Rule Responder Agents for Distributed Query Answering

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Outline

- Rule Responder Overview
- Agents
  - Personal / Organizational / External
- Infrastructure
  - Reaction RuleML Messages
  - Message Performatives
  - Agent Communication Protocols
  - Mule ESB (Communication Middleware)
- Rule Engines (for Realizing Agents)
  - Prova
  - OO jDREW
- Symposium Planner Use Case
  - Query Delegation/Answering
  - Shared Knowledge between Pas
  - Ontology Description
- Future Work and Conclusion

Overview of Rule Responder (I)

- Rule Responder is an experimental multi-agent system for **collaborative teams** and **virtual communities** on the Web
- Supports rule-based collaboration between the distributed members of such ***virtual organizations***
- Members of each virtual organization are assisted by **semi-automated rule-based agents**, which use rules to describe the **decision** and **behavioral** logic

Overview of Rule Responder (II)

- Uses languages and engines of the RuleML family for rule serialization, based on logic and XML:
  - Hornlog RuleML: Reasoning (decision)
  - Reaction RuleML: Interaction (behavior)
- Implemented on top of a Mule-based Service Oriented Architecture (SOA) as an Enterprise Service Bus (ESB)

Personal Agents

- A personal agent assists a **person** – sometimes several – of an organization, (semi-autonomously) acting on their behalf
- It contains a FOAF*-like **fact** profile plus FOAF-extending **rules** to encode ‘routine’ knowledge of its human owner

*** The Friend of a Friend (FOAF) project: http://www.foaf-project.org**

Organizational Agents

- An organizational agent represents goals and strategies shared by each member of **the organization**
- It contains rule* sets that describe the policies, regulations, opportunities, etc. of its organization

* To be brief, the term ‘rule’ encompasses ‘fact’ (which is a rule without premise)

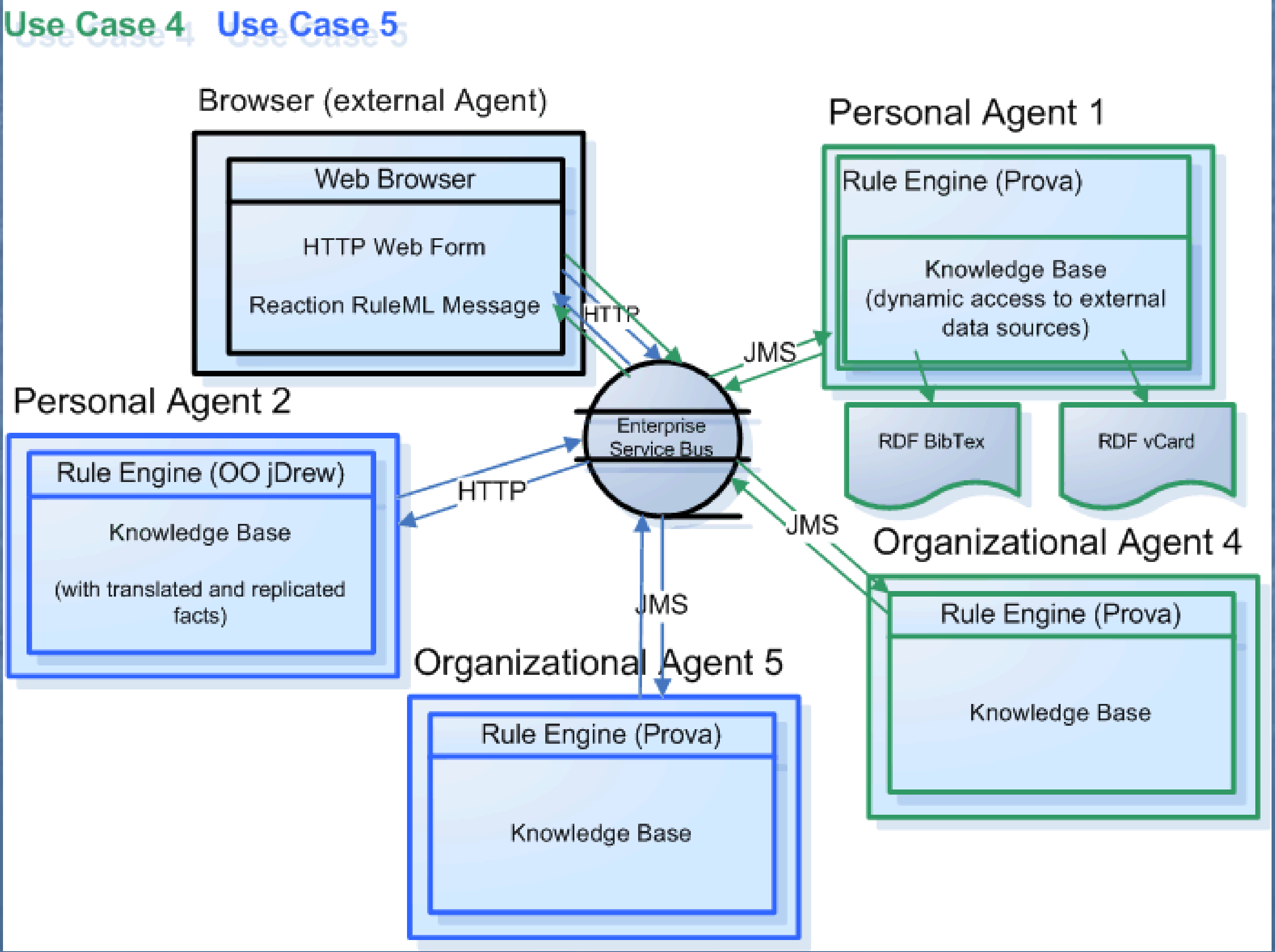
External Agents

- External agents exchange messages with (the public interface of) organizational agents, sending queries (requests), receiving answers (results), or interchanging complete rule sets
- End users, as external agents, employ a Web (HTTP) interface of Rule Responder (currently an API-like browser interface)
- Support for simultaneous external agents:
  - Currently, end users (B2C)
  - Ultimately, other organizations (B2B)

Rule Responder as a Multi-Agent Infrastructure

- Realizes Virtual Organizations in which a central OA mediates between EAs and PAs
  - Built on top of the Mule ESB
- Each OA is realized with an instance of a Rule Engine
- Each PA is realized with a Servlet using a Rule Engine – sometimes several
- Combines ideas of **multi-agent systems**, **distributed rule management systems**, as well as **service-oriented** and **event-driven** architectures

Two Simple Rule Responder Virtual Organizations on ESB Infrastructure



Translation Between PAs' Native Languages and OA's Interchange Language

- Each **rule engine** can use its *own* **rule language**
- Agents require an **interchange language** so they can communicate with each other
- Rule Responder uses RuleML as its interchange language
- Translations between the interchange language and the PA languages are done by the PAs

Reaction RuleML

- Reaction RuleML is a branch of the RuleML family that supports actions and events
- When two agents want to communicate, each others’ Reaction RuleML **messages** are sent through the ESB
- The ESB carries RuleML queries (requests), answers (results), and rule bases to/from agents

Example Reaction RuleML Message

```
<RuleML xmlns="http://www.ruleml.org/0.91/xsd"
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xsi:schemaLocation="http://www.ruleml.org/0.91/xsd
 http://ibis.in.tum.de/research/ReactionRuleML/0.2/rr.xsd"
 xmlns:ruleml2007="http://ibis.in.tum.de/projects/paw#">
        <Message mode="outbound" directive="query-sync">
                <oid> <Ind>RuleML-2009</Ind> </oid>
                <protocol> <Ind>esb</Ind> </protocol>
                <sender> <Ind>User</Ind> </sender>
                <content>
                        <Atom>
                                <Rel>getContact</Rel>
                                <Ind>ruleml2009_PanelChair</Ind>
                                <Ind>update</Ind>
                                <Var>Contact</Var>
                        </Atom>
                </content>
        </Message>
</RuleML>
```

Message Performatives

- The attribute **`directive="..."`** specifies the pragmatic performative
  - Message exchange/interaction protocols
- Rule Responder Performatives
  - In tradition of KQML and FIPA-ACL
  - Currently implemented: Query and Answer
  - Retract and Update requests planned in collaboration with RIF-PRD

Agent Communication Protocols

WSDL-like communication protocols

- **In-Only**
  - Message is sent from agent_1 to agent_2;
    then agent_2 executes performative
- **Request-Response**
  - Performs above In-Only;
    then agent_2 sends response to agent_1
- **Request-Response-Acknowledge**
  - Performs Request-Response;
    then agent_1 sends an acknowledgement to agent_2
- **Workflows**
  - Generalizes the above protocols to allow other compositions of message interchange between agents

