Semantic Supply Chain Management

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***Abstract*—Small and medium enterprises formed into a supply chain are working in a multi-cultural and multilingual environment. The eBEST platform equips these enterprises and their associations with state-of-the-art software tools for ecosystem-wide business collaboration. To ensure effective collaboration through the whole supply chain visible communication, traceable workflow and process management are required by users. In the eBEST project the semantic interoperability was realized by ontological approach and is tested by pilots in nowadays.**

Keywords-supply chain managemen; ontology based communication and workflow management

I. INTRODUCTION

The efficiencies of Supply Chain Management (SCM) are often impaired by inconsistent exchange and sharing of information semantics among supply chain partners. Semantics-based technologies, especially ontologies have key role in Semantic Supply Chain Management - they are responsible for domain conceptualization, structuring knowledge embedded in business processes. The standardized ontologies for Supply Chain Management enhance the interoperability between the various Supply Chain Management systems. They also serve as a basis for building more specialized ontologies, for example, process ontology for building workflow models. To use ontologies in the development of Supply Chain Management systems results reusable, easy to integrate applications.

This paper aims at presenting an ontology-based SCM platform within the eBEST project (Empowering Business Ecosystems of Small Service Enterprises to Face the Economic Crisis) [8]. The project deals with equipping SMEs and SME associations with state-of-the-art software tools for ecosystem-wide business collaboration. The purpose of this paper is to discuss how ontologies may be used to raise interoperability and shared understanding in inter-organisational processes. Ontologies also play decisive role in turning process models into working software, providing a visual and textual representation of the processes, data, information, resources, collaborations and other measurements.

The paper will be structured as follows: In Section 2, theoretical overview about ontologies and Supply Chain Management is described. In Section 3, the SCM platform is presented in the light of supported ontologies. Finally, conclusion and future work are shown.

II. THEORETICAL BACKGROUND

A. Supply chain management

Supply chain management (SCM) is a rather practical-oriented than theoretical domain. Due to the multidisciplinary origin and the evolution way of this domain there isn't universal supply chain management definition. Mentzer et al. [16], Tan [19] and Cooper et al. [5] consider SCM as a management philosophy, whilst the next definition given by Council of Supply Chain Management Professionals emphasizes rather the activities and processes of SCM. This definition reflects better the eBEST approach than the others.

"Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers [6]."

Based on this definition we can distinguish two main groups of supply chain activities which are related to each other: planning and management of all activities; coordination and collaboration with channel partners.

There are several approaches to present SCM processes [7][18], etc. The most widely accepted framework for evaluating and comparing supply chain activities and their performance is the Supply Chain Operations Reference SCOR® model [18]. It is built on five primary management processes of Plan, Source, Make, Deliver and Return

The planning process provides companies a strategy for managing all the resources to satisfy the actual or forecasted demand with products or services.

The sourcing strategy is based on guarantee material availability in appropriate quantities at the right time for both internal purposes and for sales and distribution. Considering stocks and instruments providing production capacities companies can get an extent list up about the materials and tools, and they can start to choose the suppliers to deliver these goods.

The manufacturing flow process includes all activities which are responsible for making products and establishing manufacturing flexibility required by serving target markets.

The activities of deliver process in SCOR model are demand management, order management and warehouse management.

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In the return process, the supply chain planners have to create and manage a flexible network on both supplier and customer side in order to handle the defective, excess products or recyclable/dangerous garbage.

Due to the complexity of supply chain, we can distinguish demand-side collaboration, supply-side collaboration or overall synchronization [16].

Barratt showed that "collaborative" culture is one of the major supporting elements of collaboration. It consists of the following elements: trust, mutuality, information exchange and openness/communication [1].

B. Ontology

In our interpretation, semantic supply chain management means the support of main activities of SCM – managing business processes, collaboration and coordination with channel partners – by semantic technologies.

