ONTOLOGY GATEWAY
Enabling Interoperability between FIPA Complaint Agents and OWL Web Services

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Abstract: The introduction of Ontology Web Language (OWL) which is a W3C standard for providing explicit semantics for establishing and sharing ontologies on the World Wide Web, has made it easier to embed semantics with web data. Similarly FIPA Semantic Language is the core of the agent platforms due to its high expressive power. Ontology plays an important role in the knowledge representation, reuse and communication between web services. Similarly in an Multi-agent system ontology also plays an important role, where the messages exchanged between agents should conform to an Ontology so that they could be understood. In this paper we will introduce a technology enabling bidirectional interoperability between FIPA compliant software agents and the Web services published in OWL. This is an extension of previous work in which we proposed the development of semantic translations in such a way that the agents can communicate with web services in an efficient manner. We will also describe and discuss the implementation in which a FIPA complaint software agent will invoke and use a web service published in OWL. Our goal for this paper is to show how a FIPA complaint agent can invoke and use the web services published on the World Wide Web by the help of ontological transformations.

1 INTRODUCTION

The semantic web (T. Berners-Lee, 2004) field within the W3C has grown rapidly during the last few years. The semantic web is aimed to unite the existing web information in order to make it easier for the third parties to share and reuse. Formal taxonomies, ontologies and the available web standards such as RDF, XML, OWL, DAML-S, etc. allow the web application developers to specify the information in a standard way, to enable reusability and sharing. The semantic web aims at providing more intelligent access and management of the Web information and more semantically richer modeling of applications and their users. The web can reach its full potential if the information available on the web can be processed both by the automated tools as well as the people.

Ontology (D. Fensel, 2003) is a specification of a conceptualization (formal taxonomy). It provides a vocabulary that describes a domain of interest and the meaning to the terms being used. Through ontologies we can produce information that is human as well as machine understandable. In fact the ontologies from the core of the semantic web and enable automated interoperation and cooperation.

Computer can just read the information currently available on the World Wide Web and cannot interpret it. The growth of the semantic web will give rise to such information that is structured and understandable by the computers. It will be an extension of the existing World Wide Web in which the information will be given a well defined meaning and better-enabled computers (T. Berners-Lee, 2004). The semantic web will enable efficient discovery and better utilization of the resources on the web. W3C and several other research groups are

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working to provide a formal language for defining ontologies and explicit semantics for the web resources. Therefore Ontology Web Language (OWL) (M. Dean, 2004) has been proposed by the W3C. OWL can be used to describe the classes and relations between them. It is capable of defining and instantiating Web ontologies and has overcome many of the deficiencies that are present in other ontological web languages.(overhead)

On the other hand Grid computing (IBM Grid Computing Homepage) has emerged as an important field; it provides a hardware and software infrastructure that enables dependable, consistent, persuasive and inexpensive access to computational capabilities and coordinated resource sharing. The semantic grid is the extension of the current Grid, with the exception that in the semantic grid information and services are given well defined meanings and enables autonomous interoperation between entities (M. Wooldrige, 1997). It is similar to the Semantic Web in a way that it uses metadata to describe information in the grid. Turning information into more than just simple information, enabling computers not only to read the data but also understand the information presented. The key idea behind semantic grid is to enable software agents to dynamically discover, invoke and monitor the semantic enabled web services.

An agent platform is an infrastructure through which agents can be deployed. A typical agent platform such as Foundation for Intelligent Physical Agents (FIPA) complaint agent platform, Scalable fault tolerant Agent Grooming Environment (SAGE) (Abdul Ghafoor, 2004) provide services like creating a multi agent application that uses services provided by the agent platform itself and services on the Grid (Ferber, 1999).