Communication Middleware

- **Mule** Enterprise Service Bus (ESB)
  - Mule* is used to create communication end points at each personal and organizational agent of Rule Responder
  - Mule supports various transport protocols (e.g. HTTP, JMS, SOAP)
  - Rule Responder currently uses HTTP and JMS as transport protocols

* **Mule – The open source SOA infrastructure: http://mulesource.com**

Rule Engines

- Prova: Prolog + Java
- OO jDREW: Object Oriented
  java Deductive Reasoning Engine for the Web

Prova

- Prova is mainly used to realize the organizational agents of Rule Responder
- It implements Reaction RuleML for agent interaction (event-condition-action rules)

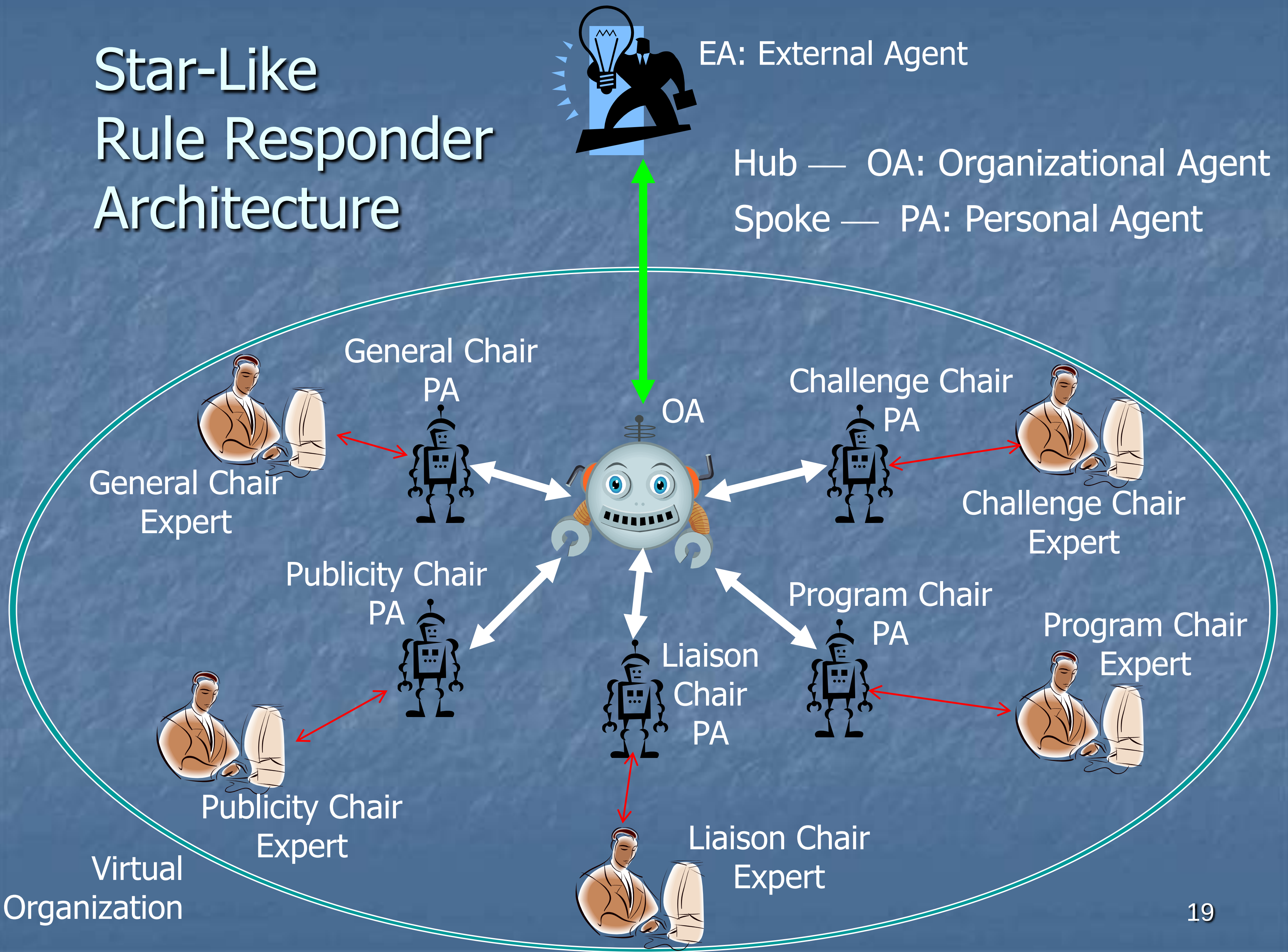
OO jDREW

- OO jDREW is used to realize the personal agents of Rule Responder
- It implements Hornlog RuleML for agent reasoning (Horn logic rules)
- Supports rules in two formats:
  - POSL: Positional Slotted presentation syntax
  - RuleML: XML interchange syntax (can be generated from POSL: http://www.jdrew.org/oojdrew/demo/translator)

Use Case: Symposium Planner

- RuleML-20xy Symposia
    - An organizational agent acts as the single point of entry to **assist** with the symposium:
        - Currently, query answering about the symposium
        - Ultimately, preparing and running the symposium
    - Personal agents have supported symposium chairs since 2007 (deployed as Q&A since 2008)
        - General Chair, Program Chair, Panel Chair, Publicity Chair, etc.

Star-Like Rule Responder Architecture



EA: External Agent

Hub — OA: Organizational Agent

Spoke — PA: Personal Agent

OA

General Chair PA

General Chair Expert

Challenge Chair PA

Challenge Chair Expert

Publicity Chair PA

Publicity Chair Expert

Liaison Chair PA

Liaison Chair Expert

Program Chair PA

Program Chair Expert

Virtual Organization

Online Use Case Demo

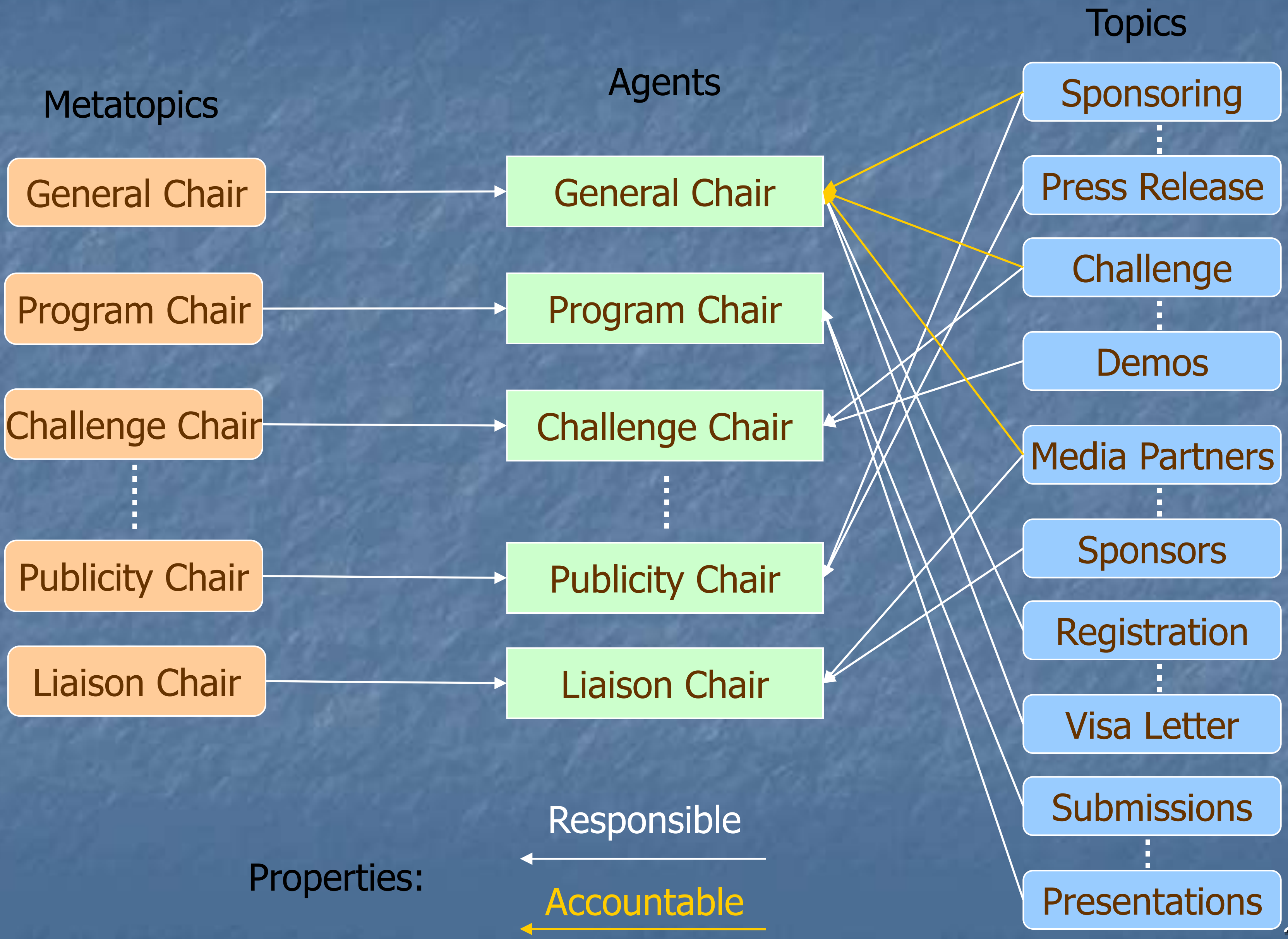
- Rule Responder:
  http://responder.ruleml.org
- RuleML-2007/2008/2009 Symposia:
  http://ibis.in.tum.de/projects/paw/ruleml-2007
  http://ibis.in.tum.de/projects/paw/ruleml-2008
  http://ruleml.org/RuleML-2009/RuleResponder
- Organizational agent:
  Supporting Symposium as a whole
- Personal agents:
  Supporting all Chairs

