SmartResource Project

Year 2005

Annual Report

"Proactivity Stage"

Industrial Ontologies Group

Agora Center, University of Jyväskylä

JSP Jyväskylä Science Park · metso automation · University of Jyväskylä · TeliaSonera · TietoEnator Building the Information Society

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SMARTRESOURCE TEKES PROJECT – ANNUAL REPORT "PROACTIVITY STAGE" (2005)

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Project's webpage: *http://www.cs.jyu.fi/ai/OntoGroup/SmartResource_details.htm*

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1 Introduction

Project Motivation

With the development of technologies, very fast creation and communication of information/knowledge has become possible. Automated knowledge accumulation and sharing is becoming the most profitable kind of business for modern, *knowledge-based*, companies. Such industries are looking for fast and global solutions related to Knowledge Management, Enterprise Application Integration, Electronic Commerce, Asset Management, etc. Various industrial standards, which have been created and implemented by different industrial consortiums, appear to be insufficient for growing interoperability demands.

One of the domains, where knowledge accumulation and its timely delivery are crucial, is industrial maintenance[1]. Development of a global environment, which would support automation of knowledge management for industrial maintenance, is a very profit-promising and challenging task. The latter is what the Smart Resource project aims at.

Our intention is to provide tools and solutions to make heterogeneous industrial resources (files, documents, services, devices, processes, systems, human experts, etc.) web-accessible, proactive and cooperative in a sense that they will be able to analyze their state independently from other systems or to order such analysis from remote experts or Web-services to be aware of own condition and to plan behavior towards effective and predictive maintenance.

Project Approach and Goal

The contribution of this ongoing SmartResource project (2004-2006) together with strong research effort includes prototype implementation of *distributed Semantic Web enabled maintenance management environment* with complex interactions of components, which are devices, humans (experts, operators) and remote diagnostic web-services. The environment will provide automatic discovery, integration, condition monitoring, remote diagnostics, cooperative and learning capabilities of the heterogeneous resources to deal with maintenance problems. Maintenance (software) agents will be added to industrial devices, which are assumed to be interconnected in a decentralized Peer-to-Peer network and which can integrate diagnostic services in order to increase the maintenance performance for each individual device. In the project, the maintenance case is expected to demonstrate the benefits and possibilities of new resource management framework and Semantic Web technology in general for Finnish industry.

Thus, project approach harnesses the potential of emerging progressive technologies – Semantic Web, Agent Technology, Machine Learning, Web Services and Peer-to-Peer – in addressing its very challenging goals.

Project Stages

Project research and development activities are divided into three yearly stages: Adaptation Stage (2004), Proactivity Stage (2005) and Networking Stage (2006). Each year of the project delivers more enhanced version of architectural design and prototype implementation for the maintenance environment.

[1] Metso Automation's customer magazine, (2003) *Automation*, *1*, 7-9.

Adaptation Stage defines Semantic Web-based framework for unification of maintenance data and interoperability in maintenance system. Its research and development tasks include development of generic semantic adapter mechanism (General Adaptation Framework) and supporting ontology (Resource State/Condition Description Framework) for different types of industrial resources: devices, software components (services) and humans (operators or experts). The key technology, which is utilized during the Adaptation Stage is *Semantic Web*. The latter is a relatively new initiative within W3C standardization effort to enable machine interpretable metadata in the Web. It provides standards and tools to enable explicit semantics of various Web resources based on semantic annotations and ontologies. Integration in general is considered nowadays as a “killer application” of Semantic Web technology, which particularly can be interpreted as heterogeneous data integration, Enterprise Application Integration and Web-service integration among other interpretations.

Proactivity Stage focuses on an architectural design of agent-based resource management framework and on enabling a meaningful resource interaction. Its research and development tasks include adding software agents (Maintenance Agents) to the industrial resources, enabling their proactive behavior. For this purpose, Resource Goal/Behavior Description Framework has to be designed, which will be the basis for making resource's individual behavioral model. The model is assumed to be processed and executed by the RGBDF engine used by the Maintenance Agents. Agent-based approach for management of various complex processes in the decentralized environments is being adopted and popularized currently in many industrial applications. Presentation of the resources as agents in the multi-agent system and use of technologies and standards developed by the Agent research community is a prospective way of industrial systems development. Creation of framework for enabling resources’ proactive behavior and such agent features as self-interestedness, goal-oriented behavior, ability to reason about itself and its environment and to communicate with other agents, can bring a value to the next-generation industrial systems.

The objective of the **Networking Stage** comprises complex behavior/interaction scenarios of Smart Resources (agent-augmented Device, Expert and Service) in the global decentralized networked environment. The scenarios assume agent-based interoperation of multiple devices, multiple services and multiple experts, which allows discovery of necessary experts in Peer-to-Peer network, using their experiences to learn remote diagnostics Web-services, making online diagnostics of devices by integrating diagnoses from several services, learning models for a device diagnostics based on online data from several distributed samples of similar device, etc. Emerging Peer-to-Peer technology and similar network architectures suite well the increasingly decentralized nature of modern companies and their industrial and business processes, whether it is a single enterprise or a group of companies. The set of advantageous features of the Peer-to-Peer model includes decentralization, scalability and fault-tolerance along with low administration expenses. Client/server architectures with centralized management policy increasingly fail with big amounts of nodes, because of their complexity and extremely high demands on computing resources. Distributed content management systems address the need to access content wherever it resides, produce content while maintaining control over it, and collaborate efficiently by sharing data real-time within a distributed network of stakeholders.

