Personal Agents in the Rule Responder Architecture

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RuleML-2008
Orlando Florida
October 30-31, 2008

Outline

- Rule Responder Overview
- Agents
  - Personal / Organizational / External
- Infrastructure
  - Reaction RuleML Messages
  - Message Performatives
  - Agent Communication Protocols
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- 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 a virtual organization
- 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
  - Reaction RuleML: Interaction
- Implemented on top of a Mule-based Service Oriented Architecture (SOA)

Personal Agents

- A personal agent assists a single person of an organization, (semi-autonomously) acting on his/her behalf
- It contains a FOAF*-like **fact** profile plus FOAF-extending **rules** to encode selected 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

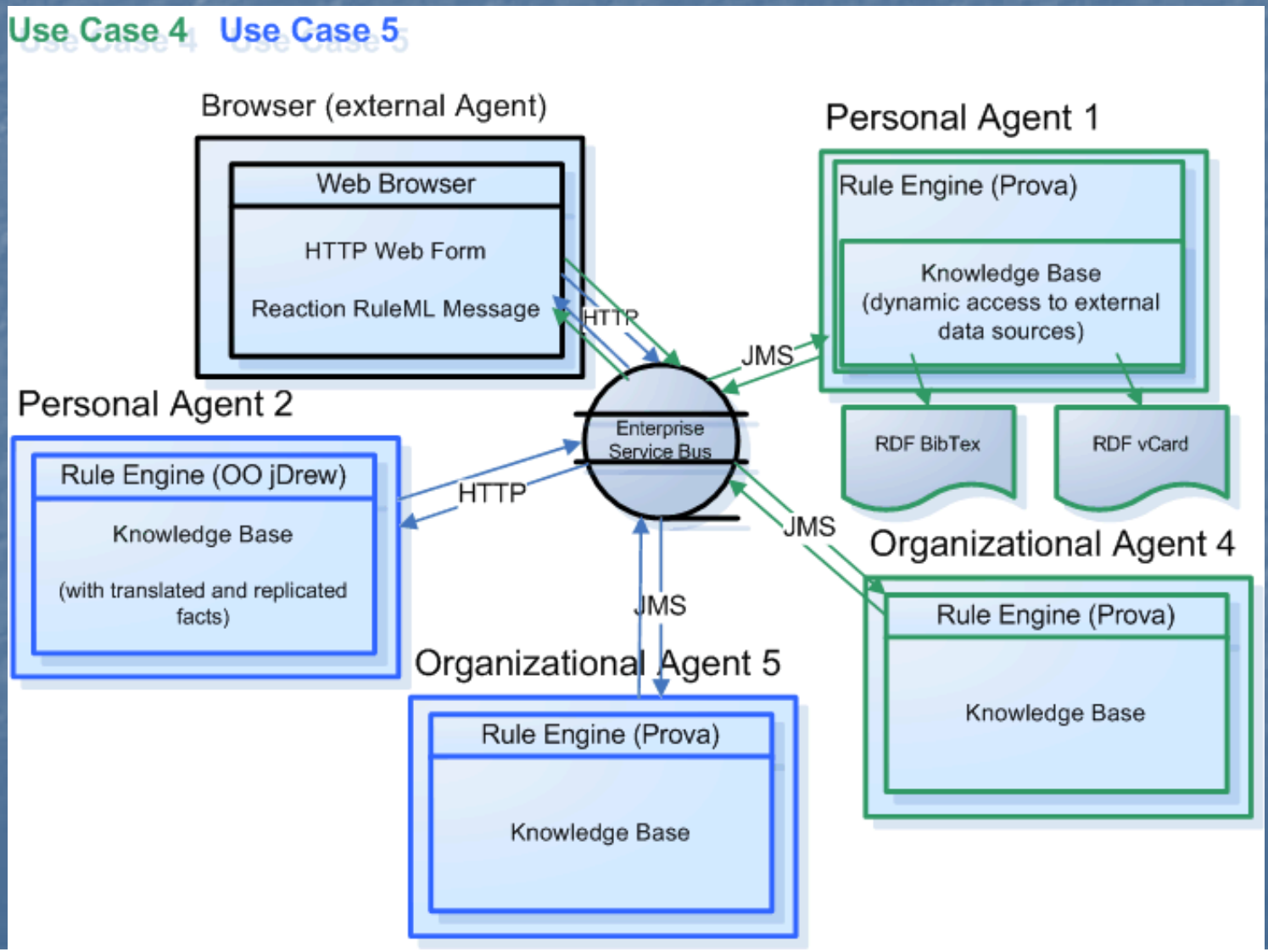
External Agents

- External agents exchange messages with (the public interface of) organizational agents, asking queries, receiving answers, 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 a System of OAs, PAs, and EAs
- Built on the Mule ESB
- The OAs and PAs are realized each with an instance of a Rule Engine
- Combines the ideas of multi-agent systems, distributed rule management systems, as well as service-oriented and event-driven architectures