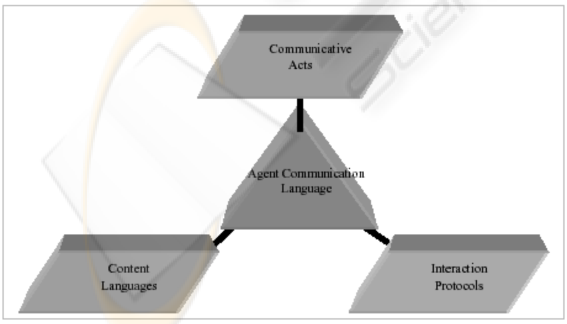

Figure 1: Agent Communication Language.

For agents to communicate with each other they need a set of instructions and standards on how agents will carry out effective and meaningful conversation. For this FIPA has proposed ACL. That provides semantics and precise syntax descriptions for messages to be exchanged between the agents.

In cases where the service or resource required by an agent to accomplish a task is not available on the Grid on which the agent platform is running, in such cases the agent will have to leave the work incomplete. We propose an Ontology Gateway that will enable an agent to consume services available on the web. In cases described above if an agent is unable to perform a task due to shortage or unavailability of a service it can then search for that service on the World Wide Web. The agent can then consume or make use of a Web service published in OWL to complete its task. We will enable such communication through ontological transformations in the Ontology Gateway. The architecture of the proposed Ontology Gateway will be explained in section 2.

2 PROPOSED ARCHITECTURE

The architecture we proposed in (Maruf Pasha, 2006) provided the semantic operability in distributed environments where technologies like agent applications and grid systems are combined and reused to provide a Semantic Grid and thus providing a service oriented framework.

In it the OWL that is a W3C standard for specifying the services on the web will be used as a content language. The communication infrastructure specified by FIPA permits agents to communicate using any mutually comprehensive content language as far as it fulfils a few minimal criteria laid down by the FIPA.

The key idea behind the proposed architecture was to enable software agents to communicate with the web services.

We will carry forward the previous architecture but will enhance it in such a way that it will be able to cater more OWL and ACL operators converting them into their appropriate OWL/ACL operators. In the enhanced Ontology Gateway we have also added a Natural Language Process (NLP) module. The NLP module will take the user query as input in the form of natural language. Then it will convert the query into an ACL query, which will then be passed to the ontology gateway that will interpret the ACL query and will locate the appropriate web service.

The NLP module implements a text mining (J. Dorre, 1999) algorithm. Text mining is similar to data mining; data mining seeks to extract data and meaningful patterns from the data (Eibe Frank, 1999), where as text mining is about looking for meaningful patterns or data in natural language text. This module will help the agent in determining the semantic meaning of a user query given in simple English and will enable users that are not familiar with the syntax of FIPA-ACL to generate queries using simple English, which will then be converted to an appropriate ACL query.

Figure 2 shows an abstract architecture of the proposed system. The addition of the NLP module will also enable users having little knowledge of the Multi Agent Systems to use the Ontology Gateway and generate ACL queries. The key idea behind the proposed architecture is to show how software agents communicate with the OWL based web services and to enable users that are not aware of FIPA syntax to use and generate queries in English that would then be converted to appropriate ACL query through the NLP module.

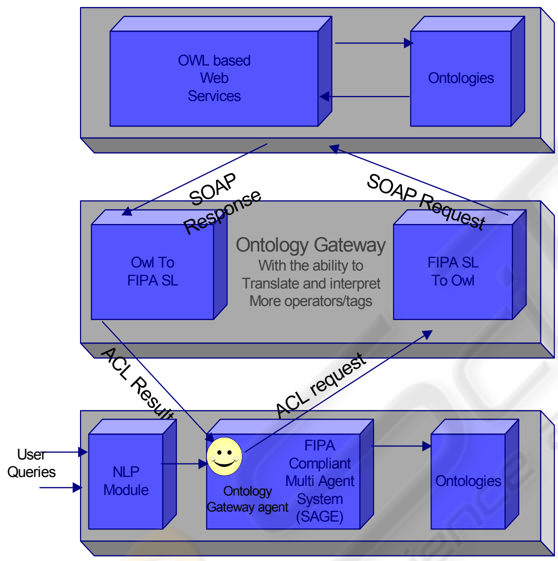

Figure 2: The Proposed Architecture.