2 Project Background Concept: a Global Understanding Environment

Global Understanding Environment (GUN)[2] is a concept used to name a Web-based resource "welfare" environment, which provides a global system for automated "care" over (industrial) Web-resources with the help of heterogeneous, proactive, intelligent and interoperable Web-services. The main players in GUN are the following resources: service consumers (or components of service consumers), service providers (or components of service providers), decision-makers (or components of decision makers). All these resources can be artificial (tangible or intangible) or natural (human or other). It is supposed that the "service consumers" will be able: (a) to proactively monitor own state over time and changing context; (b) to discover appropriate "decision makers" and order from them remote diagnostics of the own condition, and then the "decision makers" will automatically decide, which maintenance ("treatment") services are applied to that condition; (c) to discover appropriate "service providers" and order from them the required maintenance. Main layers of the GUN architecture are shown in Figure1.

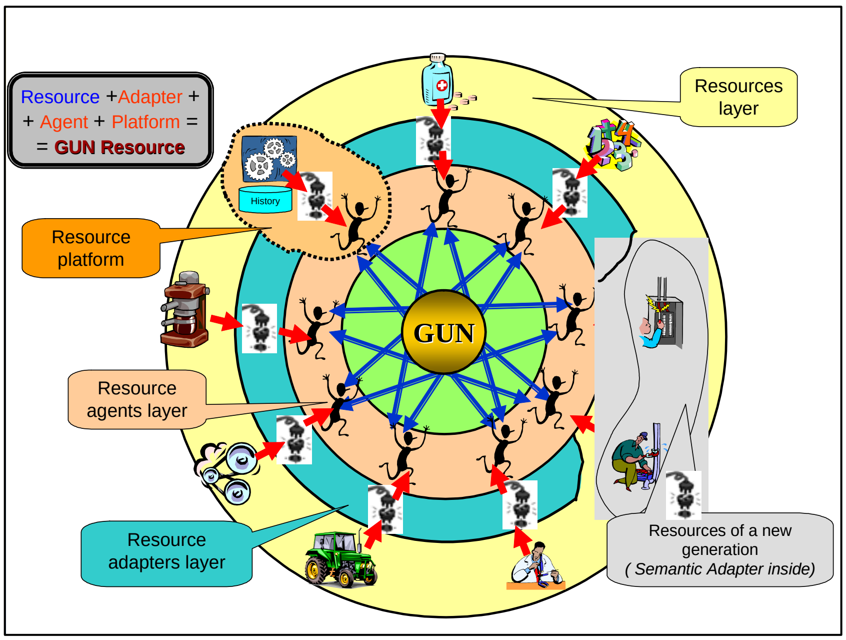

Figure 1 - Layers of the GUN architecture

Industrial resources (e.g. devices, experts, software components, etc.) can be linked to the Semantic Web-based environment via adapters (or interfaces), which include (if necessary) sensors with digital output, data structuring (e.g. XML) and semantic adapter components (XML to Semantic Web). Agents are assumed to be assigned to each resource and are able to monitor semantically reach data coming from the adapter about states of the resource, decide if more deep diagnostics of the state is needed, discover other agents in the environment, which represent "decision makers" and exchange information (agent-to-agent communication with semantically

[2] Terziyan V., Semantic Web Services for Smart Devices in a "Global Understanding Environment", In: R. Meersman and Z. Tari (eds.), *On the Move to Meaningful Internet Systems 2003*, LNCS, Vol. 2889, Springer-Verlag, 2003, pp.279-291.

enriched content language) to get diagnoses and decide if a maintenance is needed. It is assumed that "decision making" Web-services will be implemented based on various machine learning algorithms and will be able to learn based on samples of data taken from various "service consumers" and labeled by experts. Use of agent technologies within GUN framework allows mobility of service components between various platforms, decentralized service discovery, FIPA communication protocols utilization, and MAS-like integration/composition of services.

3 Project Results (Year 2005, Proactivity Stage)

Ontology-driven Modeling of Agent Behavior – Deliverable 2.1

Agent-oriented approach has proven to be very efficient in engineering complex distributed software environments with dynamically changing conditions. The efficiency of underlying modelling framework for this domain is undoubtedly of a crucial importance. Currently, a model-driven architecture has been the most popular and developed for purposes of modelling different aspects of multi-agent systems, including behaviour of individual agents. UML is utilized as a basis for this modelling approach and variety of existing UML-based modelling tools after slight extension are reused. The SmartResource project within its Resource Goal/Behavior Description Framework proposes an ontology-driven approach to modelling agent behaviour as an emerging paradigm that originates from the Semantic Web wave. The proposed approach aims at modelling a proactive behaviour of (web-)resources through their representatives: software agents. In general, the research of this deliverable has put efforts into investigation of beneficial features of ontology-based modelling of agent behavior.

Approach of RG/BDF assumes concentrating all the goals, descriptions of roles and templates of behavioural rules in ontology. The templates of behavioural rules are described in a general way with a purpose to be applied to any particular agent. Goal-driven behaviour is a part of vision of SmartResource that means performing a set of rules, which are aimed at achievement of certain goal. In return, a goal is a fact which does not exist in a description of the environment, and an agent aims at this fact to appear. As a result, we have a trio: behaviour which is driven by certain goal and which lies in performing actions following a set of behavioural rules. However, even having a rule base, which enables an agent to achieve a goal, still extra information (environmental facts) is needed. This is because each rule has to have a sufficient condition. In our case a sufficient condition is a presence of input data for action being performed. Having the sufficient condition we should take into account also a necessary condition: presence of a goal along with a certain context (set of facts of the environment) for performing the goal. Not all goals assume execution of unambiguous rule(s). Some goals can be represented by aggregation of more specific goals. See a conceptual illustration of RG/BDF in Figure 2.

