Trusted Agent-Mediated E-Services via Semantic Web Rules Inference

Yuh-Jong Hu

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jong @cherry.cs.nccu.edu.tw http://www.cs.nccu.edu.tw/ENT Emerging Network Technology(ENT) Lab. Department of Computer Science National Chengchi University Taipei, Taiwan

Talk Outline

- Research Background
- ✓ The Semantic Web
- ✓ Semantic Web Rules
- Agent-Mediated E-Services
- Trusted Agent-Mediated E-Services
- Research Challenges



Research Background

Research Background

- Achieving the semantic web vision will be one of the emerging research areas for the academic community in the near future.
- We believe that software agents will be the prime beneficiary for the success of semantic web research.
- We focus on the agent trust issue for the semantic web research based on ontology (taxonomies + axioms) and security technologies.
- Agent-mediated e-services (or e-commerce) is one of the application domains to demonstrate the feasibility of our trust verification methodology.

The Semantic Web

The Semantic Web

 A new form of Web content that is meaningful to computers will unleash a revolution of new possibilities.

The Semantic Web will enable machines to comprehend semantic documents and data, not human speech and writings.

The explicit representation of the semantics of data, accompanied with domain theories (that is, *ontologies*), will enable a Web that provides a qualitatively new level of service.

Tim Berners-Lee, James Hendler, and Ora Lassila Scientific American, May 2001

Ontology

An ontology is a <u>formal</u>, explicit specifications of a shared conceptualization.

The ontology for the Web has a taxonomy and a set of inference rules.
 The taxonomy defines classes of objects and relations among them.
 Inference rules in ontologies supply further power.

Some people treat ontology as a subset of logic, some treat logic as a subset of ontological reasoning, and others consider the terms disjoint.

Is the ontology equation shown to be: Ontology = Taxonomies + Axioms?

Ontology Language vs. Rule Language

Based on the language expressing power:

- RDF/RDF(S) <== ontology language</pre>

- DAML-Rules rule language

Ontology Languages for the Semantic Web

Taxonomies	XOL	SHOE	OML	RDF(S)	OIL	DAML+0IL	
Subclass of	÷	+	+	Ŧ	Ŧ	+	
Exhaustive decompositions	-		+/-		÷	÷	
Disjoint decompositions	<u>.</u>	925 1	+	<u> 1</u>	+	+	
Not subclass of	<u>7</u> 6	70		50	+	+	
Concepts	XOL	SHOE	OML	RDF(S)	OIL	DAML+OIL	
General Issues							
Partitions	7.	7	+	7.	+	+	
Documentation	+	+	+	+	+	+	
Attributes							
Instance attributes	+	+	+	+	+	+	
Class attributes	+	-	+	-	+	+	
Local scope	+	+	+	+	+	+	
Global scope	+		+	+	+	+	
Facets							
Default value	+	7	-	-	7	-	
Type constraints	+	+	+	+	+	+	
Cardinality constraints	+	-	-	-	+	+	
Documentation	+	+	+	+	+	+	

Asuncion Gomez-Peres and Oscar Corcho

Ontology Languages for the Semantic Web (conti.)

Instances	XOL	SHOE	OML	RDF(S)	OIL	DAML+0IL
Instances of concepts	+	+	+	+	+	+
Facts	+	+	+	+	+	+
Claims	-	+	-	+/-	+/-	+/-
Axioms	XOL	SHOE	OML	RDF(S)	OIL	DAML+OIL
First-order logic	73	+/-	+	5	+/-	+/-
Second-order logic	-	-	e.		-	
Independent axioms	2	14	12	-	-	243
Embedded axioms	-	-	+	-	-	-
Relations and functions	XOL	SHOE	OML	RDF(S)	OIL	DAML+OIL
<i>n-ary</i> relations/functions	+/-	+	+	+/-	+/-	+/-
Type constraints	+	+	+	+	+	+
Integrity constraints	÷.	-	+	4	-	-
Operational definitions	~		i.	1	1	17

Asuncion Gomez-Peres and Oscar Corcho

Agents and the Semantic Web

Many challenges of bringing communicating multiagent systems to the Web require ontologies. The integration of agent technology and ontologies could significantly affect the use of Web services and the ability to extend programs to perform tasks for users more efficiently and with less human intervention.

James Hendler

Agents and the Semantic Web (conti.)

The real power of the Semantic Web will be realized when people create many programs that collect Web content from diverse sources, process the information and exchange the results with other programs. The effective-ness of such software agents will increase exponentially as more machine-readable Web content and automated services (including other agents) become available. ...

