Enhancing Industrial Information Exchange in Service Architectures and Collaborative Business Processes

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Abstract: This paper presents the challenges and shortcomings of the current utilities and practices for industrial information exchange and collaborative business processes. While several enabling technologies exist, the data exchange between industrial enterprises is currently inefficient: even though some relevant data exists, accessibility problems may either make it difficult to utilize or prevent its use completely. The lack of common practices and modelling methods causes unnecessary costs and makes it difficult to utilize existing resources. The target of the work introduced in the paper is a doctoral degree, the contribution being a comprehensive set of architectural principles and practices to improve industrial information exchange and business collaboration.

1 INTRODUCTION

The base domain of the work presented in this paper is industrial information exchange. The term *industrial* refers broadly to the various branches of industry. It includes, for instance, process industry and piece goods industry as well as the utilization of mobile machines. *Information exchange* refers to passing information from one entity or enterprise to another. *Service architecture* is an architectural style common in the information systems of modern enterprises, and *collaborative business processes* refer to the processes of running business between partners.

The area of information technology to which this paper is related has several challenges. The problem is not always to get more data required to perform tasks but to access existing information to make it better utilizable. In addition, even if some information is available, if there is no reasonable medium to exchange it then it will be difficult to store it for later utilization. Maintenance is an example of an area where such information management challenges are present. To preserve the value of a piece of equipment, appropriate maintenance is required. However, a lot of information is required for a well-performing maintenance program. In industrial plants, the reality may be that the original engineering data is missing so finding replacement parts may be problematic. In addition, timing is very significant to get the best out of maintenance: too early maintenance may cause extra costs, and too late maintenance may cause breakdowns and downtime.

The research ideas presented in this paper are the beginning of doctoral studies, targeting to a doctoral thesis. The tangible progress from the research point of view, in addition to this paper, is an article to be presented in ICEIS 2014. There has also been research and practical work with industrial enterprises to improve information exchange. What is to be done in the future is to explore the principles required to enable information exchange that is more advanced and meets business needs better than the current technologies.

The drivers of this research are enterprises. Real-world scenarios with genuine business requirements will be presented in coming publications, and the work related to those scenarios will form the basis of the ideas and the contribution of the work.

The rest of this document is organised as follows. Section 2 explains research context. Section 3 sets objectives and section 4 discusses the methodology to reach them. Finally, section 5 gives conclusions and future work.

2 RESEARCH CONTEXT

2.1 Background

This section explains the background and the motivation of the work. The work is in the very beginning so the final objectives are still inaccurate and open for changes and discussion.

In industry, a lot of information exists in different information systems but its utilization is problematic. System integrations must be implemented to access the data, but they are difficult and laborious.

A better access to the information would facilitate at least two actions: (1) delivering information to partners as such, (2) processing information to gain added value and either utilizing the generated data locally or distributing it to partners.

2.2 Data Exchange Challenge

As any information exchange, industrial information exchange is challenging due to the heterogeneity of the information models of the various systems. Even between enterprises performing similar actions (such as running similar chemical processes or manufacturing similar piece goods), there may be considerable differences in how data is stored in the information systems of the enterprise (Figure 1). Some type of data collected by one enterprise may be completely missing from another, or its sustenance may be neglected, or its data format may be different. This may be a real challenge for the industrial partners as they have to adapt their business to the differences of enterprise data models even if they were offering similar services to all of their customers. Any additional work required for the adaptation causes unnecessary costs that do not have any value from the production point of view.

The difference of system data models reflects to system interfaces. Currently, to integrate two systems of separate enterprises, a considerable amount of work is required so the value expected from the integration must be high. If the amount of data to be exchanged is low or if it is considered too invaluable, no integration will be performed. However, if that information is important anyway, it must be exchanged manually, or worse, it will not be exchanged at all. If some useful information exists, it is far from the ideal of collaboration if bad data accessibility makes it unusable.