Referring to the trios that were discussed above, each agent should have initial set of those trios (regulated by initial role). These trios represent expertise and experience of an agent. As well as in a real world, agents can exchange their expertise (rules for execution of actions depending on the goals and direct software modules for execution of actions). Availability of a wide spectrum of the trios gives a possibility for agent to automatically divide up goals (which cannot be achieved because of lack of information) to sub goals and to create a chain of nested trios.

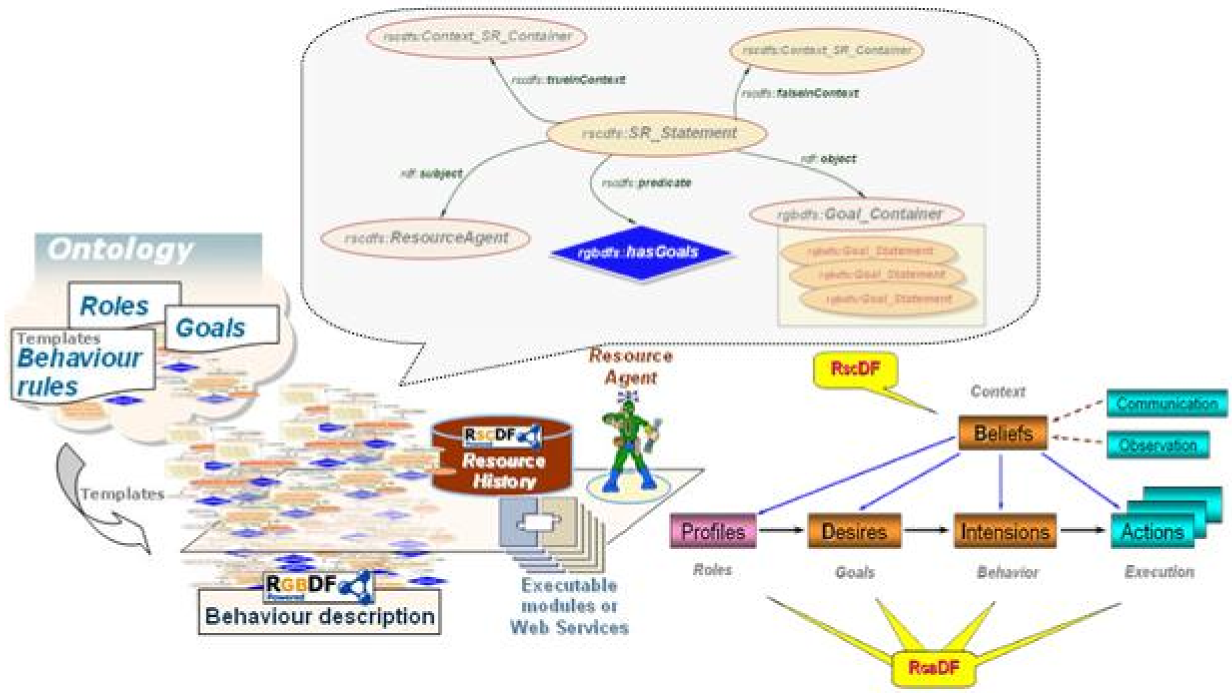

Figure 2 - Conceptual meaning of Resource Goal/Behavior Description Framework

One more thing from a modelling paradigm that can be applied to an agent is a notion of role. Agent role means aggregate of goals corresponding to a specific purpose of the agent. Individual role does not assume a fixed set of activities, the set of the goals can be different even for the same role depending on the context. Such approach to the goal and behaviour description brings a possibility for agent to be more autonomous and to act more independently. Through utilization of this approach agent can change its role, set of the goals corresponding to its purpose depending on a condition of the environment. In other words, an agent can change its behaviour based on a context.

Engine for Proactive Resource Behavior – Deliverable 2.2

This deliverable addressed a challenge of designing a framework for annotating behaviour of an agent – representative of a resource, with further enactment of the behavior. Thus, basically we faced two challenges: (a) design of a handy user interface for specifying resource behaviour in form of rules and resource mental states, and (b) design of an engine to run these rules and perform corresponding actions. Such framework is anticipated to become a basis for modelling a variety of different processes: business processes, enterprise integration, distributed maintenance, distributed diagnostics and learning, supply chain management, etc.

The architecture of the proactive layer of the SmartResource Platform is presented in Figure 3. Its structure comprises four storages: (a) a history for storing facts about events occurred in an external environment of the resource agent; (b) a storage for reasoning (mental) states of the resource agent and rules that determine its behavior; (c) a storage where an ontology and all instances (metadata related to Devices, Services, Human Experts, Agents, etc.) are located; (d) a storage for programmable executable modules. In fact, the storage for the statements of facts about the external environment is presented by two storages: one for operational purposes and another for long-term storing. Operational storage contains relevant and up-to-date data critical for performance. For example, if a statement about assigning the resource agent a new role is asserted to the operational storage, then a statement about previous role of the agent must be removed to the long-term history or otherwise irrelevant alarm statements must be removed. Such filter prevents contradiction in the latest data.

