Bolero.net in the semantic web and GRID environment

Violeta Damjanovic*, Vladan Devedzic and Dragan Djuric

GOOD OLD AI Research Group
FON-School of Business Administration
University of Belgrade
P.O. Box 52, Jove Ilica Street 154
11000 Belgrade, Serbia and Montenegro
E-mail: vdamjanovic@gmail.com
E-mail: devedzic@fon.bg.ac.yu
E-mail: dragandj@gmail.com
*Corresponding author

Dragan Gasevic

School of Interactive Arts and Technology
Simon Fraser University Surrey
2400 Central City
10153 King George Highway, Surrey
BC V3T 2W1, Canada
E-mail: dgasevic@acm.org

Abstract: In this paper, we have focused on using the bolero.net community in the semantic web and grid environment. Bolero.net represents a community with the ambitious initiatives to standardise world trade messaging and to create a community for more efficient international trade. Bolero.net uses a protocol called $\text{bolero}_{\text{XML}}$ that represents a set of standard electronic documents with the aim of facilitating interoperability amongst the members of the electronic international trade chain. The idea of making the $\text{bolero}_{\text{XML}}$ standard electronic documents in the form of an OWL ontology is shown in this paper. The main goal of using an ontology of the $\text{bolero}_{\text{XML}}$ documents is to moderate this kind of web-based community. The way this ontology is connected with web services, as well as web agents, is shown through the use of ebXML Registry and Repository.

Keywords: semantic web; semantic grid; Bolero.net community; ebXML; web services; web agents; ontologies; OWL.

Reference to this paper should be made as follows: Damjanovic, V., Devedzic, V., Djuric, D. and Gasevic, D. (2006) 'Bolero.net in the semantic web and GRID environment', *Int. J. Web Based Communities*, Vol. 2, No. 2, pp.223–236.

Biographical notes: Violeta Damjanovic is a member of the GOOD OLD AI research group and a PhD candidate at the University of Belgrade, Department for Electronic Business. At the same time, she is employed as a Senior Associate at the Postal Savings Bank, Belgrade, Serbia and Montenegro. She received her BSc in Information Systems and a degree as a specialist in Internet Technologies from the University of Belgrade in 1998 and 2003, respectively. Her interests mostly include semantic web, semantic grid, web intelligence, multi-agent systems, adaptive hypermedia systems and applications of artificial intelligence techniques to education.

Vladan Devedzic is a Professor of Computer Science at the Department of Information Systems, FON – School of Business Administration, University of Belgrade, Serbia and Montenegro. His main research interests include software engineering, intelligent systems, knowledge representation, ontologies, semantic web, intelligent reasoning, and applications of artificial intelligence techniques to education and medicine.

Dragan Djuric is a PhD candidate at the University of Belgrade, Department for Information Systems, and a member of the GOOD OLD AI research group. He received his BSc and MSc degrees in Information Systems from the University of Belgrade in 2002 and 2004, respectively. His interests mostly include enterprise software architecture, model-driven engineering, object-oriented development, Java platform, semantic web and intelligent information systems.

Dragan Gasevic is a Postdoctoral Fellow with the School of Interactive Arts and Technologies, Simon Fraser University Surrey, Canada. He received his BS, MS and PhD degrees in Computer Science from the University of Belgrade in 2000, 2002 and 2004, respectively. His research interests mostly include semantic web, ontologies, model-driven architecture, and applications of artificial intelligence techniques to education.

1 Introduction

The main technological challenges and requirements on the next-generation web-based communities can be fulfilled by using emerging technologies, such as the following ones:

- The semantic web – represents the idea of having data on the web defined and linked in such a way that it can be used for more effective discovery, automation, semantic integration, metadata annotation, and reuse across various applications (W3C, 2001)
- The semantic grid – attempts to extend semantic web approaches and solutions to take into account grid characteristics
- Knowledge grids – offer high-level tools and techniques for distributed knowledge extraction from data repositories on the grid
- Peer-to-Peer (p2p) – considers a set of protocols, a computing model and a design philosophy for distributed, decentralised and self-organising systems
- Ubiquitous computing (pervasive computing) – describes distributed computing devices, such as personal devices, wearable computers, and sensors in the environment, and the software and hardware infrastructures needed to support applications on these computing devices.