Online

Query Delegation

- Query delegation to personal agents is done by the organizational agent
- Tasks for the symposium organization are managed via a role assignment matrix
- Is defined here by an OWL Lite Ontology (alternatives: RDFS, RuleML, ...)
- Assigns (meta)topics to agents within the virtual organization: *... see next slide ...*

Role Assignment Ontology



Multiple Query Answers by PAs

- Some queries have more than one answer
- The PA will send the answers
  one at a time to the OA
  - interleaving backtracking and transmission
- When the PA finds no more answers,
  it sends an end-of-transmission message

Knowledge Shared Between Personal Agents

- Rules can be shared among personal agents
- Rules that apply to all PAs can be lifted to the OA level
- *... see next slide ...*

Organizational Symposium Agent Knowledge Base

```
% Sample Prova rule stored in the OA:
getContact(XID,Topic,Request,Contact) :-
   % Retrieve the responsible PA (Agent) for the Topic
   assigned(XID,Agent,Topic,ruleml2009_responsible),
   % Send the query to the PA
   sendMsg(XID,esb,Agent,"query",
              person(Role,Name,Title,Email,Telephone) ),
   % Receive the answer(s)
   rcvMult(XID,esb,Agent,"answer",Contact).
```

Personal General Chair Agent Knowledge Base: Fact

```
% Sample FOAF-like fact used by the OA rule:
% Example fact stored in the General Chair's PA
  person(
      symposiumChair[ ruleML_2009, general ],
      foafname[ firstName[ Adrian ], lastName[ Paschke ]],
      foaftitle[ title[ Dr ]],
      foafmbox[
        email[ adrianDOTpaschkeATbiotecDOTtuDASHdresdenDOTde ]],
      exphones[ telephoneNumbers[ office[ 4935146340074 ]]]).

   % Sample query in RuleML syntax:
```

... see next slide ...

Sample Message to Organizational Agent

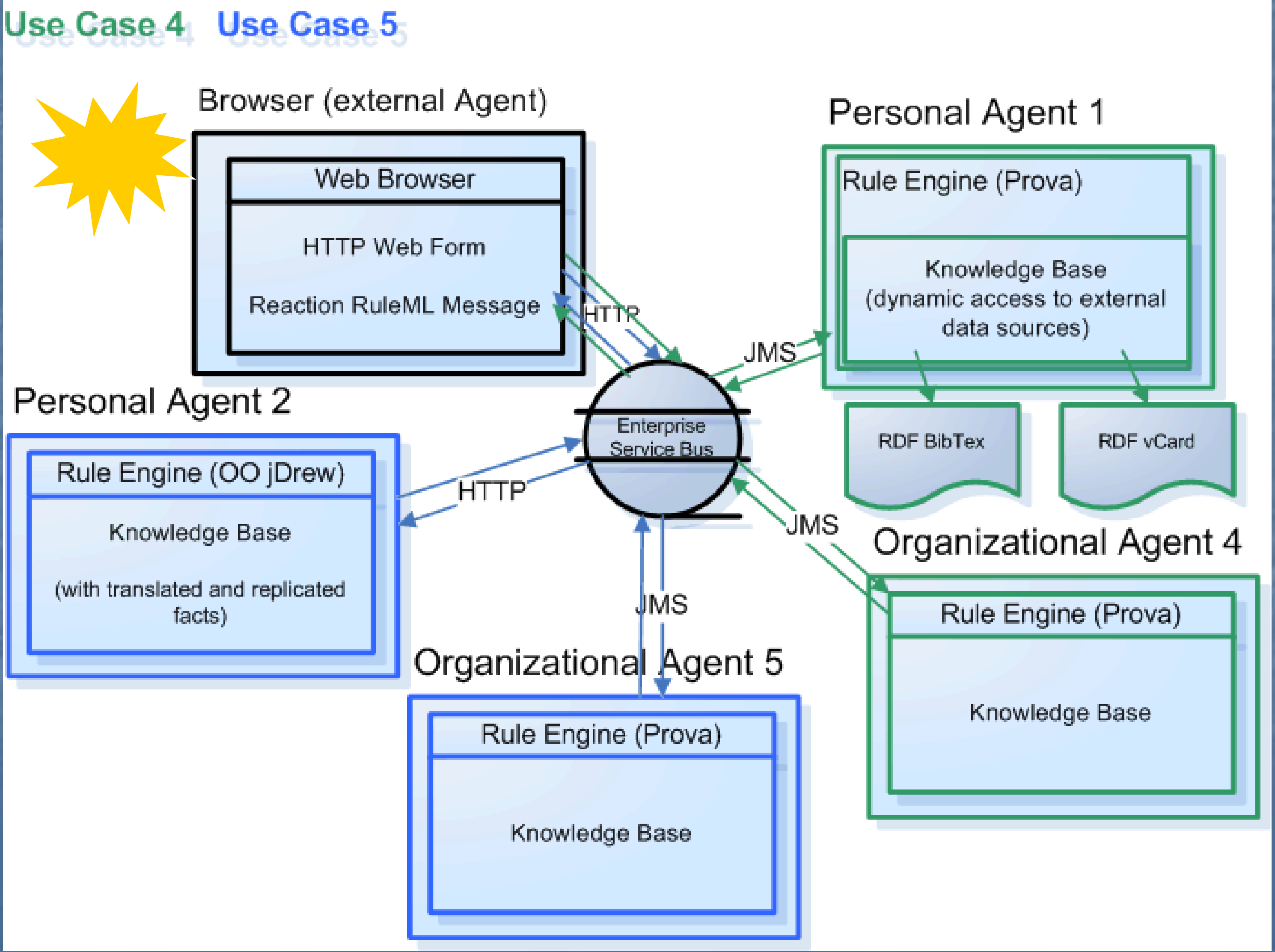
```
<RuleML xmlns="http://www.ruleml.org/0.91/xsd"
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xsi:schemaLocation="http://www.ruleml.org/0.91/xsd
 http://ibis.in.tum.de/research/ReactionRuleML/0.2/rr.xsd"
 xmlns:ruleml2007="http://ibis.in.tum.de/projects/paw#">
      <Message mode="outbound" directive="query-sync">
            <oid>
                  <Ind>RuleML-2009</Ind>
            </oid>
            <protocol>
                  <Ind>esb</Ind>
            </protocol>
            <sender>
                  <Ind>User</Ind>
            </sender>
            <content>
                  <Atom>
                        <Rel>getContact</Rel>
                        <Ind>ruleml2009_GeneralChair</Ind>
                        <Ind>update</Ind>
                        <Var>Contact</Var>
                  </Atom>
            </content>
      </Message>
</RuleML>
```

