Università di Roma "La Sapienza"

Dipartimento di Informatica e Sistemistica "Antonio Ruberti"

Discovery Park

The Cyber Center

PURDUE UNIVERSITY

CERIAS

Access Control Enforcement for Conversation-based Web Services

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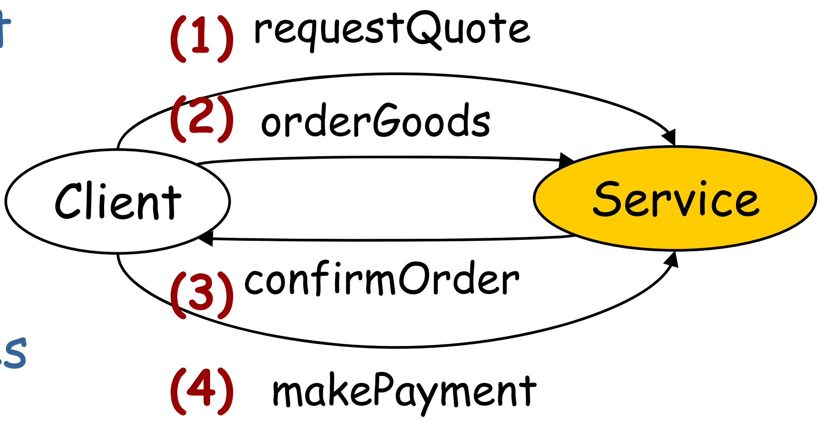
Overview

- The conversational model of Web services
- Security concerns
- Access control based on conversations
  - K-trustworthiness
- The technique
- The architecture
- Conclusions

Web Services

- A Web service is characterized by the set of (atomic) operations that it exports …
- … and possibly by constraints on the possible conversations
  - Using a service typically involves performing sequences of operations in a particular order (conversations)
  - During a conversation, the client typically chooses the next operation to invoke on the basis of previous results, among the ones that the service allows at that point



(1) requestQuote

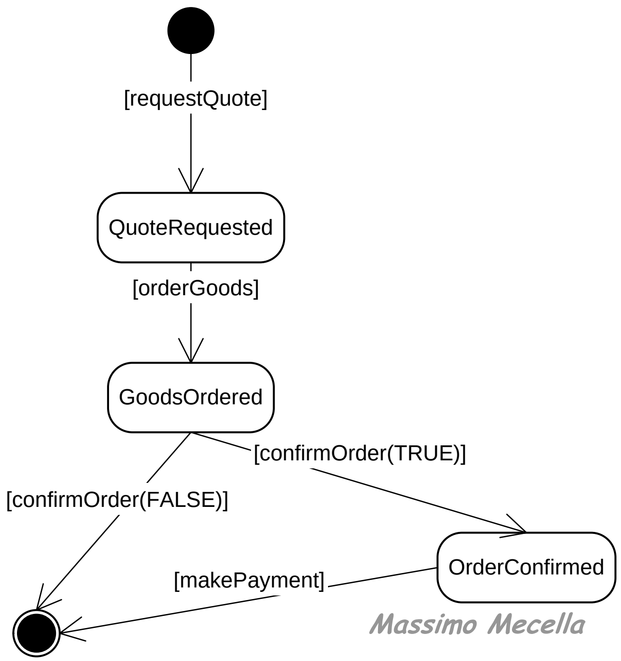
(2) orderGoods

Client

Service

(3) confirmOrder

(4) makePayment



[requestQuote]

QuoteRequested

[orderGoods]

GoodsOrdered

[confirmOrder(TRUE)]

[confirmOrder(FALSE)]

OrderConfirmed

[makePayment]