3 IN DEPTH ANALYSIS OF FIPA AND OWL

The main reason for these conversions is that both FIPA SL and OWL have different principles in terms of syntax, semantics and implementation constraints. Therefore devising translations for such a system is quite demanding and challenging, as both the languages are quite different from each other. This section will present some details on how exactly the conversions in the Ontology Gateway will take place. In this section we will also present analysis of ontologies of FIPA

Table 1 shows the mappings of OWL class. Every class in the OWL world is a member of the class owl:thing, therefore each user defined class is by default a sub class of owl:thing, where as in FIPA Ontologies every class is by default a subclass of the universal class :THING. Every OWL class provides an abstraction to group together resources with similar characteristics therefore they are mapped to frames in FIPA Ontology, which represents an entity.

OWL provides a set of complex operator for defining classes such as owl:intersectionOf, owl:unionOf, owl:oneOf etc. which are used to provide explicit semantics with the classes. Our key focus during the transformations will be to map the operators in such a way that the underlying semantics are preserved as much as possible. See Table 1 for FIPA implementation of the OWL operators and tags.

Table 1: OWL Class Mappings.

	OWL	FIPA
Basic Class	owl:Thing	:THING
	owl:Class	Frame
		:CLASS
Class Axioms	rdfs:subClassOf	subclass-of
	owl:equivalentClass	Equivalent
		:SAME-VALUES
Class Description	Individual	Individual
	Rdfs:domain	:DOMAINS
	rdfs:range	:SLOT-VALUE-TYPE
	owl:restriction	Content
	owl:minCardinality	:MINIMUM-CARDINALITY
	owl:maxCardinality	:MAXIMUM-CARDINALITY
	owl:DatatypeProperty	:VALUE-TYPE
	owl:intersectionOf	BinaryLogicalOp = "and"
	owl:unionOf	BinaryLogicalOp = "or"
	owl:complementOf	UnaryLogicalOp = "not"
	owl:oneOf	set-of
	owl: disjointWith	:NOT-SAME-VALUES

Table 2 shows the Property mapping of Ontology Web Language. The `owl:objectProperty` tag is used to define relations between instances of two classes, for example :

```
<owl:ObjectProperty
rdf:ID="fatherOf">

<rdfs:domain
rdf:resource="#Man"/>

<rdfs:range
rdf:resource="#Children"/>

</owl:ObjectProperty>
```

where as in FIPA frames (classes) has slots(properties) and each slot of a frame has associated with it a set of facets, and each facet of a slot has a set of entities associated(classes) with it, therefore while translating an OWL Ontology into a FIPA Ontology `owl:objectProperty` will be mapped onto facets. The data type properties are basically instances of classes and RDF schema and XML schema data types. Therefore, `owl:datatypeProperty` is used to define a data type for the property.

Table 2: OWL Property Mappings.

	OWL	FIPA
Property	rdfs:domain	:DOMAINS
Associat ions	rdfs:range	:SLOT-VALUE-TYPE
Property Relation ships	owl:equivalentPropert y	:SLOT-SAME-VALUES
	owl:inverseOf	:SLOT-INVERSE
	rdfs:subPropertyOf	:SLOT-SUBSET-OF-VALUES
	rdfs:Datatype	:SLOT-VALUE-TYPE
Property Restricti ons	owl:cardinality	:SLOT-CARDINALITY
	owl:maxCardinality	:SLOT-MAXIMUM-CARDINALITY
	owl:minCardinality	:SLOT-MINIMUM-CARDINALITY
	OWL	FIPA
Restricti ons	owl:allValuesFrom	:SLOT-SAME-VALUES
	owl:someValuesFrom	:SLOT-SOME-VALUES
	owl:hasValue	:SLOT-SUBSET-OF-VALUES

Whereas in FIPA Ontology :SLOT-VALUE-TYPE is used to define a data type for a slot. Hence `owl:DatatypeProperty` will be transformed to :SLOT-VALUE-TYPE.