Online

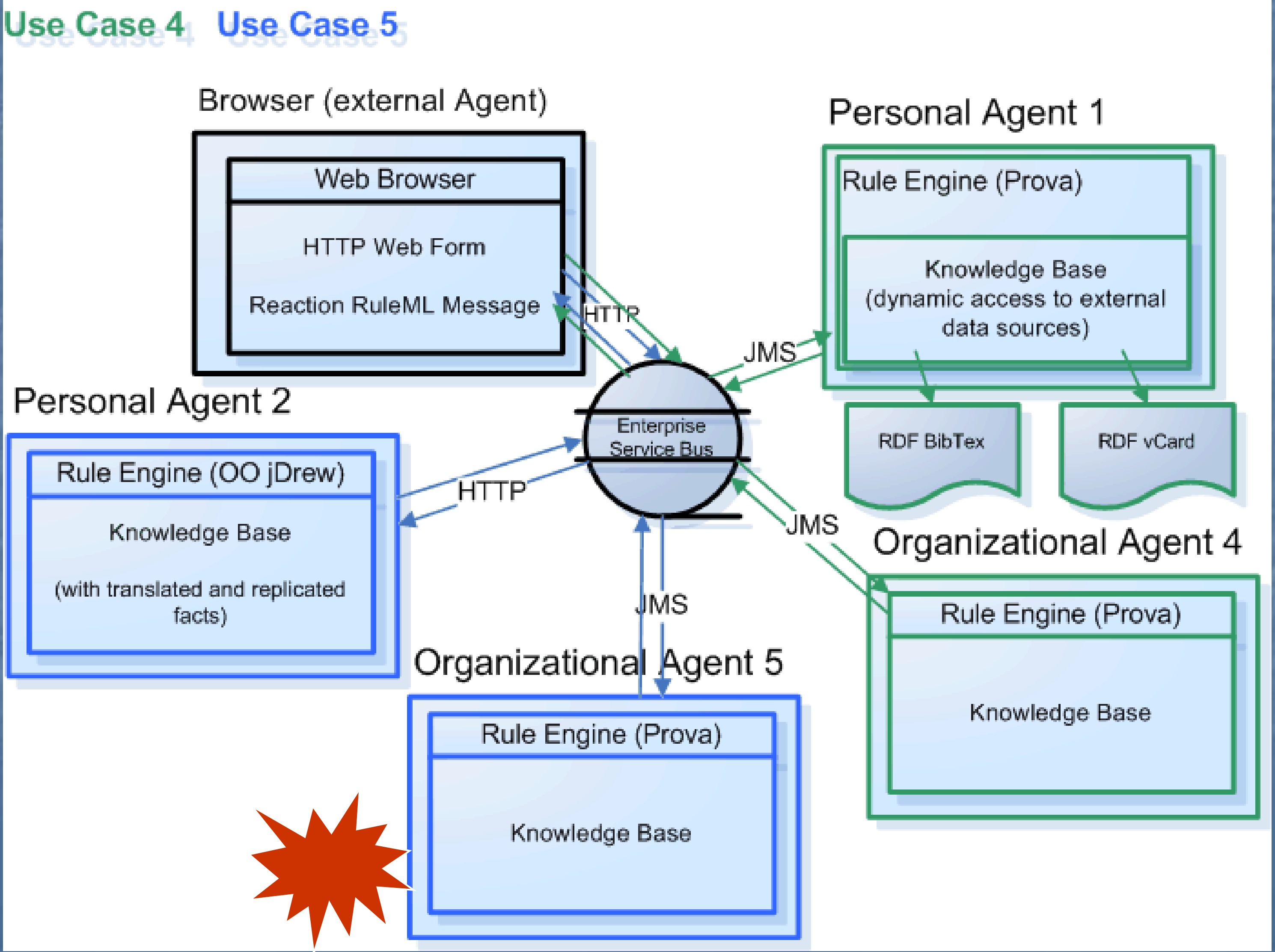
http://ruleml.org/RuleML-2009/RuleResponder/

