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Abstract: *This paper presents the concept of collaboration infrastructure, which is intended to unify existing standards relevant for supply chain management and to provide the automated or semi-automated support in various decision making process, related to selection, production planning, capacity management, risk management and exception handling in manufacturing supply networks. In addition, the foreseen collaboration infrastructure is intended to facilitate and enhance the required knowledge management processes. In an industrial setting, the proposed collaboration infrastructure is expected to reduce involvement of individual SME's in networking efforts, enable better and faster decisions and promote the development of the business brokerage services sector.*

Keywords: *Inter-organizational network, Virtual Enterprise, Supply Chain Management, Semantic Web, Ontology*

1. INTRODUCTION

Today's market dynamics is putting high pressure to long-term planning activities and introduces demand for flexible production environments, capable to respond to market opportunity in competitive way. Recently, it became obvious that single enterprise cannot meet these challenges independently. Joint coordination of previously isolated individual functions of an enterprise has been one of the major challenges in exploration of opportunities for improvement of supply chain productivity, particularly since current view of supply chains is shifting from linear chains of supplier's supplier to customer's customer into complex networks which entail groups of companies with varying degrees of integration.

The main objective of this paper is to present the research, performed at Faculty of Mechanical Engineering, University of Nis, with goal to design, develop and demonstrate an innovative, generic approach and appropriate technical infrastructure, intended to be used by business brokers and architects, for the improvement of partners' selection and diverse collaboration processes in virtual enterprises, by using semantic Service Oriented Architecture (SOA) concepts. The concept of collaboration infrastructure is presented, which is intended to unify existing standards relevant for supply chain management and to provide the automated or semi-automated support in various decision making process, related to selection, production planning, capacity management, risk management and exception handling in manufacturing supply networks. In addition, the foreseen collaboration infrastructure is intended to facilitate and enhance the required knowledge management processes (such as knowledge acquisition and retrieval, epresentation and annotation, synthesis and evaluation). In an industrial setting, the proposed collaboration infrastructure is expected to reduce involvement of individual SME's in networking efforts, enable better and faster decisions (by exploiting legacy and/or collaboratively elaborated knowledge) and promote the development of the business brokerage services sector.

This paper is a position paper that will elaborate the concepts of operational and non-operational competences and the related clusters of ontologies and contribute to the guidelines for development of associative methods for their concentration and formalization of networking impact, encompassing the required organizational changes and individual performance improvement effects. Clusters of ontologies are intended to be used to support definition of goal statements for the selection of an "optimal" supply chain, as well as capability statements, against which the selection is made.

The main outcome of research presented in this paper will be a software platform with the associated configuration assets (method of use, technical artefacts, metrics, etc.), which

implement the developed concept, namely the Semantic Information Pool for Supply Networks (SIP4SUP). SIP4SUP aims at proposing solutions to four specific groups of problems:

- development of Meta Semantic Coordination Services (MSCSs) – generic functional web services, from ontology of operational and non-operational supply competences of partners and their on-demand composition on the basis of business opportunity and relevant reference process templates;
- development of a model of complex manufacturing supply competences characterized by their aggregated impact value and association parameters and derivation of composite MSCSs;
- mapping of MSCSs to existing web services;
- support of asynchronous processes for human collaboration (also addressing the related knowledge management issues).

SIP4SUP will exploit and build on cutting-edge technologies for enterprise application integration – service oriented architecture (SOA), enabled with semantic components, and supported by reference models and processes, represented by appropriate ontologies and templates.

2. PROGRESS BEYOND THE STATE OF THE ART

Continuous development of supply chain management (SCM) practices has been driven by growing trends of diversification of a demand market, specialization, outsourcing, mass-customization and extensive development of ICT technologies. Process of SCM evolution is characterized by continuous efforts in reduction of response times, encompassing the selection and configuration of optimal supply chain; reduction of involvement in coordination function, enabling the partners to focus at their core competences; increase of non-operational and operational diversity; and increase of supply network openness, achieved by loosely-coupled integration. It is considered that cornerstones of recent SCM practices development are work in definition of dynamic networks (Miles, et al., 1984) – "combinations of independent business processes with each contributing what it does the best to the network", extended enterprises (Childe, 1998), defined as "function of closer coordination in the design, development and costing", and finally – virtual enterprises (Brown and Zhang, 1999), "temporary networks of independent companies who come together quickly to exploit fast-changing opportunities".