Web Services

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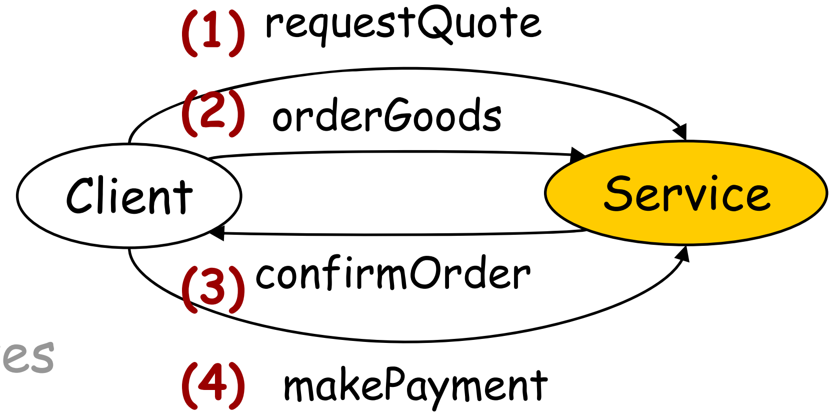
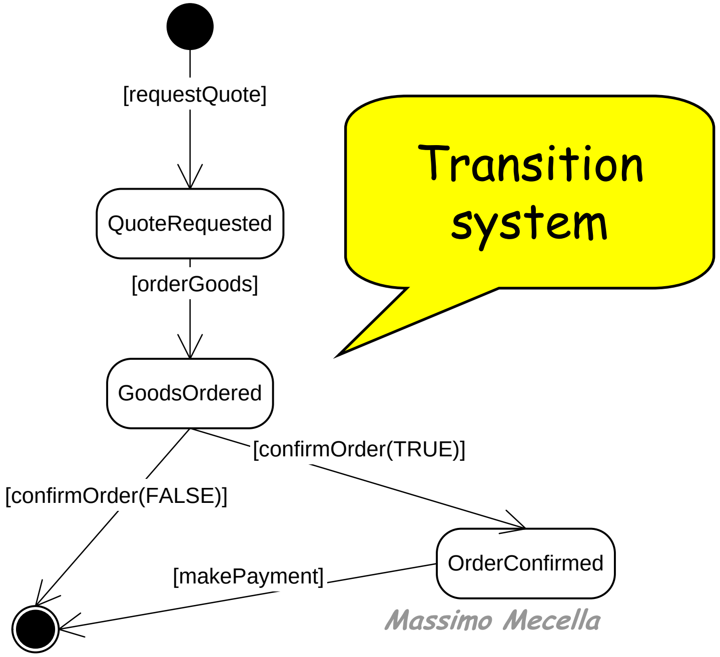
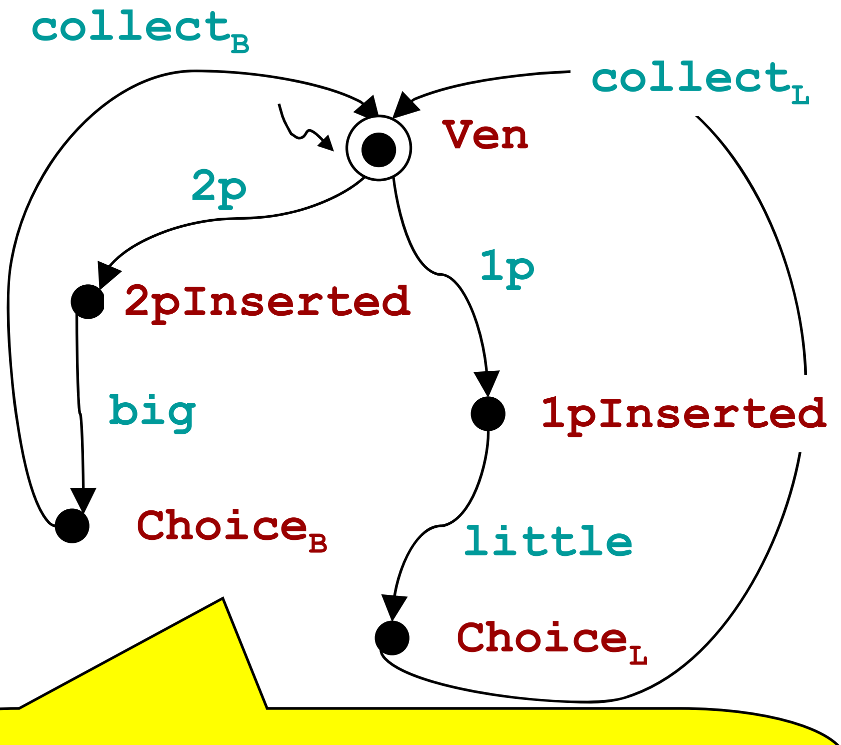