Infrastructure - Overview



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 that they can understand each other
- Rule Responder uses Reaction RuleML as its interchange language
- Translation is done with an XSLT stylesheet

Reaction RuleML

- Reaction RuleML is a branch of the RuleML family that supports actions and events
- When two agents need to communicate, each others' Reaction RuleML messages are sent through the ESB
- Carries RuleML queries, answers, 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-2008</Ind> </oid>
           <protocol> <Ind>esb</Ind> </protocol>
           <sender> <Ind>User</Ind> </sender>
           <content>
                <Atom>
                     <Rel>getContact</Rel>
                     <Ind>ruleml2008_PanelChair</Ind>
                     <Ind>update</Ind>
                     <Var>Contact</Var>
                </Atom>
           </content>
      </Message>
</RuleML>
```

Message Performatives

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

Agent Communication Protocols

WSDL-like protocols

- In-Only
  - Message is sent to $agent_1$ from $agent_2$; then $agent_1$ executes performative
- Request-Response
  - Performs above in-only; then $agent_1$ sends response back to $agent_2$
- Request-Response-Acknowledge
  - Does Request-Response; then $agent_2$ sends a response back to $agent_1$
- Workflows
  - Generalizes the above protocols to allow arbitrary compositions of agent messages

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)

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 in 2008)
    - General Chair, Program Chair, Panel Chair, Publicity Chair, etc.

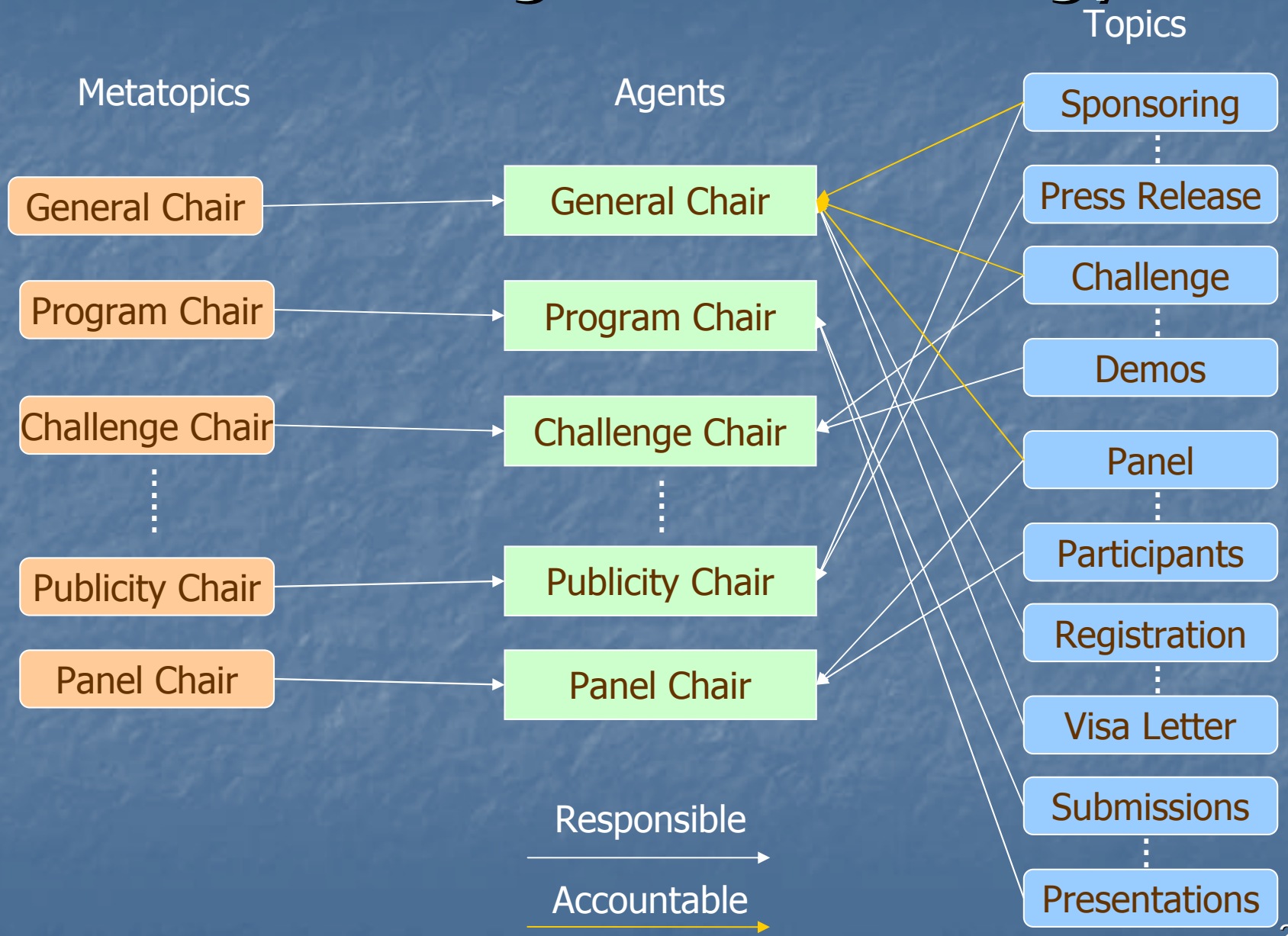
Online Use Case Demo

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

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 (interleaved backtracking and transmission)
- When no more answers are computed, an end-of-transmission message is sent back

Shared Knowledge Between Personal Agents

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

Organizational Symposium Agent Knowledge Base

