ABSTRACT: European enterprises, which contain several heterogeneous systems, create fuzzy networks of interconnected applications, services and data sources, and cooperate with international partners in the enlarged Europe, need holistic Enterprise Applications Integration (EAI) solutions in order to operate their e-business effectively. The FUSION project aims to promote efficient business collaboration and interconnection between enterprises (including SMEs) by developing innovative technologies for the semantic fusion of heterogeneous service-oriented business applications. Such applications may exist either within an enterprise or in several collaborating companies within the enlarged Europe. This paper presents the vision and technical architecture of the FUSION IST project

KEY WORDS: Enterprise Application Integration, Service-Oriented Architecture, Semantic Web Services, Semantic-enriched Service-oriented Business Applications, Business Process Fusion
1. Introduction: Background and Rationale

In today’s fiercely competitive global economy, companies are realizing that new initiatives such as e-business, customer relationship management and business intelligence go hand-in-hand with the proven organization-wide enterprise application integration (EAI) strategy. The goal of EAI is to integrate and streamline heterogeneous business processes across different applications and business units while allowing employees, decision makers and business partners to readily access corporate and customer data no matter where it resides.

Business process fusion is the transformation of business activities that is achieved by integrating the interfaces of previously autonomous business processes by pipelining different middleware technologies and enabling the effective (semi-) automated exchange of information between various systems within a company or between enterprises. The development of Service Oriented Business Applications (SOBA, which constitutes a set of independently running services communicating with each other in a loosely coupled message-based manner – Haller et al. 2005) and the publishing of Web Services may implement the vision of business process fusion, by providing an abstraction layer for the involved interfaces through the Web Service Description Language (WSDL). This architecture will also play a significant role in streamlining mergers and acquisitions, by linking previously incompatible systems (IBM, 2004).

However, semantics and ontologies are important to application integration solutions because they provide a shared and common understanding of data, services and processes that exist within an application integration problem domain, and how to facilitate communication between people and information systems. By leveraging this concept we can organize and share enterprise information, as well as manage content and knowledge, which allows better interoperability and integration of inter- and intra-enterprise information systems.

We claim that recent innovations in the development of Semantically-enriched Service-Oriented Business Applications (SE-SOBA) – which enlarge the notion of SOA by applying Semantic Web Service technology and using ontologies and semantic web mark up languages to describe data structures and messages passed through web service interfaces – combined with the rule-based formalization of Business Scenarios and Processes will provide a dynamically reconfigurable architecture that will enable enterprises to respond quickly and flexibly to market changes, thereby supporting innovation and business growth, increasing the potential for an improved return on IT investments and a more robust bottom line.

This paper aims at the announcement and presentation of the EC co-funded IST project entitled “Business Process Fusion based on Semantically-enabled Service-Oriented Business Applications” (FUSION). FUSION project, a 30-month project
officially started at February 1st, 2006, addresses both enterprise application and business processes heterogeneity problem by proposing a Semantic Web Services – based innovative framework and holistic solution for both intra- and inter- EAI. Led by SAP AG, FUSION consortium consists of 14 partners from five European countries (Germany, Greece, Poland, Hungary, and Bulgaria), including Research Institutes, Technology Developers, Innovation Transfer bodies as well as end users.

The structure of this paper is as follows: in the following section, we present the innovation challenges addressed by FUSION project. The proposed conceptual framework and technical architecture referring to the innovative business-driven semantic-enriched service-oriented architecture are defined in section 3, while, in section 4, we present the proposed business-oriented FUSION ontology. Moreover, the state-of-the-art survey and comparative analysis regarding semantic web services frameworks are performed in section 5. Finally, section 6 presents further work and concluding remarks.

2. FUSION Innovative Challenges

SMEs cooperating with international partners in the enlarged Europe need holistic Enterprise Applications Integration (EAI) solutions in order to operate their e-business effectively. At the same time they are facing intercultural barriers, since current interoperability and integration efforts are more focused on “data” of the systems rather than on “processes”.

Our vision is that the FUSION solution will enable business collaboration and interconnection between SMEs by developing a framework for the semantic integration of service-oriented business applications that exist within an enterprise or in several collaborating companies, taking into consideration the intercultural, regulatory and legacy aspects of the enlarged Europe countries.