Nowadays the web brings a number of possibilities to concatenate different ideas, collects knowledge, improves the existing communities on the web and builds new ones. Therefore, a number of new web-based communities are arising, but the facility of searching the web is not yet achieved. In this paper, we glance at some new and emerging technologies, such as the ontologies, web agents and web services in the semantic web and grid environment. The main intention of this paper is to explore using the bolero.net community on the semantic web, as well as on the semantic grid, and to point out certain potentials in further improving this kind of community on the web. In addition, we consider possibilities to moderate and to adapt bolero.net community to the requests of future knowledge that is organising in the form of ontologies. Ontologies represent a common machine-level understanding of topics that can be communicated between users (or web-based communities) and applications on the semantic web and grid environment.

Originally, the semantic grid initiative set out to promote e-science, but nowadays extends to the industry, e-business, e-government and e-learning as well. The semantic grid represents an extension of the semantic web. The semantics underlying data, programmes, pages and other web resources will enable a knowledge-based web that provides a qualitatively new level of services on the web.

The paper is organised as follows. After the brief introduction, some general explanations of the semantic web, as well as the semantic grid environment, are explained. Section 3 gives some general explanations of bolero.net community, a set of electronic trade documents known as the bolero$_{XML}$, and the usage of ebXML to exchange messages and business documents. Section 4 shows the semantic web implications on bolero.net community. In Section 5, an example of creating an ontology of the bolero$_{XML}$ documents is shown. Section 6 gives an example of using bolero.net in the semantic web environment. Section 7 discusses related work and contains some conclusions and directions in the research of how to moderate web-based communities.

2 Semantic web and semantic GRID environment

The vision of the future web brings two orthogonal features: the semantic web – as the future of the web; and the grid – as the future of the internet. Both of these visions have developed separately, but the need nowadays to store, annotate, mine, manage and explore a huge distributed collection of heterogeneous data brings novel, advanced applications of grid-computing infrastructure in the semantic web environment. The semantic web's goal is to establish not only machine-readable but also machine-understandable web resources, and thus to provide more accurate filtering, categorisation and searches of various information resources. From the future web perspective, both technologies become necessary and integrated in the form known as the semantic grid.

The notion of the semantic grid came about in 2001, and the first semantic grid papers were written the following year (papers – Goble and De Roure, 2002a; Goble and De Roure, 2002b). The semantic grid vision represents an extension of the grid, until the grid represents (Foster *et al*., 2001) "flexible, secure, coordinated resource sharing among dynamic collections of individuals, institutions, and resources – what we refer to as virtual organizations".

In addition:

> "the real and specific problem that underlies the Grid concept is coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations. The sharing that we are concerned with is not primarily file exchange but rather direct access to computers, software, data, and other resources, as is required by a range of collaborative problem-solving and resource brokering strategies emerging in industry, science, and engineering." (Berners-Lee and Miller, 2002)

The semantic grid is an initiative to develop effective methods for enabling complex resource sharing. It represents (Cannataro and Talia, 2004):

> "an extension of the current Grid in which information and services are given well-defined meaning, better enabling computers and people to work in cooperation. The Web will reach its full potential when it becomes an environment where data can be shared and processed by automated tools as well as by people."

The future grid intends to enable effective and meaningful resource sharing on each of these levels, which can be summarised as (Cannataro and Talia, 2004):

- Grid fabric level – encompasses the following: high-performance network protocol, network monitoring, computation resources and various instruments
- Grid services level – attends to security and authorisation, authentication, resource management, metadata management, distributed file systems, *etc*.
- Semantic grid level – handles the creation and management of metadata, database management, workflow management, digital rights, adaptation and personalisation, *etc*.
- Knowledge grid level – automatic annotation and summarisation, dynamic hyperlinking and metatagging, knowledge representation and visualisation, *etc*.

Recently, the grid has been proposed to provide a common infrastructure to build the various web-based implementations. E-business and various web-based communities need to use new technologies in order to provide advanced knowledge sharing and collaboration between different user profiles and different user needs. Thus, the semantic grid can be used for the creation of new scientific results, new businesses and even new research disciplines.