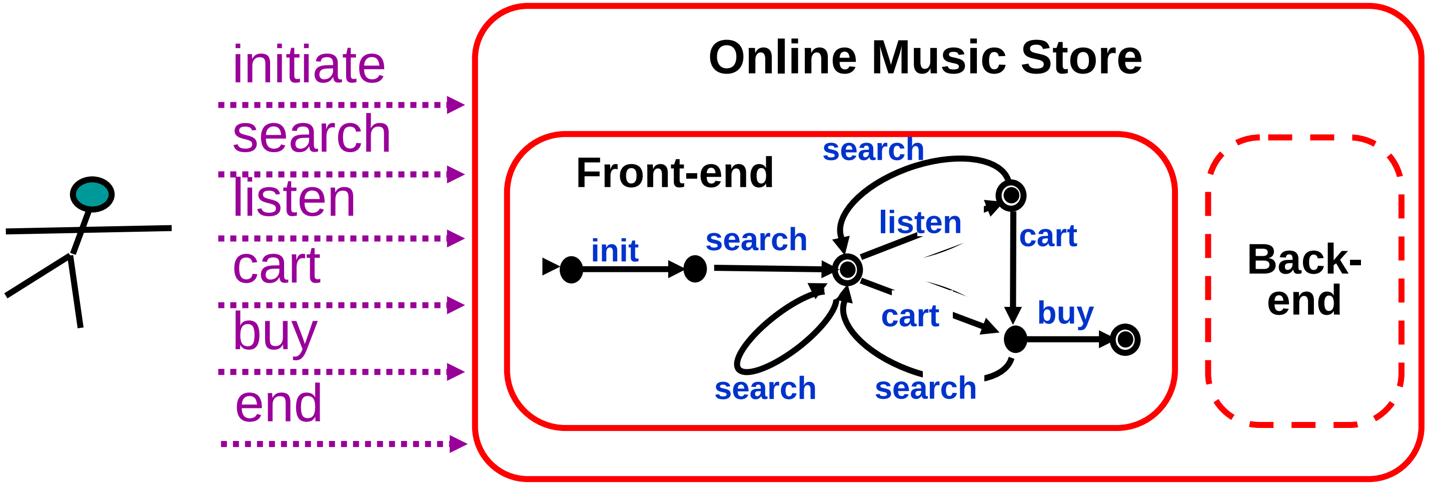
Transition Systems

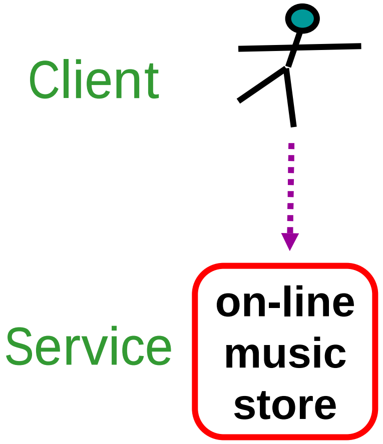
- A transition system (TS) is a tuple
  T = < A, S, S^0, δ, F >
  where:
  - A is the set of actions
  - S is the set of states
  - S^0 » S is the set of initial states
  - δ » S § A § S is the transition relation
  - F » S is the set of final states



- **Initial state:** the client starts the interaction
- **Final state(s):** the client can terminate the interaction (it has reached its own goal and the service is not "dangling")

The Conversational Model





Abstract Behavior of the Service:

Do until Client selects "end"

1. Give Client a choice of actions to be performed
2. Wait for Client choice
3. Perform action chosen by Client

Conversations supported by the service as a TS

Security Concerns

- Access Control
  - Credentials
    - signed assertions describing properties of a subject that are used to establish trust between two unknown communicating parties before allowing access to information or services
  - Access control policies
    - rules stating that only subjects with certain credentials satisfying specific conditions can invoke a given operation of the Web service

Current Approaches (1)

- Single operation model
  - operations are not related to ("independent" from) each other
- Access control is enforced
  - at the level of the ***entire Web service***
    - the Web service could ask the client, in advance, to provide all the credentials associated with all operations of that Web Service
      - ➡ – A subject will always arrive at the end of whichever conversation
      - ❌ – The subject will become aware of *all policies on the basis of which access control is enforced*
      - ❌ – The client may have to submit more credentials than needed

Current Approaches (2)

- at the level of ***single operations***
  - to require only the credentials associated with the next operation that the client wants to perform
    - ➡ – Asking from the subject only the credentials necessary to gain access to the requested operation
    - ✗ – The subject is continuously solicited to provide credentials for each transition
    - ✗ – After several steps, the client may reach a state in which it cannot progress because the lack of credentials (and *the service provider has wasted resources*)

Challenges

- Access control not only at the level of single operation
- Should consider conversations
    - Willingness of the client to reach a "goal"
    - Willingness of the service provider not to waste resources
    - Willingness of the service provider to limit disclosure of access control policies

The Idea

- Considering access control mainly at the level of conversations (sequences of operations leading to a final state of the TS)
- The service provider gives a k-trustworthiness level k to a client in a given state
- On the basis of such a k, asks the client to provide credentials for the conversations of length less/equal k (starting from the current state and with operations not yet "controlled")

The Rationale (1)

- The approach maximizes the likelihood that a client reaches a final state and doesn't drop off due to lack of authorization
  - Likelihood and not guarantee as the client is free, and can take different conversations
- The approach maximizes also the likelihood that the service provider doesn't waste resources, even without disclosing the access policies

