SEMANTIC INTEROPERABILITY FOR E-BUSINESS IN THE ISP SERVICE DOMAIN

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Keywords: Ontology, semantic interoperability, eBusiness, virtual organisation, ISPs.

Abstract: Enterprise interoperability is a challenging goal that has many facets, one of which being the need for cooperating enterprises to have a precise understanding of the information that they exchange with each other. Internet Service Providers (ISPs) collaborating in a virtual cluster to market, customize and provision services to customers require the same understanding of these services and their features. This paper describes the work being undertaken in the European IST project VISP (IST-FP6-027178) to meet this requirement. ISP services are being classified and formally specified and an ontology is being developed for the ISP service domain.

1 INTRODUCTION

Enterprises wishing to undertake eBusiness by cooperating in a virtual organization must agree on the definitions and meanings of concepts used in their cooperation, and the software infrastructure supporting their eBusiness transactions must be aligned with this understanding so that services can be offered and provisioned for customers dynamically, efficiently and effectively. This paper is concerned with the work being developed in the European IST project VISP (IST-FP6-027178) to support semantic interoperability for a virtual cluster of small ISPs collaborating to market, customize and provision services for business customers.

The structure of the paper is as follows. First the eBusiness context of small ISPs and their collaboration in a virtual cluster is briefly outlined. Reference is then made to the significance of knowledge and semantics for enterprise interoperability in the European research area and to research projects here. Work that has been undertaken in the VISP project on the specification and classification of ISP services is introduced. Then the ontology that has been developed for the services in the ISP domain is presented, including an application of its use in composing services for eBusiness. A brief summary of the work undertaken concludes the paper.

2 ISPS AND VISP

Since the advent of the Internet, the traditional ISP market has been in constant evolution due to the gradual globalization and commoditization of ISP services and to deregulation initiatives aimed at fostering competition. Small ISPs are best at targeting niche markets; they can respond rapidly and provide excellent customer service. However, small ISPs cannot offer the wide range of services now required by increasingly demanding business customers nor offer the geographical coverage that is necessary in a globalized marketplace.

Collaborating in a virtual cluster to undertake eBusiness enables small ISPs to offer a wider range of services, particularly when customizing tailored services that are composed from individual services. Tailoring composite services from the services of other partners in the cluster in order to offer innovative and higher value solutions to customers is indeed one of the principle advantages and reasons

Hall J. and Koukoulas S. (2008).
SEMANTIC INTEROPERABILITY FOR E-BUSINESS IN THE ISP SERVICE DOMAIN.
In *Proceedings of the International Conference on e-Business*, pages 390-396
DOI: 10.5220/0001910103900396

behind the idea of collaborating in a virtual VISP cluster with other small SMEs.

However, when composing services it is necessary to have a precise understanding of the features of each service element so that the composition of individual services into a service bundle is consistent and the composite service can be validated. In order to meet these requirements, work was undertaken within the VISP project to develop a service decomposition and characterization methodology and to establish an ontology for semantic interoperability within the cluster.

3 KNOWLEDGE MANAGEMENT AND ONTOLOGY FOR ENTERPRISE INTEROPERABILITY

The relevance of knowledge management and semantic interoperability for cooperating enterprises is a topic of current significance. One of the four Grand Challenges in the *Enterprise Interoperability Research Roadmap* (Li et al., 2006) is Knowledge-Oriented Collaboration, now renamed Knowledge-Oriented Collaboration and Semantic Interoperability to emphasize the significance of semantics in enterprise interoperability (Charalabidis et al., 2008). Knowledge-based collaboration allows the sharing of knowledge within virtual organisations to the mutual benefit of all partners. The advances being undertaken in the area of knowledge management and ontology development are intended to be of direct benefit to enterprise collaboration. Those sharing the knowledge need have the same understanding of it, hence the requirement for ontology definitions in this area.

Despite a rapidly changing research area, work already undertaken was studied in the VISP project to establish the state of the art in ontology specification methods and ontology management techniques. Existing approaches were examined and their strengths and weaknesses evaluated in conjunction with the specific requirements of the VISP project for the use of an ontology.

The On-to-Knowledge IST project (www.ontoknowledge.org) was investigated and although the standards used in the project have evolved, the experiences gained were found to be useful input (Davies et al., 2002). The OTS methodology and architecture in particular were used as input to the VISP ontology work.