```
% Sample Prova-like rule (in POSL syntax)
   stored in the OA:
getContact(?topic, ?request, ?contact) :-
% Uses the topic and request to delegate the
   following query to appropriate PA
person(
    ?contact, ?role, ?title, ?email, ?telephone).
```

Personal Panel Chair Agent Knowledge Base

% Sample FOAF-like facts used by the OA rule:

% Example fact stored in the Panel Chair's PA

person(John, PanelChair, PHD,
john@email.com, 1-555-555-5555)

% Example fact stored in the Publicity Chair's PA

person(Tracy, PublicityChair, PHD,
tracy@email.com, 1-444-444-4444)

% Sample query in RuleML syntax:

... see next slide ...

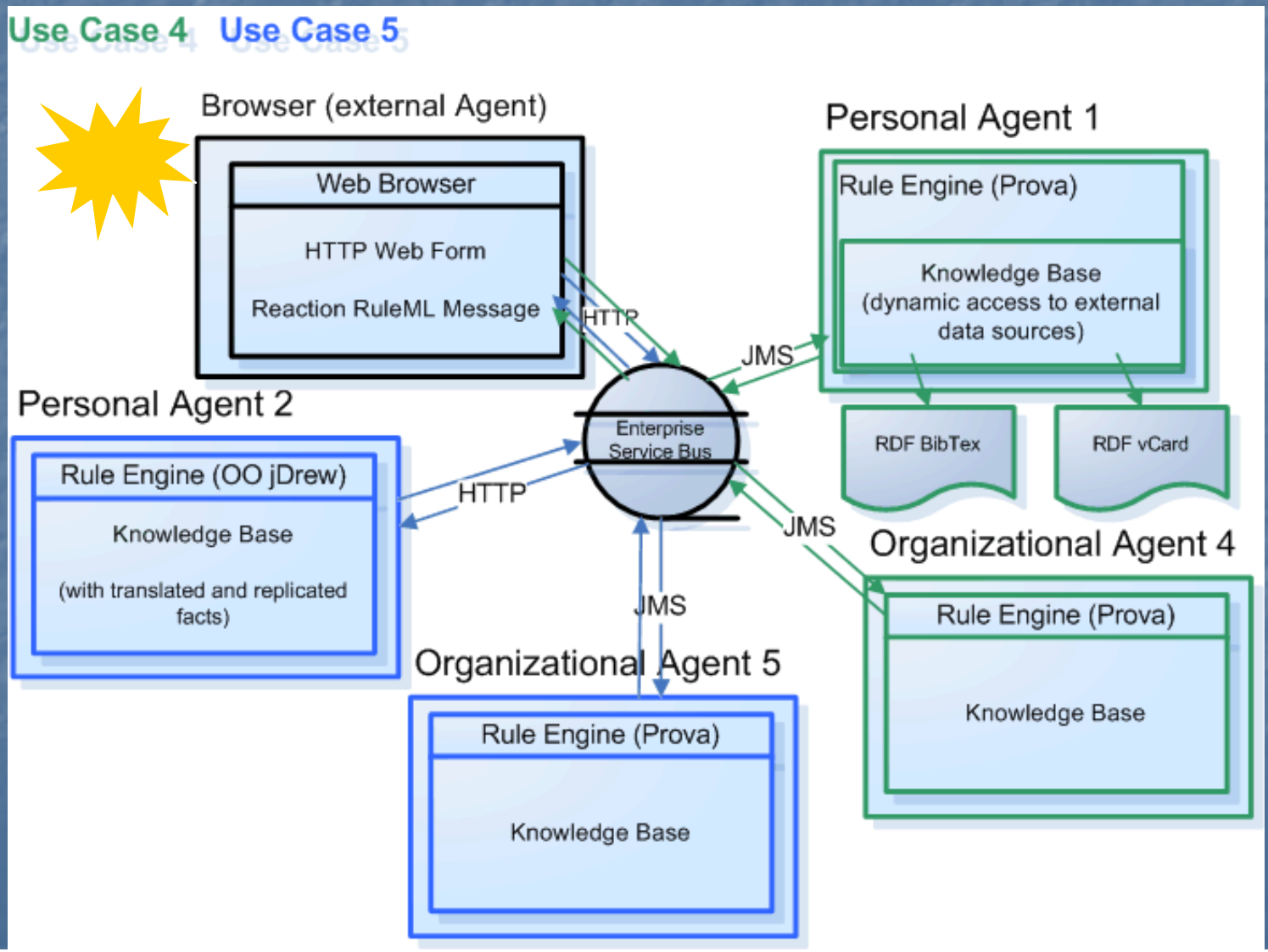
Sample Message to Organizational Agent