The 30-month FUSION project will, finally, result (see Figure 1), through the FUSION deliverables (both reports and prototypes), in:

- An innovative FUSION approach for Semantic Service-oriented Business Application integration (i.e. CRM and ERP) covering essential business processes of and between collaborative organizations, especially SMEs, based on increasingly familiar and stable standards that are designed to facilitate agility, loose coupling and easy interaction, like WSDL, UDDI and SOAP,

- The FUSION Methodology for Semantic Service-oriented Business Application Integration that will facilitate the integration of business software applications that exist in the same or different organizations,

- The FUSION Ontology constituting the corner stone of SE-SOBA Integration and serving as a common reference for the association with the business application repositories and the semantic description of Web Services Instances,
– The FUSION Integrated System allowing the interconnection of heterogeneous information systems, resource sharing and services provision. The mechanism will enable the implementation of service-oriented business applications based on Web Services standards (like UDDI, WSDL and SOAP) and Semantic Web technology standards (OWL-S), and

– Three trans-national FUSION cases that will prove the concepts and tools of the solution, concerning three different “Enlarged Europe” use cases will be deployed and executed.

Figure 1. Graphical representation of FUSION expected results

All three use cases, regarding a franchising firm, an international Network of independent international career managers and a chain of schools of foreign languages and computing, are operating in the “old” and the “new” European part and would like to facilitate the globalization of their business by supporting the collaboration between the different legal entities and the interoperability of their business applications.

Figure 2. Intra-organizational Enterprise Application Integration
Finally, FUSION consortium aims at wide-scale dissemination of knowledge obtained and exploitation of the project results to the software industry as well as to the SMEs market in general. All project partners will collaborate in the dissemination of the results among the academic community, the IST community and the software market. Commercial exploitation aims at the fulfilment of the long term IST and e-Europe strategic objective for the growth and competitiveness of the European economy across the enlarged Europe.

3. FUSION Approach and Technical Architecture

The FUSION solution is an holistic framework that facilitates the integration of heterogeneous enterprise applications that exist in the same organization (Figure 2) or in different organizations (Figure 3).

The FUSION solution will invoke the creation, administration and deployment of Web Services Instances of the pre-selected features of the enterprise applications and their semantic description (Semantic Profile) based on a business concept model, called FUSION ontology, which serves as a common reference allowing the semantic integration of the business applications. The deployed Web Services Instances will be published at a semantic-enriched UDDI service registry, while the created Semantic Profiles of Web Services Instances will be registered in the FUSION semantically-enriched registry, which is part of the FUSION Semantic Repository, powering the system-integrated categorization and discovery services.

Figure 3. Inter-organizational Enterprise Application Integration

The way we envision business analysts to work with the FUSION solution is that they:
– define the concepts that exist inside the business application (e.g. product, contact, order, etc) and use well-defined business ontologies / concept models that are independent from the technical architecture of the business application,

– associate the concepts and services with the business application repository / resources,

– create and administrate Web Services Instances, create semantic profiles of Web Services Instances and publish the profiles on the FUSION semantically-enriched registry, and

– orchestrate aggregate compositions of semantic web services based on FUSION-enabled descriptions of various business applications

As mentioned above, the FUSION solution may be applied on either Intra-Organizational Enterprise Application Integration or Inter-Organizational Enterprise Application Integration to support semantic workflows and added-value supply chains. FUSION system constitutes of two main components: a) the Semantic Services Analyzer and b) the Integration Mechanism (see Figure 4).

The Semantic Services Analyzer is a graphical environment that facilitates the semantic conceptualization of Service-Oriented Business Applications regardless their technical infrastructure. The Semantic Services Analyzer enables the utilization of the produced business conceptualization for the automatic creation of Web Services. The graphical environment enables system analysts to associate the theoretical concepts to the business application resources providing a connection between the system semantics and their technical realization.
The Integration Mechanism is the component of the FUSION Solution responsible for the administration of the Semantic Repository (containing the Concept Models and Services Repository, the Web Services Software Instances Repository and the Semantic-enriched Service Registry), for the creation, administration and the maintenance of the Web Services and the publication of Web Services in the semantic-enriched UDDI Registry. The Integration Mechanism does not offer any graphical interface but it communicates via SOAP with the Semantic Services Analyzer. This enables the remote creation and deployment of Web Services Software Instances by a group of users, potentially from multiple legal entities, that have the proper rights to connect to the Integration Mechanism, and the administration of the Mechanism by authenticated personnel (e.g., in case of inter-organizational EAI, the authenticated personnel comes from the “core partner” of the inter-organizational supply chain that potentially owns the FUSION System).

4. Business-driven FUSION Ontology

The FUSION ontology constitutes the corner stone for the semantic modelling of FUSION-enabled services, workflows and supply chains. The FUSION ontology will enable efficient business collaboration and interconnection between SMEs supporting the semantic fusion of service-oriented businesses applications that exist within an enterprise or in several collaborating companies.

