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IFAC-PapersOnLine 48-3 (2015) 038–045

Information Realignment in Pursuit of Self-Sustainable Interoperability at the Digital and Sensing Enterprise

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Abstract: In order to remain competitive with big corporations, small and medium-size enterprises (SMEs) often need to be more dynamic, adapt to new business situations, react faster, and thereby survive in today's global economy. To do so, SMEs normally seek to create consortiums become aligned with the new Internet trends, thus gaining access to new and more opportunities. However, this strategy may also lead to complications, especially at the level of interoperability. Systems become more and more dynamic with evolving information models and "liquid" semantic domains with fuzzy boundaries. Collaboration networks and partnerships frequently change to answer new customer's requirements, causing new interoperability problems and a reduction of efficiency when not solved. A similar situation is occurring at the level of IoT with the replacement of devices from different manufacturers. This work proposes a mediator system to enable self-sustainable interoperability, monitoring existing enterprise information systems and their devices, by predicting future behaviors and automatically detecting past changes that may harness interoperability. With this, network harmonization disruptions are detected in a timely way, and possible solutions are suggested to regain the interoperable status, thus enhancing robustness for reaching sustainability of business networks along time.

Keywords: Self-Sustainable Interoperability; Sensing Enterprise; Model Morphisms; Multi-Agent Systems; Monitoring and Assessment; Information Management, Cyber-Physical Systems.

1. INTRODUCTION

In an era of globalization, organizations cooperate with each other to reach new markets, increase production, and decrease operational costs, hoping to achieve better results and, consequently increase sales. However, globalization and the Future Internet (FI) imply working with organizations scattered over the world, from complementary domains, using different semantics, and adopting diverse management culture. Sometimes they do not have a proper concern to manage business processes formally, due to the often-daunting scale of operation. Even good managers sometimes pass up the opportunity to use appropriate software solutions that support the management of network production. Software such as Enterprise Information Systems (EIS) is created to support the management of the various resources (personnel, material, equipment, process, devices, etc.). However, this does not oblige the different enterprises to use the same enterprise systems, and as a result, different companies often have their own system (ATHENA 2007).

The usage of different EIS may cause difficulties to enterprises willing to collaborate due to different standards, information models, and not interoperable services. This is a critical point when working with other companies, as it can happen that the information is misunderstood, causing delays in production and perhaps the loss of considerable profits. An example is the 1993 NASA program to explore Mars: in the production phase everything ran well, finalizing the product on time; However, during the Mars Orbit insertion manoeuvre, mission control lost contact with the spacecraft; As it turned out, one engineering team used metric units (International System of Units - SI) while another used Imperial units, causing a loss of $125 Million due to a simple interoperability problem not managed by EIS.

In this example, it is possible to identify the problems that can occur when working in a Collaboration Network (CN). Each enterprise has its own EIS, and consequently its own standards and models, which offer resistance when interacting with other enterprises. On the other hand, with each passing day the need for a seamless sharing of information is becoming more important. Failures should never occur during the information exchange process. Hence, research needs to contribute towards the support and integration along the full Product Life-Cycle (PLC) phases, with manufacturers, distributors, designers, retailers adopting interoperable solutions. Maintaining interoperability between them is also crucial. For that, the collaboration of independently developed systems require the information structures to be standardized throughout the industry to allow the communication between them to run without problems, for that, it is important to implement a Model-Based Interoperability (Hendriks and Wevers 2007).

The same happens at the level of the enterprise's sub-systems. When pursuing the paradigm of the digital and sensing enterprise (DSE) (Santucci et al. 2012), requirements in a network of collaborative devices include a good functional collaboration, dynamic configurability and interoperability, enabling a self-management of the network. Embracing new models for innovative business relations and supporting extended, virtual and agile enterprises in the FI, the combination of FInES (Future Internet Enterprise Systems)

10.1016/j.ifacol.2015.06.055

and the IoT is extending the "Digital" to the "Sensing" capability. DSE brings benefits to the organizations, including context awareness capabilities and sensorial technology to enable shorter response times, reduced cycle times from order to cash, reduced inventories, and a reduction in the number of costly errors, keeping companies ahead of competition and positioning them for world-class performance (Danila et al. 2013).

However, in a network several things can occur to disrupt or harness the interoperability status. To avoid this, it is necessary to create a support system able to monitor the network, searching for problems, and every time that one is detected, be able to repair it in time, perhaps avoiding serious problems in the future. This scenario, where the network is interoperable and at the same time dynamic and resilient to the occurrence of new interoperability problems, is called a "self-sustainable interoperable network".