Tim Berners-Lee, James Hendler, and Ora Lassila

The "Original Layer Cake" for the Semantic Web



Tim Berners-Lee

The "Layer Cake" for the Semantic Web



The "Layer Cake" for the Semantic Web with Associated Ontology Language



Embed Ontology in Agent Communication Language FIPA Nomadic Application Support



FIPA Nomadic Application Support Spec., XC00014D

FIPA Nomadic Application Support: Flow of Message Transport Protocol Negotiation



FIPA Nomadic Application Support: Flow of Message Transport Protocol Negotiation (conti.)

```
(request
:sender
  (agent-identifier
    :name A-AgentiM@mobile.com[10])
:receiver (set
  (agent-identifier
     :name CaiM@mobile.com))
:ontology FIPA-Nomadic-Application
:language FIPA-SL0
:protocol FIPA-Request
:content
  (action
    (agent-identifier
      :name CAiM@mobile.com)
    (activate (sequence
      (transport-protocol
        :name x.uh.mdcp)
      (transport-protocol
        :name fipa.mts.mtp.wap.std
        :dest-addr wap://gateway.com:1234/acc))))
```

FIPA Nomadic Application Support: Flow of Message Transport Protocol Negotiation (conti.)

```
(agree
:sender
  (agent-identifier
    :name CAiM@mobile.com)
:receiver (set
  (agent-identifier
    :name A-AgentiM@mobile.com))
:ontology FIPA-Nomadic-Application
:language FIPA-SL0
:protocol FIPA-Request
:content
  ((action
    (agent-identifier
      :name CAiM@mobile.com))
   (activate (sequence
     (transport-protocol
       :name x.uh.mdcp)
     (transport-protocol
       :name fipa.mts.mtp.wap.std
       :dest-addr wap://gateway.com:1234/acc))))
 true))
```

Agents and Ontology

- Ontology specifies the concepts and terms in a well-defined format for agents to refer and communicate.
- If the ontology specifies that a particular class has a particular property and that the property has some restriction, then each agent can assume that the other has legal values for that property maintaining that restriction.
- Agents that are not using the same ontology might still be able to communicate. If you can find a common ontology for each agent's ontology to map into.

Semantic Web Rules

RuleML

- RuleML is a rule markup language for the Semantic Web.
- RuleML rulebase exchange will require a taxonomy of the relations defined in the rulebase, where a relation with its arguments becomes a class with its slots.
- DAML+OIL taxonomies will require a rule system to derive/use certain implicit information that is not captured by the taxonomy alone.

Agents and RuleML

- A sophisticated software agent may be specified by
 - ✓ an RDFS-based taxonomy for defining the schema of its mental state
 - ✓ a set of RDF facts for specifying its factual (extensional) knowledge
 - ✓ a set of RuleML integrity constraints for excluding non-admissible mental states
 - a set of RuleML derivation rules for specifying its terminological and heuristic (intensional) knowledge
 - a set of RuleML reaction rules for specifying its behavior in response to communication and environment events

DAML-OIL DAML-Rules and RuleML

- DAML+OIL is based on Description Logic (DL) and RuleML is based on logic programs (LP).
- DAML-Rules is a semantic rule markup language for Web resources and it builds on XML and RDF(S).
- DAML+OIL is an ontology language and RuleML is a rule markup language.
- No matter DAML+OIL, RDF(S)+RuleML, DAML-Rules, or DAML+OIL and RuleML, we need a consistent shared taxonomies and portable and interoperable axioms, and rules for agents to achieve *autonomous, pro-active, reactive*, and *flexible* service characteristics.

Axioms and Rules for DAML+OIL

Based on our observations, the DAML+OIL only provides axioms and rules for reasoning on the followings:

Ontology design

Check class consistency and (unexpected) implied relationships

✓ Particularly important with large ontologies/multiple authors

Ontology integration

- Assert inter-ontology relationships
- Reasoner computes integrated class hierarchy/consistency

Axioms and Rules for DAML+OIL (conti.)

Ontology deployment

✓ Determine if set of facts are consistent w.r.t. ontology

Answer queries w.r.t. ontology, e.g. DQL

Are those axioms and rules enough for us to define our arbitrary trust validation rules once we have built the trust ontologies?