The DIP IST project (http://dip.semanticweb.org) objective was to develop and extend Semantic Web and Web service technologies, and it undertook an exhaustive state of the art analysis in many of the fields relevant to VISP (DIP, 2004). It developed the DIP Ontology Management Suite, which is an integrated set of tools for efficiently and effectively managing ontologies. VISP was able to input this work into its own state of the art analysis.

The Semantically-Enabled Knowledge Technologies (SEKT) IST project (www.sekt-project.com) objective was to develop and exploit the knowledge techniques underlying Next Generation Knowledge Management. It also performed a state of the art analysis on ontology evolution which was used as input to the work undertaken by VISP (SEKT, 2004).

Other projects undertaking work in this area include INTEROP, where ontology was one of its three key thematic components and research was undertaken to investigate ontology in conjunction with interoperability (http://interop-vlab.eu); FUSION, which is developing technologies for the semantic integration of a heterogeneous set of business applications within SMEs (www.fusionweb.org/fusion); SUPER, which is aiming to integrate Semantic Web Services and business processes into one consolidated technology (www.ip-super.org); and SYNERGY, one of the aims of which is to provide semantic ontology-based modelling of knowledge structures on collaborative working (Popplewell et al., 2008).

The work carried out in these and other projects provided generic results that could be evaluated and used in VISP as a basis for developing a specific ontology for services in the ISP domain.

4 SPECIFYING ISP SERVICES IN VISP

A VISP cluster can only work efficiently if all partners have the same view not only of what a service is and what it offers but also of relationships and constraints between services, service characteristics and characteristic values. In a federation of independent autonomous entities, there is no centralized control but there must be a common understanding between the partners of services and their properties in order to collaborate dynamically in real time. Properly specifying the properties of the elementary service components is “a key aspect of supporting the proper specification of (composite) services' semantics" (Leymann, 2007). The composite service must behave correctly when provisioned for the customer.

A primary objective of the VISP project is to build an ISP service knowledge base. A service has been defined in VISP as representing an atomic set of capabilities or activities that can be provisioned and used alone, or that can be grouped with other services to form a composite service. A set of elementary services for the virtual cluster has been investigated, classified and specified. The result is a knowledge base of ISP services formally represented using standard representations.

The VISP Service Knowledge Base (SKB) is a service catalogue that contains the technical information relating to the individual services that can be used to offer services to customers either standalone or as part of a composite service. The SKB thus provides a common technical understanding of services in the cluster, i.e. a common "language" shared by all partners that ensures consistency within the cluster.

Services described in the SKB are organized in categories and sub-categories. The nine categories comprise access services, bandwidth services, hosting services, application services, network services, security services, support services, and also software supplies and material supplies. Each of the nine categories defined is divided into sub-categories. The SKB can be centralized, distributed or replicated at each partner, depending on the functional architecture adopted.

A basic service modelling approach was adopted. A service is specified by a list of characteristics and each characteristic comprises a list of values. The service, each characteristic and each value has an associated description plus other parameters. This approach is very simple, generic and reusable. It does not depend on any particular technical or business environment and is applicable to many fields apart from the ISP/telecom domain.

Each service is thus characterized by a general description, a set of mandatory and optional parameters with their possible values, usage limitations and exclusions together with information on how they can be composed. All services offered by partners in the cluster are described using this specification. This information constitutes the VISP service knowledge base that, as the reference for ISP services in a VISP cluster, is being used to specify the VISP ontology.

5 ONTOLOGY FOR THE ISP DOMAIN

An ontology is being developed in the VISP project for VISP purposes, i.e. to enable partners in the cluster to collaborate in providing tailored services to customers as dynamically and in as automated a manner as possible. An ontology can be regarded as a "set of shared conceptualisations of entities within an application domain" (Wilson et al., 2006). In order to carry out eBusiness dynamically and in close cooperation with other partners in a virtual enterprise, all partners in the cluster need to adopt a common semantic model for their interactions, a shared understanding that can be automated by using a software infrastructure supporting the eBusiness of the ISPs. The VISP ontology thus constitutes one of the innovative results of the project.

Although problems are associated with the development of ontologies (Hepp, 2007), it was felt that the requirement for automating what can be a complex task meant that an ontology was essential for a VISP cluster. Work undertaken on developing an ontology for service components is often of a quite generic nature, for example (Sheth et al., 2006) and (Wang and Xu, 2008). However, the ontology here is being developed for VISP cluster purposes, to support the validation of ISP services composed automatically and dynamically from other services in an eBusiness context. It therefore has a restricted purpose and a limited circle of users and it should not be the bottleneck mentioned by Hepp when ontologies that are created by a small community are intended for much wider use.