For other properties such as `owl:equivalentProperty`, `owl:inverseOf`, etc and property restrictions such as `owl:cardinality`, `owl:allValuesFrom`, `owl:hasValue`, etc there are appropriate equivalent operators in FIPA, which also perform the same functionality as that of OWL tags. For further mappings see Table 2.

4 TEST BED AND RESULTS

First Machine has Tomcat web server, Eclipse version 2.1 installed in it and Jena 2.4 to enable web server to create and deploy OWL web services.

On the second machine, the above mentioned system is installed to provide required transformations.

The third machine contains FIPA compliant agent platform SAGE (Abdul Ghafoor, 2004), on which agent providing some services have been deployed.

The successful ontological transformations depends on the provided information of the web service, if the provided information is valid then the transformation will be successful and 100% results can be obtained. Agents with the help of AgentWeb Gateway (Hiroki Suguri, 2004) (Muhammad Omair Shafiq, 2005) (H. Farooq Ahmad, 2004) searches for the required service in the UDDI. Upon successful search it retrieves the web service. Now the software agent needs to know about the ontology, the predicate schema and the concept schema therefore it passes the OWL ontology to the Ontology Gateway which transforms the Web Serviced published in OWL to its equivalent FIPA Ontology. The agent can then use the transformed ontology to populate its knowledge base.

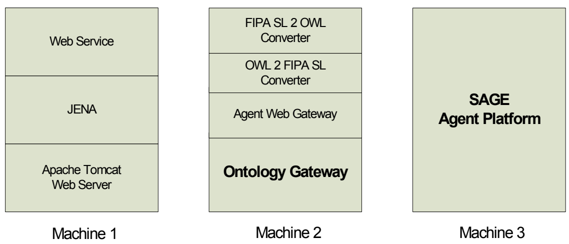

Figure 3: Testbed Cofiguration.

The time required for the transformation depends on the number of classes involved and their corresponding properties.
The proposed system will also help the W3C compliant OWL based web services (Grid entities) to communicate with the software agents. The Grid entity sends a SOAP based UDDI query which is converted into a valid ACL based DF query with the help of the AgentWeb Gateway. If the required service is found it is then forwarded to the Onotlogy Gateway which then converts the FIPA Ontology into its equivalent OWL ontology. And the converted Ontology is then embedded into its original SOAP message with its name and certain other parameters, which is then forwarded to the Web Service client that requested for the service. This can be established using the same testbed configuration as described above.

5 FUTURE WORK

This paper proposes ontology gateway architecture and detailed mappings that is our research focus for enabling flexible, autonomous interaction between Semantic Web services and agent services. A prototype implementation of this architecture is under development at NUST-Comtec lab. It is intended to improve the proposed design so as to cater more semantically enriched communication.

We expect that this effort of conducting communication between agents and web services via a Gateway service, bridging agents and WS is only a prelude to exploring the immense potential it offers as a means to compose, invoke, administer and manipulate heterogeneous service populations. As OWL is based on description logic so it comparatively less expressive then FIPA ACL/SL therefore we need to introduce new operators while transforming from SL to OWL.

6 CONCLUSION

In this paper we have proposed an enhanced version of Ontology Gateway as compared to the version proposed in (Maruf Pasha, 2006). The system will now allow the user to enter queries in natural language which will then be processed by the NLP module which extract keywords from the query and generate an equivalent ACL query. Our proposed system will provide mappings/translations for more operators and tags for the interoperability of FIPA Semantic Language with Ontology Web Language (OWL) and will prove to be a vital step in achieving a semantic web and ultimately the Semantic Grid.

In order to achieve this milestone, this paper contains the key issues and the detailed comparison of the two technologies. The paper describes the testbed configuration and the results when OWL ontologies are mapped/transformed using the Ontology Gateway. We have also described the proposed architecture that will enable us to achieve autonomous coordination in the messages that are exchanged between the FIPA compliant Multi agent systems and OWL based web services. And will allow agents to interact with OWL based Web Services.

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