Combining Rules with Ontologies for the Semantic Web: DAML+OIL vs. RuleML

Two techniques for combination

- Meta-ontology: use DAML+OIL at a logical meta-level in order to describe classes of rules and rule sets.
- KR (Knowledge Representation) fusion: build rules on top of ontologies or build ontologies on top of rules.

Benjamin Grosof

The Trust on the Semantic Web

- The Web of trust is based on the proofs on the Web but very little has been done on this layer.
- The proof will be a chain of assertions and reasoning rules with pointers to all the supporting material on the WWW.
- A semantic Web will not require proof generation, i.e. find the path that constructs a valid proof, to be useful so proof validation will be enough.
- This proof validation w.r.t. Web of trust is a decidable reasoning process.
- An important facet of agents' functioning will be the exchange of "proofs" written in the Semantic Web's unifying language. (the language that expresses logical inferences made using rules and information such as those specified by ontologies).

Agent-Mediated E-Services

Web(or E)- Services

"Web Services are a new breed of Web application. They are self-contained, self-describing, modular applications that can be published, located, and invoked across the Web. Web services perform functions, which can be anything from simple requests to complicated business process. ... Once a Web service is deployed, other applications (and other Web services) can discover and invoke the deployed service."

IBM web service tutorial

Agent-Mediated E-Services (AMES)

The Semantic Web should enable users (or agents) to locate, select, employ, compose, and monitor Web-based services **automatically**. So the primary motivations for Agent-Mediate E-Services (AMES) are:

Automatic Web service discovery

Automatic Web service invocation

Automatic Web service composition and interoperation

Existing E-Services Frameworks

WSDL/UDDI/SOAP

< ebXML

RosettaNet



Existing AMES Frameworks

DAML-S + OAA

RETSINA/LARKS





Ontologies for DAML-S Framework

DAML-S has the following ontologies but it lacks of trust ontologies to prove the trustworthiness of its AMES framework.

Service ontology

Process ontology

Process control ontology (Not Ready Yet)

Trusted Agent-Mediated E-Services

Trusted Agent-Mediated E-Services

- The trust issue will be one of the most important issues for the successful deployment of agent-mediated e-services framework.
- People still do not know what are the specific trust issues need to be considered and resolved.
- Security mechanisms can solve some of trust problems but not all of them so we need a total solution for the agent trust on the WWW.
- We must find out what are the trust verification rules besides the security validation rules.

Why Trust Agent and Delegate our Authority?

- The reasons for human (or agent) to trust their (peer) agents and delegate its authority to these agents are: efficiency, convenience, fault tolerance.
- The most important one for agent's delegation is that agents are cyberspace creatures.
- If you fully(partially) trust your agent, then we assume you might delegate your complete(partial) authority to your agents.

Agent Trust Issues

There are at least two facets to deal with agent trust problem:

- The trust on agent delegation must satisfy the "competence" (capability) and "disposition" (willingness) criteria.
 - Do you (or your agent) trust agent (or another agent) so that the important mediation e-services authority can be granted to the delegatee agent?
 - How do you make sure that agent can proceed and finish the task as your intention?
 - Do you have to monitor and control your agent's operations al the time to guarantee quality of trust?

Agent Trust Issues (conti.)

- The trust on access control for guardian agent must satisfy the "authentication" and "authorization" criteria.
 - Once you trust your agents and delegate the access control authority for them to protect your precious resources, what kinds of methodologies are available for your guardian agent to ascertain the access control trust?
 - Achieving agent trust on delegation and access control, we propose that the validation of agent's authentication and authorization is an fundamental issue.
 - What other issues are needed to consider for agent trust besides authentication and authorization criteria?

Agent Delegation Logic: Complete Authority Delegation

- Complete authority delegation from principal A to principal B is denoted as either of the following:
 - ✓ Principal A says principal B(or $threshold(m, [B_1, \dots, B_n]))$ speaks for A on some authority under conditions ~ .
 - ✓ Principal A delegates some authority to principal B (or $threshold(m, [B_1, \dots, B_n])$) under conditions ~.

Agent Delegation Logic: Partial Authority Delegation

Partial authority delegation as role is denoted as:

✓ Principal A says principal B(or $threshold(m, [B_1, \dots, B_n])$) speaks for A with role as ~ on some authority under <u>conditions</u> ~.

Agent-Oriented PKI



Identity Certificate

 $ID_{CA\mapsto p} - Cert = (Id_p, Pu_p, V, Option, Sig_{CA})$

where:

 Id_p : principal p's distinguished identity.

 Pu_p : principal *p*'s public key.

V: validation period for identity certificate.