The FUSION ontology will conceptualize the identified attributes, concepts and their relationships of the service-oriented businesses applications and will be developed in three layers: upper, middle, and lower. This multi-layer architecture of FUSION ontology development provides a rich representation of service-oriented business applications, captures the significant requirements of both services and workflows, supports efficient representation of services, workflows and supply chains in intra- and inter-organizational level and provides a flexible structure that could be easily refined and updated.

The upper layer of the FUSION ontology will capture the semantic modelling – including a vocabulary of terms and their specification and structure – of workflows and supply chains covering the following aspects of workflow modelling:

- Data/Information Semantics: capturing the (semi-) formal definition of data in input and output messages of a Web Service, supporting discovery and interoperability by annotating input and output data of Web Services using ontologies,

- Functional Semantics: capturing the (semi-) formal representation of the capabilities of Web Services in order to support discovery and composition of Web Services annotating operations of Web Services as well as provide preconditions and effects,
– Execution Semantics: capturing the (semi-) formal representation of the execution or flow of services in a workflow or supply chain or of the operations in a service, in order to support analysis (verification), validation (simulation) and execution (exception handling) of the workflow models using State Machines, Petri nets, activity diagrams etc., and

In order to enhance the discovery, composition, and orchestration of Web services, it is necessary to increase the semantic description of their interfaces. The FUSION middle-layer ontology will incorporate several data, functional and quality aspects encountered in provided web services in general. This ontology specifies domain-independent web services concepts – concerning input and output parameters, quality criteria and functional description – and is typically completed by the (domain-) business application- specific lower-layer FUSION ontology.

5. Semantic Web Services State-of-the-art

As it has already been stated, FUSION project will specify and develop an innovative framework, based on Service-Oriented Architecture and Semantic Web Technologies, realizing semantic-enabled service-oriented applications applied to EAI scenarios. The Semantic Web initiative’s purpose is similar to that of the Web Services (Preece & Decker, 2002): to make the Web machine-processable rather than merely “human-processable”. Thus, Web Services are considered as an essential ingredient of the semantic web and benefit from the semantic web technologies. The emerging semantic web technologies and standards provide an abstraction layer, using well defined semantics, contained in formal domain ontologies, to annotate Web Services and Processes in a machine-processable way. Key components of the Semantic Web technology are a) a unified data model such as RDF (Resource Definition Framework), b) languages with well defined, formal semantics, built on RDF, such as the Web Ontology Language – OWL (DAML+OIL, DARPA Mark-up Language and Ontology Inference Layer), and c) ontologies of standardized terminology for marking up web resources, used by semantically enriched service level descriptions, such as OWL-S (former DAML-S, DAML-based Web Service Ontology).

Enriching Web Services descriptions with formal defined semantics by introducing the notion of semantic mark-up, leading towards the Semantic Web Services, enables machine-interpretable profiles of services and applications, realizing the vision of dynamic and seamless integration. As this semantic mark-up is machine –processable and –interpretable, the developed semantic profiles of web services can be exploited to automate the tasks of discovering web services, executing them, composing them and interoperating with them (McIlraith et al., 2001), moving a step forward towards the implementation of intelligent, semantic web services.
The combination of Web Services and Semantic Web technologies, resulting in the deployment of machine-processable and, therefore, usable for automation semantic web services, supports and allows a set of essential automated services regarding the use of deployed web services (McIlraith et al., 2001; McIlraith et al., 2001-b):

- automatic Web Service discovery, involving automatic location Web Services that provide a particular functionality and that adhere to requested properties expressed as a user goal,
- automatic Web Service composition, involving dynamic combination and aggregation of several web services to provide a given functionality,
- automatic Web Service invocation, involving automatic execution of an identified Web Service by an agent, and
- automatic Web Service interoperation within and across organizational boundaries.

These semantically enriched web services oriented features can constitute the ideal solution to integration problems, as they enable dynamic, scalable and reusable cooperation between different systems and organizations. Currently four different standards for semantic web services are emerging: OWL-S, METEOR-S, SWSF and WSMO. In the following these standards will be explained and compared:

- OWL-S: OWL-S (Martin et al., 2004), formerly DAML-S (DAML, 2003), is a service model (a service ontology written is OWL) that tends to become a standard regarding Semantic Web Services. OWL-S is an upper ontology for services, already developed and presented to the Semantic Web Services project of the DAML program. OWL-S upper service ontology provides three essential types of knowledge about a service, each characterized by the question it answers: a) What does the service provide for prospective clients? The answer to this question is given in the "profile", which is used to advertise the service, b) How is it used? The answer to this question is given in the "process model", and c) How does one interact with it? The answer to this question is given in the "grounding". Grounding provides the needed details about transport protocols. Moreover, a variety of third party software components for OWL and OWL-S have been already developed and can be utilized in potential OWL-S based solutions.