```
<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-2008</Ind>
                </oid>
                <protocol>
                        <Ind>esb</Ind>
                </protocol>
                <sender>
                        <Ind>User</Ind>
                </sender>
                <content>
                        <Atom>
                                <Rel>getContact</Rel>
                                <Ind>ruleml2008_PanelChair</Ind>
                                <Ind>update</Ind>
                                <Var>Contact</Var>
                        </Atom>
                </content>
        </Message>
</RuleML>
```

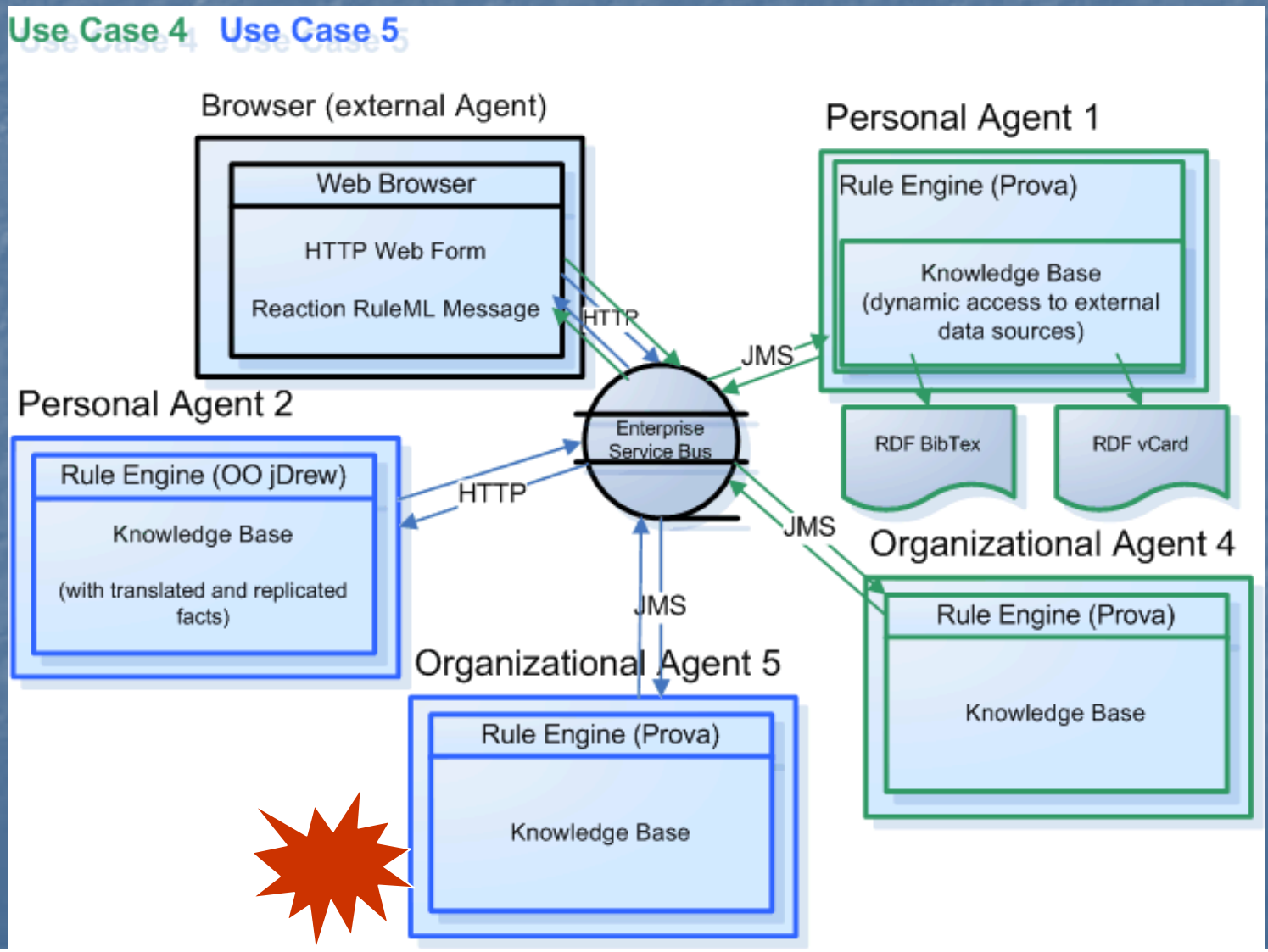
http://www.ruleml.org/RuleML-2008/RuleResponder

Query Selection: Panel Chair Contact

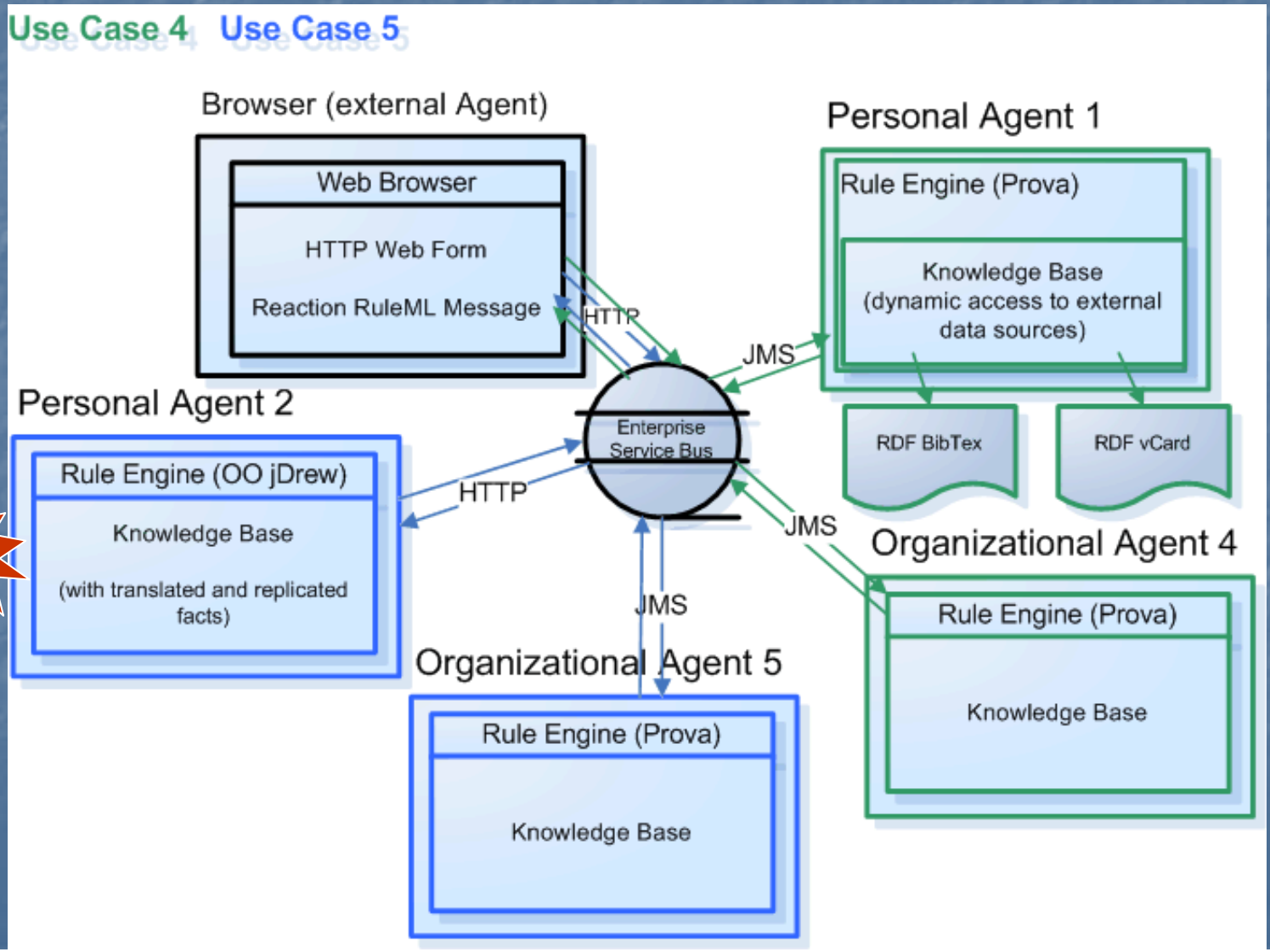
Architecture - Execution



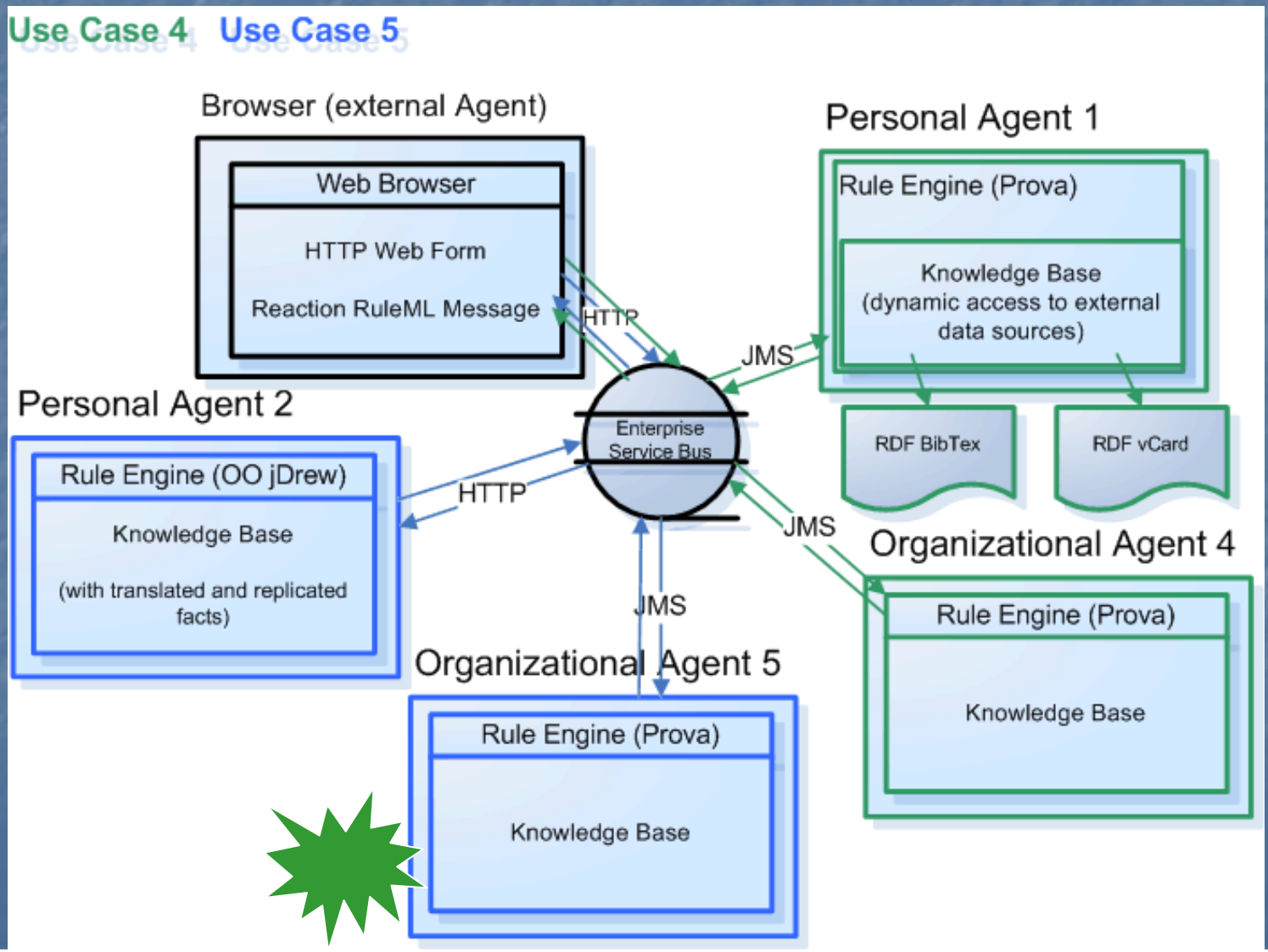
Architecture - Execution



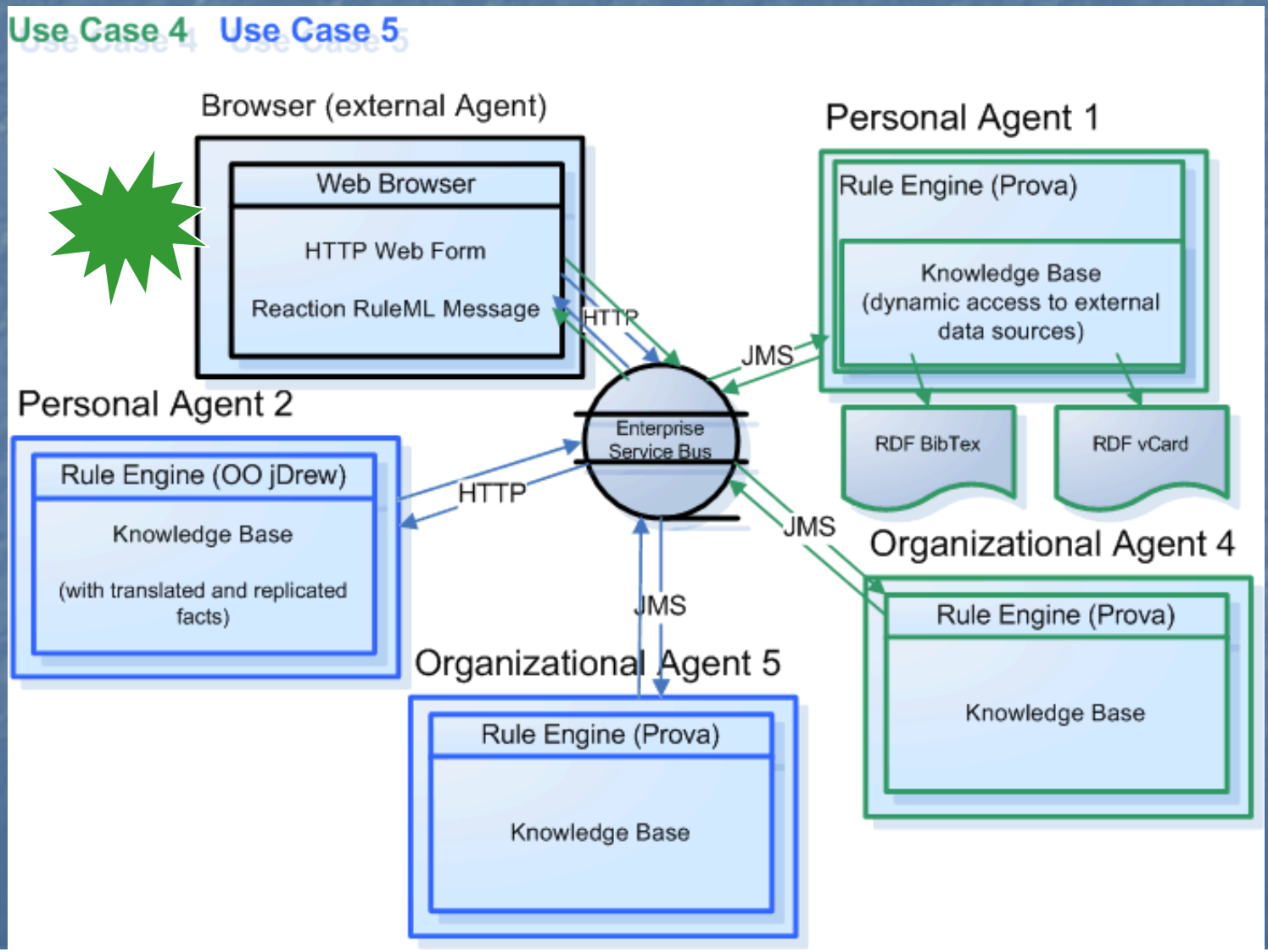
Architecture - Execution



Architecture - Execution



Architecture - Execution



Latest News

Updated - June 20, 2008

Calls for lightning talks, highlight talks and fast abstracts opened.
read more news

The Symposium

- Who Will Attend
- Highlights
- Keynote Speakers
- Venue
- Business Rule Forum

Authors

- Objectives
- Topics
- Open Calls
- RuleML-2008 Challenge
- Submission Guidelines
- Call for Papers (PDF)
- Important Dates

Organisation

- Organising Committee
- Program Committee
- Sponsorship

Rule Responder: RuleML-2008 Experimental Demo

DEMO ARCHITECTURE DESCRIPTION INTENTION ONTOLOGY

Use this text form to send a query in Reaction RuleML format ***to the RuleML-2008 Organizational Agent:***