The core concept of virtual enterprise has been addressed by numerous authors, providing different approaches. Virtual enterprises are customer-oriented, focused primarily to single opportunity, in contrast to supply chains which are being built on basis of a market share. They can be formed to perform one-of-a-kind production or service task (Sari, et al., 2006) or even to deliver after sales services for a product line (Hamel, 1999). Although virtual enterprise is designed to create a value of a business opportunity, it is argued (Katzy and Dissel, 2001) that the value of a virtual enterprise is also created within itself, as internal processes and services are adapted to the requirements of short-term business opportunity. Hence, one of the impacts of competences restructuring is also stimulation of organizational flexibility, resulting with improved performance in future occasions.

Approach to a legal form of organization of the network is currently not unified, and it is directly related to a level and the scope of coordination. In some circumstances, only small headquarters staffs are required, to deal with administrative details. It is also argued (Katzy, et al., 2004) that the role of business brokers or business architects, in charge of order acquisition, network marketing and internal assembly, must be anticipated. Networks will become responsibility of independent business services brokering companies, fully dedicated to improvement of network's performance. Presented concept aims at setting up the infrastructure for their core business – selection and coordination of virtual enterprises. Specialization of these functions would reduce the involvement of partners in coordination tasks. Also, it would open the opportunities for application and management of expanded set of criteria and impacts, enabling better and faster decisions.

Temporality of a virtual enterprise is one of the major problems for establishment of supportive framework for facilitation of effective collaboration among its members. Namely, investments in technical framework for enterprise integration, which could maximize the efficiency and productivity of the network, cannot be justified in a short term. Therefore, another approach is required, characterized by transparent, loose, dominantly asynchronous, externally coordinated integration, based on semantic interoperability where models may be classified with regards

to the needed maturity level of interoperation and the way networked enterprises applications have to cooperate (Panetto, 2007). Furthermore, during formation of a supply chain, enterprises are usually introduced or identified by the scope, availability and quality of their resources. Such, resource-based representation is too implicit and requires great human effort in associating individual enterprise resources to a role in a fulfilment of a common, inter-organizational objective. It opens the field to risky assumptions and time extensions, required for additional contacts and assessments. Also, in decision making about the selection of partners of a virtual enterprise derived from complex inter-organization network, some level of automated reasoning could significantly reduce the partners' involvement, improve the performance and accuracy of selection process, as well as the transparency of the network coordination.

Therefore, a new approach must be characterized by a parameterized and quantified representation of enterprise's abilities to perform, with the goal to reduce the scope and volume of associative thinking in the associated decision making processes.

3. SIP4SUP CONCEPT

For the purpose of development of a common framework for inter-organizational network collaboration, SIP4SUP will use production competences as primary elements of virtual enterprise configuration. These are generically defined as quantitatively described abilities of a partner to perform in a certain area of business, and are the result of decomposition of all network actors' capabilities to perform on market.

The conceptual architecture model of SIP4SUP is presented in Figure 1.