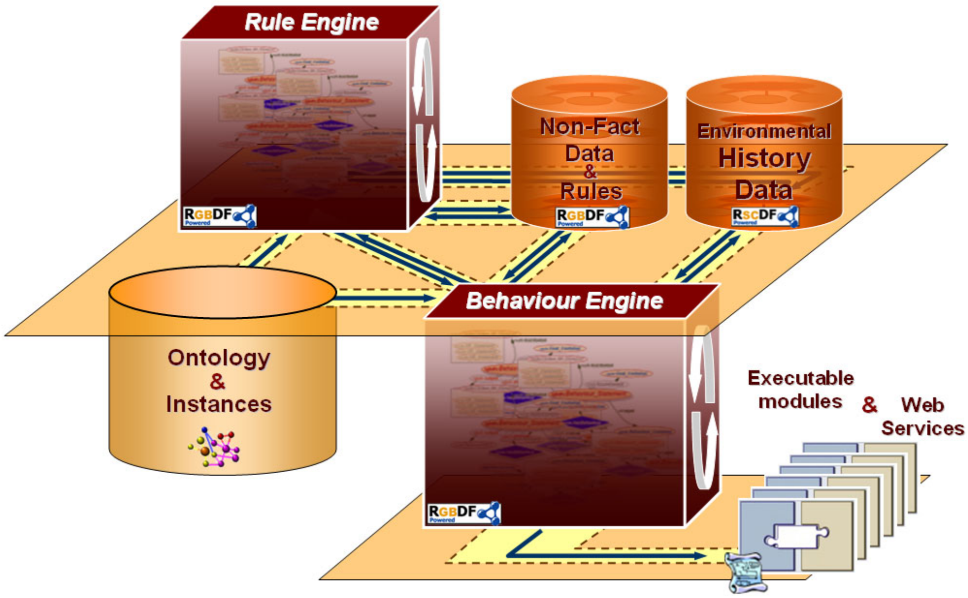

Figure 3 - Proactivity Layer of the SmartResource Platform

The architecture includes two engines, too: one for rules and another for a behavior. The engines iteratively check the rules, execute them and launch necessary actors (modules). The main role of the rule engine is to generate (to change) a context for the resource behavior.

From the user's perspective, the information that will be needed from him/her is (a) a starting role or goal for the resource agent and (b) input data/facts. For this purpose, the user interface must provide all available information from the ontology and data, stored on the platform: a list of instances, a list of properties, etc. If semantic profiles of accessible executable modules and web services are available, then this makes a good basis for automated generating behavioural rules by the platform. Otherwise, a semantic profile has to be specified for all executable modules available on the platform and for web services that will be used. If there is no any executable module or a web service, which can achieve the goal, then the goal can be divided into a set of sub-goals based on corresponding information in the ontology or on an iterative process of generating sub-goals automatically (based on required inputs for modules, which can reach the goal but inputs are not provided).

SmartResource Prototype Environment v. 2.0 – Deliverable 2.3

The second version of the SmartResource prototype environment automates the scenario of interaction between Device, Expert and Web Service that was implemented during previous project stages. The logic of interaction has been implemented based on a multi-agent system and the prototype has become a practical testbed for research deliverables of the second project year.

As a basis for implementation of the interaction scenario between SmartResource agents, Java Agent Development Framework (JADE)[3] has been chosen. Such choice is made, because Java language is the basis for JADE that makes its integration with previous version of the SmartResource Prototype Environment easy. Additionally, the JADE platform is mature in providing a variety of tools for the debugging and deployment phases of the agents. JADE fully follows FIPA[4] specifications, that is a very positive point.

In general, the implementation task assumes migration of the scenario's logics from the Control Servlet to the community of agents implemented in JADE (see Figure 4).

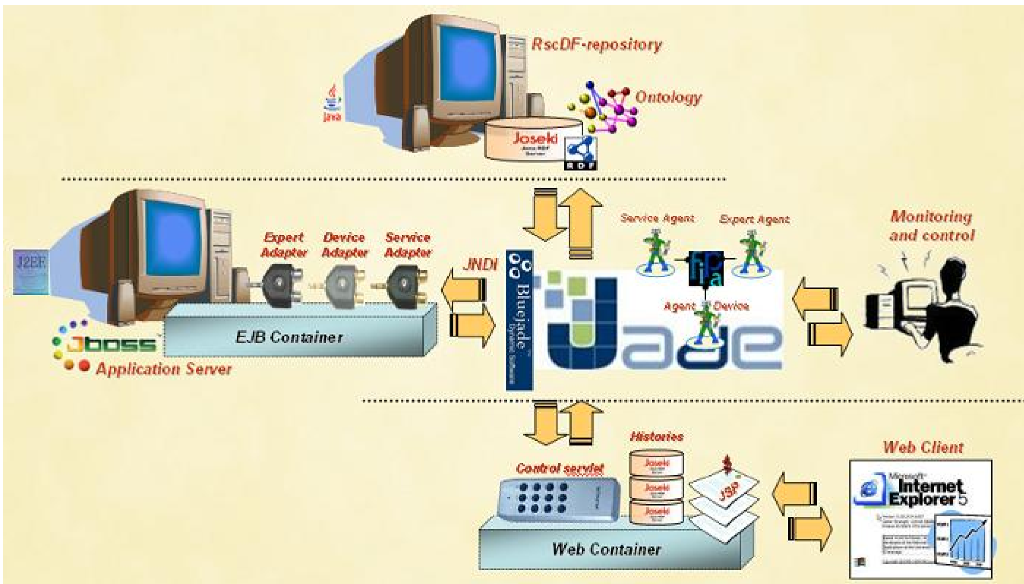

Figure 4 - Evolution of the SmartResource Prototype Environment

On the other hand, adapters that were implemented during previous project year, reside at the JBoss Application Server as they are. It was one of the challenges to implement the access of agents hosted by JADE to the adapters.

