47   TOWARDS SEAMLESS INTEROPERABILITY IN COLLABORATIVE NETWORKS

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The goal of achieving full interoperability is still not achieved, despite the high number of tools and infrastructures developed. The objective of this article is to present a framework aiming at supporting seamless interoperability in a business collaborative networked environment. An implementation example from the footwear sector validating the framework proposed is also described.

1   INTRODUCTION

Collaborative Networks'(CNs) paradigm has emerged world wide as a way to increase organizations' efficiency and bring them added value. CNs consist of heterogeneous organizations with different competences but symbiotic interests, which join and efficiently combine their skills and resources to achieve a common objective (Chituc, Azevedo, 2006).

In order to leverage the potential benefits of CNs, it is needed to develop operational infrastructures supporting inter-organizational operations and real time information exchange, so that independent organizations can work as a single integrated unit, while preserving their autonomy (Camarinha-Matos, et al., 1998), (Camarinha-Matos, Afsarmanesh, 2003). Despite the relatively high number of tools and infrastructures supporting (or claiming to support) seamless interoperability in a collaborative networked environment (CNE), this goal is still unachieved (Pollock, 2001) (Camarinha-Matos, Afsarmanesh, 2003a, b).

The objective of this article is to present a framework aiming at supporting seamless interoperability in a CNE. An operational infrastructure from the footwear sector, developed within the scope of a project pursued at national level, validating this framework, is then described.

The rest of the paper is organized as follows. The next section addresses the concept of interoperability. Section three describes the framework proposed towards achieving seamless interoperability. An implementation example from the footwear industry is then described. The article concludes with a section addressing the needs for future research.

2   INTEROPERABILITY AND SEAMLESS INTEROPERABILITY

2.1   Interoperability – a brief overview

Interoperability, in a broad sense, refers to the use of computer-based tools that facilitate inter-organization information flow and coordination of work. It aims at harmonizing the heterogeneous CNE, improve task coordination and real-time information sharing. According to (IEEE, 1990), interoperability represents the capability of two or more systems to exchange information and to use the information exchanged.

Main requirements for interoperability in a networked environment are presented in (Li, 2000); they refer to technical, business and policy interoperability requirements. However, the focus in the area of interoperability continues to be on technological aspects, and research on semantic and business aspects is scarce.

Causes for not achieving yet a fully interoperable infrastructure in a CNE are diverse: e.g., inadequate implementation, poorly managed risks and requirements, human errors, the lack of guiding standards for interoperability, and, as emphasized in (Camarinha-Matos, Afsarmanesh, 2003a), the lack of common reference models and appropriate supporting tools and infrastructures.

2.2   A holistic view on interoperability

Seamless interoperability assures that heterogeneous and geographically distributed entities/systems communicate and make use of the information exchanged (that is meaningful context driven information), and the systems are added or removed without requiring reconfigurations.

Towards seamless interoperability in a CNE, four main views on interoperability have been identified by the authors. They concern Technical aspects (e.g., messaging infrastructure), Business issues (e.g., strategic, operational and economic aspects), Information (e.g., information sharing and retrieval, messages exchanged) and Semantic aspects (e.g., common dictionary, common set of business documents-BDocs). We argue all these aspects should be tackled by an interoperability framework, and this follows the approach of two EU funded projects: ATHENA (http://www.athena-ip.org) and IDEAS.

Our vision for seamless interoperability relies on a set of attributes to be considered in the development of an interoperability framework and ICT platform. The selection of these attributes is the result of an in depth literature review, analysis of available frameworks, operational infrastructures, independent and industry-specific initiatives, and the experience gained by participation in national and European R&D projects in this field. These attributes are: reliability; time (e.g., to set-up or reconfigurate a CN); cost (e.g., to set-up or operate a CN); openness or extensibility (e.g., the use of open-source software); transparency (e.g., of messages exchanged); scalability, traceability (e.g., collaborative business activities, BDocs exchanged), and other non-functional properties, e.g., security.

2.3   Relevant initiatives

An overview of the current trends towards the establishment of flexible and configurable infrastructure developments is available in (Camarinha-Matos, Afsarmanesh, 2003): layered-based frameworks, agent-based frameworks, and specialized collaborative frameworks.

Important to mention are also advancements of independent (ebXML, http://www. ebxml. org), and industry-specific initiatives, such as RosettaNet (http://www. rosettanet.org) for high-tech and semiconductor industry, papiNet for paper and forest products industry (http://www.papiNet.org).