Option: optional information.

 Sig_{CA} : certificate signature signed by CA's private key.

Attribute Certificate

 $AT_{TA\mapsto p} - Cert = (Id_p, Ar_p, V, Option, Sig_{TA})$

where:

 Id_p : principal p's distinguished identity.

 Ar_p : principal *p*'s attribute information.

V: validation period for attribute certificate.

Option: optional information.

 Sig_{TA} : certificate signature signed by TA's private key.

Authorization Certificate

$$AU_{p\mapsto q} - Cert = (Pu_p, Pu_q, A, D, V, Sig_p)$$

where:

 Pu_p : a public key for the issuer of principal p to grant authorization.

 Pu_q : a public key for the subject of principal q to receive authorization.

- A: expression for authorization.
- *D*: delegation bit with value 0 or 1.
- V: validation period for authorization certificate.

 Sig_p : certificate signature signed by p's private key.

Rule Certificate

 $RU_{RA\mapsto RS_i} - Cert = (RS_i, Assertions, Sig_{RA})$

where:

 RS_i : access authority for resource(or service)

Assertions: a set of rules in Conjunct Normal Form (CNF) to indicate the requirements

of both identity and attribute certificates to unlock the resource access authority RS_i .

 Sig_{RA} : certificate signature signed by RA's private key.

Closed Group Delegation Scenario

Internet bank Morgan-Trust provides customer m_1 with

 \checkmark Valid customer citizenship ID - Cert

 \checkmark Bank account's AT - Cert

to perform a variety of transaction operations, such as check, withdraw, transfer, and deposit, on his account on the Internet. In this delegation scenario, all of the AT - Cert issuers are the same as the resource owners so the attribute certificate verification process is a closed loop w.r.t the $RU_{Morgan-Trust} - agent$.

Trust Establishment Scenario: Granting Initial Authority for Service Requesting Agent



Access Control Rules for Morgan-Trust Bank

Rules

- The second state of the second state
 - 2. Morgan-Trust delegates the *issuing* operations for $AT_{HTA\mapsto h} - Cert = (?Id_h, ?IsAccountOwner(?Id_h, ?Acc), ?V, Option, ?Sig_{HTA})$ to HTA If $HTA \in (Morgan - Trust)$.
 - 3. Morgan-Trust delegates the operations for $(Check(?Id_h, ?Acc), Withdrawal(?Id_h, ?Acc, ?Val), TransferFrom(?Id_h, ?Acc, ?Val), Deposit(?Id_h, ?Acc, ?Val))$ to $Name(?Id_h)$ If $ID_{HCA\mapsto h} - Cert \wedge AT_{HTA\mapsto h} - Cert \wedge IsAccountOwner(?Id_h, ?Acc) \wedge IsAccountBalance(?Val \ge 0, ?Acc).$
 - 4. Morgan-Trust says PublicKey(?Pu_h) speaks for Name(?Id_h) with role as IsAccountOwner(?Id_h,?Acc) on the operations for (Check(?Id_h,?Acc),TransferFrom(?Id_h,?Acc,?Val), Withdrawal(?Id_h,?Acc,?Val), Deposit(?Id_h,?Acc,?Val)) If IsPublicKey(?Pu_h,?Id_h).

Access Control Facts for Morgan-Trust Bank

Facts

- 1. $ID_{E-Trust\mapsto m_1} Cert = (Id_{m_1}, 12345, 2001/01/01 2002/12/31, Option, Sig_{E-Trust})$
 - 2. $AT_{Morgan-Trust\mapsto m_1} Cert = (Id_{m_1}, IsAccountOwner(Id_{m_1}, B10234), 2001/02/02 2002/12/31, Option, Sig_{Morgan-Trust})$
 - 3. IsPublicKey(12345, Id_{m1})
 - 4. IsPublicKey(45123, Id_{o_1})
 - 5. IsPublicKey(51234, Id_r)
 - 6. IsPublicKey(23456, $Id_{E-Trust}$)
 - 7. IsPublicKey(34567, $Id_{Morgan-Trust}$)
 - 8. IsAccountOwner(Id_{m_1} ,B10234)
 - 9. IsAccountBalance(\$5000,B10234)