```
xmlns:ruleml2007="http://ibis.in.tum.de/projects/paw#">
        <Message mode="outbound" directive="query-sync">
                <oid>
                        <Ind>RuleML-2008</Ind>
                </oid>
                <protocol>
                        <Ind>esb</Ind>
                </protocol>
                <sender>
                        <Ind>User</Ind>
                </sender>
                <content>
                        <Atom>
                                <Rel>getContact</Rel>
                                <Ind>ruleml2008_PublicityChair</Ind>
                                <Ind>update</Ind>
                                <Var>Contact</Var>
                        </Atom>
                </content>
        </Message>
</RuleML>
```

Send Message

Query Selection

Use the drop down box to select which query you want to send to the RuleML-2008 Organizational Agent:

Publicity Chair Contact

```
<?xml version="1.0" encoding="UTF-8" ?>
- <RuleML xmlns="http://www.ruleml.org/0.91/xsd" xmlns:xsi="http://www.w3.org/2001/XMLSchema-insta
  - <Message mode="outbound" directive="answer">
    + <oid>
    + <protocol>
    + <sender>
    - <content>
      - <Atom>
          <Rel>person</Rel>
        + <Expr>
        + <Expr>
        + <Expr>
        + <Expr>
        - <Expr>
            <Fun>foafname</Fun>
          - <Expr>
              <Fun>firstName</Fun>
              <Var>N@@82_Title</Var>
              <Ind>tracy</Ind>
            </Expr>
          - <Expr>
              <Fun>lastName</Fun>
              <Var>N@@82_Title</Var>
              <Ind>bost</Ind>
            </Expr>
          </Expr>
        </Atom>
      </content>
    </Message>
  - <Message mode="outbound" directive="answer">
    + <oid>
    + <protocol>
    + <sender>
    - <content>
      - <Atom>
          <Rel>person</Rel>
        + <Expr>
        + <Expr>
        + <Expr>
        + <Expr>
        - <Expr>
            <Fun>foafname</Fun>
          - <Expr>
              <Fun>firstName</Fun>
              <Var>N@@82_Title</Var>
              <Ind>matthias</Ind>
            </Expr>
          - <Expr>
              <Fun>lastName</Fun>
              <Var>N@@82_Title</Var>
              <Ind>nickles</Ind>
            </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>
```

http://www.ruleml.org/RuleML-2008/RuleResponder

Query Selection: Publicity Chair Sponsoring