Concerning semantic interoperability, of relevance are: OASIS's Universal Business Language (http://www.oasiss-open.org) providing a library of XML schemas for common BDocs; the development of industry-specific dictionaries (e.g., RosettaNet Business and Technical Dictionary), and ontologies. However, the use of dictionaries falls short for cross-industry communication, since it would be naïve to believe it is possible to make everybody use the same vocabulary. We strongly support the development of XML schemas for developing common BDocs, which support intra- and inter-industry semantic interoperability.

3   ON THE DESIGN OF A FRAMEWORK FOR SEAMLESS INTEROPERABILITY

3.1   Introduction

Aiming at achieving seamless interoperability in a CNE, a framework comprising **six elements** has been thought: (1) **a messaging service**, responsible for e-communication among organizations, e.g., exchange of BDocs; (2) a **Collaboration Profile/ Agreement Definition and Management** (CP/ADM) service responsible for the definition and management of the organizations' Profile and inter-organization collaboration agreements; (3) a **collaborative business activity** (CBA) service, responsible for the management and integration of the inter-organization BAs; (4) a centralized **Repository** (e.g., storing information on organizations' Profiles, including the description of the products/models produced or supplied; collaborative agreements; messages exchanged); (5) a set of **BDocs** assuring semantic interoperability; (6) a service supporting an **economic analysis**.

The actors involved are: (1) **organizations** (e.g., SMEs), aiming at attaining, for example, shorter negotiation times, faster and cheaper access to new markets and business opportunities, faster and cheaper CN set-up, operation and reconfiguration; (2) a **Business Enabler** (BE)(Section 3.2), (e.g., a Shoe Association in the case of footwear industry) responsible to ease inter-organizations partnerships and agreements setting and management, supporting CNs (and their member organizations) to achieve their goals. Several BEs may exist in a CNE (e.g., one for each industry or services sector).

3.2   Business Enabler for a Collaborative Networked Environment

The framework proposed relies on the concept of BE. Its main responsibility is to enable inter-organizations partnerships and agreements setting and management in a CNE. A BE is an entity within the CNE which is not member of any CN, but it

supports CNs (and their member organizations) to achieve their goals, by performing different functions, such as: manage a common Repository; assure reliable and scalable communication among CN members; solve potential conflicts that may occur among CN members (e.g., concerning message repudiation). Depending on each industry or service sector, a BE may support only one or two of the above mentioned functionalities, or may perform additional roles.

3.3   The Messaging Service

The BE assures reliable and scalable communication among CN member organizations. Thus, organizations do not have to set an agreement concerning the communication protocol to be used, that is time and cost consuming and generates errors; the BE is responsible for the secure and reliable transmission of messages/ BDocs among CNE member organizations (e.g., finding an alternative communication way when e-communication fails). In this way, all messages/BDocs sent reach their destination in the time specified. However, some organizations (within the same CN) might choose to communicate on a P2P basis in order to increase their privacy, but this has to be specified in the collaboration agreement.

The messaging service alone is not enough to achieve broad scale interoperability across heterogeneous systems. Research has been pursued to design all the elements of the framework proposed (Section 3.1). As a first step, different business scenarios have been mapped on ebXML. Figure 1 illustrates a high-level overview of two organizations (A and B) conducting e-business according to the framework proposed. The dashed lines illustrate the logical exchange of BDocs, with respect to ebXML scenario, while the actual communication between them (which has been represented with thick arrowed lines) is performed through the BE.
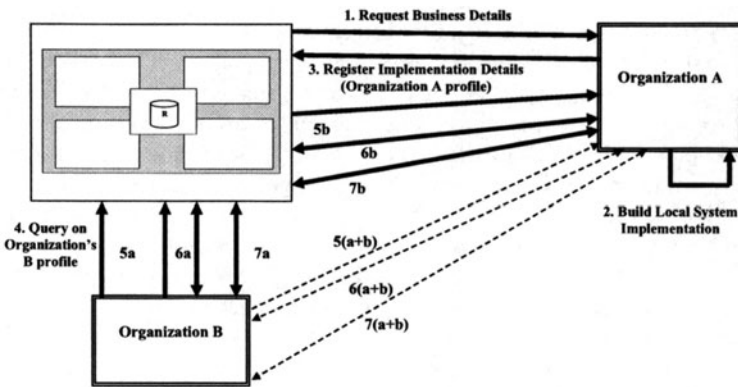

Figure 1. A high-level overview of the interactions of two organizations conducting e-business according to the framework proposed