Due to integration challenges and the high price of system integration with current tools and

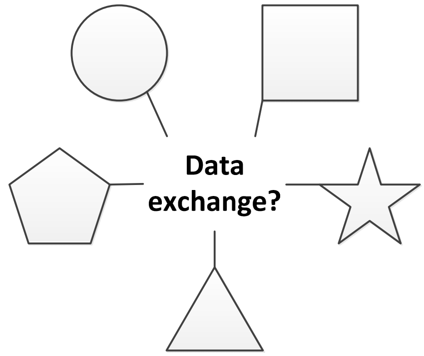

Figure 1: Exchanging data between heterogeneous systems or enterprises.

methods, a lot of information is exchanged manually. Compared to electronic data exchange, more laborious manual communication is required to reach the same business value. In addition, if the information exchange was to be tracked later, problems may occur as discussions by email or by phone rarely leave any easily accessible log entries. Besides, one of the most important business functions is invoicing as it will generate revenue to enterprises. If information exchange is manual, invoicing related to the provided service will require manual work as well, and it is also subject to human errors.

To conclude, several points are suggesting the benefits of system integration but its high price is problematic. This is due to the heterogeneity of enterprises.

2.3 Data Management Challenge

As from the data exchange point of view, the diversity of enterprise data models is a challenge for data management as well (Figure 2). While some information may exist, it may be too difficult to access it. The information could even exist in some physical media (such as DVD) that is only accessible by humans. That is, the case may be that an enterprise practically exploits only a fraction of some information storage because the access to it is too expensive. In many cases, existing information would enable building added value.

In industry, data management is not only about information systems but also about devices. As the computational capability of devices keeps improving, it is advantageous if their data can be accessed for use. Such information can include, for example, condition information that suggests when maintenance is required. Having more accurate information about devices may enable more efficient use of workload for maintenance and other actions.

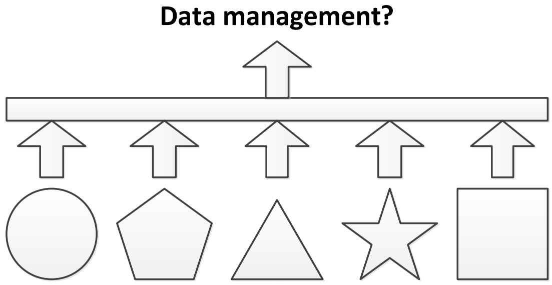

Figure 2: Managing data in heterogeneous systems.

The lack of information access causes unnecessary costs. Labour is required to check the details that could be retrieved quickly from data. Data once produced cannot be utilized anymore. Another problem is that the sustenance of existing data may be too difficult. After several years with no maintenance, the reliability of data can be low – if one cannot trust the data, does it have any use if a human being must check data correctness anyway? That is, it should be easier to not only collect and store data but also integrate it so its potential can be exploited for the actual business of the enterprise.

The data management challenge occurs especially when a business partner needs data from several systems. The more fragmented the enterprise architecture is, the more significant is the problem. Due to the quick evolution of business, new information systems, constant organisational changes and constant enterprise fusions, information fragmentation is expected to be typical rather than exceptional.

In summary, accessibility problems make data management needlessly difficult. The result is that information cannot be utilized as a resource as effectively as it should.

2.4 Events

In addition to data exchange and collection challenges, one important point of view is *events*. Various types of data are generated by various systems and devices, and it is meaningful to interpret that data to detect when some business action is appropriate. This gap – from data to business actions – is bridged by events that are detected in constantly changing data. As the number of data changes may be simply too large to handle, only some of them are observed to detect events. Moreover, not all the detected events are likely to trigger a business action. This can be illustrated as a triangle (Figure 3). On the bottom, the number of items is large but their significance is low, while items on the top are fewer but they may be very significant for the enterprise. Generating events and triggering business actions from events has been presented by, for example, Michelson (2006) and McGovern et al (2006). Practical event-based architectures have been developed by, for instance, Dunkel et al. (2011) and Terfloth et al. (2006).

