



A process-oriented service infrastructure for networked enterprises



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ABSTRACT

The *networked enterprise* is a short-term partnership of business organizations aimed at sharing the partners' services without restrictions on size or organizational structure. Our approach considers two software solutions developed for supporting the creation and maintenance of such business collaborations in interoperable networks. The first one addresses a business alliance formation based on combining competences, processes and services of several organizations into a single value chain. Our emphasis is mainly on the interoperability and security of the provided services. The second approach focuses on the collaboration between large enterprises with rich IT ecosystems and SMEs with poor or missing IT infrastructure. Interoperable data sharing is supported by light-weight semantics, while standard inter-SME communication is enriched to grant authentication among partners. Alternatives for enabling technologies for service orchestration, process modelling, and event routing are investigated for the solutions. Based on the evaluation results obtained from pilot testing of the system prototypes, we discuss the implications of the technologies on quality indicators such as usability, performance, and business applicability.

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1. Introduction

The concept of *networked enterprises* became popular in the last decade as a progressive method enabling flexible business collaboration (Bughin and Chui, 2010). This approach for outsourced and distributed resources, coordinated toward a well-defined business goal, has been identified as advantageous for *small and medium-sized enterprises* (SMEs), since it supports supply chain management (Mentzer et al., 2007), facilitates logistics integration between networked companies (Marcuta and Marcuta, 2013), and helps to increase the competitiveness of cooperating SMEs in the global market. To proceed from theory to implementation though, the overall solution has to cover organizational and technological aspects of companies' integration.

From the organizational perspective, the management of collaboration among several organizations is recommended to follow best practices and methodologies, such as Six Sigma, PRINCE2, related ISO standards, and so on. In the IT industry, the ITIL standard (ITIL, 2014) is well adopted and widely used.

Technological aspects of collaboration among networked enterprises are handled by installing advanced infrastructure with con-

temporary *information and communication technologies* (ICTs). They include web services orchestrated into process chains, employing standardized data exchange protocols and interfaces, and can be applied in line with the Web 2.0 paradigm (Bughin and Chui, 2010). Other advanced technological approaches supporting business collaboration networks include the utilization of business process models managing collaboration workflow, the enterprise service bus for control and monitoring a flow of events, semantic knowledge representation structures facilitating service orchestration, and adapters and enablers of interoperable information exchange between alliance partners and their legacy applications.

We emphasize the technological aspects of IT infrastructure supporting the creation and maintenance of networked enterprises. We view the organizational aspects as methodology drivers and performance indicators. Our findings in this area are demonstrated for solutions developed within two independent but highly related R&D projects, SPIKE and VENIS. Both were accomplished under the 7th Framework Programme (FP7) of the European Union (EU). The architecture, implementation details, and functionality of these systems are presented together with the results of experimental evaluation of pilot applications. We focus on identification, analysis, and investigation of influences that combinations of technology frameworks and approaches may have on performance, usability, business applicability and quantitative or qualitative cri-

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teria of software solutions enabling business collaboration for networked enterprises.

2. Motivation and challenges

A number of business cases (Barchetti et al., 2012; Solaimani et al., 2015; Yam et al., 2007) indicate that the lack of efficient collaboration technologies, trust and guidelines has a notable impact on the exploitation of new business opportunities. This is especially obvious in the area of component and device manufacturers (typically SMEs), where limited access to collaboration systems, cooperation models and know-how lead to a situation where suppliers serve one major client instead of providing their services to a larger customer base. Today, business is especially open to subcontracting, outsourcing and other forms of cooperation, but the lack of flexibility and limited abilities to adapt internal processes of organizations to new requirements are often showstoppers for developing new partnerships and products.

To overcome these difficulties, software solutions that enable efficient and flexible maintenance of business alliances are expected to be accessible for a wide range of business organizations, especially SMEs with limited resources for advanced and expensive IT infrastructure. This implies that systems supporting business alliances need to be built on open standards and frameworks, with a preference for open source components. Moreover, the systems must provide interfaces to a wide range of data repositories, information systems, and communication platforms commonly used by SMEs and businesses of various types. These assumptions have also driven the conceptual design of the systems developed within the SPIKE and VENIS Projects, as we will shortly discuss in greater detail.