▶

Example

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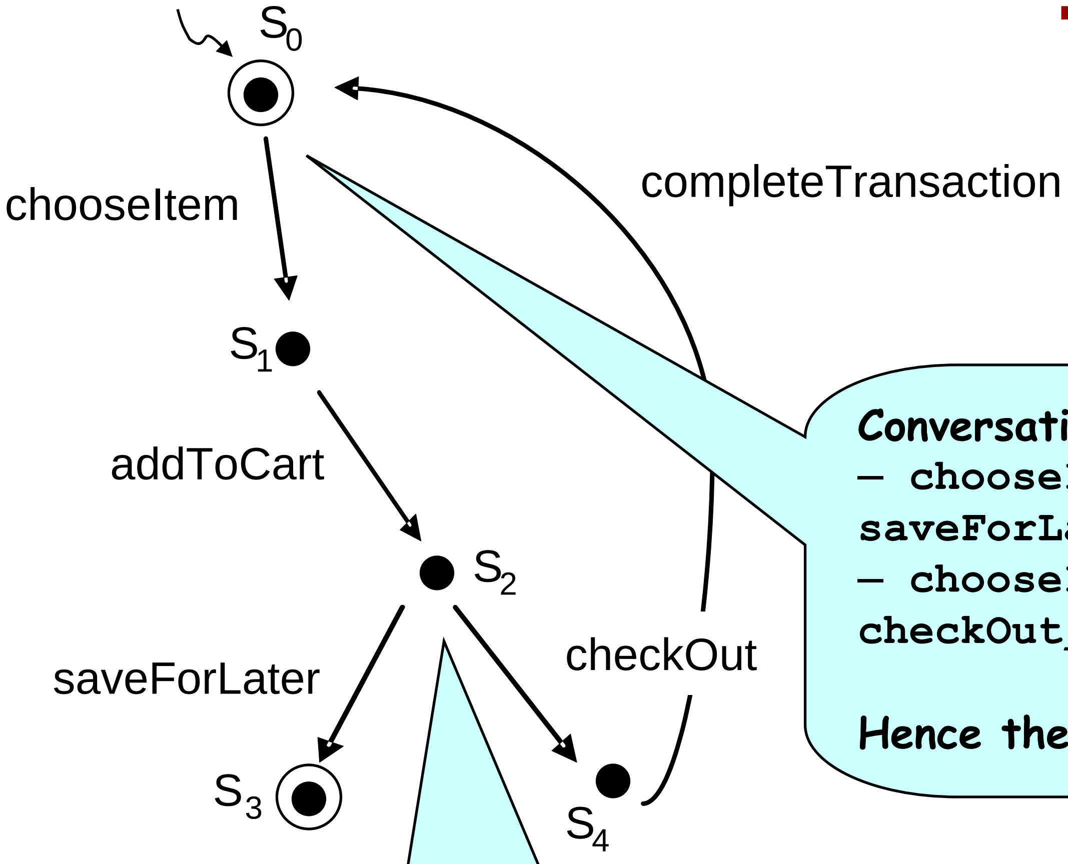


Conversations from S_0:

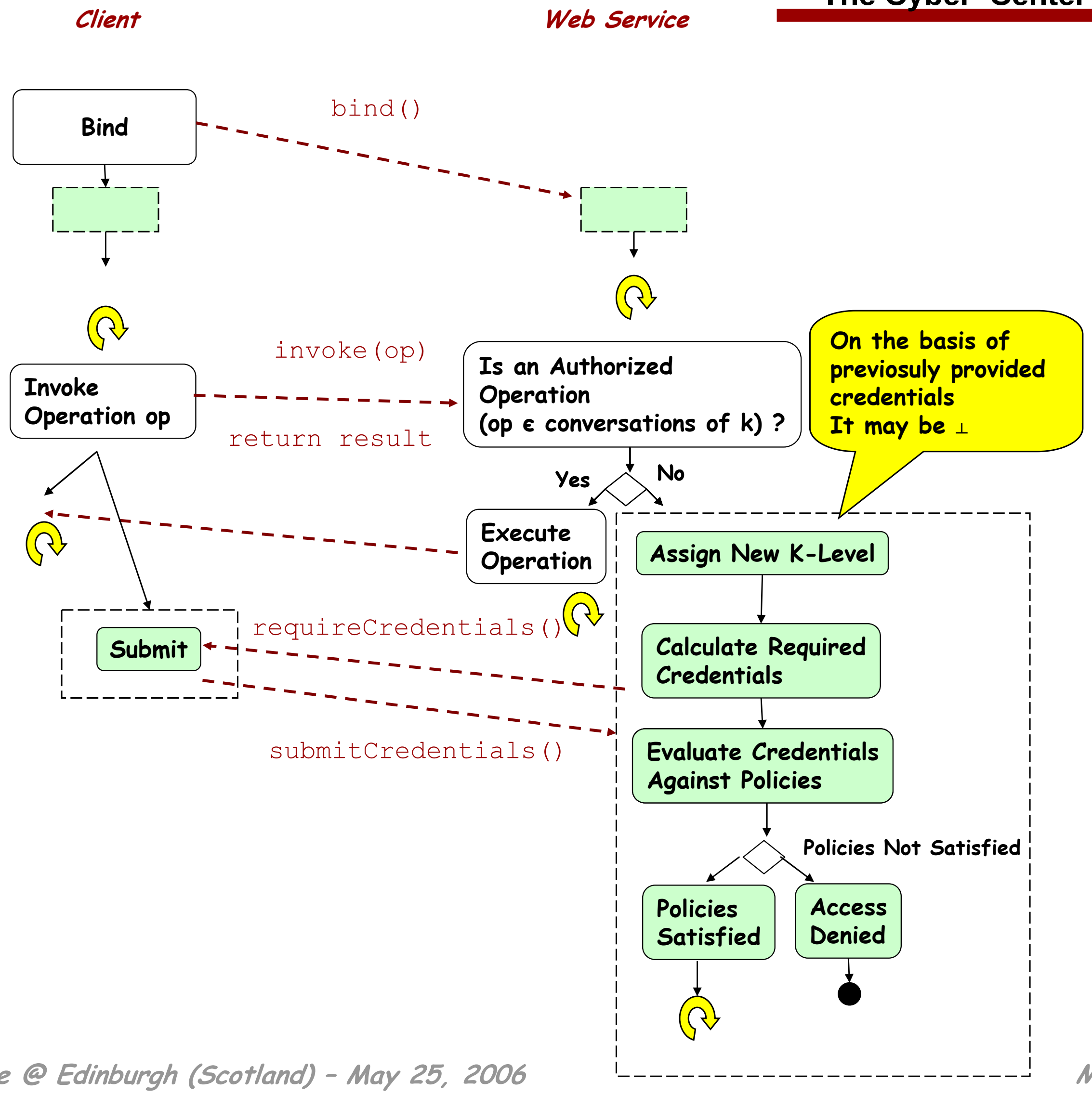
– chooseItemƒaddToCartƒ saveForLater

– chooseItemƒaddToCartƒ checkOutƒcompleteTransaction

Hence the k-levels for S_0 are {3,4}

k-levels for S_2 are {1,2}

Interaction Model



On the basis of previosuly provided credentials
It may be ⊥

Basic Concepts (1)

- Credential
  - Attribute (pair <name, value>)
- Attribute condition
- A credential satisfies an attribute condition if one among its attributes makes true the condition
- Operation access control policy
  - Rule specifying credentials and attribute conditions to grant access to the operation
  - Can be checked by a reasoning service that verifies if the access request is a logical consequence of the policy and the credentials

Basic Concepts (2)

- Conversation access control policy
  - Conjunction of the access control policies of the operations in the conversation
- Trustworthiness level
  - Length of "allowed" conversations
- k-trust policies
  - Given a state with different possible k-levels, defines which one to assign

The Technique (1)

- Given a TS, compute, for each state, all the possible k-levels
  - Requires computing all possible conversations
  - Are infinite for cyclic TSs !!
  - But for access control, once an operation has been checked, we do not have to check again

- We need to resort to the concept of
  - strongly connected component (SCC) of a TS
  - Graph of SCCs (G^{SCC}): acyclic, and can be computed by the Tarjan's algorithm

The Technique (2)

