Support of Semantic Interoperability in a Service-based Business Collaboration Platform

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Abstract. The paper describes a system that supports flexible project-oriented collaboration of enterprises. The system, which was developed within the FP7 project SPIKE, employs semantic technologies and structures such as ontologies and abstract business process models to achieve an interoperability of possibly heterogeneous services provided and consumed by members of the collaboration environment. The architecture of the main system modules is presented and the processing of semantically annotated services orchestrated in a collaboration workflow is explained in more details.

Keywords: Semantic annotation of services, business process ontologies, semantic interoperability, networked enterprises.

1 Introduction

Recent achievements in information and communication technologies (ICT) towards the cross-network communication, cloud computing, service-based architectures and standardized interfaces bring new opportunities and challenges in many areas. When applied in the e-Business domain, these advanced technologies may improve the flexibility and adaptability of business collaboration in so-called networked or cloud enterprises [7], which can be established as a temporal inter-organizational business alliance of enterprises and organizations co-operating on a well-defined project. Such a collaboration, which is usually characterized by rapidly varying business environments, requires proper technological background enabling interoperable provision and consumption of services between the alliance members. Moreover, business processes in this type of networked enterprises need to be defined, organized and maintained as an inter-company composition of particular processes and services provided or consumed by the alliance participants in an interoperable manner.

The concept of interoperability in its technical, organizational, and semantic aspects was identified and emphasized in numerous initiatives and reports as a crucial, cross-cutting task in e-Business field [5] and in other related areas. The semantic interoperability, which will be specifically addressed in next sections of this paper, refers to seamless service invocation, communication, and information exchange in an ICT environment of e-Business solutions based on SOA principles. According to this approach, the services, which are described (i.e. annotated) by concepts of a standardized and shared knowledge base, can be provided, accessed, orchestrated and used in a flexible manner. Inputs, outputs, and characteristics of possibly heterogeneous services can be semantically matched and integrated, which enables a composition of the services into customizable workflow structures. Moreover, the advanced technology of Enterprise Service Bus (ESB) [4] can be integrated with the underlying semantic infrastructure and employed to mediate incompatibilities of communicating applications, orchestrate their interactions, and make the integrated services available for broad access and re-use [9].

Various approaches towards the ICT solutions enabling networked enterprises were designed and proposed in R&D projects integrated in the FINeS cluster [7]. As for example, the FP7 projects such as COIN, K-NET, NisB, or SPIKE can be particularly mentioned. In this context, we will describe here the approach and outcomes of the project SPIKE (Secure Process-oriented Integrative Service Infrastructure for Networked Enterprises, http://www.spike-project.eu), which lasted from January 2008 till March 2011 and was coordinated by the University of Regensburg, Germany.

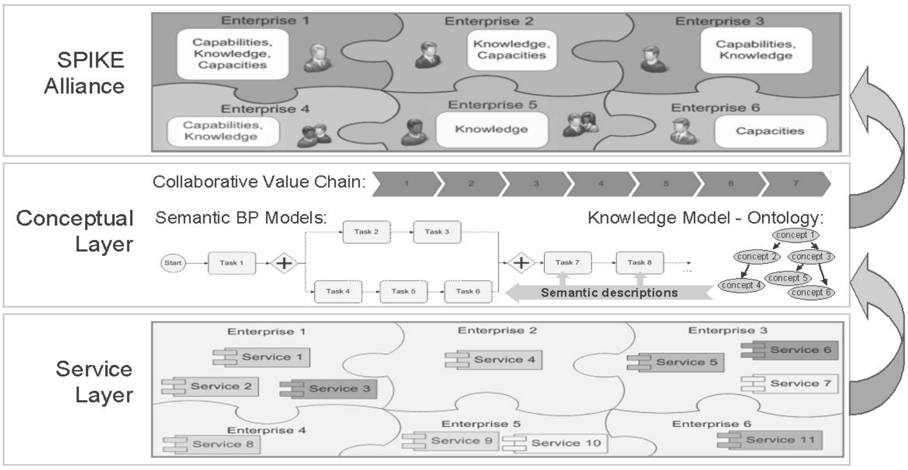

Fig. 1. Basic schema of the SPIKE approach towards the networked enterprises

The approach adopted in the SPIKE project is schematically depicted in Fig. 1. Three phases of the alliance life cycle, i.e. setting-up, running, and closing down, were addressed together with proper security settings and federation of identities enabling to access internal services or information resources of an alliance partner in a single-sign-on mode [2]. Business organizations, presented in the top bar of the Fig. 1, may decide to form an alliance focused on a production of an artifact. A collaborative value chain, which determines particular steps and the main target of the short-time alliance, is defined as a first step. The value chain is then modeled and expressed in the Conceptual Layer in the standardized BPMN notation, which can be further semantically enriched using the concepts from a shared knowledge model [8]. The resources and services of participating organizations can then be mediated and integrated according to known and formalized meaning. On the Service Layer, particular tasks in the process model are grounded to the executable services provided by the alliance partners. It allows sharing and using the services in the scope of defined processes by authorized organizations. Identities and credentials necessary for the service invocation are distributed to the authorized users in a secure way. The alliance can then operate according to a dynamic process model, which, if needed, may be modified and adapted in the run time.