In addition, we can stress the possibility of envisaging the semantic grid, which behaves like a constantly evolving organism, with ongoing, autonomous processing rather than on-demand processing (De Roure *et al*., 2005). So, the semantic grid becomes an organic grid which itself can generate new processes and new knowledge, manifested in the physical world through ambient intelligence vision (it builds on three recent key technologies: Ubiquitous Computing, Ubiquitous Communication and Intelligent User Interfaces).

3 Bolero.net community

Bolero.net (**B**ills **O**f **L**anding **E**lectronic **R**egistry **O**rganization) was created by (Bolero.net, 2003):

- world logistics community – represented by the Through Transport (TT) Club
- world banks – represented by the international banking cooperative SWIFT (**S**ociety for **W**orldwide **I**nterbank **F**inancial **T**elecommunication).

The mission of the bolero.net organisation is to become the standard platform for conducting world trade on the internet and making the process of buying and selling across borders much more efficient. In essence, bolero.net allows anyone engaged in the process of buying and selling across borders to exchange trade data and electronic trade documents over the internet securely and with legal certainty (Bolero.net, 2003).

3.1 Bolero.net in general

Bolero.net has a goal of eliminating the need for bilateral data interchange agreements that describe the structure and content of electronic data being exchanged between two companies by providing a set of common standards that can be applied multilaterally (Bolero.net, 2003). Therefore, all members of the bolero.net community can use the same basic messaging standards; all parties of a trade chain will be able to 'talk' to each other by automating their information exchange.

To implement the document definitions, bolero.net community has chosen to use eXtensible Markup Language (XML) through the form of the $bolero_{XML}$ documents. The objective of using $bolero_{XML}$ is to enable users of bolero.net to take full advantage of electronic commerce by providing a set of standard electronic trade documents that will facilitate interoperability amongst the members of the trade chain (Bolero.net, 2003). So far, it has to be flexible enough to tolerate the constant advances of technology.

Standards are vital to the exchange of information (messages and documents) amongst different parties. The $bolero_{XML}$ standards are developed independent of any syntax but implemented on the messaging service in the syntax that has the most long-term support at this time (currently XML).

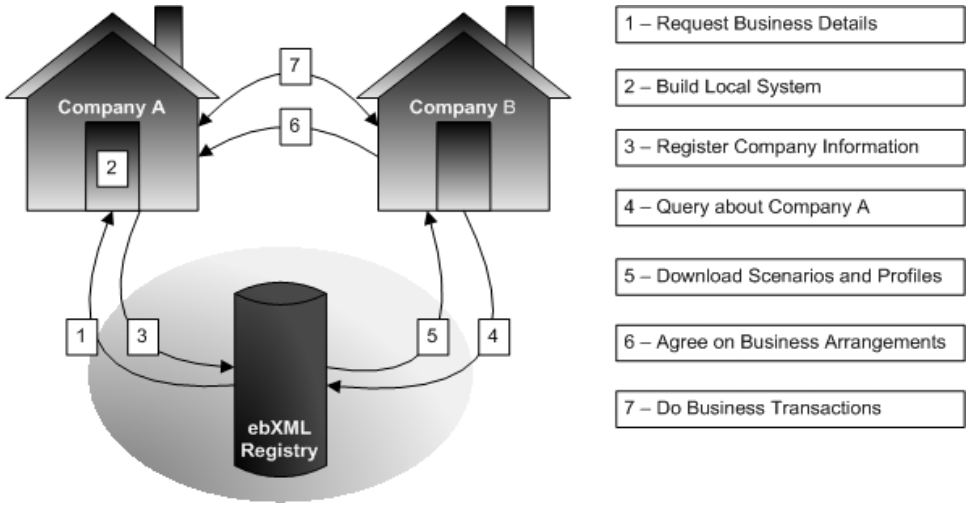
3.2 ebXML in brief

$Bolero_{XML}$ is a source standard for ebXML (**e**lectronic **b**usiness using e**X**tensible **M**arkup **L**anguage). ebXML is being designed with an end result to provide the catalyst in standardising electronic business vocabularies (semantics), infrastructure and business documents (Graham, 2003). ebXML can be used to exchange messages (business documents) between different business entities (enterprises) of any size and in any geographical location (ebXML, 2000). These messages will be based on clear definitions of the underlying business processes, documented in the Unified Modelling Language (UML). ebXML can be seen as a 'unified global EDI'[1] standard for companies of all sizes, both large international companies and SMEs (Small and Medium Enterprises) in every industry sector. So far, ebXML can be implemented and deployed on just about any computing platform and programming language.