As it was planned, the implemented agents access the adapters for data transformation needs. For this purpose, an abstract class ResourceAgent has been designed. It implements the initialization of local history storage of an agent from common history stored at the Joseki server. Additionally the class makes necessary preparations for a successful lookup of the adapters by agents: an instance of a context (JNDI naming directory) that allows finding adapters (implemented as EJBs) using their names.

So far, developers of JADE have provided a possibility to implement behaviors of agents using a hierarchy of classes. This structured approach to modeling behaviors makes JADE platform even more suitable for experimental research of the RGBDF schema and RGBDF engine.

The track of ACL messages sent between agents in the SmartResource platform was monitored using SnifferAgent in JADE (see Figure 5).

[3] http://jade.tilab.com/
[4] http://www.fipa.org/

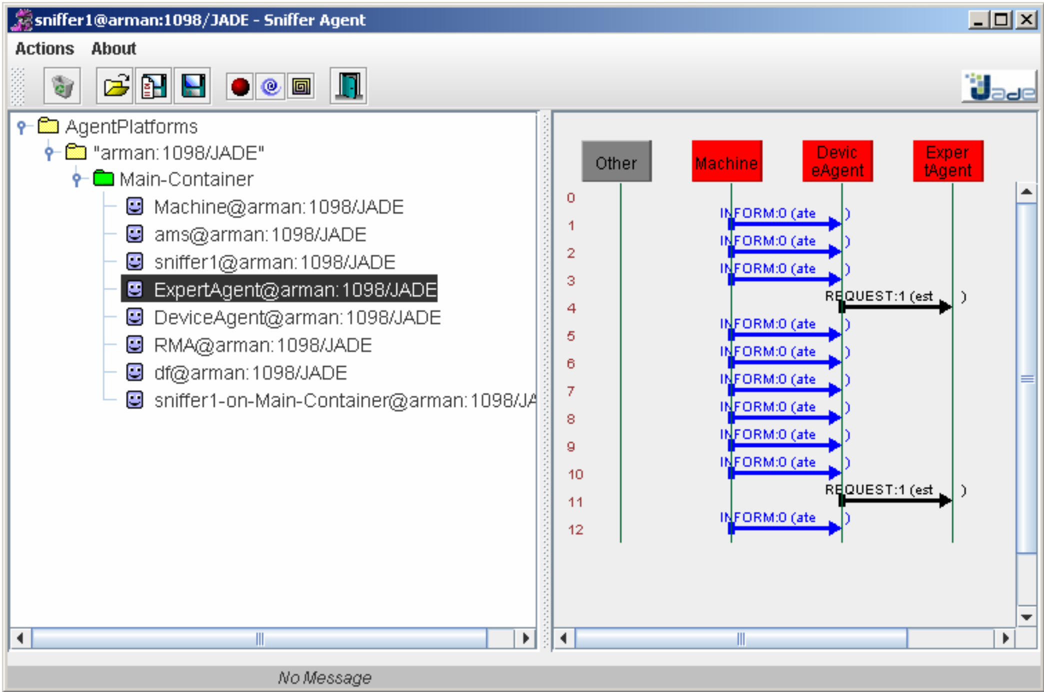

Figure 5 - Monitoring of a message flow between agents

4 Evaluation of the Project Results (Year 2005)

Considering the second project year results, we should accent a fact that project team got less money that it was planned for the second project year. Lack of the funding brought a need for two PhD students to get part of the funding from COMAS. For the reasons given above, some team members have been participated in several other projects. But, even in this situation project team have covered all project deliverables and show good performance level.

Scientific Value

First of all, the project results gained during its second year (year 2005, Proactivity Stage) have quite a significant scientific value. The research efforts undertaken by a group of young perspective researchers led by experienced supervisors have been addressed to exploring the beneficial features of a synergy between young Semantic Web technology and more mature technology of Multi-Agent Systems. More precisely, we have concentrated on using ontology in meta-modeling proactive multi-agent systems, because this approach has not been elaborated in science so far. As known, meta-modeling defines concepts, on which designers or developers have to focus during the development process[5]. In the methodology of SmartResource for endowing resources with self-maintained behavior, main attention is devoted to Goals, Behavior and Context.

[5] C. Bernon, M. Cossentino, J. Pavón. An Overview of Current Trends in European AOSE Research. Informatica Journal, 2006 (in printing).

Resource Goal/Behaviour Description Framework (RG/BDF), that has been designed within the second stage of the SmartResource project (Proactivity Stage), continues development of a modelling basis for the overall SmartResource platform. Further tools and use cases that should be developed within the Proactivity Stage based on RG/BDF, will form a ground in favour of ontology-driven approach to modelling proactive resources behaviour.