2 Architecture of the SPIKE Business Collaboration System

With the respect of the described functionality, the SPIKE system architecture was designed in line with the SOA principles as highly modular and extensible [10]. Four main functional subsystems were specified as follows:

- The SPIKE System Core (SSC), a back-end providing functions for accessing and processing all the system data, namely the data storage, security, and maintenance of semantically enhanced business processes, workflow sequences, and services;
- The SPIKE Portal Instance (SPI), a web-based user interface that acts as a front-end to the SSC functionality;
- The SPIKE Administration, Monitoring and Reporting (SAMR), a subsystem that provides tools for overall system maintenance and day-to-day operation;
- The SPIKE Service Bus (SSB), an infrastructure that handles the communication between other SPIKE subsystems and external entities.

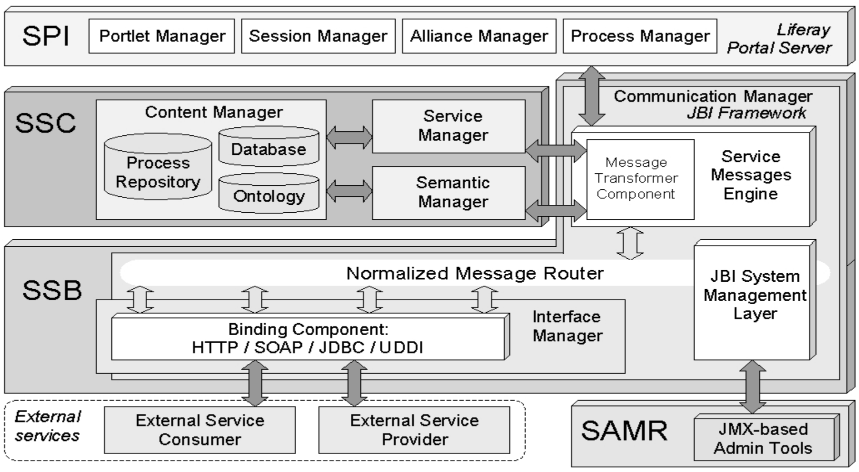

Fig. 2. The JBI architecture adapted for the SPIKE system modules

Each of subsystems is divided into a set of loosely coupled components, so-called managers, which provide autonomous and elementary functionality. The components of SSB and SSC subsystems are responsible for semantic workflow maintenance, including the mediation, orchestration and execution of services in a pre-defined business process that corresponds to the alliance value chain. The communication infrastructure for service messages, which is presented in Fig. 2, is built on the Java Business Integration (JBI) specification JSR 208. The designed JBI-compliant ESB uses the Normalized Message Router as a central messaging backbone. The Binding Component acts as a proxy to remote services. It makes the services available to the service bus in a form of normalized messages, independently of the service's actual transport protocol and data format. Finally, the Service Messages Engine provides the lifting-lowering semantic transformations and the related business logic during the processing of external services (see also Fig. 3). The grounded services are then orchestrated into a process workflow and exposed to the portal interface of SPI subsystem and are provided to the authorized alliance members.

3 Semantic Enhancements for Services and Business Processes

The underlying semantic structures for the SPIKE system were built on the WSMO framework [11]. The value chain of a business alliance is semantically represented by an abstract business process model, which is implemented by the BPMO representation of WSMO [1]. The resource ontologies were created in the WSML format and are divided into three logical groups: Process-related, System-related, and Domain ontologies [6]. The Process-related ontologies provide conceptual models for semantic description of business processes and their elements such as Process, Task, Service, etc. The System-related ontologies that semantically describe the platform environment, while the Domain ontologies extend the conceptual models towards particular pilot applications of the SPIKE project. Both the developed abstract business process models and resource ontologies are publicly available at http://www.spike-project.eu/BPmodels/ and http://www.spike-project.eu/ontologies/, respectively.