Query Selection: General Chair Contact

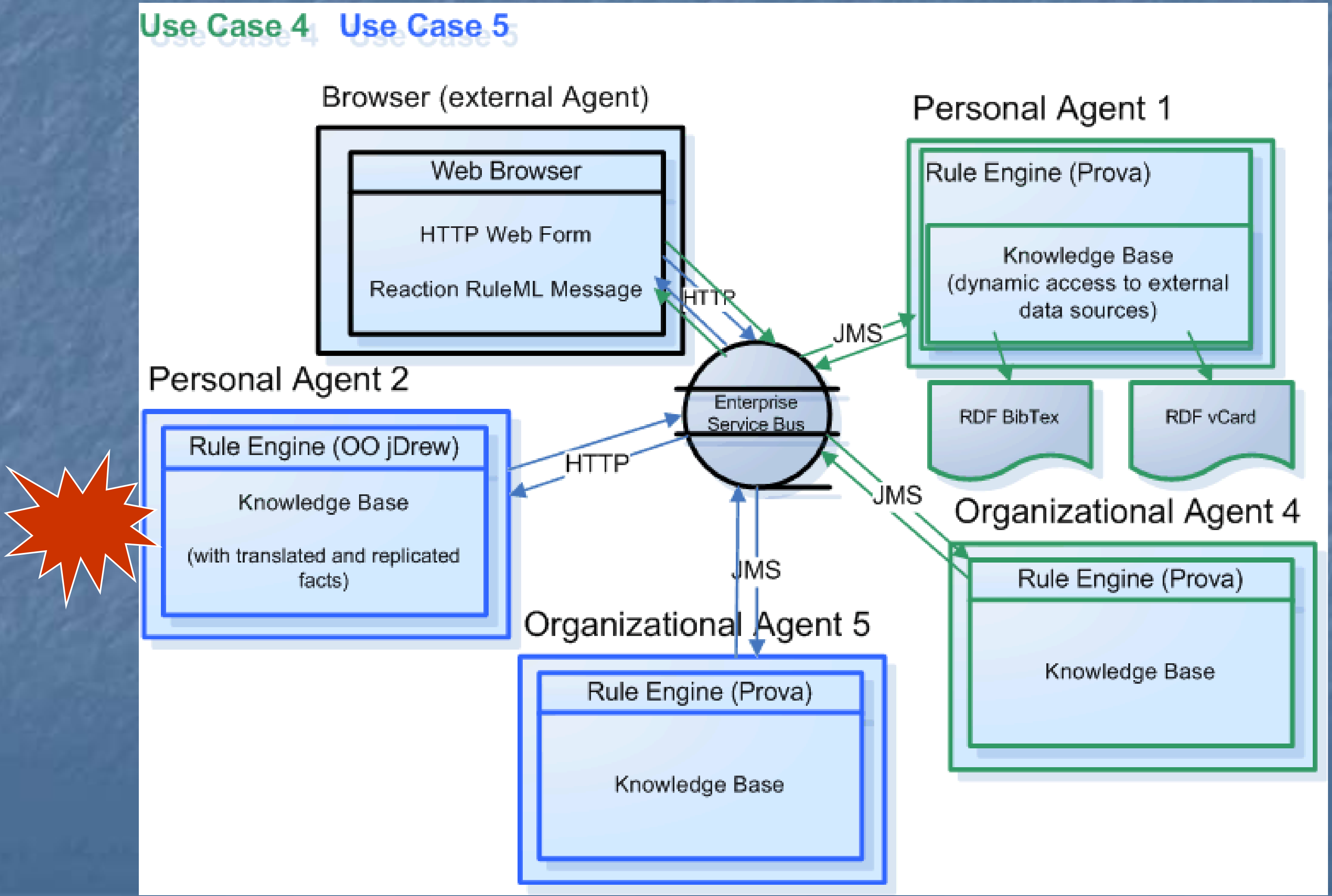
Architecture - Execution



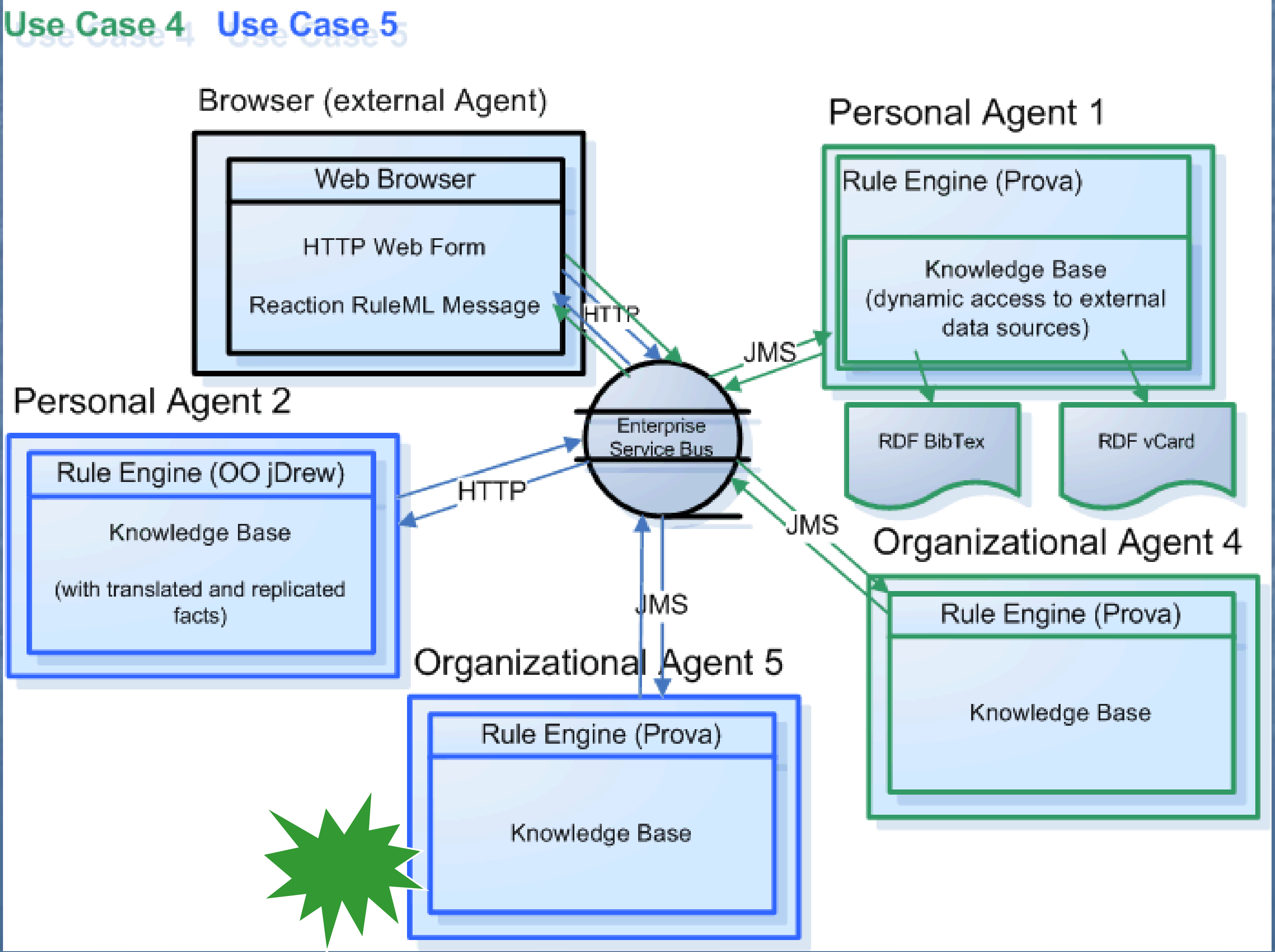
Architecture - Execution



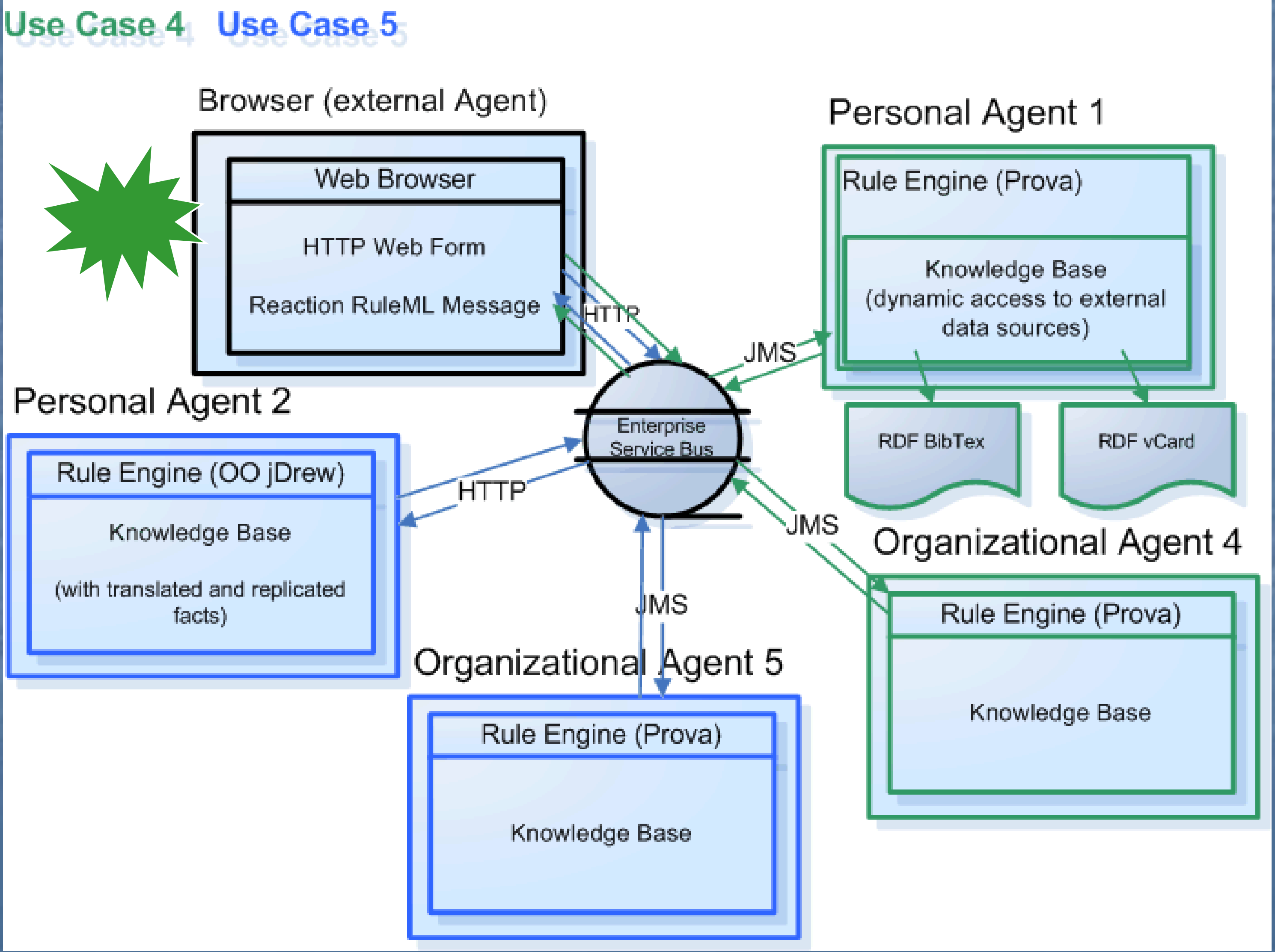
Architecture - Execution

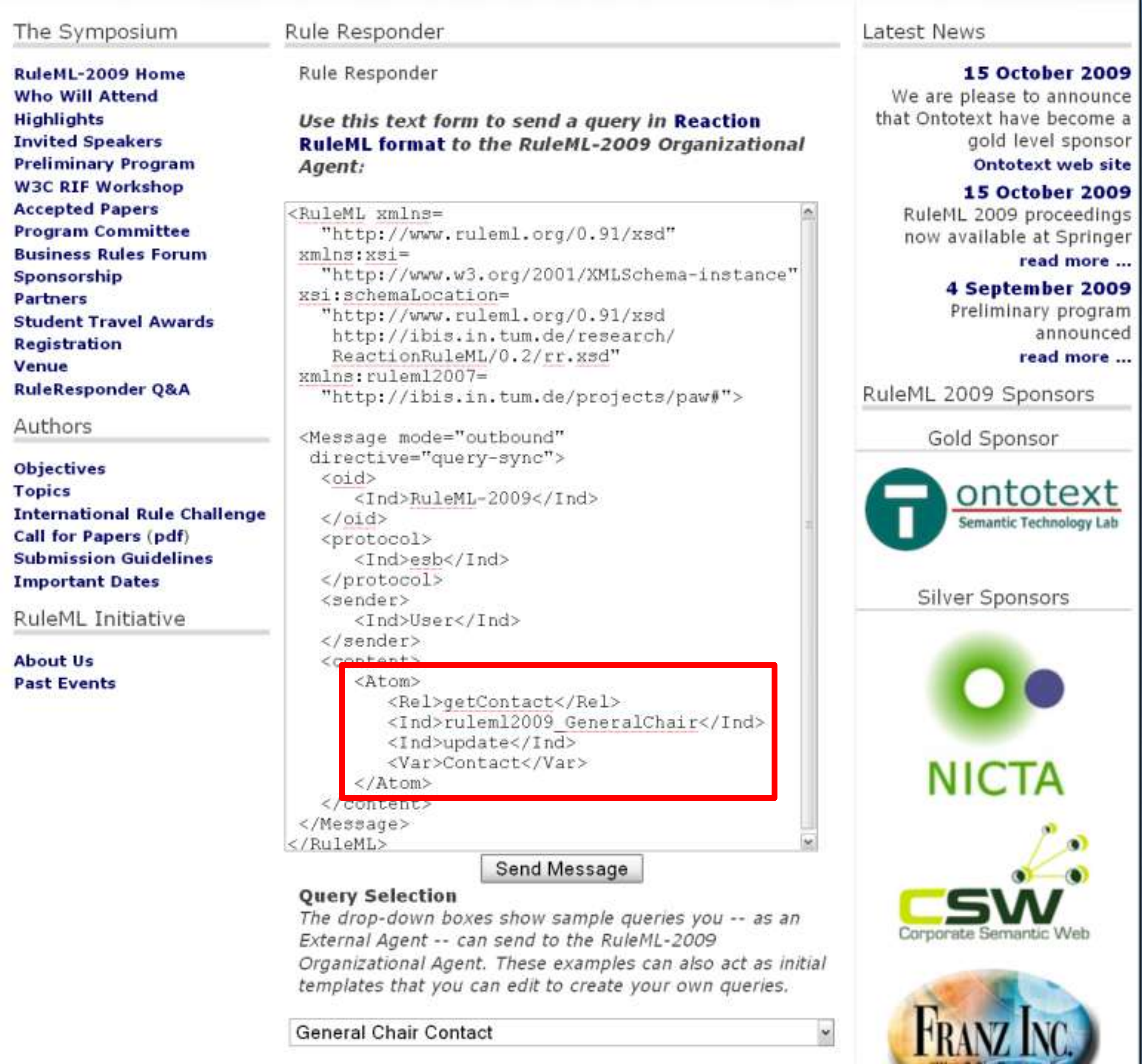


Architecture - Execution



Architecture - Execution





The Symposium

- RuleML-2009 Home
- Who Will Attend
- Highlights
- Invited Speakers
- Preliminary Program
- W3C RIF Workshop
- Accepted Papers
- Program Committee
- Business Rules Forum
- Sponsorship
- Partners
- Student Travel Awards
- Registration
- Venue
- RuleResponder Q&A

Authors

- Objectives
- Topics
- International Rule Challenge
- Call for Papers (pdf)
- Submission Guidelines
- Important Dates

RuleML Initiative

- About Us
- Past Events

Rule Responder

Rule Responder

Use this text form to send a query in Reaction RuleML format to the RuleML-2009 Organizational Agent:

```
<RuleML xmlns=
  "http://www.ruleml.org/0.91/xsd"
 xmlns:xsi=
  "http://www.w3.org/2001/XMLSchema-instance"
 xsi:schemaLocation=
