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Technical, semantic and organizational issues of enterprise interoperability and networking☆

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ABSTRACT

Enterprise networking refers to any kind of organization structures in which two or more geographically dispersed business entities need to work in interaction. This can happen within a single distributed enterprise (networked enterprise) or among several enterprises (network of enterprises), including the extended enterprise or virtual organizations. This concerns any kind of organizations, e.g. industrial firms, public organizations or large government agencies. Enterprise interoperability is a sine qua non-condition for enterprise integration and networking. It largely relies on information and communication technologies (ICT), especially Internet computing. The paper uses the European Interoperability Framework (EIF) as a foundational baseline to first discuss technical, semantic and organizational aspects of enterprise interoperability and networking and finally to address some open research issues.

1. Introduction

Enterprise networking is becoming a reality for nearly any kind of business entities or organizations, be they industrial firms, service companies, public organizations or government agencies and institutions. None of these organizations can operate in isolation anymore. Due to the effect of market globalization, of e-commerce, of having to be a member of a large supply chain, of having to maintain strong partnership with other members of an enterprise network or a virtual organization or, for government organizations, of having to cooperate with other state institutions to offer advanced and compound services to citizens, business entities need to communicate, cooperate, collaborate or inter-operate with other business entities, which can be located next door or anywhere on the planet. Information and communication technologies (ICT), and especially telecommunications and Internet computing (Singh, 2005), have made this possible at the technical level. However, enterprise networking also relies on enterprise integration and interoperability principles, which have strong semantic and organizational dimensions.

Enterprise integration and interoperability come into play any time that two or more business entities need to work together or need to share common information. This can happen at the data level, at the information system or IT application level, at the service or organization unit level as well as at the business process level. This either concerns the internal business processes and services of a given enterprise or cross-organizational business processes spanning partner companies or flowing across enterprise networks.

The paper first clarifies the articulation between enterprise integration and enterprise interoperability, which are two closely connected concepts that are too often opposed or confused in the literature. Next, the European Interoperability Framework (EIF) is introduced and will be used as the baseline foundation for discussing technical, semantic and organizational aspects of enterprise interoperability. Finally, some additional aspects of enterprise interoperability and networking are discussed from a research point of view before concluding.

2. Enterprise integration and systems interoperability

Enterprise integration and underlying systems interoperability aim at facilitating seamless operations between business entities, be they from a single, networked or virtual organization. While enterprise integration has a strong organizational dimension, interoperability has a more technical nature.

Enterprise integration (EI), which emerged after the Computer Integrated Manufacturing (CIM) era, has been heavily discussed and investigated since the late 80s with the seminal work on the CIMOSA architecture (AMICE, 1993; Petrie, 1992). According to the

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Webster dictionary, integration means "to make a whole" or "to bring parts into a whole". Thus, EI occurs when there is a need of removing organizational barriers and/or improving interoperation and collaboration among people, systems, applications, departments and even companies (especially in terms of material flows, information/decision flows and control or work flows). The goal is to create synergy within the enterprise or the enterprise network, i.e. creating a situation in which the integrated system offers more capability than the sum of its components would simply do.

From a pure organizational standpoint, EI is concerned with facilitating information, control and material flows across organization units by connecting all the necessary functions and heterogeneous functional entities (e.g. information systems, devices, applications and people) in order to improve communication, cooperation and coordination within this enterprise so that it behaves as an integrated whole, therefore enhancing its overall productivity, flexibility and capacity for management of change (i.e. reactivity) (Vernadat, 1996). Li and Williams (2004) provide a broader definition of EI stating that enterprise integration is the coordination of all elements including business, processes, people and technology of the enterprise(s) working together in order to achieve the optimal fulfillment of the business mission of that enterprise(s) as defined by the management.

From a technical standpoint, integration can range from loosely coupled to tightly coupled and further to fully integrated systems. Full integration means that component systems are no longer distinguishable in the integrated whole. Tightly coupled integration means that components are still distinguishable in the whole but any modification on one of them may have direct impact on the others. Loosely coupled integration means that component systems are autonomous and continue to exist on their own but can as well work as components of the integrated system. It can be argued that loosely coupled integration equates to interoperability.