Developed semantic structures of ontologies and abstract process models are initial steps towards the orchestrated workflow of interoperable services. To anchor an abstract process model into real services and artifacts, its activity elements such as goal tasks, web service tasks, and manual tasks were grounded to a concrete WSDL representation of executable services. The online services obtain the WSDL descriptions inherently. However, in the case of SPIKE pilot applications, most of the services were of off-line type, where a human interaction was required. For this type of services, referenced as human tasks, the description of properties can be modeled by means of standardized XForms format, while the BPEL4people extension was used to model these tasks in the executable process. The inputs and outputs of all the services that represent the tasks were enhanced by a SA-WSDL reference to semantic representations of particular artifacts exchanged in the workflow. The abstract business process with semantically annotated and grounded tasks was then semi-automatically transformed into the corresponding executable form of BPEL notation. The BPMO-to-sBPEL translation mechanism [3] was combined with the Eclipse BPEL Designer tool. To process the executable workflow, a specific JBI runtime environment is created in service bus for each of the SPIKE collaboration processes. The orchestration of services in a complex workflow is handled by the Apache ODE BPEL engine, where a service resolving mechanism was implemented as an iterative selection of the best candidates for service execution, according to the semantic Quality of Service properties.

The XSLT transformation of semantic properties in a service request is provided and maintained by the Message Transformer component of the Service Messages Engine, as it is depicted in Fig. 3. The service requester creates a new message exchange request, sends it to the message router, which then delivers the request to the Message Transformer. In this exchange, the Message Transformer acts as a service provider and sends the requested interface, described by the SA-WSDL annotation, to the Semantic Manager of SSC. The SA-WSDL description of the requested interface contains definitions of the input messages annotated with the *sawsdl:liftingSchemaMapping* attributes pointing to XSL style sheet for data lifting transformation. The output of the lifting transformation is delivered as a set of instances that semantically represent the input data. The input instances are then sent to the Semantic Manager, which evaluates semantic mappings between the mediated types and infer a set of output instances.

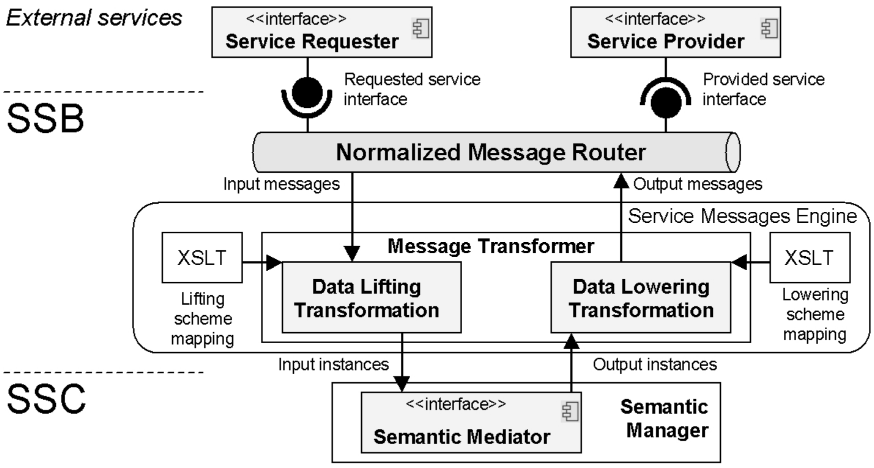

Fig. 3. Interactions during the semantic transformation of service messages

The output instances correspond to the output messages described in the SA-WSDL of the provided interface. Instances are transformed to normalized messages using the XSL style sheet referenced by the *sawsdl:loweringSchemaMapping* attributes. The Message Transformer then creates a new message exchange(s) with the output messages and sends it to the service provider(s) through the message router - in this case, the Message Transformer acts as a service requester. The return values of the requests (or fault messages) are handled similarly as the input messages; however, the way of transformation is opposite, i.e. the lifting schema is used for data lifting and the lowering schema serves for a creation of exchange results.

4 Conclusions

The SPIKE system was implemented as a prototype, which is now available under the LGPL / Apache 2.0 / X11 open source license. The prototype was tested on pilot applications focused on scenarios of collaborative manufacturing and documentation development. Achieved testing results proved the usability of the developed solution, namely the capability to integrate various heterogeneous services in an interoperable manner. However, further enhancements could be considered, for example, towards a more advanced support of service contracts, service level agreements and standardized service operation and management processes.

Acknowledgments. The SPIKE project was co-funded by the European Commission within the contract No. 217098. The work presented in the paper was also supported by the Slovak Grant Agency of the Ministry of Education and Academy of Science of the Slovak Republic within the 1/0042/10 Project "Methods for identification, annotation, search, access and composition of services using semantic metadata in support of selected process types".

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