  "http://www.ruleml.org/0.91/xsd
   http://ibis.in.tum.de/research/
   ReactionRuleML/0.2/rr.xsd"
 xmlns:ruleml2007=
  "http://ibis.in.tum.de/projects/paw#">

 <Message mode="outbound"
  directive="query-sync">
   <oid>
      <Ind>RuleML-2009</Ind>
   </oid>
   <protocol>
      <Ind>esb</Ind>
   </protocol>
   <sender>
      <Ind>User</Ind>
   </sender>
   <content>
      <Atom>
         <Rel>getContact</Rel>
         <Ind>ruleml2009_GeneralChair</Ind>
         <Ind>update</Ind>
         <Var>Contact</Var>
      </Atom>
   </content>
 </Message>
</RuleML>
```

Query Selection

The drop-down boxes show sample queries you -- as an External Agent -- can send to the RuleML-2009 Organizational Agent. These examples can also act as initial templates that you can edit to create your own queries.

General Chair Contact

Latest News

15 October 2009
We are please to announce that Ontotext have become a gold level sponsor
Ontotext web site

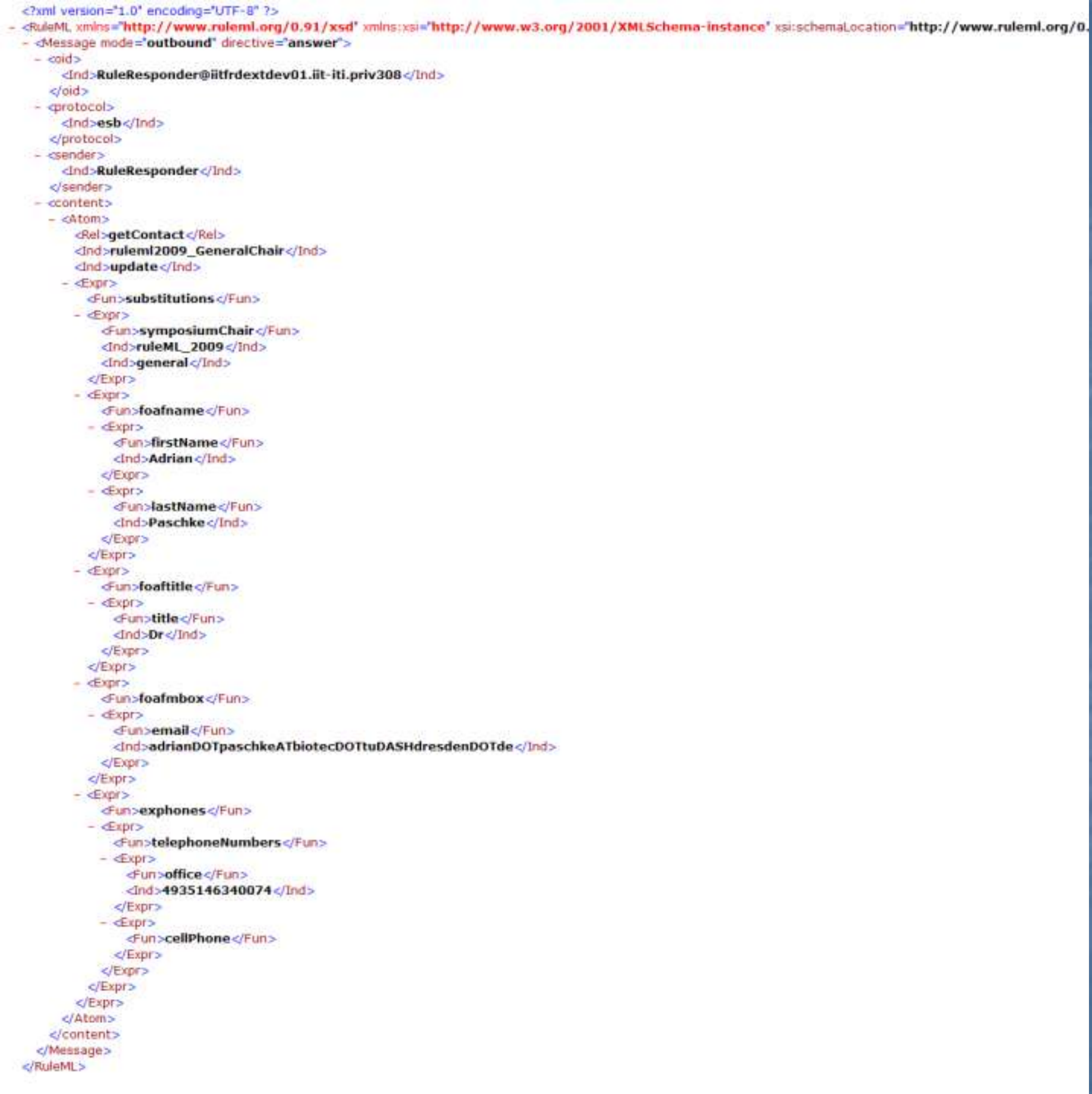
15 October 2009
RuleML 2009 proceedings now available at Springer
read more ...