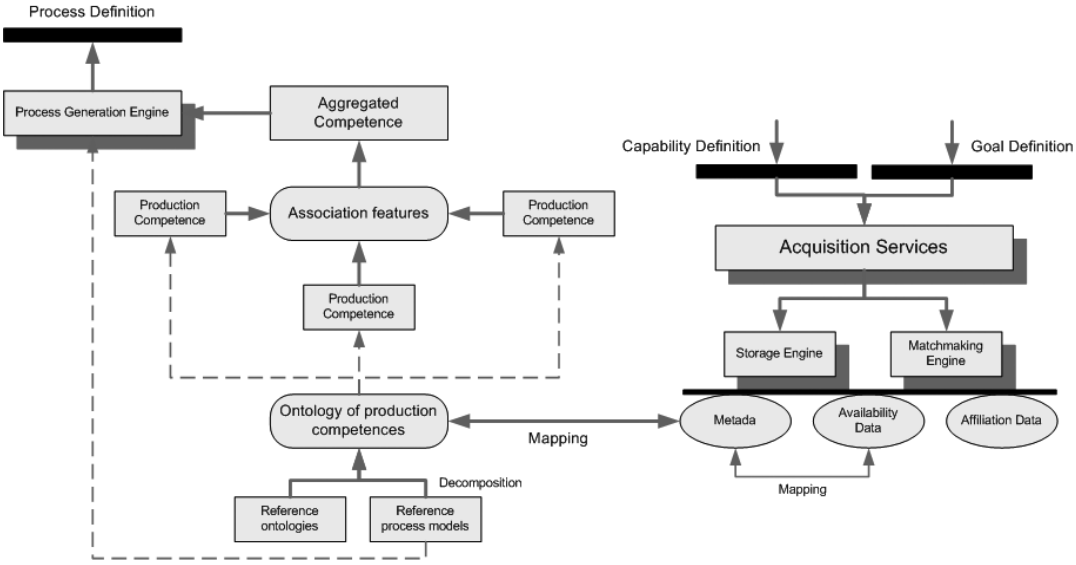

Figure 1. Conceptual model of SIP4SUP

The SIP4SUP's data acquisition process will be performed in an asynchronous or synchronous manner, depending on the partners' affiliation conditions or existence of appropriate integration channels, and will be implemented by using SOA (Service Oriented Architecture) technologies (MacKenzie, et al., 2006). SIP4SUP will be responsible for the management of the following types of information:

- Asset Data and Metadata. General information on partners' competences (location, ownership, product, resources, knowledge, historical performance etc.) availability, ontologies, registered services for pulling availability information and their service contracts;
- Competence availability data. Accurate Available-To-Promise (ATP) stock for all products; Accurate schedule and scale for planned machining and human resources utilization;
- Networking affiliation data. Various aspects of networking and affiliation. For example, stock and resources availability data accessibility (synchronous or asynchronous communication), IPR issues, privacy issues, terms and conditions for affiliation, import and export permits, etc;

While dedicated channels expose the status and behaviour of partners' resources, relevant for selection of supply chains, metadata encompass long-life information, with generalized competences of the partners and semantic baseline for the coordination – cluster of ontologies.

3.1. Guidelines for assembly of optimal virtual enterprise configuration

A crucial step towards the selection of an optimal supply chain configuration, to be implemented in SIP4SUP, aims at the improvement of assembly process as well as the exhaustive examination of impacts on a single enterprise and the overall collaboration environment. This is considered from multiple aspects, widening the scope of selection criteria from simple eligibility to complex set of conditions, derived from expected impact to be achieved by two or more networked operational or non-operational competences, forming the aggregated competence. Methods and algorithms for propagation of networking impact of aggregated competence to an overall business environment will be developed, as well as tools for the assumption and evaluation of the internal impact – rate of required re-configuration and consequent organizational learning and adaptation. Latter rates might be used to point at possibilities for enlargement of the domain of selected competence's appearance, enabling adaptive behaviour of involved resources, reduction of re-configuration and lead time, as well as overall improvement of product/service quality. In the context of development of an inter-organizational network, frequency of the relationships of particular purpose might determine an agenda for further capacity strengthening and enlargement, or even set the path for consolidation within the network and formation of extended enterprise. With regard to this, identification and recognition of relationship impact multiplication patterns could provide a valuable insights towards the most effective and efficient collaborations in virtual enterprises.

Assembly of optimal supply chain configuration from the inter-organizational network of competencies is one of two major groups of problems in managing the lifecycle of the virtual enterprises. Another is related to on-demand generation of customized group of supporting collaborative business processes.

3.2. Collaborative business processes in SIP4SUP

For enterprise network design and implementation, business process modelling serves as a fundamental starting point (Vanderhaeghen and Loos, 2007), with business processes as ideal design items. Cooperative process design and management have been dominant subjects of research in the area of virtual enterprise networking for some time, with different but similar approaches. SOA (Service-Oriented Architecture) concepts, providing the framework for definition of business services and their orchestration, have dominated the area of implementation of ICT architectures for inter-organizational networks.

The general objective of SOA is conceptualization of traditional IT system's capabilities into autonomous, distributed business services. However, since syntax elements are being used for their representation, understanding of service's capability is still dependant on service customer understanding. Furthermore, service definitions vary from one company to another and therefore cannot be used as-is as modelling elements for inter-organizational processes, without intermediary coordination.

Therefore, dynamic business process definition and coordination of associated loosely-coupled capabilities are crucial for virtual enterprises. The main argument for this is uncertainty of the business process structure, due to heterogeneity problems, but also to impossibility to predict and anticipate human collaboration activities and intermediate results exchange necessity (Perrin, et al., 2003), imposed by strong interdependency of partners' parallel work. Another problem is that high level of conceptualization – one of the guiding principles of SOA implementation, can contribute additionally to the heterogeneity of data, services and applications.