The main use of an ontology in VISP is in the area of service composition and tailoring of innovative and often complex customized services. When new services are composed of individual component services, it must be ensured that the features of each service comprising the composite service do not conflict or result in inconsistency in the tailored service. The use of ontology is intended to assist the representation of the complex semantic and the relationships between the services offered by the partners in a VISP cluster. Validation of a service bundle requires a validation of the rules and restrictions among all services that form the service bundle. Semantic information such as restrictions, relationships between services, rules for the values of characteristics, etc. is static. It was therefore decided to model the content of the SKB using an ontology whose instance data are the service descriptions of all VISP services.

An analysis was performed within the VISP project to compare ontology tools and languages and to decide on the approach to take given the VISP requirements. Languages such as Topic Maps (www.isotopicmaps.org/sam/sam-model), RDF Schema specification (www.w3.org/TR/rdf-schema), OWL Web Ontology Language, (www.w3.org/TR/owl-ref/), OWL-S (www.w3.org/Submission/OWL-S) and F-Logic (Kifer et al., 1995) were investigated. Ontology editors were evaluated based on (Gomez-Perez et al., 2002) and work performed in SEKT (SEKT, 2004). Repositories for storing and retrieving ontologies and ontology change management systems were also evaluated.

Based on the evaluation results and the requirements of the VISP cluster in doing eBusiness, Protégé (http://protege.stanford.edu) was selected as the ontology editing tool, providing not only ontology editing capabilities but also constituting ontology library systems and offering various functions for managing, adapting and standardizing groups of ontologies while enabling ontology reuse. No tool fulfilled all the requirements for a reliable, secure, interoperable ontology management environment although most seemed to provide adequate solutions for most of the main issues in the VISP eBusiness environment. Protégé was one of the first editors available, it is open source and supports a variety of plugins and import formats, such as RDF Schema and OWL. It is also widely used; 68.2% of respondents in a survey were using Protégé as their ontology editor (Cardoso, 2007).

The principle requirement for an ontology specification language in VISP is expressive power and OWL was selected here. It supports the RDF data model, is used in the Semantic Web world and was felt to be the most appropriate choice for the eBusiness domain to be modelled in VISP. It too is widely used; 75.9% of respondents in the survey mentioned above are using OWL to develop their ontologies (Cardoso, 2007).

A two-phase methodology was developed for designing, developing and using the ontology-based knowledge management system for the VISP software environment. In the first phase, the application area and use of the ontology were determined. In the second phase, the ontology was built based on the information sources identified in the first phase and the concepts used there. Although the area of tools and technologies enabling the application of ontologies on a business level is not considered mature and much work is still in progress, the use of an ontology in VISP was recommended. Given the increasingly complex requirements of the VISP eBusiness environment and the need for rich, consistent and reusable semantics, ontologies represent an optimal answer to the demand for an intelligent system that operates more closely to the human conceptual level.

5.1 Description of the SKB Ontology

The ontology has been developed in VISP to represent the semantic information included in the VISP domain, i.e. ISP services. This ontology is intended to model the SKB but would also describe the classification of service descriptions, the attributes of service descriptions as well as the rules, constraints and relationships between them.

The service descriptions were classified as presented in section 4 above. The goal of the SKB ontology definition is to support this classification of service descriptions, to include the attributes of service descriptions and the relationships between them as well as to demonstrate the rules and the constraints for these attributes in a formal way that can be used to validate a composite service, or service set as it is termed in VISP.

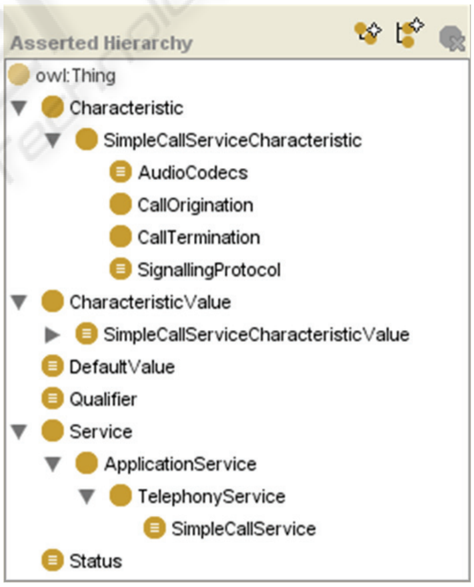

Figure 1: Class hierarchy for the SKB ontology in Protégé.