4 September 2009
Preliminary program announced
read more ...

RuleML 2009 Sponsors

Gold Sponsor

Silver Sponsors



```
  <?xml version="1.0" encoding="UTF-8" ?>
- <RuleML xmlns="http://www.ruleml.org/0.91/xsd" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.ruleml.org/0.
  - <Message mode="outbound" directive="answer">
    - <oid>
        <Ind>RuleResponder@iitfrdextdev01.iit-iti.priv308</Ind>
      </oid>
    - <protocol>
        <Ind>esb</Ind>
      </protocol>
    - <sender>
        <Ind>RuleResponder</Ind>
      </sender>
    - <content>
      - <Atom>
          <Rel>getContact</Rel>
          <Ind>ruleml2009_GeneralChair</Ind>
          <Ind>update</Ind>
        - <Expr>
            <Fun>substitutions</Fun>
          - <Expr>
              <Fun>symposiumChair</Fun>
              <Ind>ruleML_2009</Ind>
              <Ind>general</Ind>
            </Expr>
          - <Expr>
              <Fun>foafname</Fun>
            - <Expr>
                <Fun>firstName</Fun>
                <Ind>Adrian</Ind>
              </Expr>
            - <Expr>
                <Fun>lastName</Fun>
                <Ind>Paschke</Ind>
              </Expr>
            </Expr>
          - <Expr>
              <Fun>foaftitle</Fun>
            - <Expr>
                <Fun>title</Fun>
                <Ind>Dr</Ind>
              </Expr>
            </Expr>
          - <Expr>
              <Fun>foafmbox</Fun>
            - <Expr>
                <Fun>email</Fun>
                <Ind>adrianDOTpaschkeATbiotecDOTtuDASHdresdenDOTde</Ind>
              </Expr>
            </Expr>
          - <Expr>
              <Fun>exphones</Fun>
            - <Expr>
                <Fun>telephoneNumbers</Fun>
              - <Expr>
                  <Fun>office</Fun>
                  <Ind>4935146340074</Ind>
                </Expr>
              - <Expr>
                  <Fun>cellPhone</Fun>
                </Expr>
              </Expr>
            </Expr>
          </Expr>
        </Atom>
      </content>
    </Message>
  </RuleML>
```

Sample Message to Publicity Chair Agent (I)

```
<content>
 <Atom>
    <Rel>sponsor</Rel>
    <Expr>
      <Fun>contact</Fun>
      <Ind>Mark</Ind>
      <Ind>JBoss</Ind>
    </Expr>
    <Ind type="integer">500</Ind>
    <Expr>
      <Fun>results</Fun>
      <Var>Level</Var>
      <Var>Benefits</Var>
      <Var>DeadlineResults</Var>
    </Expr>
    <Expr>
      <Fun>performative</Fun>
      <Var>Action</Var>
    </Expr>
 </Atom>
</content>
```

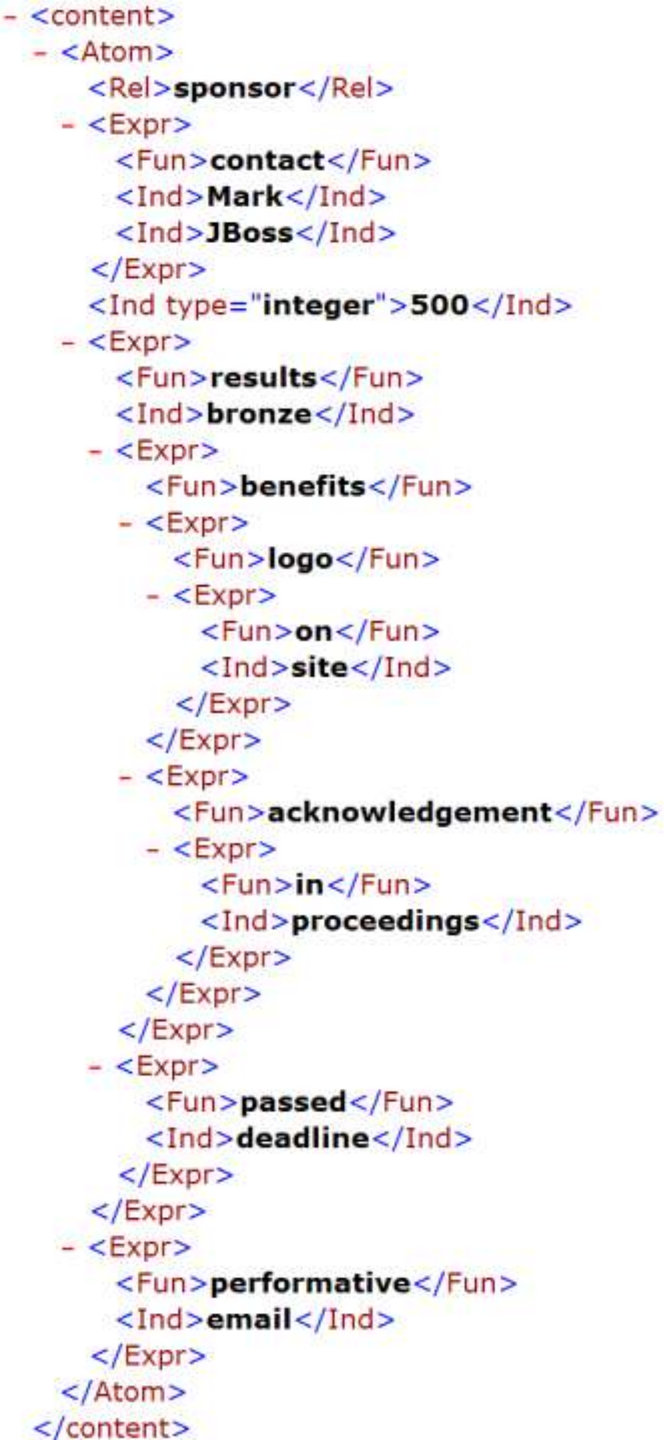
Online

http://www.ruleml.org/RuleML-2009/RuleResponder

Query Selection: Publicity Chair Sponsoring

English Description:

Mark from JBoss would like to sponsor RuleML-2009 with $**500**. What level, benefits, and deadline results will this provide, and what kind of action should be taken?



```
- <content>
  - <Atom>
      <Rel>sponsor</Rel>
    - <Expr>
        <Fun>contact</Fun>
        <Ind>Mark</Ind>
        <Ind>JBoss</Ind>
      </Expr>
      <Ind type="integer">500</Ind>
    - <Expr>
        <Fun>results</Fun>
        <Ind>bronze</Ind>
      - <Expr>
          <Fun>benefits</Fun>
        - <Expr>
            <Fun>logo</Fun>
          - <Expr>
              <Fun>on</Fun>
              <Ind>site</Ind>
            </Expr>
          </Expr>
        - <Expr>
            <Fun>acknowledgement</Fun>
          - <Expr>
              <Fun>in</Fun>
              <Ind>proceedings</Ind>
            </Expr>
          </Expr>
        </Expr>
      - <Expr>
          <Fun>passed</Fun>
          <Ind>deadline</Ind>
        </Expr>
      </Expr>
    - <Expr>
        <Fun>performative</Fun>
        <Ind>email</Ind>
      </Expr>
    </Atom>
  </content>
```

Personal Publicity Chair Agent Knowledge Base: Rule

```
% Rule stored in the Publicity Chair's PA
sponsor(contact[?Name,?Organization],
          ?Amount:integer,
          results[?Level,?Benefits,?DeadlineResults] ,
          performative[?Action])    :-

   requestSponsoringLevel(?Amount:integer,?Level),
   requestBenefits(?Level,?Benefits),
   checkDeadline(?DeadlineResults),
   checkAction(?Action,?Level,?Amount:integer).
```

Orange:
Query
other rules

Personal Publicity Chair Agent Knowledge Base: 1st & 2nd Rule Premise

requestSponsoringLevel(?Amount:integer,?Level),

% Satisfied by rule:

```
requestSponsoringLevel(?Amount:integer,?Level) :-
    sponsoringLevel(rank0,
                    ?Level,
                    under[us$[?UnderBronzeAmount:integer]]),
    lessThan(?Amount:integer,?UnderBronzeAmount:integer).
```

Light Red:
Query facts

requestBenefits(?Level,?Benefits),

% Satisfied by rule:

```
requestBenefits(?Level,?Benefits) :-
   benefits(?Level,?Benefits).
```

Personal Publicity Chair Agent Knowledge Base: 3rd & 4th Rule Premise

```
checkDeadline(?DeadlineResults),
% Satisfied by rule:
checkDeadline(passed[deadline]):-
    date(?X:integer),
    deadline(sponsoring,?D:integer),
    greaterThan(?X:integer,?D:integer).

checkAction(?Action,?Level,?Amount:integer).
% Satisfied by rule:
checkAction(?Action,?Level,?Amount:integer) :-
    actionPerformed(?Action,?Level,?Amount:integer).
```

Yellow:
Query further rule

What happens if we now provide a ***$5000*** *sponsorship?*
... see next slide ...