The ebXML interaction between two companies is shown in Figure 1 (Graham, 2003). Company A retrieves content within the ebXML Registry and provides an ebXML product/service suitable for its ebXML exchange. Company A creates and registers its company profiles (business processes and information models) into the ebXML Registry. Company B makes a query about compatibility between these two

companies, and defines an agreement CPA (Collaborative Partner Agreement) with company A. The two companies start doing business transactions (exchanging messages between business partners).

Figure 1 The ebXML process of electronic data interchanges between the two companies



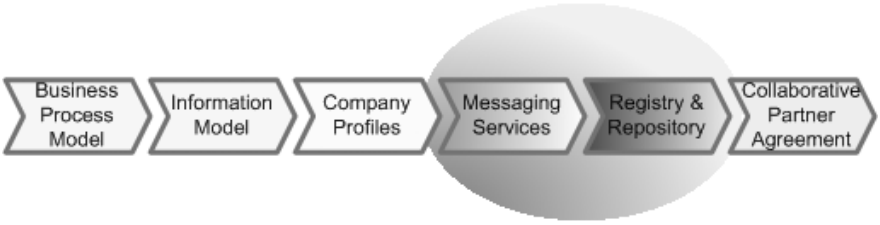
Source: Graham (2003)

ebXML is a set of specifications to enable secure, global, electronic business using proven, open standards such as TCP/IP, HTTP and XML. ebXML is designed to work with existing EDI solutions, or be used to develop an emerging class of web-based electronic business applications based on XML. By implementing ebXML, a company can provide automation methods for its electronic business transactions, which increase the reliability and effectiveness of services, and provide a value method for cost reduction and technology innovation. The technical architecture of the ebXML is composed of the following areas (ebXML, 2000), shown in Figure 2:

- Business Process and Information Model:
  - a The Business Process model – defines how business processes are described, and enables the integration of business processes within a company, or between companies
  - b The Information model – defines reusable components that can be applied in a standard way within a business context
- Company Profiles – provide a number of notable information about companies
- Messaging Services – define the set of services and protocols that enable electronic business applications to exchange data

- Registry and Repository – provide a number of key functions. For the user (application) it stores company profiles and trading partner specifications. These give access to specific business processes and information models to allow updates and additions over time. For the application developer it will store not only the final business process definitions, but also a library of core components.
- Collaborative Partner Agreements (CPA) – defines technical parameters for conducting electronic business.

Figure 2 The main areas of the ebXML technical architecture



ebXML Registry & Repository will be discussed as an essential part of the ebXML architecture, together with Messaging Services (shown in Figure 2). Both of them form an inherent part of the ebXML architecture: one is for discovering business partners, the other one is for communicating with them. Both of them can be observed from the point of web services, where ebXML Registry & Repository could be compared with UDDI (Universal Description, Discovery and Integration), while ebXML Messaging Services could be compared with Simple Object Access Protocol (SOAP). The way that both of these parties of the ebXML architecture will be able to connect with the semantic web environment will be discussed in detail in the upcoming section.

At the same time, a recent trend in the hardware community is to turn away from integrated, large-scale systems and towards networks of normal personal computers that jointly work on a computationally demanding task in the semantic grid environment. These supercomputers combine the advantage of lower costs through the use of standard hardware with an extreme scalability that allows adding more computational resources whenever this is necessary.

4 Bolero.net and the semantic web implications

Nowadays, XML represents the world standard platform for electronic business transactions that promise to change completely the way that electronic business works. XML provides a data format for structured documents without specifying a real grammar. Hence, it can provide information about the document structure, but nothing else.

The vision of the future web means putting more intelligence into the web, through the knowledge about knowledge (metaknowledge, metadata, ontologies), description about processes on the web, rules about knowledge and processes, and many more.