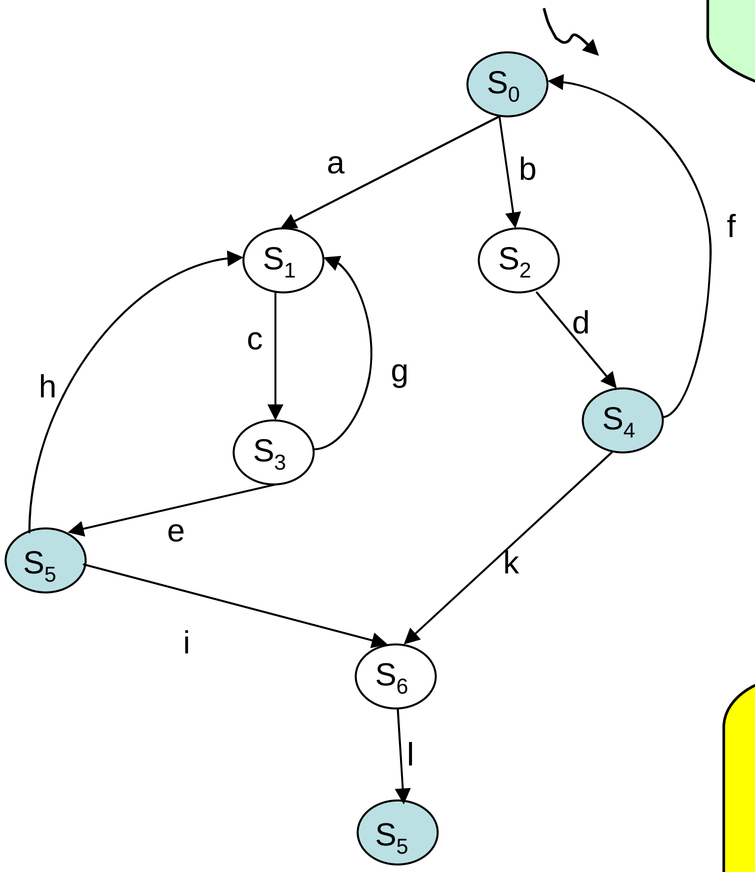
- For any SCC, we need to determine all possible conversations that will lead from an in-going node, i.e., coming from outside the component, to an out-going node, i.e., going outside the component
- These conversations should have the properties to cover all potential operations within the given strongly connected component
  - Given a node in G^{SCC}, formal concepts of cardinality, coverage and rank

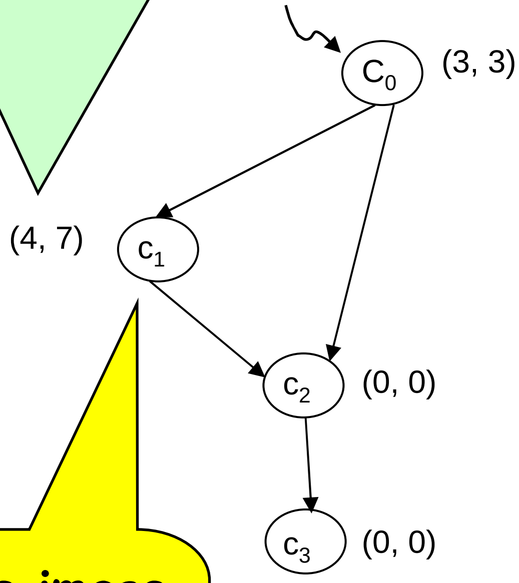
The Technique (3)

- The overall idea of the algorithm, which finds all potential k-trustworthiness levels for all states, is:
  - for a given state, determine all subsequent SCCs, including the one to which the current state belongs to
  - Traverse the transition system from that state and record all conversations leading to a final state

The Technique (4) [An Example]