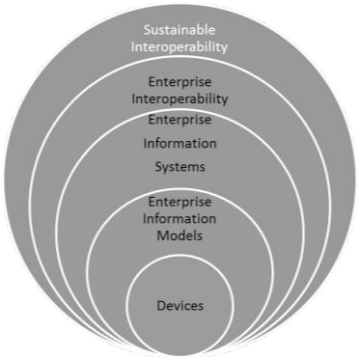

Fig. 1. Sustainable Interoperability Paradigm.

To better understand sustainable interoperability, one can follow Fig. 1 that works like an onion, in which each layer represents a more complex and complete interoperability status. This onion starts in the centre with the representation of the devices (1st layer), i.e. objects, machines, or pieces of equipment made for some special purpose. These devices are represented as part of information models (2nd layer), e.g. as resources in their EIS, which also contemplate internal procedures, system data structures, enterprise organizational structure, etc. The more complete these models are (requirements, processes, business strategy, etc.), the more companies could benefit from good management decisions, along with operational traceability and quick identification of possible problems. EIS software (3rd layer) implements the enterprise information models, executing the enterprise services and managing processes. Hence is fundamental to allow collaboration (inside and outside the company). The "granularity" between different EIS (or devices) can be mitigated through interoperability solutions directly at the level of the EIS or using mediators. At this point the enterprises have reached the networked Enterprise Interoperability level, (the 4th). To continue working smoothly, models would need to be static, since every time a change is made, an interoperability harmonization breaking in the system may occur (Jardim-Goncalves et al. 2012). As that does not reflect the reality, a 5th layer is required, where the network needs to be sustainable, allowing each enterprise to make modifications in their EIS, models, and devices.

1.1. General Situation and Problem Breakdown

The goal of this work is to contribute to the creation of a sustainable interoperable environment in a collaborative network of DSE's. Fig. 2 shows an example of a network, which is composed of three enterprises that cooperate among each other in a sustainable interoperability environment. To communicate seamlessly, these enterprises use services regulated by mappings relating their information models. Each enterprise has its own structure and semantics to represent resources or devices, and each device also uses a different model, which also needs to be interoperable in the network (lower part of the figure). Since the whole network is not static, several situations can occur to disrupt the harmonization of the network. As explained, such situations arise when an enterprise makes changes in its procedures, models, EIS, devices, or even when there is a new entry in the network. For these situations not to create inefficiencies, it is necessary for the systems to be prepared to constantly receive feedback about its neighbours, propose reaction and adapt in real time, i.e. behaving as a self-adaptive system (Jardim-Goncalves et al. 2012; Agostinho et al. 2014).

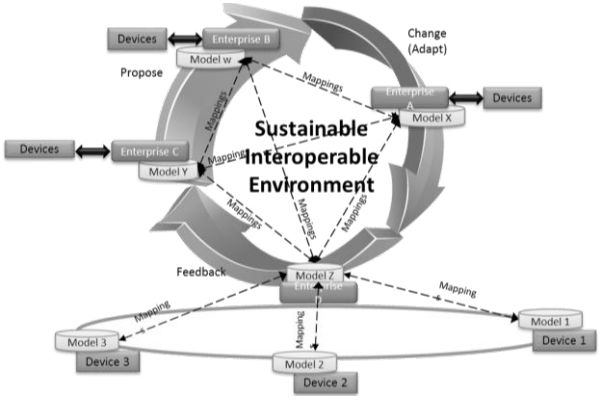

Fig. 2. Sustainable Interoperable Environment.

When such environment is achieved it allows changes at all the inner levels of the onion of Fig.1 without causing problems to the other members. The task in hand is divided into several steps/challenges that facilitate the final goal.

Cooperation implies systems interoperability at the semantic, technical, application, and at the business levels as addressed by Berre et al. (2007). By looking to the systems in this four levels perspectives, and considering the state of the art in the domain (see section 2 of the paper), 3 main issues arise:

1. **How to reach full interoperability between two or more enterprises?** Most of the times that is impossible. The correct answer to this question is to reach the possible integration on all the levels. Enterprises are usually able to achieve good integration on one or two levels, but have problems with the others. For example, an enterprise can reach a good technical integration but the semantic integration has several difficulties;
2. **How to enable different devices to be seamlessly integrated in the enterprise systems?** In an era of IoT devices, where availability is not an issue and there are many competing offers, it starts to be very important for enterprises to take advantage of this situation, and avoid