As a continuation of the base approach, another elaborated work provides a semantically enhanced way for the rule and meta-rule definition. The ontology-driven approach in toward modeling agent behaviour as a context-sensitive dynamic change of standardized and reusable roles, goals and actions, is anticipated to become a powerful solution for providing some benefits compared to conventional model-driven approaches. The case of the Rule Engine execution, based on the Production System approach and possible utilization techniques of other execution engines, was presented. The most beneficial issue in usage of the standardized data representations is a possibility to operate and work cooperatively with other heterogeneous resources; it provides the opportunity for knowledge sharing and reuse.

The results of the research and development gained during 2005 project year have been published in about 10 papers. Very positive impact has been obtained from the First International Conference on Industrial Applications of Semantic Web organized in the end of August 2005 by executive group of the SmartResource project. This activity has allowed to gather people from many countries with a unique experience in Semantic Web and collaboratively discuss a challenge of a gap between academic and industrial adoption of this technology. The SmartResource project and its main challenges has served as a good basis for constructive discussions and cooperation with other nationally and internationally known research groups. The papers gathered on this conference, have been published in a proceedings of Springer IFIP series:

Bramer M., Terziyan V. (eds), Industrial Applications of Semantic Web, *Proceedings of the 1st International IFIP/WG 12.5 Working Conference on Industrial Applications of Semantic Web*, Springer IFIP, Vol.188, 2005, ISBN: 0-387-28568-7, 340 pp.

During the first project year, the following travels related to the dissemination of the project research results have been carried out:

1. Nikitin S., International Workshop on Autonomous Intelligent Systems – Agents and Data Mining (AIS-ADM-05), Travel to: St. Petersburg, Russia, June 6-8, 2005.
2. Kaykova O., Khriyenko O., Naumenko A., Terziyan V., SmartResource Status and Future, Research Seminar, TeliaSonera, Travel to: Helsinki, Finland, September 22, 2005.
3. Kaykova O., Khriyenko O., Naumenko A., Terziyan V., SmartResource Status and Future, Research Seminar, Metso Automation, Travel to: Tampere, Finland, September 23, 2005.

Very significant result of the local activities of the project team has been a fact that ABB Oy joined the SmartResource Consortium for the year 2006. The initial high level of abstraction of the idea of smart self-maintained resources causes the applicability of the project results to a wide range of companies.

Academic and Professional Growth

The active project research and related public activities has contributed much in the academic and professional growth of the project team members, especially of the young ones. Hardly any young project member has participated in such big research projects before and this possibility has given to them an experience of coherent joint work and an insight into efficient management of the project activities, rational labor division between all team members.

Thanks to the wide research field of the project, two doctoral students participating in the project have been able to gain the required doctoral credits in a comparatively short term (2 years), and another two team members started their PhD studies during the last project year. They have published few papers that contain material appropriate for their dissertations. Also, practical orientation of the project results will make the doctoral research more remarkable and significant for the world's scientific community. Participation in the project's seminars and conferences will influence positively on the oral abilities of the future Ph.D.s.

Partner Network Widening

In addition to the existing partner contacts of the project team, which comprise Kharkov National University of Radioelectronics (Ukraine), Free University of Amsterdam (Netherlands), "OntoWeb" European Network of Excellence, Berkeley University (USA), Metso, TeliaSonera, TietoEnator, Jyväskylä Science Park, new contacts have been established that broadens teams' horizons and channels of the experience transfer and opens new commercial opportunities.

The going-on active cooperation with TITU-group led by Prof. Jari Veijalainen gives a great possibility to get experience from a huge European Adaptive Services Grid Project, which aims to develop a proof-of-concept prototype of an open development platform for adaptive services discovery, creation, composition, and enactment in web environment based on their semantic specifications. Mutual experience exchange in the area of Semantic Web Services will significantly increase the research results of the local part of ASG and SmartResource projects. Particularly, Ville Törmälä and Jarno Heikkilä from the ASG Project will write their Ms. Thesis with guiding support from the SmartResource project and vice versa, Sergiy Nikitin from SmartResource project group has contributed much to the development of ASG prototype.

Industrial Ontologies Group is a finnish node of KMR Group: "Knowledge Management Research Group" (http://kmr.nada.kth.se/) Centre for User-Oriented IT Design among partners from Sweden, Norway, Finland, Greece, Spain, Romania, Ukraine. Our team will be a partner in EU project eTHESES, which application will be submitted by members of KMR group later in 2005.

IOG closely cooperate with Vaasa University (Finland) and other international partners in MODE: "Management of Distributed Expertise in R&D Collaboration" Regional Development Project (contact person – Kimmo Salmenjoki). The topic of cooperation is knowledge management and service oriented software usage in industrial information systems; from operability and data integration questions towards more unified approaches in sharing the data and the interoperability of related information systems.

Close cooperation with the VTT research unit aims to find the local industrial partners for participation in SHIVA: "Automatic Generation of e-Maintenance Platform Dedicated to the Equipment to Maintain" (continuation of Proteus project), ITEA Project (coordinating Company – Cegelec Cigma, France). The SHIVA initiative aims at enabling fast and easy creation of equipment modeling, so as to generate PROTEUS based e-maintenance platform in any industrial domain. This project will contribute to an improvement of the usability of the plant equipment and efficiency of maintenance activities.