Seven main steps have been identified: (1) Organization A requests business details from the BE/Repository; (2) Organization A decides to build its own ICT platform-compliant application; (3) Organization A submits its Profile information in the Repository (e.g., by filling in a form in HTML format). The information submitted concerns its capabilities and constraints, information of the products it produces or supplies, the business scenarios and roles supported; (4) Organization B,

which already uses an ICT platform-compliant application discovers in the common Repository the Organization's A profile; (5) Organization B contacts Organization A, by sending a first valid draft of a Business Collaboration Agreement document (BCA-Doc). In this way, Organization B asks Organization A if it is interested to engage in a business scenario, by making a first business proposal; (6) Organizations A and B negotiate (e.g., by exchanging different versions of the BCA-Doc) till they reach an agreement. The final BCA-Doc outlines the mutually agreed upon business scenarios, and specific terms; (7) Organizations A and B are now ready to engage in e-business.

3.4 The Collaboration Profile/Agreement Definition and Management Service

This service aims at assuring the definition and management of the collaborative profiles and agreements by supporting different functionalities, e.g., organization's Profile definition, collaboration agreement management; information maintenance. An organization defines and submits its Profile (e.g., capabilities, business scenarios, BDocs and roles supported) to the common Repository through a Portal. This information can be viewed by other organizations (registered in the CNE), and which are searching for potential business partners.

Before organizations actually conduct business with each other, they should define a *business collaboration agreement*, which corresponds to an intersection of their *Profiles* and includes additional results on negotiating variable parameters.

3.5 Collaborative Business Activities

This element of the framework is supported by an activity-oriented view of the several business interactions between CN member organizations (e.g., BDocs exchanged). The inter-organization interactions are, in fact, CBAs. The choreography of these interactions/activities may be globally specified and stored in the common Repository (e.g., allowing the specification of individual and concrete workflow processes, which can be integrated). Some collaborative activities in a given workflow process will need to be integrated with third-party applications in the organization (e.g., ERP solutions). Thus, these organizations will make available a set of Web services whose invocation will be done and coordinated by a CBA integration and coordination service (e.g., which should be able to differentiate human-based from automatic activities, and coordinate their execution).

As a first step, a set of five **operational CBA clusters** has been identified, which define inter-organization interactions in a CNE: *(1) Order Management* (e.g., from price and delivery quotation, Order initiation, till invoicing and payment); *(2) Design and Manufacturing* (e.g., the exchange of information related with the design configurations necessary to manufacture a certain product); *(3) Marketing and Commercialization*, enabling communication of marketing information; *(4) Inventory Management*, enabling inventory management collaboration; *(5) Post-sale Support* (e.g., request warranty claim).

3.6   Centralized Repository

The total set of business scenarios registered in the Repository defines the possibilities of e-business. Each organization may define its capabilities (at the technical and business levels) of a subset of what is possible. The Profiles registered allow other organizations to query on potential business partners Profiles (by accessing a service designed to retrieve information from the common Repository) and on possible ways to conduct business with them.

3.7   The Service Supporting an Economic Analysis

This service aims at providing CNs (and their member organizations) a basis for elaborating an economic analysis (e.g., cost-benefit analysis), as support for their performance assessment. This service can be implemented based on the economic model proposed by (Chituc, Nof, 2007).

4   CONCEPT VALIDATION: AN IMPLEMENTATION EXAMPLE FROM THE FOOTWEAR INDUSTRY

Based on this framework, an ICT platform supporting B2B in the footwear industry is currently being implemented, within the scope of a national project ShoeBiz@PT pursued in partnership between the Portuguese Shoe Technological Center and INESC Porto. It aims at achieving seamless interoperability in this sector.

The footwear industry has a significant delay concerning ICT developments and e-business adoption, compared to other industry sectors, as emphasized in (EC, 2006). Main characteristics of this sector, its requirements, specific scenarios, relevant projects and their main outcomes have been summarized in (Chituc, Toscano, Azevedo, 2007a, b).

Actors. Two main actors are involved in the footwear sector: **(1) SMEs** (e.g., producer, subcontractor, supplier), performing different roles (e.g., buyer, seller, delivery recipient, payer, payee), and which aim at attaining decreasing costs (e.g., for operation), shorter negotiation times, faster and cheaper access to new markets and business opportunities, faster and cheaper CN set-up, operation and reconfiguration; **(2) the Shoe Association**, performing the role of Business Enabler, having the following three main responsibilities: it acts as a communication hub between all SMEs; resolves potential conflicts; manages the Repository.

