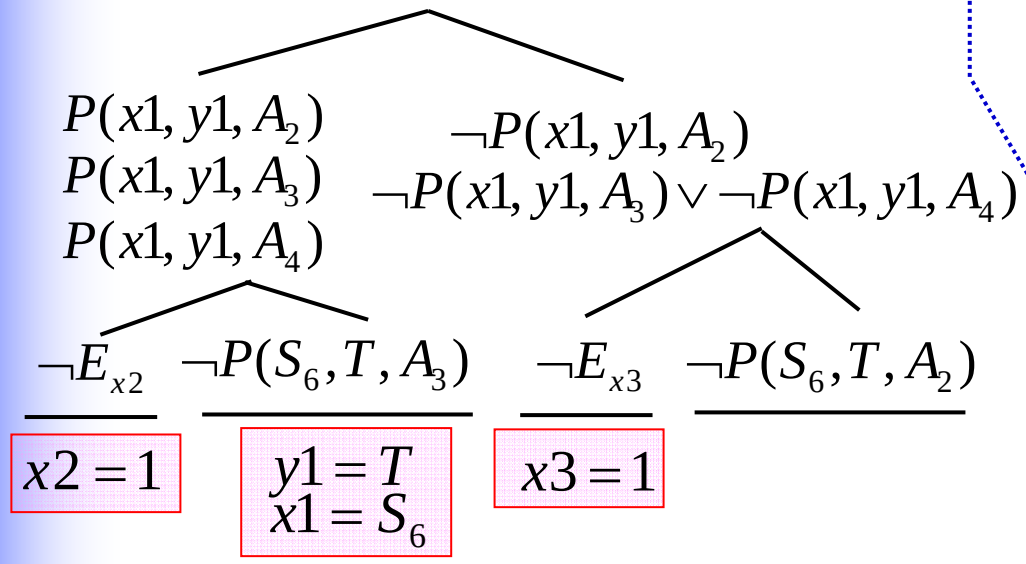
Auth+(S6,T,A2) $\mapsto \forall x(E_x \rightarrow P(S_6, T, A_2))$

Auth+(S6,T,A3) $\mapsto \forall x(E_x \rightarrow \neg P(S_6, T, A_3))$

Auth-(S6,T,A4) $\mapsto \forall x(E_x \rightarrow \neg P(S_6, T, A_4))$

A2=A3∧A4 $\mapsto$

$\forall x, y(P(x, y, A_2) \leftrightarrow P(x, y, A3) \wedge P(x, y, A_4))$



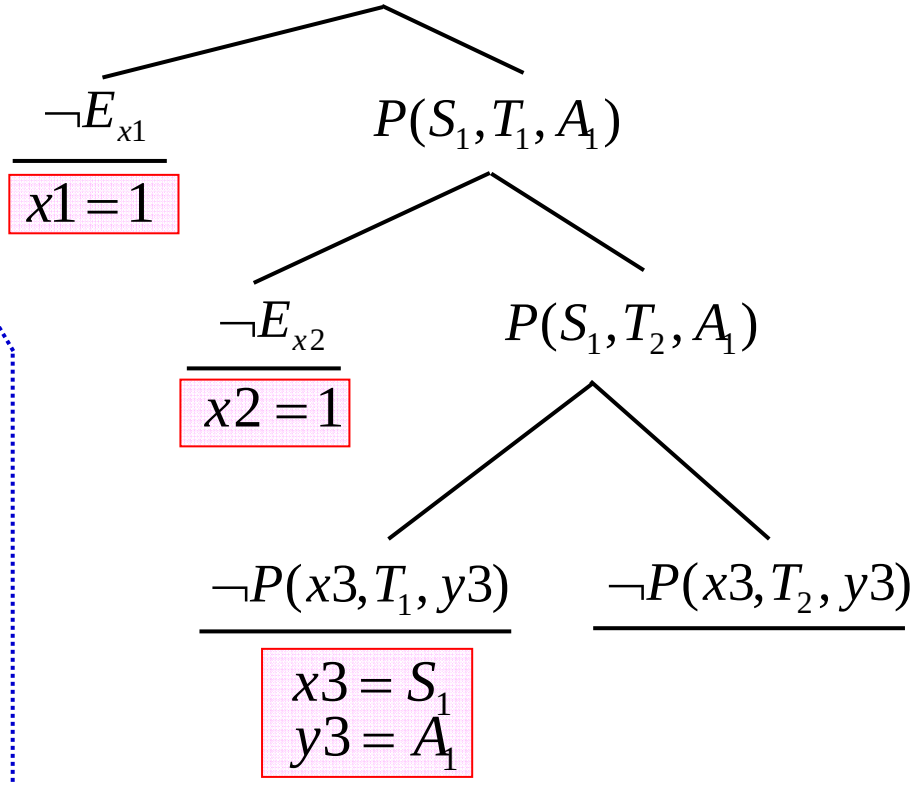
Conflict caused by an action composition policy is detected.