Sample Message to Publicity Chair Agent (II)

```
<content>
  <Atom>
         <Rel>sponsor</Rel>
         <Expr>
            <Fun>contact</Fun>
            <Ind>Mary</Ind>
            <Ind>Super</Ind>
         </Expr>
         <Ind type="integer">5000</Ind>
         <Expr>
            <Fun>results</Fun>
            <Var>Level</Var>
            <Var>Benefits</Var>
            <Var>DeadlineResults</Var>
         </Expr>
         <Expr>
            <Fun>performative</Fun>
            <Var>Action</Var>
         </Expr>
  </Atom>
</content>
```

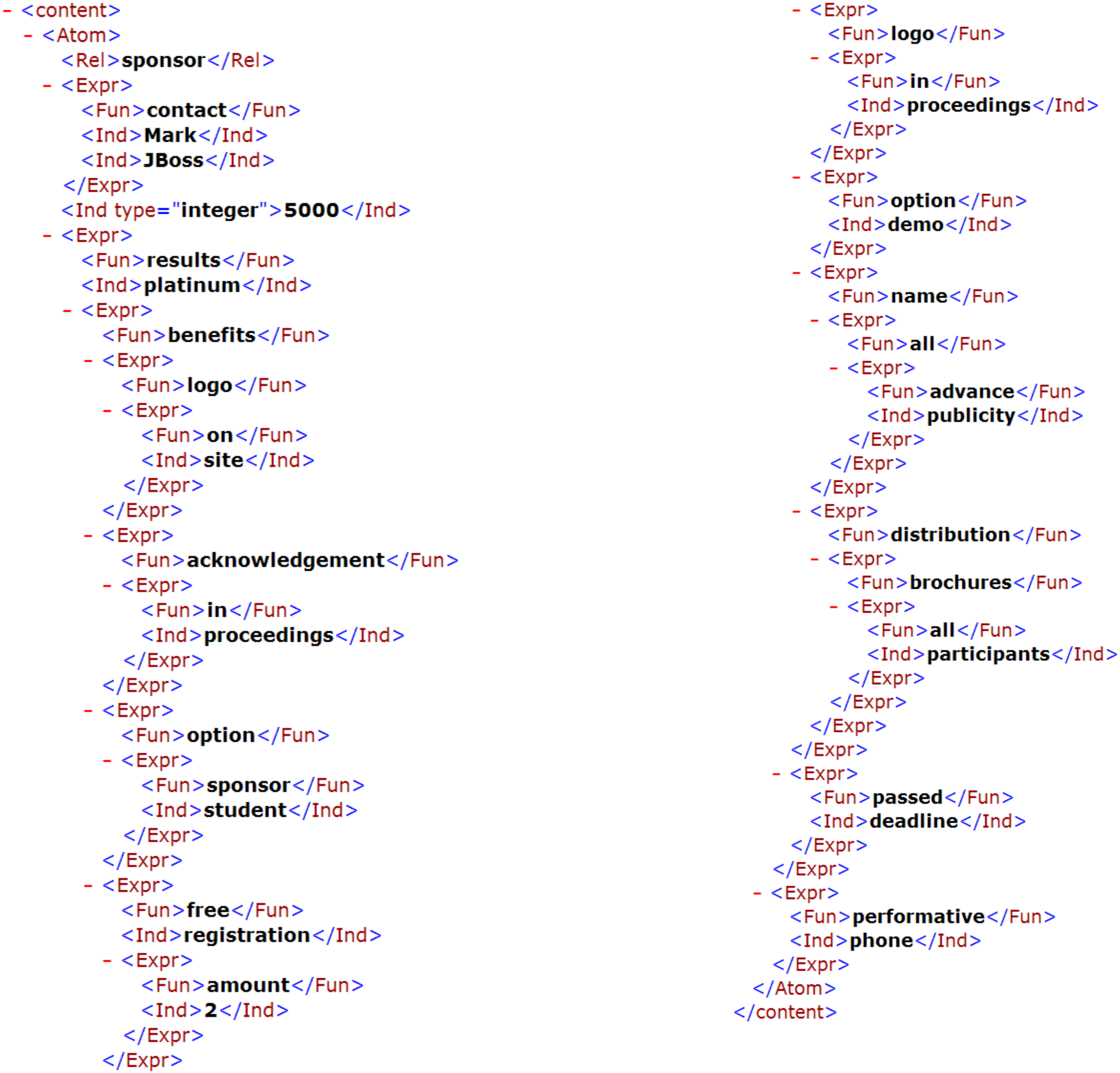
Online

http://www.ruleml.org/RuleML-2009/RuleResponder

Query Selection: Publicity Chair Sponsoring (edit)

English Description:

Mark from JBoss would like to sponsor RuleML-2009 with $**5000**. What level, benefits, and deadline results will this provide, and what kind of action should be taken?



```
- <content>
  - <Atom>
      <Rel>sponsor</Rel>
    - <Expr>
        <Fun>contact</Fun>
        <Ind>Mark</Ind>
        <Ind>JBoss</Ind>
      </Expr>
      <Ind type="integer">5000</Ind>
    - <Expr>
        <Fun>results</Fun>
        <Ind>platinum</Ind>
      - <Expr>
          <Fun>benefits</Fun>
        - <Expr>
            <Fun>logo</Fun>
          - <Expr>
              <Fun>on</Fun>
              <Ind>site</Ind>
            </Expr>
          </Expr>
        - <Expr>
            <Fun>acknowledgement</Fun>
          - <Expr>
              <Fun>in</Fun>
              <Ind>proceedings</Ind>
            </Expr>
          </Expr>
        - <Expr>
            <Fun>option</Fun>
          - <Expr>
              <Fun>sponsor</Fun>
              <Ind>student</Ind>
            </Expr>
          </Expr>
        - <Expr>
            <Fun>free</Fun>
            <Ind>registration</Ind>
          - <Expr>
              <Fun>amount</Fun>
              <Ind>2</Ind>
            </Expr>
          </Expr>
        - <Expr>
            <Fun>logo</Fun>
          - <Expr>
              <Fun>in</Fun>
              <Ind>proceedings</Ind>
            </Expr>
          </Expr>
        - <Expr>
            <Fun>option</Fun>
            <Ind>demo</Ind>
          </Expr>
        - <Expr>
            <Fun>name</Fun>
          - <Expr>
              <Fun>all</Fun>
            - <Expr>
                <Fun>advance</Fun>
                <Ind>publicity</Ind>
              </Expr>
            </Expr>
          </Expr>
        - <Expr>
            <Fun>distribution</Fun>
          - <Expr>
              <Fun>brochures</Fun>
            - <Expr>
                <Fun>all</Fun>
                <Ind>participants</Ind>
              </Expr>
            </Expr>
          </Expr>
        </Expr>
      - <Expr>
          <Fun>passed</Fun>
          <Ind>deadline</Ind>
        </Expr>
      </Expr>
    - <Expr>
        <Fun>performative</Fun>
        <Ind>phone</Ind>
      </Expr>
    </Atom>
  </content>
```

Conclusion (I)

- Rule Responder was implemented & tested for various use cases (http://responder.ruleml.org) and deployed for RuleML-2008/2009 Q&A
- Its organizational agents delegate external queries to topic-assigned personal agents
- It couples rule engines OO jDREW & Prova (& Euler) via Mule middleware and RuleML 0.91 XML interchange format

Conclusion (II)

- Without a Reaction Rule Dialect, RIF could not be used for behavioral Responder logic
- Current system is reusable on all levels: Symposium Planner, Rule Responder, POSL, RuleML, OO jDREW, Prova, Mule
- RuleML Techn. Group with Adrian Paschke, Alexander Kozlenkov and Nick Bassiliades
- Integrated another 'partner engine', Euler, for recent use cases, e.g. in WellnessRules

Future Work (I)

- Communication between
  Personal Agent and Expert Owner
  - The PA may need to interact with its expert owner
  - The intended formal interaction between PAs and their owners could use email (SMTP)
  - The initial interaction language for these emails could be Reaction RuleML
- Query Decomposition
  - Each subquery of a rule can be decomposed for different PAs, followed by answer integration

Future Work (II)

- Centralized, Distributed-Hierarchical (here), and Distributed-Networked (future) Query Answering
- Centralized: Avoids Communication Overhead
- Distributed: Fault Tolerance
  - Alternative agents when an agent becomes defunct
  - Hierarchical: OA still a bottleneck
- From Centralized to Distributed Knowledge Maintenance
  - Easier to keep Distributed Rules up-to-date
- Technical Report: http://ruleml.org/papers/EvalArchiRule.pdf