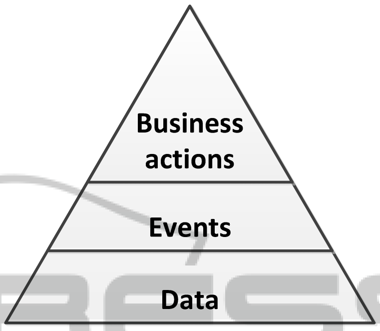

Figure 3: Data is utilized to detect events that may lead to various business actions.

While events are an important concept alone, they are also closely related to the problems presented in the previous subsections. Data collection and exchange is present even in the generation of events. Discovering events to react to them with correct business actions can be beneficial to one enterprise or provide competitive advantage, but it can also bring added value to collaborative industrial business. Through events, a business partner may improve their service in a way that might be impossible or at least harder or slower if correct business actions were to be triggered by humans.

2.5 Related Work

The issues of enterprise information exchange have been studied by several authors before. While data exchange between enterprises is the main concern of this paper, even system integration inside a single enterprise is related.

The challenges of inter-enterprise data exchange have been addressed by Chen & Doumeingts (2003). They recognize that ICT systems contain the data forming the essential knowledge, which is the basis of business. The paper proposes that three technical domains should be combined to improve the basis of data exchange: Enterprise Modelling, Architecture & Platform and Ontologies.

Hausladen & Bechheim (2004) discuss the aspects of optimizing industrial business processes with E-maintenance, a maintenance process that exploits modern IT and communication technology for better results. The result is that a comprehensive business process analysis and documentation are required. Finally, the utilization of an E-maintenance platform is suggested.

Han & Yang (2006) propose an E-maintenance system to improve the performance of maintenance operations and to gain competitive advantage. They suggest having a local maintenance system in each production plant and a single maintenance centre that provides help when the abilities of local maintenance are not sufficient. Information is shared comprehensively by effective communication methods.

Vernadat (2007) discusses how the information systems of enterprises can be designed for easier collaboration. The mutual trust of organisations is an aspect that has not been addressed enough this far. Furthermore, collaboration is not only about technical issues but also strategy, organisation and people. Customers should form the basis of the enterprise architecture. Flexibility should be promoted in design: for example, loose coupling and asynchronous communication should be favoured.

Chen et al. (2008) have studied the challenges related to enterprise architectures and problematic issues that cause shortcomings. It is stated that a common terminology and a common ontology have been missing, and there have been several proposals that cover them but only partially. Additionally, there have been no proper methods for comparing architecture proposals, no interoperability has been possible between existing architectures, standards have not been mature enough, and no proper architecture description methods have existed. Several suggestions to overcome the problems in the future are given, covering the development process, tools and design principles.

Muller et al. (2008) review the status of E-maintenance. Several research and other working needs are addressed including the adoption of standards to promote interoperability, adopting of new technologies to raise the intelligence of devices, more comprehensive process modelling and the development of new E-maintenance systems. Finally, the current knowledge must be analysed in order to create a new framework to form the groundwork of E-maintenance.

Panetto & Molina (2008) write that system integration in the manufacturing domain organizes machines and people as a system. They state that current middleware and standards based systems often fail to scale well so more research is required to overcome the problems. They propose that the introduction of semantic web services could help overcoming the problem.

Chituc et al. (2009) propose a conceptual framework for collaborative interoperability. It consists of six elements: messaging service, collaboration profile, inter-organizational collaborative activities, a centralized repository, a set of essential documents and a performance assessment service. While the coverage of the framework is wide, there is no implementation following the principles as far as is known.

Vernadat (2010) discusses the issues of enterprise interoperation. While the current technologies and service orientation make interoperation possible, there are still unaddressed issues such as data semantics and organizational support. In addition, there are shortcomings in, for example, security, language support in multilingual cases and confidentiality.

Clark & Barn (2011) suggest promoting loose coupling and complex component interaction in enterprise systems by favouring Event-Driven Architecture (EDA) over conventional Service-Oriented Architecture (SOA). However, as there has been no modelling notation specifically for EDA, a proposal is introduced together with a simulation language. The modelling notation is an extension to UML (Unified Modelling Language), a common language in software engineering.