The Protégé OWL editor provides three views for the definition of an ontology, namely description of classes (see Figure 1), description of properties (see Figure 2) and description of individuals. For the description of classes the SKB ontology is primarily based on the schema of the SKB repository. However, the schema includes several details that are not required in the definition of an ontology, the primary purpose of which is to enable the validation of a service set from within the VISP software infrastructure. Such information includes mainly fields that are used to describe static attributes inside the SKB and which are of no special interest inside the SKB ontology, for example, Description, GenericDeploymentInformation, References.

The second view is the description of properties. OWL properties model all relationships between individuals of different classes. Apart from this pure listing of the ontology properties, this model also includes a description of the restrictions that each property of each class should satisfy. This aspect is further discussed in the following section.

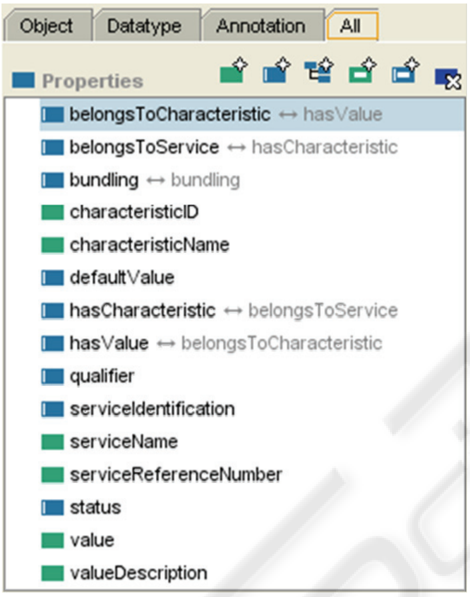

Figure 2: List of OWL properties in the SKB ontology.

The third view is the description of individuals. Individuals are instances of classes such as in object-oriented programming languages. Thus the descriptions of classes mentioned above also provide general descriptions for the individuals of these classes.

5.2 Restrictions to be Represented

The use of an ontology cannot only be justified by the need to model the domain of interest in a fairly simple way by using OWL classes and properties that resemble capabilities of UML diagrams and objected-oriented design. The need for an ontology has evolved due to the need to define complicated rules and constraints governing the domain of interest (in this case the ISP service domain). The definition of these restrictions is probably the most important part of the SKB ontology in the sense that it differentiates it from a flat database schema such as the SKB itself. Such rules and constraints can be defined in OWL provided that it is possible to express them as logical expressions.

Therefore, the definition of the SKB ontology is a two-step process:

1. First, the "skeleton" ontology model has to be specified. The class hierarchy, the listing of properties and the definition of individuals form the necessary schema elements of this model and will be utilized to describe the domain restrictions in the next step.
2. Then the rules and constraints governing the ISP services domain have to be transformed into logical expressions that can then be expressed using the expressive syntax of OWL.

Although the work on the classification of ISP services and their specification using the service description template (as described in section 4 above) has been almost completed and fully documented, the work on the documentation of the exact rules that each service will have to comply with has not started yet. Since it is expected that this task will involve a great amount of work which will be continued even after the end of the project, a workaround has been used to ensure that OWL is adequate to express all possible rules and restrictions in the ISP world. A demo service was described and the following possible types of restrictions that the modeller could be asked to represent were identified:

1. The set of selectable enumerated values of a characteristic depends on the value of another characteristic.
2. The existence of a characteristic depends on the value of another characteristic.
3. The range of values of a characteristic depends on the values of another characteristic (very similar to case 1 but more complex to represent because deals with ranges).
4. Characteristics are mutually exclusive, but at least one must be present although they are indicated as optional.

The first type of restriction essentially constitutes an "if" statement: if the value of characteristic A is greater than 5, characteristic B can only take values 1, 2 and 3. The representation of an "if" statement can be easily achieved with the help of the logical operators AND, OR and NOT. If X then Y is equivalent to NOT X OR Y. Of course, OWL allows the definition of such a logical restriction.

As the same analysis has been performed for all the above types of restrictions, it is clear that OWL and the definition of the SKB ontology model satisfy the requirements of the ISP domain as well as of the VISP use case called “validation of a service set”.

A technical restriction imposed by the current OWL specification is the lack of support for numeric ranges. While OWL has cardinality restrictions, datatype values cannot be further restricted. One of the solutions evaluated was to extend OWL files with URI references into an (external) XML Schema file. This means that a separate XML Schema file together with the OWL file will have to be maintained. Another solution is to define an extension ontology to be imported by the SKB ontology, which defines RDF properties that can be used to represent XML Schema facets. Other solutions are also being evaluated and hopefully the next OWL specification will be enriched with the capability of expressing restricted datatypes.