Enterprise interoperability provides two or more business entities (of the same organization or from different organizations and irrespective of their location) with the ability of exchanging or sharing information (wherever it is and at any time) and using functionality of one another in a distributed and heterogeneous environment. This has only been made possible due to international standardization efforts as reviewed in Chen and Vernadat (2004) and thanks to recent and rapid advances in the fields of ICT and Internet computing (Singh, 2005).

Broadly speaking, interoperability can be approximated as a measure of the ability of performing interoperation between two or more different entities (be they pieces of software, processes, systems, business units, etc.). Thus, enterprise interoperability is concerned with interoperability between organizational units or business processes either within a large (distributed) enterprise or within an enterprise network. From a technical standpoint, it therefore relies on systems interoperability defined, according to the Webster dictionary, as "the ability of a system to use part of another system".

Enterprise integration and interoperability are too often confused or opposed in the literature. In fact, they are complementary concepts. Enterprise integration should not be reduced to the single enterprise. Both can apply to the single or to the networked enterprise. Enterprise integration provides the global picture while enterprise interoperability is only a subset of EI. Enterprise integration nowadays strongly relies on systems interoperability, but interoperable enterprise systems do not necessarily need to be integrated. Loose coupling of systems is the state of the art and the easiest solution for EI implementation (Vernadat, 2006).

Integration and interoperability are being addressed by three different communities, namely industrial engineering, software engineering and business sciences. For computer science and software engineering, interoperability is a question of levels of compatibility in terms of communication protocols, communication interfaces, data accesses, data types, data semantics, application functionality and dynamic behavior (IEC, 2002) while integration is a matter of database schemas and information systems integration (Bernstein & Haas, 2009). For management sciences, integration and interoperability are more a question of business process alignment and optimal management of value chains. Industrial engineering looks at enterprise integration and interoperability in a more global point of view, using advances and techniques from system theory, management sciences and computer sciences to address the problem from its functional, information, technical and organizational aspects. To conciliate these various approaches, reference frameworks are necessary.

3. Enterprise Interoperability Frameworks and EIF

Reference frameworks are useful instruments to position and relate to one another, but also to compare, concepts, principles, methods, standards, models and tools in a certain domain of concern. Some well-known examples concern Enterprise Architecture Frameworks or reference architectures for enterprise modeling and integration such as CIMOSA (AMICE, 1993), PERA (Williams, 1992), the Zachman Framework (Zachman, 1996) or GERAM (GERAM, 1997). A number of similar frameworks have recently been proposed for enterprise interoperability. They have been reviewed by Chen, Doumeingts, and Vernadat (2008).

3.1. Enterprise Interoperability Frameworks

Among the major frameworks and maturity models proposed for interoperability, one can mention:

- The LISI Reference Model: LISI or 'levels of information systems interoperability' has been proposed by the Architecture Working Group of the US Department of Defence (on Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance – C4ISR). It provides the common vocabulary and structure needed to discuss interoperability between IT systems. It defines five levels of interoperability as follows (C4ISR, 1998):
  - Level 0 – isolated systems (manual extraction and integration of data).
  - Level 1 – connected interoperability in a peer-to-peer environment.
  - Level 2 – functional interoperability in a distributed environment.
  - Level 3 – domain-based interoperability in an integrated environment.
  - Level 4 – enterprise-based interoperability in a universal environment.
- The ATHENA Interoperability Framework (AIF): This framework has been developed as part of the EU-funded R&D project ATHENA (http://modelbased.net/aif/). AIF provides a compound framework and associated reference architecture for capturing the research elements and solutions to interoperability issues that address the problem in a holistic way by inter-relating relevant information from different perspectives of the enterprise. The framework is structured in three parts, namely:
  1. *Conceptual integration*, which focuses on concepts, metamodels, languages and model relationships. The framework defines an *interoperability reference architecture* that provides a foundation for systemizing various aspects of interoperability.
  2. *Application integration*, which focuses on methodologies, standards and domain models. The framework defines a