Da Xu (2011) surveys the state of the art of enterprise information systems. The evolution of Enterprise Resource Planning (ERP) systems is discussed as well as Enterprise Application Integration (EAI). Originally, the term EAI covered only the integration of systems in one enterprise but it has later extended to cover integration with partners as well. Multiple technologies facilitating inter-enterprise communication are suggested, including SOA and XML (Extensible Markup Language). While the paper focuses mostly on the point of view of a single enterprise, it effectively explains the current situation of enterprise information management.

Several enabling technologies have been suggested but a concrete overall solution is still lacking as additional layers are still required on the enabling technologies; that is the gap where this work is targeted to. In addition, even if the typical business process elements such as quotation, order and delivery were covered, the requirement to cover technical data would still be unaddressed. There may be a lot of similarities in business processes between different branches, but the format of technical data varies inevitably.

2.6 Research Questions

Even though there are several technologies to take control over data exchange and data management challenges, the problem that remains is that there is no methodology to control everything as a whole. While the existing technologies contribute to some specific detail, their functionality is insufficient from the point of view of controlling data in the ever-changing business environment. That is, there are several enablers, but the actual solution is missing. This is illustrated in Figure 4: more architectural principles are required. Not only should the business of a single enterprise be considered but also the collaboration between multiple organisations.

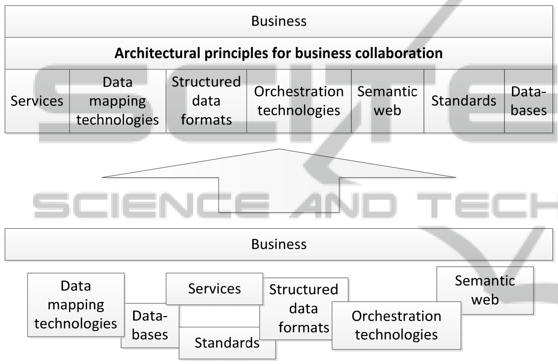

Figure 4: Architectural principles are required to fill the gap between business requirements and enabling technologies to bring more control over business collaboration

From the introduced research problem, the following questions arise.

1. Information system architecture
   a. What kind of architectural solutions promote data management in various systems?
   b. What components are required to build a concrete collaboration platform?
2. Integration
   a. How to make a collaboration platform customizable enough to meet the diversity of industrial enterprises and their business?
   b. How to meet the diversity of device and machine related data in industrial systems?
3. Collaboration
   a. What kind of architectural solutions promote collaboration?

To address the questions, a lot of knowledge is required. The fields include enterprise collaboration, data management and event-driven architectures. To understand the business requirements of enterprises, it is required to receive steering and advises from the personnel in the business.

3 OBJECTIVES

This section gathers the objectives of the work. As there are several high-level objectives, the goal is to focus in the chosen domain as a whole rather than to contribute to a narrow area. From a domain point of view, high-level concepts can be considered strategic in the sense of setting the coarse common direction of low-level actions. While low-level functionality is what realizes systems as a whole, it is important to reach a consistent overall result from them. Even though industry domain is wide, is does not mean the work itself should have a wide focus; instead, the work is related to specific architectural questions that occur in several areas in the domain.

The high-level objective of this work is to study ways to improve what currently exists. As the result of the work, more efficient processes and ways of working are expected while the core actions and goals of business processes might remain as they are. Several paradigms and ideas suit well for different points of view. The objective is to gain technical contribution that is not limited to any specific industry domain but can be applied in several areas. The final objectives can be given as follows.

Contributing to Information System Architecture. In the large scale, architecture is paramount as it effectively sets the limits of what kind of functions can be included in the resulting system or system group. In managing and maintaining a running system, several questions arise. What kind of architectural choices are the best to enable a system that can be customized at runtime? What if the system is distributed in a geographically wide area? What if some customization should be managed globally but local customization is also required?