5.3 Use of the SKB Ontology

The use of the ontology comprises two concepts: how to manipulate the ontology and how to exploit it to enable the validation of a service set.

When manipulating the SKP ontology, Protégé allows for a series of actions regarding a definition of an ontology, such as to:

- create the ontology definition
- browse the ontology
- edit/update the ontology definition
- query the ontology
- store the ontology persistently
- apply various ontology checks
- compute the inferred taxonomy

The last two actions are performed with the assistance of an OWL reasoner, which can be combined with Protégé if it supports the DIG interface. An OWL reasoner provides the following standard inference services:

- Consistency checking: determines whether the ontology contains any contradictory facts.
- Concept satisfiability: determines whether it is possible for all classes to have any instances.
- Classification: computes the inferred class hierarchy.

In general, Protégé supports all features expected of an OWL editor. The SKB ontology will be manipulated through the use of Protégé, at least until the end of release 3 of the VISP software infrastructure. In the future it may be desirable to be able to perform certain actions on the ontology from the VISP platform itself.

The primary reason for the definition of the SKB ontology was to enable the implementation of the validation of a service set. When a customer requests one or more services from VISP, a sales representative creates a service set that comprises various services offered by partners in the cluster. After a service set has been created, it needs to be validated to ensure it can be instantiated. The sales representative uses the VISP GUI to click on the “validate” button to validate this service set.

The use of the SKB ontology allows for a more sophisticated validation strategy than the rather simple and incomplete validation undertaken in the first two releases of the VISP infrastructure software. The ontology is being used to enhance the first implementation, e.g. checking intra-service constraints between characteristics and values, checking inter-service constraints between services, characteristics and values, etc.

Compared with the current implementation, the additional necessary architectural element will be a framework enabling the manipulation and the usage of the ontology. Such a framework can be Jena (http://jena.sourceforge.net/index.html). Jena is a Java framework for building applications related to the Semantic Web in general. It includes:

- RDF API
- OWL API
- Rule-based inference engine
- In-memory and persistent storage
- SPARQL query engine (www.w3.org/TR/rdf-sparql-query/)

Its most useful feature for VISP is that it allows an ontology or a data set to be represented with an object model, as well as incorporating reasoning capabilities.

A main prerequisite before the validation can start is the existence of a consistent SKB ontology. A service description is added to the SKB ontology when it is approved in the VISP cluster with the appropriate restrictions. The next steps are then followed inside the implementation code of the validation of a service set:

1. The system reads the service set that is to be validated either through the repository containing information about the service sets and their component services or through an XML file.
2. It creates a model representing the data set of this service set.
3. It loads the ontology model of the SKB ontology. This can be read and created each time from the respective OWL file or it can be stored persistently inside a database.
4. It validates the data model against the existing ontology model, i.e. it performs a global check across the schema and instance data looking for inconsistencies.

5. The result will report whether the validation check has passed and detail any detected inconsistencies.

This approach is quite simple and can be seamlessly integrated with the current implementation of the service set validation since Jena is a Java framework that can used by the existing classes.

6 CONCLUSIONS

The VISP project has developed both a methodology for categorizing and describing ISP services and an ontology for the ISP service domain. The need to add semantic content to ISP service descriptions is fundamental for ISPs carrying out eBusiness for innovative, complex and composite ISP services.

The VISP ontology has been produced for a specific context and is being applied in this context. This is indeed a recommended approach when the aim is a lightweight ontology that can be cost effective to design, build and maintain (Alani et al., 2008). Ontologies do not need to be large and complex and the intention of the VISP project was innovative in that it has designed an ontology that could be part of the VISP platform in a running environment. Decisions taken in developing the ontology tended therefore to be pragmatic with the context, stakeholders and potential users in mind.

The intention is to further develop the results of the VISP project for commercial use in a virtual cluster of small ISPs. The ontology is an essential part of this aim and has been designed for such use. The work depicted here has built on existing research work in the area and has applied it to a specific context. This has required a lightweight approach avoiding any undue complexity and the development of a small and highly focussed ontology that fits in with the specific requirements of the VISP cluster and its partners. First results have shown that the ontology has met these requirements and that ISP composite services can be automatically validated with the ontology during service provisioning.

ACKNOWLEDGEMENTS

This work was carried out with partial funding from the EU through the IST project VISP (IST-FP6-027178). Further information on VISP can be obtained from www.visp-project.org.

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