The semantic web represents a new way of organising knowledge on the web in the form of decentralised vocabularies (Semaview Inc., 2002) – called ontologies. Ontologies represent meta-organised knowledge that is designed to give the semantic meaning to represented data. One of the central roles of ontologies is to establish further levels of interoperability, *i.e.*, semantic interoperability, between web agents and web applications on the emerging semantic web (Berners-Lee *et al*., 2001), as well as to add a further representation and inference layer on top of the web's current layers (Decker *et al*., 2000; Hendler, 2001).

Using widely accepted ontology development languages and standards represents a prerequisite for successful ontology development. It will be helpful to briefly review some of these languages, known as the semantic web languages:

- RDF[2] – Resource Definition Framework – represents a general language for the description of metadata on the web
- RDFS[3] – Resource Description Framework Schema – represents an abstract data model that defines associations between entities (resources) as semantic networks. In addition, RDFS extends RDF to include a larger vocabulary with more complex semantic constraints.
- OWL[4] – Web Ontology Language – facilitates machine interpretability of web content by providing additional vocabulary along with formal semantics. OWL can be used to explicitly represent the meaning of terms in vocabularies and the relations between those terms. OWL has three expressive sublanguages: OWL Lite, OWL DL and OWL Full.

These languages can be used to represent the meanings separately from data, web content or programme code (web applications), using the common open standards for the semantic web. These standards enable communication using the form understandable and readable to users, as well as for machines, processes, agents and applications on the web. At the same time, such languages are appropriate for the description of complex links between domain terms, as well as for descriptions of defined domain constraints, associations and know-how about the uses of things on the web.

On the intelligent web, web agents will use the semantically annotated and understandable information represented in some languages, which will be readable to them. So far, intelligent web agents will be able to create new and to use existing metaknowledge that come from the ontologies, to resolve their conflicts by themselves, to plan processes and discover new processes that arise between the existing web ontologies. An important fact about using intelligent web agents is the agent's ability to use web services, and to combine them to achieve certain goals, specified by their users. Web services represent modular applications, which provide dynamic and distributed exchange of the collections of requested information. Web services are applications that can be described, published, located and called anywhere on the web (McIlraith and Martin, 2003). The plan for web services is to give the ability to automatically and dynamically compose more complex services than the existing ones. This ability can be realised via web services choreography and web services orchestration, as web services management mechanisms.

5 The ontology of the bolero$_{XML}$ documents

In this chapter, we start to introduce the semantic web technology into the bolero.net community. The bolero.net community, with the bolero$_{XML}$ documents based on using ebXML, represent a good example of developing and using the ontologies as shared meaning about the electronic business processes. The first step in ontology development consists of collecting all the relevant bolero$_{XML}$ documents for defining business processes and information models. There are a number of bolero$_{XML}$ documents which can be classified in the following ways (Bolero.net, 2003):

- commercial
- transport
- certificate of goods
- insurance
- banking
- customs.

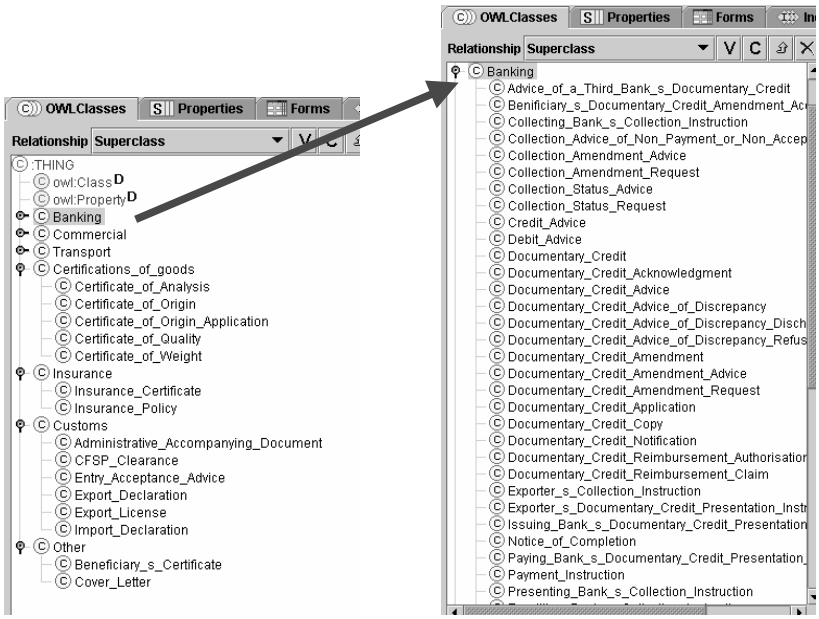
In this paper, we consider only the documents from the area of banking, shown in Table 1.