The following travels were intended for the widening and strengthening of the partner networks:

1. Kaykova O., Terziyan V., Cooperation with Kharkov National University of Radioelectronics, Travel to: Kharkov, Ukraine, June, 2005.
2. Terziyan V., Cooperation with Tampere University of Technology, Travel to: Tampere, Finland, August 1, 2005.
3. Terziyan V., Cooperation with University of Vaasa, Travel to: Vaasa, Finland, August 9, 2005.
4. Terziyan V., SmartResource: Invitation to Join, Research Seminar, Wärtsilä, Travel to: Vaasa, Finland, September 27-28, 2005.
5. SeMill …

5 Further Development

To meet the requirements of the networked business processes the following challenges have been revealed and which have to be addressed during the 3rd and forthcoming project years:

5.1 Networking model

This challenge relates to a networked model to be chosen as a basis for integration of the SmartResource's components (Web Services, human experts and smart devices) and specifically their agents. There are three options for the model: centralized, decentralized or hybrid.

Peer-to-peer (distributed) model represents a multitude of interconnected nodes with equal roles and responsibilities in the network. This model has recently gained an interest in the scientific community due to its beneficial features: fault tolerance, high scalability, and low administrative expenses. On the other hand, the pure peer-to-peer networking is challenging by its search algorithms, control of an unendorsed dissemination of content, security (availability, authenticity, anonymity, and access control), resource management (towards fair contribution from all nodes)[6].

Centralized model is a conventional client-server solution so popular until recent times. In this model, there is a central point of access, where all resources are located and where the administration policy is concentrated. This model is beneficial by a maturity of its existing technological solutions. In the centralized models, the owner has a full control over access to data/metadata and over updates of the content. On the other hand, such model is not scalable enough and fails in administering very large amounts of clients (especially taking into account recent trends in global networking). Very often, being even effective from the technological point of view, the business partners refuse to adopt the centralized model in order to protect privacy of content or metadata.

Research on *hybrid networking* models represents attempts to combine advantages of centralized and pure peer-to-peer models. In hybrid networking models some of its architectural components are based on a centralized approach. In the case of the SmartResource platform, centralized solutions for the ontology and registries can become beneficial, leaving interactions between resources integrated by the platform peer-to-peer. Different variants of the hybrid model architecture are under a research and evaluation in the world[7].

[6] M. Bawa, et al.: Peer-to-peer research at Stanford. SIGMOD Record 32(3): pp. 23-28 (2003).
[7] B. Yang, H. Garcia-Molina: Comparing Hybrid Peer-to-Peer Systems. VLDB 2001: pp. 561-570.

There are a number of entities (components) in the SmartResource platform, which are a subject of analysis of a distribution strategy:

Resource: a real-world physical object that consists of software and hardware components and which is the subject of a proactive maintenance by the SmartResource platform. This kind of components is stationary and can be hardly ever moved.

Adapter: a software component of the SmartResource platform that provides a unified interface for retrieving sensor data of a Resource and for transforming the data to a semantic representation - Resource State/Condition Description Framework (RscDF).

SmartResource History: a semantically represented log of events occurred at the SmartResource platform during its lifecycle. The lifecycle of the platform begins from collecting the history of the Resource: its states, contexts, conditions and diagnoses accumulated through time via an interface of an Adapter. Then the process of gathering the history of the Resource Agent starts as its behavior is activated. This history stores all behavioral acts of the agent, including outgoing/incoming messages, reasoning process ("mental" states), effectors activated and other sensor data. As an experience of the 1st and 2nd project years has revealed, a balanced solution of history sharing between different SmartResource platforms must be developed. For instance, an interaction between different platforms (their agents) during the process of the Resource diagnostics requires sharing fragments of Resource history: size of the fragments and a strategy of their retrieval depend on the diagnostic method used. The question of how to distribute those histories between local (memory based, e.g. Jena models) private, external (based on databases, e.g. RDF servers like Joseki) private and external public storages needs further investigation. The strategy of history sharing between Resource Agents will be reflected in their interaction protocols.

Resource Agent: a software agent that is an intelligent representative of the Resource and which encapsulates goals of the Resource performing a proactive behavior according to its Goal/Behavior Description.

Goal/Behavior Description: description of Resource's goals, contexts in which the goals occur, and behaviors to achieve these goals. The description is made in the format of Resource Goal/Behavior Description Framework (RGBDF) and is intended for a Resource Agent.

Semantic Profile: description of a type of the Resource, its properties and capabilities and how to access its Resource Agent. The description adheres to standards of the Semantic Web.

Ontologies: various vocabularies for all semantic descriptions used by the SmartResource platform: RscDF, RGBDF (behavioral vocabulary has to be shared between agents to interpret properly requests in the content of communicative messages), domain specific metadata (e.g. business processes in paper industry), vocabulary of metadata used in the interaction protocols between the Resource Agents.

5.2 Registries

Depending on the networked model chosen the issues related to resource registries have to be studied: the infrastructure of the registries (or architecture of the central registry), semantic descriptions of the resources (profiles), mechanism of publishing profiles to registry, search engine for lookup of requested services/experts/devices through registries.

Accumulation of local registries by the resources is possible too. Those local registries refer to trusted and/or permanent partners. The local registry entries originally are obtained from public registries. There have to be a possibility of exchanging local registries between Smart Resources.

Most probably, this research will cover registries on multi-agent platforms. As a use case for the analysis, Directory Facilitators in the FIPA standard can be taken.

5.3 Ontologies

The research challenges in this area concern ontology storing, maintenance, versioning (control over rights to change ontologies), control of access to data/metadata. These issues highly depend on the underlying networked model of the platform.