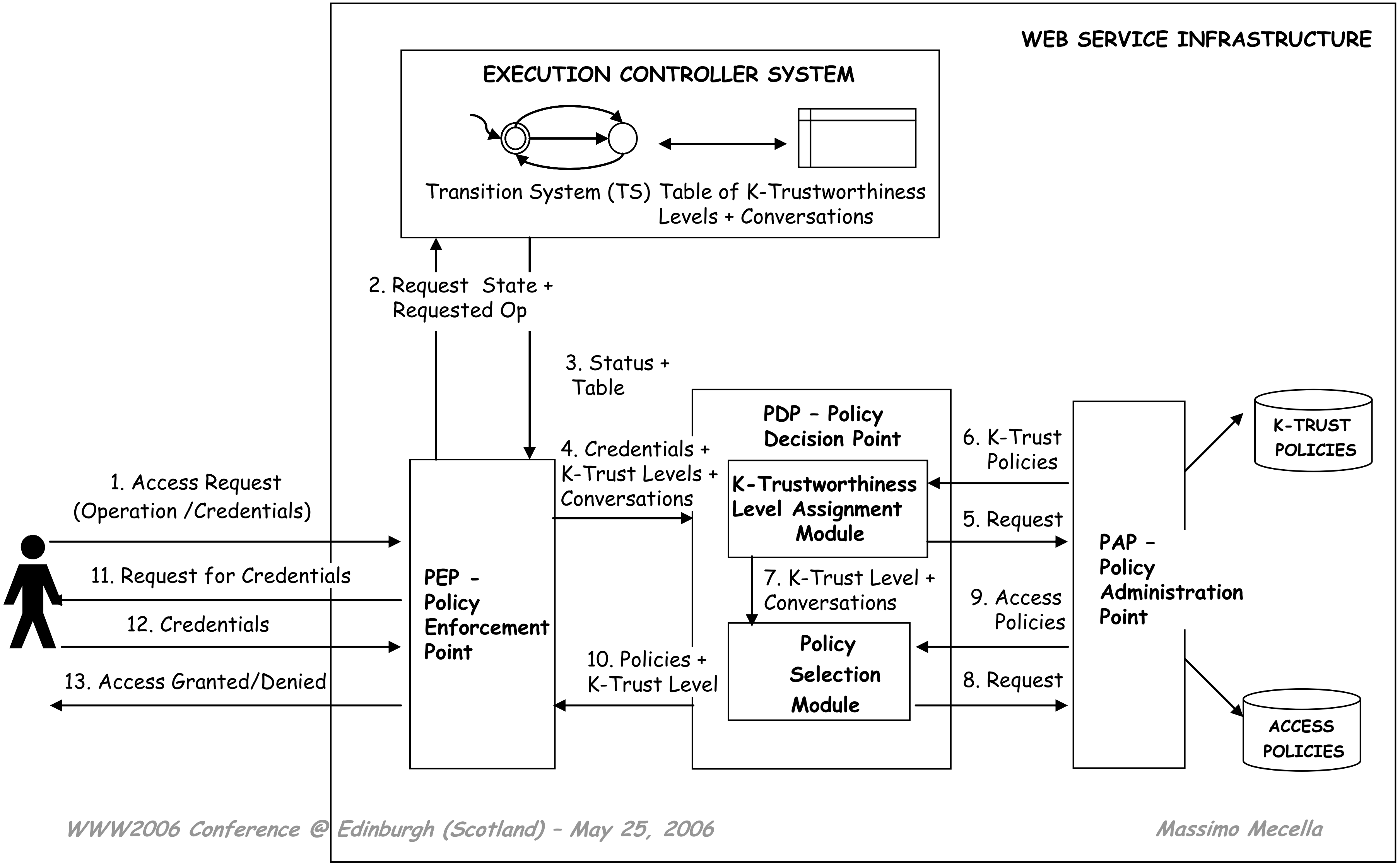
4 is the cardinality of C_1, as there are 4 different symbols: {c,g,h,e}
7 is the coverage, as you need a sequence of length 7 (c ƒe ƒh ƒc ƒg ƒc ƒ e) to include all the four symbols going from the root to the end of the SCC





C_1 is the image (SCC) of the set of states $\{S_1,S_3,S_5\}$

Architecture


WEB SERVICE INFRASTRUCTURE
EXECUTION CONTROLLER SYSTEM
Transition System (TS)
Table of K-Trustworthiness Levels + Conversations
2. Request State + Requested Op
3. Status + Table
1. Access Request (Operation /Credentials)
11. Request for Credentials
12. Credentials
13. Access Granted/Denied
PEP - Policy Enforcement Point
4. Credentials + K-Trust Levels + Conversations
10. Policies + K-Trust Level
PDP - Policy Decision Point
K-Trustworthiness Level Assignment Module
7. K-Trust Level + Conversations
Policy Selection Module
6. K-Trust Policies
5. Request
9. Access Policies
8. Request
PAP - Policy Administration Point
K-TRUST POLICIES
ACCESS POLICIES

Conclusions & Future Works

- A novel technique for access control enforcement taking into account the conversational nature of Web service
  - tradeoff between step-by-step (minimize the disclosure by maximizing the risk) and request-all (minimize the risk by maximizing the disclosure)
  - Good if k-level assignment is fine tuned (trough client profiling)

- Conclude the on-going implementation of the access control enforcement platform
  - Performance and scalability tests
- Apply the idea of k-trustworthiness to Web service choreographies
  - Compositions (i.e., orchestrators a-la Roman way) are already seamlessly included in the model

Backup

The Rationale (2)
[A Simple Probability Model]

- Given an operation a, we consider P_a as the probability that the client DOES NOT have the credential(s) satisfying the access control policy guarding the operation
- *Damage* of having a client dropping off is the number of executed operations
- *Leakage* in terms of disclosure of access control policies is proportional to the number of executed operations
- Let's consider a conversation conv = $\{a_1, \ldots, a_n\}$

The Rationale (3)
[A Simple Probability Model]