2.1. Infrastructure for short-term business alliances in the SPIKE Project

The concept of a *short-term business alliance* has two main distinguishing characteristics. It is a mutually agreed upon partnership of organizations aimed at sharing the partners' business services without restrictions on organizational size or structure. These partnerships usually tend to be temporary to accommodate the changing business environment. Further, ad hoc process-oriented collaboration is often required, both on the level of individual employees and working teams. These conceptual specifications formed the functional requirements in the SPIKE Project, which started in 2008 and lasted till 2011 as a joint effort of several European SMEs and universities. The projects did R&D work for a prototype solution enabling previously unacquainted companies to establish and manage short-term business alliances.

The formation of a business alliance is based on the combination of competences, resources and services of several organizations into a single value chain to serve customers with a jointly developed product or service. The organizations conduct joint production and combine their forces by outsourcing or partnering with other service providers in the scope of a networked enterprise. Fig. 1 illustrates the structure of three layers to describe them, as proposed in the SPIKE Project (Broser et al., 2009).

The purpose and composition of each of the proposed layers is as follows:

- The *Networked Enterprise Layer* of a business alliance shares skills, knowledge, expertise, capabilities, and high-level services between the companies in mutually beneficial collaboration.
- The *Conceptual Layer* models shared artefacts and processes in a value chain, with related process models, and information support and semantic knowledge representations and structures.

- The *Service Layer* consists of tools and technologies enabling an implementation of the value chain processes. It includes low-level services of various types, such as standardized web services, custom online e-services for accessing data, and manual tasks, from the partners.

A platform that enables the creation and management of such business alliances was designed and developed as a prototype in the SPIKE Project (Furdik et al., 2011a). It focused on the conceptual layer, by emphasizing secure and interoperable access to services. Key aspects, such as the federation of identities, the security model for services, and the orchestration and composition of low-level services based on semantically-annotated business process models have been investigated. We will discuss the solutions that were developed in more detail later in this article.

Due to the limited project budget and its early lifecycle phase of development, only a prototype system was implemented, and many of the features to scale it for commercial use are in the planning phase only. They mostly are related to support schemas and operational models, which depend on a business case and platform configuration for integrated processes, services, and needs-based customization.

2.2. The paradigm of virtual organization in VENIS

To overcome the limitations of the SPIKE Project and to proceed with a solution for networked enterprises, the research team decided pursue additional outcomes in another EU FP7 Project, VENIS (Laclavik et al., 2012), which was implemented in 2011–2015. The general objectives of the VENIS Project were similar to those of SPIKE: to increase interoperability in service provision, data exchange, and communication between companies cooperating in a business network. The VENIS project, however, was more focused on networking and interoperability between *large enterprises* (LEs) and *medium and small enterprises* (SMEs). It did so according to the *virtual organization paradigm* (Mowshowitz, 2003), which is based on:

- A distributed and secure *repository* to share the information contained in the file systems, databases, ERPs, CRMs, and other legacy applications of the enterprises, connecting IT Infrastructures of various size companies (from LEs to SMEs).
- A set of light-weight *web services* to enable integration of the information exchanged in joint work, based on legacy e-mail systems and boosted by semantic annotation and search.
- A distributed *process engine mechanism*, able to link and execute business processes in the value chain defined for the networked enterprise, to assist the work and create novel synergies in the joint production supply chains.

An overall goal of the VENIS Project was to develop a platform that helps to reduce interoperability barriers between LEs and SMEs at the technical, semantic and organizational levels. To achieve, the project implements light-weight approaches supporting interoperable information storage and exchange.

At the technical level, the challenge was to achieve interoperability on the top of protocols for e-mail and web applications, with web service adapters for various legacy applications. In contrast to the SPIKE solution, which was solely based on WSMO platform (Fensel et al., 2010), the approach adopted in VENIS is compatible with many contemporary IT infrastructures. It relies on RESTful web services and e-mail messaging for tasks such as document management including tagging and search, creation of collaborations, and notifications about the activities of collaboration members. At the semantic level, VENIS focuses on the sharing

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