The ontologies used by the SmartResource platform represent a vocabulary of the concepts agreed and used among cooperating partners ensuring their interoperability. The task will be to analyze through use cases that occur in the SmartResource platform, what kind of requests are sent to ontology storages, by whom and how often. Software that meets those requirements will have to be designed and implemented. The option of the architecture can be based on multi-agent platform, where each agent will represent a separate community or organization that adheres to certain terminology and takes part in standardization efforts negotiating about meaning of concepts, their taxonomy and properties with other communities. Since the task of collaborative ontology engineering and its further maintenance is challenging, agent-oriented approach can be relevant here.

The elaboration of a common complete agreement about a terminology might become in many cases beyond the strength of communities. For such situations adoption of a common upper ontology can become a beneficial trade-off. The upper ontology comprises general concepts of a domain and their meaning agreed between all members of a domain-specific community. On the other hand, an upper ontology provides a flexibility of extending its general concepts by more specific sub-concepts. These rights create a necessity in using versioning tags for ontologies or even for single concepts in them. The necessity number two is Unique Resource Identifiers (URIs) that denote communities or individual organizations, which conform to the concepts in an ontology.

Other approach to interoperability on a conceptual level is an ontology mapping, when concepts of one ontology are interpreted in terms of concepts from another ontology. Automated ontology mapping is the hot topic in scientific world nowadays; see for example[8].

Additional challenge that comes with ontologies is related to control of access to ontology in the multi-partner environment of the SmartResource. Typical cases that reflect needs in access to private ontologies between partners have to be determined. The question of balancing shared and private parts of ontologies in a collaborative environment brings new challenges. So far the experience shows that it is really hard to find a trade-off between interoperability and privacy even in alliances of mutually interested partners. These hard situations may occur in supply chains composed of independent commercial players. Presence of a central coordinating point in alliances can certainly mitigate the problems with sharing ontologies.

If to talk about a driver of policies for access control, semantic approach can bring its benefits. Currently, there are many publications that study the application of Semantic Web standards (e.g. OWL) in specifying access policies. Further, the specified policies can be assigned to a software agent that will enforce them. Finally, a multi-agent system can become a practical solution for controlling access to ontologies between partners in an alliance, where an agent

[8] Y. Tzitzikas and C. Meghini. Ostensive Automatic Schema Mapping for Taxonomy-based Peer-to-Peer Systems. In Seventh International Workshop on Cooperative Information Agents, CIA-2003, pp. 78-92, Helsinki, Finland, August 2003 (Best Paper Award).

represents access policies of each partner and in addition independent alliance agent verifies the commitments of the partners to alliance in their policies.

5.4 Communicative protocols

Protocols of the interaction scenarios between the resource agents at the SmartResource platform, have to be elaborated. The protocols reflect underlying business processes and will likely be based on existing protocols of inter-agent communication, e.g. FIPA protocols. Engineering of appropriate metadata schemata that will include concepts of interaction acts, roles and actors, is a part of the challenge. For this purpose two immediate candidates occur: FIPA ACL[9] and KIF[10][11][12]. In any case, to be interoperable during their communication acts the agents must share the same set of concepts form the final schemata. Logics of a resource composition (what services/devices/experts to choose from the search results, mechanism of specification of the filters e.g. in a form of OWL restrictions based on accumulated opinions) and message queuing are among important aspects with regards to the communicative protocols, too.

5.5 Knowledge integration

This relates to a development of sample logics for integration of knowledge from multiple sources:

- Device integrates diagnosis/condition labels from multiple experts or Web Services according to its algorithm (e.g. weighted selection according to accumulated expert's QoSs and those QoSs, which were determined during testing of an expert or Web Service).
- Learning Web Service builds (trains) its diagnostics model during a process of learning from multiple devices. Many techniques can be used for sample development: the Web Service could build (train) a set of models – a separate one for every device or a single model for a family (class) of devices. The latter approach provides knowledge exchange between similar types of devices.
- Web Service reconfigures or even rebuilds its underlying model using models or model configurations of other Web Services. Complex integration processes can result in creation of models of new types.

5.6 Trust and Certification

Another concern of the General Networking Framework is a *trust*, which should be based on an opportunity to provide the resource with a reliability evaluation during the business process monitoring. Trust requires all the autonomous "actors" of the business process to provide exactly the functionality agreed by the process scenario and guarantee high precision of the decisions made. Trust in General Networking Framework can be managed by providing certification services, which can compute the estimated reliability values for each component in advance, and also by providing peer-to-peer personal trust evaluation and exchange of trust estimations among various proactive resources within a business process.

[9] FIPA Specifications of the Agent Communication Language (ACL): http://www.fipa.org/repository/aclspecs.html.
[10] ANSI Knowledge Interchange Format, http://logic.stanford.edu/kif/kif.html
[11] Knowledge Interchange Format as an RDF Schema, http://www.w3.org/2000/07/hs78/-KIF#KIF1
[12] An Axiomatic Semantics for RDF, RDF-S and DAML+OIL, http://www.daml.org/2001/03/axiomatic-semantics.html

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[3] Khriyenko O., Terziyan V., A Framework for Context-Sensitive Metadata Description, In: International Journal of Metadata, Semantics and Ontologies, ISSN 1744-2621, 15 pp. (submitted 7 November 2005).

[4] Terziyan V., Bayesian Metanetwork for Context-Sensitive Feature Relevance, In: Proceedings of the 4-th Hellenic Conference on Artificial Intelligence, 18-20 May, 2006, Heraklion, Crete, 12 pp. (submitted 31 October 2005).

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