Arbitrary event $\mapsto E_1$

Auth+(S1,T1,A1) $\mapsto \forall x(E_x \rightarrow P(S_1, T_1, A_1))$

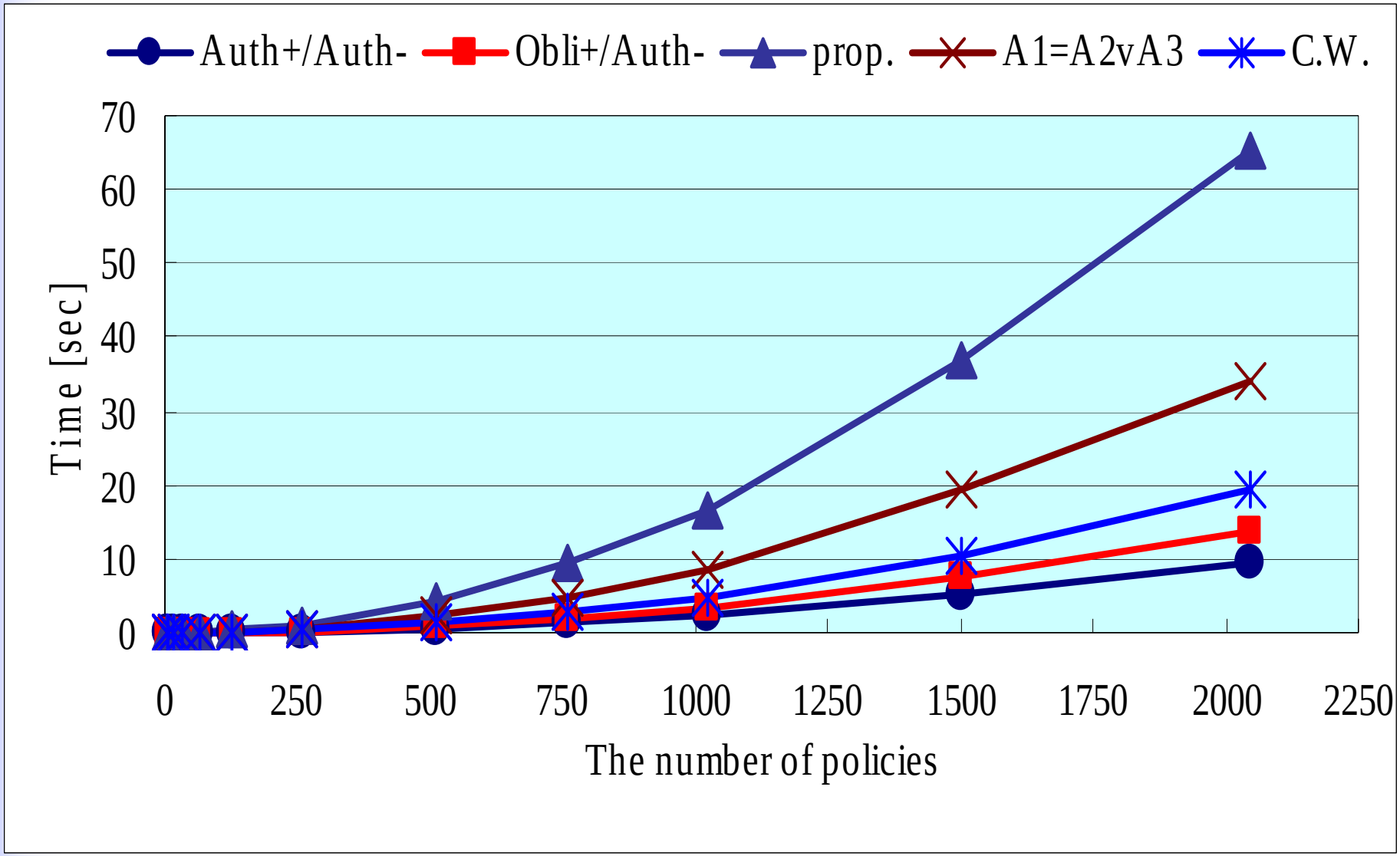
Auth+(S1,T2,A1) $\mapsto \forall x(E_x \rightarrow \neg P(S_1, T_2, A_1))$

cw(*,{T1,T2},*) $\mapsto \forall x, y \neg(P(x, T_1, y) \wedge P(x, T_2, y))$



Conflict caused by Chinese Wall policy is detected.

Computational Time for Conflict Detection



Conclusions and Future work

- **Conclusions**
  - We have presented an approach to statically detect a conflicting policy by using the free variable tableaux.
  - It is realized by translating each access control policy into first order logic.
  - The method can detect not only modality conflict but also constraint conflicts all in a uniform way.
  - Also it can provide helpful information to resolve the conflict by using abductive inference.
  - It has advantage that it can be applied to various policies written in different policy definition languages.

- **Future Work**
  - Extension
    - We will consider the formalization of more complex policies such as delegation policies.
  - Implementation
    - We will implement the approach and use it to develop a tool that detects conflicting policies written in such as XACML or Ponder.