Table 1 Bolero$_{XML}$ documents from the area of banking

Advice of a third bank's documentary credit	Documentary credit acknowledgement	Documentary credit reimbursement authorisation
Beneficiary's documentary credit amendment acceptance or refusal	Documentary credit advice	Documentary credit reimbursement claim
Collecting bank's collection instruction	Documentary credit advice of discrepancy	Exporter's collection instruction
Collection advice of non payment or non acceptance	Documentary credit advice of discrepancy discharge	Exporter's documentary credit presentation instruction
Collection amendment advice	Documentary credit advice of discrepancy refusal	Issuing bank's documentary credit presentation instruction
Collection amendment request	Documentary credit amendment	Notice of completion
Collection status advice	Documentary credit amendment advice	Paying bank's documentary credit presentation instruction
Collection status request	Documentary credit amendment request	Payment instruction
Credit advice	Documentary credit application	Presenting bank's collection instruction
Debit advice	Documentary credit copy	Remitting bank's collection instruction
Documentary credit	Documentary credit notification	Standby documentary credit

The real semantic annotation of all the above-mentioned documents, represented in some of the semantic web languages (*i.e.*, OWL), brings significant improvement in their usability as well as their readability. OWL provides a standard way to define the web-based ontologies. Development of the ontology of the bolero$_{XML}$ documents has been done through the use of the ontology editor, well known as Protégé-2000 (1999). The ontology of the bolero$_{XML}$ documents represents a domain ontology that defines the terminology and concepts relevant to a particular topic or area of interest. The following figure, Figure 3, shows the way in which the ontology of the bolero$_{XML}$ documents is created (Damjanovic *et al*., 2005).

Figure 3 Semantics of the boleroXML documents

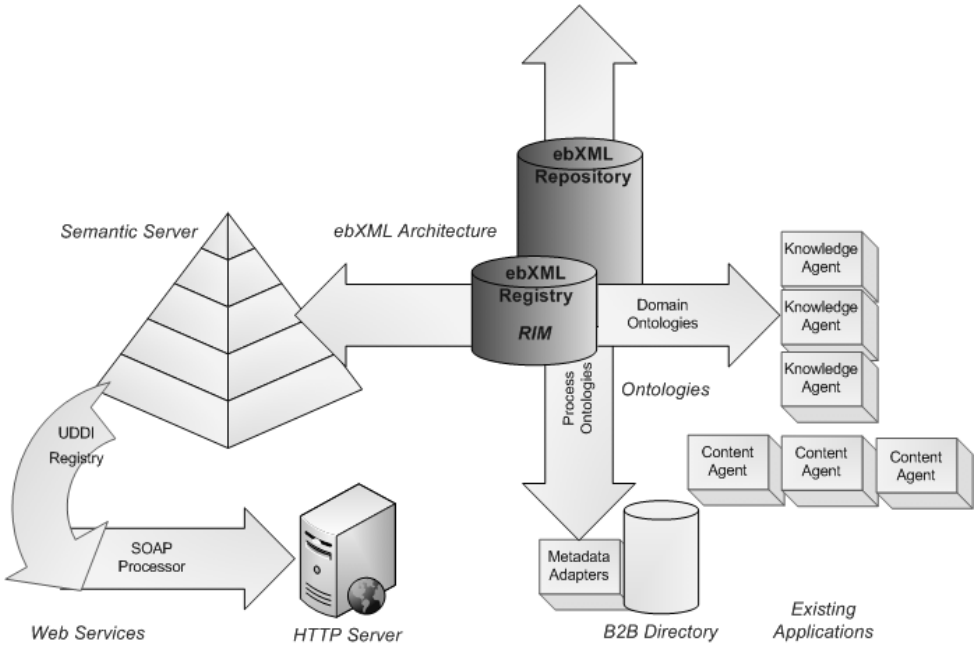


6 Using bolero.net on the future web

The bolero.net community uses the specific bolero$_{XML}$ standards based on ebXML. The primary goal for ebXML is to "provide an open technical framework to enable XML to be utilized in a consistent and uniform manner for the exchange of electronic business data in application to application, application to person and person to application environments" (ebXML, 2000). XML has notable characteristics from the point of using the future technologies on the web, so XML and related semantic web technologies represent a way that bolero.net community can be adapted to the future web. The future web does not consider only the use of the domain knowledge in the field of the semantic web technology, but the use of knowledge that comes in different times, from different sources, in different forms (W3C, 2003). This knowledge must be equally accessible and recognisable for the different web applications.