System architecture. The architecture of the system is illustrated in Figure 2. A **Hub** assures inter-organizations communication, manages the common Repository, and makes available a set of services for the eMail application. The **Connector** is the link with the SMEs' ERP system, keeping track of all BDocs sent and received by the company where it is installed. The **eMail application** is a GUI for information management, supporting human-oriented tasks of BDocs creation, reception and printing. This application works as a regular e-mail front-end allowing users to send/receive BDocs.

Messaging service. After an in depth analysis, the research team has decided to adopt Hermes platform as messaging service. Main reasons for this decision were: it is open-source and in compliance with OASIS ebMS v2; supports any kind of data in the body of the messages exchanged. However, Hermes has been used here in a
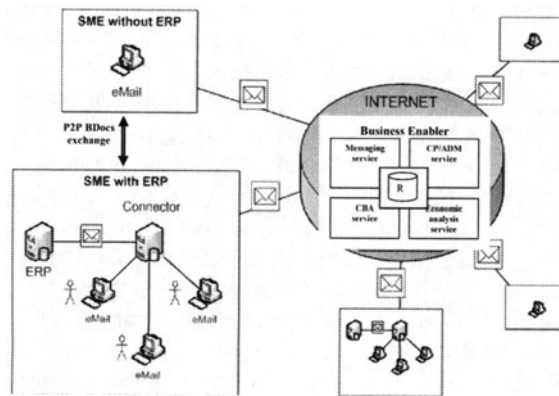
Figure 2. System architecture (footwear industry)

different way: while ebXML encourages communication among SMEs on a peer-to-peer basis, this approach uses a communication Hub allowing a third-party entity (e.g., Shoe Association) to play the role of BE. Elements required implementing this messaging platform are: a messaging service (e.g., ebXML Hermes); a mail service (e.g., ebXML eMail); interfaces (e.g., for to end-users of each organization in order to see the BDocs received/sent).

This element is message-oriented. It supports trading partners to conduct business through a reliable and secure exchange of BDocs. Additional elements (e.g., APIs) may also be present at this level of integration. For example, external applications (e.g., ERP solutions) may use the API to send and receive BDocs from external trading partners.

XML-based Business Documents. Aiming at covering most of the different collaborations and relationships among the actors in this sector, a set of 17 XML-based BDocs has been developed within SHOENET project, and which are used for this implementation. This set of common BDocs assures semantic interoperability among business partners, and supports cross-industry communication.

CP/ADM element has already been designed and it is currently being implemented (by making use of open-source software). **CBA** element is currently being design, considering the *Clusters* identified (Section 3.5) and the specificities of this sector. BPEL will be used for the implementation.

5   CONCLUSIONS AND FUTURE RESEARCH WORK

Although there are available numerous tools and infrastructures supporting interoperability in a collaborative networked environment, this goal is unachieved.

The framework proposed towards seamless interoperability relies on a set of attributes (e.g., reliability, cost, time, traceability) identified by the authors, and four main views on interoperability: technical, semantic, information and business. It comprises six main elements: a messaging service; a Collaboration Profile/Agreement Definition and Management service; a system assuring Collaborative Business

Activities' integration and management; a centralized Repository; a set of business documents; a service supporting an economic analysis.

This framework relies on the concept of *Business Enabler* (e.g., a Shoe Association in the case of footwear industry), which assures communication among organizations, solves conflicts, and manages the Repository. However, some organizations might communicate directly in order to increase the privacy of their communication, but this has to be specified in the collaboration agreement.

Based on this framework, an information and communication technology (ICT) platform is currently being implemented for the footwear sector within the scope of ShoeBiz@PT project pursued at national level in partnership between the Portuguese Shoe Technological Center (CTCP) and INESC Porto. The messaging service has already been implemented, and developments are being pursued to implement the CP/ADM and CBA elements. A common set of 17 XML-based business documents already available is used, assuring semantic interoperability.

This ICT platform represents a significant contribution for the SMEs in the footwear sector by providing them shorter negotiation times; decreased costs; faster and cheaper CN set-up, operation and reconfiguration; faster and cheaper access to new markets and business opportunities; reliable communication among business partners. It assures BDocs reliable delivery, confidentiality, authentication, privacy, non-repudiation, and information integration.

Future work will focus on analyzing the possibility to implement this approach to other industry sectors, and to quantify its impact.

Acknowledgements

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