Contributing to Information System Integration. *Integration* refers to connecting information systems so that information can be exchanged between them. While integration as a concept has existed since long, there is a lot to be improved in terms of the required human work or adaptability when business requirements or systems evolve. As the amount of available information is constantly growing in industry, more and more integration requirements arise, which raises the importance of integration-related improvements. Could the concepts of integration be improved to have a better control over system interaction and system management?

Contributing to Business Collaboration. Business collaboration refers to interaction between two or more business organisations that provides advantage for all parties. Whatever the collaborative function is, it can be executed in any of the organisations or divided to be executed in several of them. One important point of view of collaboration is that it can generate added value from existing systems. According to Marttinen (2013), a significant challenge is the ownership of data and processes. While each party takes care of its own business, collaborative business processes are not explicitly owned by anyone as they occur *between* enterprises. In addition, it is important to recognize which party has the ownership of each type of data required for collaboration. In industry, a lot of information may have its origin in a location other than where it is utilized so managing information exchange is crucially important.

Finally, the contribution of the thesis will be a comprehensive set of principles about designing system architectures to support industrial information exchange. The business process point of view, both internal and collaborative, will be emphasized. As the field of science is applied and practical, the contribution will not be entirely new technologies but rather an experimentation of applying practices and technologies. The practical drivers of the work being real-life enterprises, the contribution will be close to current business needs, providing added value in near future.

The tangible result will be contributing to both the efficiency and the effectiveness of information management in industry. It will improve the understanding of the correct ways to design collaborative information exchange. Efficiency comes from being able to manage information with less work so personnel can focus on what is valuable rather than spending time on digging information whose retrieval should be automatic. Effectiveness comes from exchanging more information than previously. This results from the improved availability of data that may even exist today but in a format or system not easy to access.

However, it is also evident that the expected outcome will evolve over the writing period of the thesis. The topic being wide and abstract, the author is likely to learn and gain more understanding thus setting new targets. Moreover, the understanding of information exchange needs will evolve in the enterprises driving the research.

In summary, the expected outcome is a set of architectural principles to build a well-controlled layer to support data management and exchange. The principles should be universal in industry rather than relate to a specific domain as the actual challenges are similar regardless of the type of data.

4 METHODOLOGY

The research approach to be applied can be seen as a combination of two methodologies: constructive research and design science research. According to Crnkovic, the idea of constructive research is to build artefacts to meet a problem so new knowledge is gained. The contribution of the artefacts can be both theoretical and practical, and the way solutions are created is design and development rather than discovery. (Crnkovic 2010) On the other hand, design science aims at creating, evaluating and improving IT artefacts so goals can be reached (Hevner et al. 2004). According to Piirainen & Gonzalez (2013), design science and constructive research can coexist and complement each other. Based on their analysis, it could be said that the two approaches have a common goal while their points of view are slightly different.

The selected research approach is expected to suit well for this work considering the research problem and the research questions. New solutions, i.e. artefacts, will be constructed and designed to find responses for the questions.

The results of the work made for publications and other practical work will be exploited to gain more understanding in the domain. While each problem must be understood solidly before a solution can be designed, domain understanding will constantly improve during the work. Finally, the gained knowledge will be formulated as the outcome of this entire research.

5 CONCLUSIONS AND FUTURE WORK

This document introduces an initial plan for a doctoral degree. The work is in the very beginning so the plan is currently not very accurate. In addition, the requirements of the enterprises driving the research are not completely clear at this point.

Currently, there is a lot to be improved in industrial data exchange and data management. Despite several enabling technologies, there is no consistent solution to utilize the enormous collaboration potential of existing information systems. The problem is not the amount of data but rather the lack of ways to access and exchange it so it could bring business advantage.

The objective of the doctoral degree is to explore the architectural principles required to have a better control over the situation. Clearly, a new abstraction layer is required to fill the gap between business and the enabling technologies. The goal is to make contribution in the terms of architecture, integration and business collaboration.

The next step is to make a more thorough literature review to gain more understanding in the field of science, what research is already done and what are the most significant problems. Also, it will help narrowing the scope of the work. Then, a publication plan should be created to support the work and to form the basis of the doctoral degree.

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