At the same time, ebXML is complementary with Business-to-Business (B2B) initiatives, such as SOAP, UDDI standard, RosettaNet and OAGIS frames. ebXML Registry & Repository represents a part of ebXML architecture, which can be compared with the UDDI standard for web services, until ebXML Messaging Services can be compared with the SOAP standard. UDDI represents the standard for description, online registration, announcing and dynamic finding of announced web services (Ankolekar *et al*., 2001). The mechanism for searching through the UDDI Registry is based on searching the keywords (by name, location, business, bindings or by pattern within UDDI TModel), but without the possibility of searching through the semantic contents that are related to the description of web services in Registers. This disadvantage can be overcome by connecting web services with the semantic web technology. On the other hand, SOAP represents the main technology for message exchange in web service architecture (W3C, 2003). SOAP has the function of creating and processing the structure of data package that is being exchanged. Both UDDI and SOAP are XML based. According to the fact that XML describes web contents without defining their semantics, and web services without considering their possibilities, it is necessary to introduce an appropriate transformation that will provide correct modelling and usage of semantics described within domain ontology (metadata adapters shown in Figure 4).

Figure 4 The scenario of using bolero.net community in the future semantic web and grid environment



Source: Damjanovic *et al*. (2005)

We can stress the role of ebXML Registry & Repository from the point of view of the semantic web ontologies. First, ebXML Registry is able to store metadata that describes content, while the ebXML Repository is able to store any type of electronic content (Dogac *et al.*, 2005). ebXML Registry defines a Registry Information Model (RIM), which specifies the standard metadata that may be submitted to the Registry. The current Registry implementations store registry data in a relational database, and Registry Objects are constructed by retrieving the information from the database using SQL queries. On the future web, it will be achieved by retrieving the semantically annotated information from the ontologies (domain and process ontologies). The way to use bolero.net community in the future semantic web and grid environment is shown in Figure 4.

7 Related work

The ebXML Registry & Repository (SourceForge open source project) should support ontologies in the next project version (SourceForge, 2003). The current version is capable of managing arbitrary content (*e.g.*, OWL ontologies) described by standardised metadata. The ebXML Registry standard enables collaborative building of distributed content and metadata stores. Authentication and access control features provide secure access. Content-based event notification features allow human and agent subscribers to be notified of relevant events within the distributed content store.

So far, the ebXML Registry TC (Technical Committee) (ebXML Registry, 2002) at OASIS has recently approved the creation of the Semantic Content Management SC (SCMSC). With SCMSC features, the ebXML RIM and API will be extended to add direct support for the publish/discovery/usage of OWL ontologies and other RDF content. Knowledge bases maintained within the envisioned service will be distributed using the existing federation model of ebXML Registry. All functionality will be available with access control and other security measures already supported by ebXML Registry. The goal is to enable collaborative building of distributed knowledge bases and using these knowledge bases as metadata to describe arbitrary content.

The SCMSC will identify specific semantic web technologies that are necessary to support the requirements identified for semantic content management (SC, 2004). The proposal will address changes to RIM, XMLS, Relational Schema and Registry Service interfaces that will be necessary to support the new features.

Finishing this project means providing direct support for using the semantic web technologies in the area of electronic business.

8 Conclusion

With some of the biggest names in world trade that represent the members of the bolero.net community, this community has the potential to transform global business practices by creating a common electronic platform coupled with the relevant industry standards, which are prerequisites for automated world trade. At the same time, common trends in the area of electronic business lead to the increasing use of XML for B2B communication in all industry sectors. We can notice that they all need a certain level of adaptation to real semantically and ontology-driven commercial use.