It is expected that a new trend of integrating SOA with upcoming semantic web technologies would bring its real power in industrial practice by shifting the value focus from the service provider to the customer who has a problem to be solved. For this reason, current achievements in definition of semantic web services, resulting with WSMO (Web Services Modelling Ontology) environment will be used in SIP4SUP as reference technology approach. It is expected that the application of WSMO would solve the inconsistency of enterprise-owned individual, context-dependent business processes by mapping them semantically to predefined, context-independent, reusable process templates (Choi, et al., 2006). These encompass and coordinate self-contained business processes or services with pre-determined functionality, exposed through particular interface and implemented by specific technology or a standard. In fact, WSMO will contribute to solve the semantic interoperability issue by facilitating the

formalization of concepts mapping between networked enterprises internal models (Panetto and Molina, 2008).

SIP4SUP will use this approach by formalizing existing reference supply network operational process models, like SCOR and CPFR and decompose them for the purpose of identification of meta services (MSCSs) and more important, their association features, aiming at, not only the definition of their aggregation capability but also the expression of semantics enrichments reflecting the possible concepts alignment needed to build SIP4SUP (Boudjlida, et al., 2006). Association features of the meta-services would be used as parameters for association methods, used for concentration and formalization of networking impact. Also, the composition of business processes of existing services can be backed by intermediate ontologies, which could be used to organize services, providing means for their effective discovery and management. With regard to this, past work in development of TOVE ontology (Fox and Gruninger, 1998), Enterprise Ontology (Uschold, et al., 1998), UEML (Unified Enterprise Modelling Language) (Panetto, et al., 2004) is extremely useful. They aim at the development of a formal specification of semantics of enterprise models, providing generic and explicit representation of the structure, activities, processes, information, people, behaviour, goals and constraints of an enterprise. From the viewpoint of inter-organizational processes, practical implications of such an ontology-based knowledge have great potential and will be used as a baseline for development of SIP4SUP ontology cluster.

4. FINAL REMARKS AND CONCLUSIONS

Large organizations are not sensitive on market dynamics. Actually, their development roadmaps and strategies are at the top of market causality chain, propagated downstream and creating short-term opportunities at the bottom, usually exploited by SME's, directly or indirectly. Where first-tier suppliers' operations are tightly integrated in strategic plans of large organizations and strictly determined in a long-term, the bottom part of a supply chain is characterized by short-term opportunities, appearing and disappearing in relatively short periods of time. Although it adds a great amount of value to a final product or service, often being out of the reach of large organizations, this area of supply networks is usually not coordinated in a structured and integrated way. For this reason, the greatest interest of a whole supply chain is to enable its optimal performance, by improving the selection and coordination processes. This task should be delegated to third-parties, specialized in business brokerage. SIP4SUP and its related assets are expected to deliver the conceptual and technical framework for provision of the core tools and practices for a third-party support in creation, management and dissolution of virtual enterprises, as a transition towards the self-configurable industrial supply chains. Today, growing trend of outsourcing and advances in ICT impose the requirements for agile response and re-configuration of manufacturing SMEs, which are very hard to meet, particularly in different supply chain contexts. Still, the capabilities above are recognized by the industry as crucial competitiveness factors, and therefore they receive growing attention of European research teams and manufacturing companies.

Complexity of the overall environment for decision making calls for its automation, at the greatest possible rate, and therefore limits the impact of human decisions of business brokers and architects. Reduction of human involvement in decision making processes contributes to its transparency, having crucial impacts to business networking. One of them is related to the selection processes, which should be based on objective and quantified criteria and, therefore, be easier to manage. Another is related to clear awareness of individual partners of their exact position in a supply chain. Understanding of a value, contributed to a final product or a service, can affect internal configurability of partners, as well as provide the guidelines for its improvement.

Usage of reference process models and derived optimal process configurations is not strictly enforced, but customized to the specific characteristics of each partner, within the intersection scope of optimal supply chain behaviour and agility of partners. In addition to dominantly asynchronous collaboration, this is expected to reduce the value effect of partners' developed ICT infrastructure to decision making and keep the focus of value of their core competencies. By providing tools for transparent supply chain selection, integration and management, SIP4SUP would improve the networking performance of manufacturing SME's. In the process of virtual enterprises' life cycle management, they would gain clear benefits, such as seamless inclusion, full understanding of added value and guidelines

for re-configuration requirements in the earliest possible phase of a supply chain assembly.

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