- METEOR-S: Another proposal for a semantic web service standard is METEOR-S that is developed in LSDIS laboratory of the University of Georgia, aiming to extend Web Services standards with Semantic Web technologies to achieve greater dynamism and scalability (METEOR-S). Specifically, METEOR-S focuses on adding semantics to WSDL and UDDI (this work termed WSDL-S is being provided as input for next version of WSDL that will support semantic representation), and to BPEL4WS, while METEOR-S discusses a semi-automatic approach for annotating Web services described using WSDL. METEOR-S provides specific tools per each phase regarding the Semantic Web Services lifecycle: a)
Semantic Annotation of web-services, b) Semantic Publication of web-services, c) Semantic Discovery of web Services, and d) Orchestration & Composition of Web Services.

- SWSF: Another Semantic Web Services project of the DAML program is the Semantic Web Services Framework (SWSF) (Battle et al., 2005) which represents an attempt to extend the work of OWL-S and consists of two major parts: a) the language SWSL as an underlying basis, containing two sublanguages: SWSL-FOL which is based on first-order logic and primarily used to express the formal characterization of web service concepts and SWSL-Rules that is similarly to WSML-Rule based on logic programming; and b) the Semantic Web Service Ontology (SWSO) that presents a conceptual model by which web services can be described.

- WSMO: Based on the Web Service Modelling Framework (WSMF) (Fensel & Bussler, 2002), the Web Service Modelling Ontology (WSMO) (Lausen et al., 2005), developed – mainly – in DERI (Galway, Ireland), is a formal ontology and language that consists of four different main elements for describing semantic web services: a) Web Services representing the functional and behavioural aspects which must be semantically described, b) Ontologies (formal semantics provision), c) Goals constituting objectives that the client might have when consulting a web service, and d) Mediators that are used as connectors (interoperability). Furthermore, WSMO comes along with a web services modelling language (WSML) (deBrujin & Lausen, 2005) and an integrated environment for execution (WSMX).

In comparison, METEOR-S and OWL-S semantic web services frameworks are rather complementary in a way, as OWL-S can provide the conceptual high-level model, while METEOR-S can provide implemented and fine-tuned tools and algorithms. Moreover, SWSF extends the OWL-S standard by enabling rule languages and extends the description-logic framework used in OWL-S to first-order logic making easier the description of concepts and their relationships. On the contrary, WSMO and OWL-S are rather contradictory semantic web services approaches, as they provide incompatible tools and languages (WSML vs. OWL/OWL-S).

METEOR-S and OWL-S approaches fully respect the industrial Web Services Standards (i.e. WSDL, UDDI, BPEL and BPEL4WS), while WSMO promotes WSML that is an alternative to OWL – that is an official W3C standard. However, the compatibility among WSML and OWL is supported through custom parsers WSML2OWL and vice versa – that could not be considered, both conceptually and technically a best practice. In addition, existing OWL-oriented tools, e.g. editors, validators, inference tools, matchmaking algorithms are fully compatible and could be used to enrich the OWL-S approach.

Summarizing the above mentioned trends and comparative results regarding Semantic Web Services standards, FUSION project will adopt the OWL-S approach.
for deploying its own semantic web services–based solution for both intra- and inter-EAI.

6. Future Work

In this paper, we have given a short overview of FUSION, a newly started IST project. The FUSION objectives and research interests do not focus on basic research in the field of semantic web services (SWS); hence the FUSION project does not aim to deliver a new semantic web services development framework. The consortium will examine and use the current state-of-the-art SWS frameworks and apply them to e-business processes and transactions, focusing its research activities towards the semantic enrichment of business processes within the concepts of service-oriented enterprise architecture.

Therefore, the main contribution of the FUSION project will be an approach, methodology and a multi-layer FUSION Ontology for conceptualizing the modelling of FUSION-enabled services as building blocks for business processes and for establishing shared concept models enabling different applications to define semantically same information using a common reference.

The combination of Web Services, Semantic Web technologies and SOA results in the deployment of Semantic SOA architectural framework, which is based on machine-processable and, therefore, usable for automation semantic web services, supporting a set of essential automated services regarding the use of the deployed semantic-enriched service-oriented business applications (SE-SOBAs). The proposed Semantic SOA framework, FUSION, enables the formalization and the documentation of the semantics related to the interfaces and the data structures of the deployed web services, a capability that could not be supported by the current web services enabled SOA and technologies.

Currently, we work towards the in-detail functional and technical specification of the FUSION architecture and the basic technical, structural components. However, a lot of work is still to be done towards the development and the finalization of the integrated FUSION technical solution, its deployment in real enterprise scenarios, and the evaluation of the proposed semantic service-oriented architecture.

References