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- Step-by-step
  - Risk faced before involving the i-th operation (a_i is the next operation the client may not possess credentials)

$$R_i = P_{a_i}\ f(i - 1) \qquad\qquad i = 1 \ldots n$$

  - Leakage after the i-th operation (a_{i+1} is the next operation

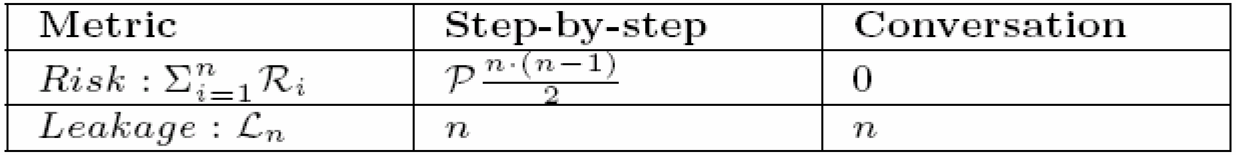
$$L_i = P_{a_{i+1}}\ f i \qquad\qquad i = 1 \ldots n$$

- Conversation-based
  - Risk faced after conv (being conv the conversation the service provider has requested the credentials)

$$R_i = \Pi_{i=1}^{n} P_{a_i}\ f 0 = 0 \qquad\qquad i = 1 \ldots n$$

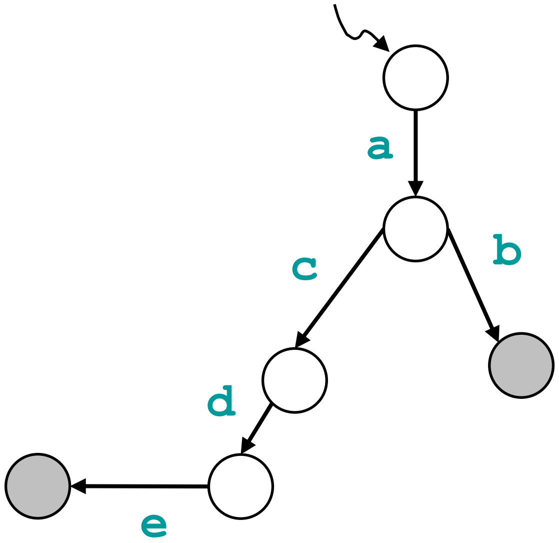
  - Leakage after the i-th operation (a_{i+1} is the next operation

$$L_i = P_{a_{i+1}}\ f n \qquad\qquad i = 1 \ldots n$$



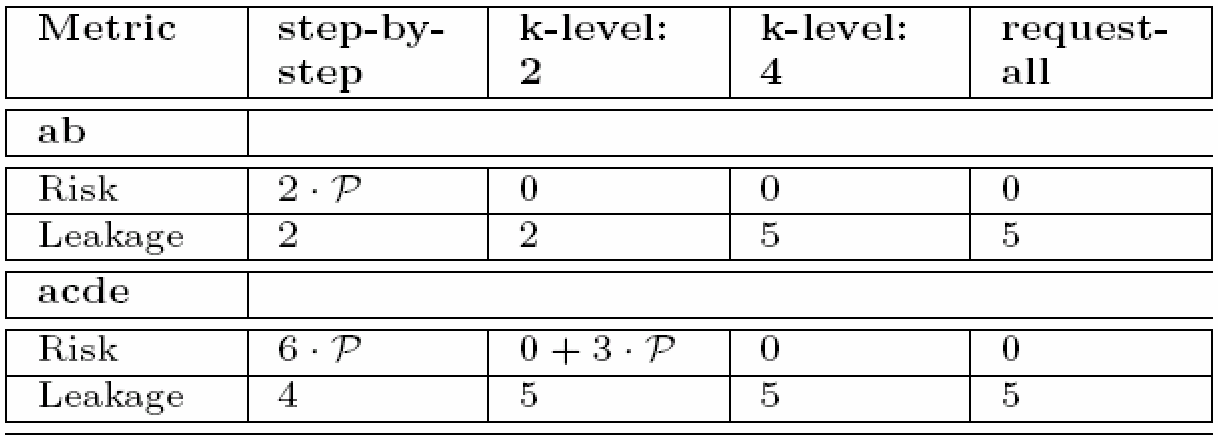
Metric	Step-by-step	Conversation
$Risk : \Sigma_{i=1}^{n} \mathcal{R}_i$	$\mathcal{P}^{\frac{n \cdot (n-1)}{2}}$	0
$Leakage : \mathcal{L}_n$	n	n

The Rationale (4)
[A Simple Probability Model]



Conversation based is a tradeoff between step-by-step (minimize the disclosure by maximizing the risk) and request-all (minimize the risk by maximizing the disclosure)

Good if k-level assignment is fine tuned (trough client profiling)



Metric	step-by-step	k-level: 2	k-level: 4	request-all
ab				
Risk	$2 \cdot \mathcal{P}$	0	0	0
Leakage	2	2	5	5
acde				
Risk	$6 \cdot \mathcal{P}$	$0 + 3 \cdot \mathcal{P}$	0	0
Leakage	4	5	5	5