Open Group Delegation Scenario

A researcher m_1 is going to apply for financial support from the NSF (National Science Foundation)-Trust to participate in the AMEC 2002 conference. The NSF-Trust requirements for the approval of financial support must have the following digital certificates:

an applicant must have a legal citizenship

 an applicant must be an faculty member at an MOE(Minister of Education) certified university

 an applicant must have full paper(s) accepted by the AMEC 2002 conference

Access Control Rules for NSF-Trust

Rules

- ✓ 1. NSF-Trust delegates the *issuing* operations for $ID_{HCA\mapsto h} Cert = (?Id_h, ?Pu_h, ?V, Option, ?Sig_{HCA}) \text{ to } HCA$ If $HCA \in (US Trust)$.
 - 2. NSF-Trust delegates the *issuing* operations for $AT_{HTA\mapsto h} - Cert_1 = (?Id_h, ?IsFacultyOf(?Id_h, ?Id_{HTA}), ?V, Option, ?Sig_{HTA})$ <u>to</u> HTA If HTA has $AT_{MOE-Trust\mapsto HTA} - Cert_2$.
 - 3. NSF-Trust delegates the *issuing* operations for $AT_{HTA\mapsto h} - Cert_3 = (?Id_h, ?IsFullPaperAcceptedBy(?Id_h, ?Id_{HTA}),$ $?V, Option, ?Sig_{HTA}) \text{ to } HTA$ If $HTA \in (ACM - Trust, IEEE - Trust, AMEC - Trust, \cdots).$
 - 4. NSF-Trust delegates the operation for $(UseTravelCredit(?Id_h, ?T - Amount) \land$ $UseRegistCredit(?Id_h, ?R - Amount))$ to $Name(?Id_h)$ If $ID_{HCA\mapsto h} - Cert \land AT_{HTA\mapsto h} - Cert_1 \land AT_{HTA\mapsto h} - Cert_3.$
 - 5. NSF-Trust says $PublicKey(?Pu_h)$ speaks for $Name(?Id_h)$ with <u>role as</u> $IstheAuthorFor(?Id_h,?Id_{HTA})$ on the operations for $UseTravelCredit(?Id_h,?T-Amount) \land UseRegistCredit(?Id_h,?R-Amount))$ If $IsPublicKey(?Pu_h,?Id_h)$.

Access Control Facts for NSF-Trust

Facts

- The second state of the second state
 - 2. $AT_{NCCU-Trust \mapsto m_1} Cert_1 = (Id_{m_1}, IsFacultyOf(Id_{m_1}, Id_{NCCU-Trust}), 2001/02/02 2004/12/31, Option, Sig_{NCCU-Trust})$
 - 3. $AT_{MOE-Trust \mapsto NCCU-Trust} Cert_2 = (Id_{NCCU-Trust}, IsCertifiedBy(Id_{NCCU-Trust}, Id_{MOE-Trust}), 2001/02/02-, Option, Sig_{MOE-Trust})$
 - 4. $AT_{AMEC-Trust\mapsto m_1}-Cert_3 = (Id_{m_1}, IsFullPaperAcceptedBy(Id_{m_1}, Id_{AMEC-Trust}), 2002/02/02 2002/02/31, Option, Sig_{AMEC-Trust})$
 - 5. IsPublicKey(12345, Id_{m1})
 - 6. IsPublicKey(54321, $Id_{NSF-Trust}$)
 - 7. IsPublicKey(56789, $Id_{NCCU-Trust}$)
 - 8. IsPublicKey(67891, $Id_{MOE-Trust}$)
 - 9. IsPublicKey(78912, *Id_{AMEC-Trust}*)

Research Challenges

On-Going Research Issues

- Design and implement the trust ontology taxonomies and rules for agent-mediated e-services to evaluate agent's authentication, authorization, delegation, and trust verification criteria.
- Establish the semantic web rules inference framework to execute our trust and delegation e-services rules on the Web.
- Use both the trust ontology taxonomy and semantic web rules inference to verify our trusted agent-mediated e-services model on the Internet.
- Build a generic trusted open agent e-services framework based on FIPA abstract agent architecture to serve a variety of e-service models.

Conclusion

- The Semantic Web is one of the important emerging research areas and the results are very promising in the near future.
- The real power of the Semantic Web will be realized when pep ole create a lot of software agent programs to fulfill the agent characteristics for automated e-services.
- The relationships among Semantic Web, ontology, agent, and trust need to be established.
- The ontology equation: Ontology = Taxonomies + Axioms (Rules) needs to be verified.
- One of the challenge issues for the successful deployment of agent-mediated eservices is to resolve the Web of trust problem on the Semantic Web.
- The trusted Semantic Web has been done very little at this moment but people are very interested in achieving this objective.

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