```
- <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>onGoing</Fun>
          <Ind>deadline</Ind>
        </Expr>
      </Expr>
    - <Expr>
        <Fun>performative</Fun>
        <Ind>email</Ind>
      </Expr>
    </Atom>
  </content>
```

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>
```

http://www.ruleml.org/RuleML-2008/RuleResponder

Query Selection: Publicity Chair Sponsoring (edit)

```
- <content>
  - <Atom>
      <Rel>sponsor</Rel>
    + <Expr>
      <Ind type="integer">5000</Ind>
    - <Expr>
        <Fun>results</Fun>
        <Ind>platinum</Ind>
      - <Expr>
          <Fun>benefits</Fun>
        + <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>
            <Var>Benefits</Var>
            <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>
          <Var>Benefits</Var>
          <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>onGoing</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 Q&A
- Its organizational agents delegate external queries to topic-assigned personal agents
- It couples rule engines OO jDREW & Prova 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: Looking for more 'partner engines' (mainly Flora-2) for use case, e.g. on RuleML FOAF

Future Work (I)

- Communication Between Personal Agent and Expert Owner
  - The PA at some point may need to interact with its expert owner
  - The formal interaction between PAs and their owners is email (SMTP)
  - The interaction language of these emails is Reaction RuleML
- Query Decomposition
  - Each premise of a rule can be delegated to different PAs, followed by Integration

Future Work (II)

- Centralized, Hierarchical (Distributed), and Networked (Distributed) Query Answering
- Centralized and Distributed Knowledge Maintenance
  - How to keep your rules updated
- Distributed: Fault Tolerance
  - Alternative agents when an agent stops working
- Communication Overhead vs. Centralized Processing