The vision of the future web-based communities is significantly changing by aggregating new technologies such as the semantic web, web services, Business Process Execution Language for Web Services (BPEL4WS), Business Process Management Language (BPML), Web Services Choreography Interface (WSCI), and many more.

References

Ankolekar, A., *et al.* (2001) 'DAML-S: semantic markup for web services', *International Semantic Web Workshop*, Stanford, CA, pp.411–430.

Berners-Lee, T. and Miller, E. (2002) 'The semantic web lifts off', *Ercim News Online Edition*, No. 51.

Berners-Lee, T., *et al.* (2001) 'The semantic web', *Scientific American*, Vol. 284, No. 5, pp.34–43.

Bolero.net (2003) *Introduction to BoleroXML*, http://www.bolero.net/solutions/trade_platform/messaging.html.

Cannataro, M. and Talia, D. (2004) 'Semantics and knowledge grids: building the next-generation grid', *IEEE Intelligent Systems*, Vol. 19, No. 1, pp.56–63.

Damjanovic, V., Gasevic, D., Djuric, D. and Devedzic, V. (2005) 'Bolero.net in the semantic web whirl', *Proceedings of the IADIS Web Based Communities 2005 Conference*, Algarve, Portugal.

Decker, S., *et al.* (2000) 'The semantic web: the roles of XML and RDF', *IEEE Internet Computing*, Vol. 4, No. 5, pp.63–74.

De Roure, D., Jennings, N.R. and Shadbolt, N.R. (2005) 'The semantic grid: past, present and future', *Proceedings of the IEEE*, Vol. 93, No. 3, pp.669–681.

Dogac, A., *et al.* (2005) 'Enhancing ebXML registries to make them OWL aware', *Distributed and Parallel Databases Journal*, Kluwer Academic Publishers.

ebXML (2000) *Enabling Electronic Business with ebXML*, http://www.ebxml.org/white_papers/whitepaper.htm.

ebXML Registry (2002) *ebXML Registry TC*, http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=regrep.

Foster, I., Kesselman, C. and Tuecke, S. (2001) 'The anatomy of the grid: enabling scalable virtual organizations', *International Journal of Supecomputer Applications*, Vol. 15, No. 3.

Goble, C.A. and De Roure, D. (2002a) 'The grid: an application of the semantic web', *ACM SIGMOD Record*, Vol. 31, pp.65–70.

Goble, C.A. and De Roure, D. (2002b) 'The semantic web and grid computing', in V. Kashyap and L. Shklar (Eds.) *Real World Semantic Web Applications*, *Frontiers in Artificial Intelligence and Applications*, IOS Press, Vol. 92.

Graham, J. (2003) *XML and ebXML: Emerging Standards for Global Convergence*, Drake Learning Solutions, http://www.ecominfo.net/xml/arts/graham_drakeintl.htm.

Hendler, J. (2001) 'Agents and the semantic web', *IEEE Intelligent Systems*, Vol. 16, No. 2, pp.30–37.

McIlraith, S. and Martin, D. (2003) 'Bringing semantics to web services', *IEEE Intelligent Systems*, Vol. 18, No. 1, pp.90–93.

Protégé-2000 (1999) *What is Protégé-2000*, Stanford University, http://protege.stanford.edu/publications/UserGuide.pdf.

SC (2004) *Semantic Content Management SC*, http://www.oasis-open.org/apps/org/workgroup/regrep-semantic/index.php, (accessible only to OASIS members)

Semaview Inc. (2002) *Concept to Reality: What the Emerging Semantic Web Means to your Business*, http://www.semaview.com/d/whitepaper.pdf.

SourceForge (2003) *ebXML*, http://ebxmlrr.sourceforge.net.

W3C (2001) *W3C Semantic Web*, http://www.w3.org/2001/sw/.

W3C (2003) 'Web services architecture', *W3C Working Draft*, http://www.w3.org/TR/2003/WD-ws-arch-20030514/.

Notes

1 Electronic Data Interchange (EDI) is a standard designed to provide business forms for the transmission of electronic data from one trading partner to another one. The main limitation of the EDI standard is that it is practical only for large enterprises.

2 http://www.w3.org/RDF/

3 http://www.w3.org/TR/rdf-schema/

4 http://www.w3.org/TR/owl-absyn/