Ontologies have key role in Semantic Supply Chain Management; they are responsible for domain conceptualization, structuring knowledge embedded in business processes. Considering the scope of ontology-based applications (for example cooperative information systems, information retrieval, knowledge management, system analysis and design, etc.) we can distinguish the next three categories of ontology applications which are related to the above-mentioned SCM activities:

- Communication: between humans - informal, unambiguous ontology can be used for these purposes.
- Cooperation: between systems - it means translation among different tools, paradigms, languages and software instruments. In this case the ontology is the basis of data change.
- System design and analysis - the ontology can support the analysis and design of software systems with submitting a conceptual description.

The ontology approach has several advantages:

- Reusability: the ontology is the root of the formal description and coding of the most important entities, attributes, process and its internal relations. This formal description provides (maybe through automated translation procedure) the reusability and the common or shared use inside the given software.
- Knowledge acquisition: speed and reliability of knowledge acquisition can be accelerated, if ontology can be used for analysis or knowledge base creation.
- Reliability: automatic verification of consistency can be assured by the formal description.
- Specification: ontology enables the analysis of requirements and the determination of information systems specification.
- Standardization: top-level ontologies can be used well in different situations. New types of task and application ontologies can be derived from these top-level models with specialization.

Ontologies have key role in semantic web [15]. More authors draw parallels between ontologies and the role of XML in data representation. Ontology describes not only data, but also the regularity of connection among data. Probably the most important description language of semantic web is the OWL (Web Ontology Language)[17] preferred by W3C[22].

In the process ontology, the goal is to be able to apply machine reasoning for the translation between the business process and executable process spheres, in particular for the discovery of processes, process fragments and for process composition [2]. Within process ontology two types of ontologies are utilized: domain ontologies and process specific ontologies. Domain ontologies support process modelling in terms of describing the actual data that is processed during process execution. Via this semantic description of the data, business process analysis can be semantically enhanced since the semantic meaning of the data is preserved during all phases of the process lifecycle [13].

C. Supply Chain Management supported by ontologies

In SCM, the ontology development is to facilitate effective information change and knowledge sharing among collaborative supply chain partners [21], to model operational processes of supply chains and to capture and organize knowledge necessary for managing these workflows [3]. In agent-based approach ontologies can serve as a knowledge base to manage the agent behaviour through a conversation [12] or a base of workflow process modelling to facilitate customer service [21].

In the eBEST approach, ontologies serve as a standardized base to exchange data and to model workflow process. But the role of our ontologies firstly is to avoid communication problems like linguistic and translating problems, and to support the cooperation of companies community as an ecosystem by providing tools for modelling collaboration processes beyond built-in operational processes.

III. The E-best Platform

The main objective of the eBEST project was the introduction of new collaboration practices in ecosystems of SMEs belonging to different industrial sectors. So, it aims at providing easily accessible ICT applications and services to enable community building, SME network constitution, and SME network operation for the network lead and its members. The eBEST platform supports the operation of digital business ecosystems. These are clusters of companies, small companies in particular, that collaborate within an operational context. These companies collaborate with each other in a multi-cultural and multilingual environment. In the first phase of the project, the collaboration habits and needs in the business ecosystems were analyzed and the

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fundamental functional and non-functional requirements were determined [9]:

- Help shaping the ecosystem: to support the work of a group of Ecosystem Architects who are responsible for discovering, exploring and shaping interesting potential ecosystems.
- Find out collaboration units: to grasp business opportunities proposed by costumers and to participate or promote the definition of the relative distributed workflows.
- Increase company visibility: to form a supply chain where a company can play a supplier and a costumer role simultaneously implies the creation of visible profiles and offers provided by companies.
- Ease communication between companies: to provide a private workspace to manage documents and clearly defined concepts and terms both in offer and demand catalogue too in order to facilitate the exchange a variety of documents with the minimum need of human intervention.
- Support network planning: to find out the most convenient network configuration for each of the services to perform. The network planning algorithm assumes that a service is associated to a process model, the process is composed by activities and each activity can either be executed internally or assigned to candidate suppliers.
- Support internal resource scheduling: to provide easy but effective scheduling functions to assure that the tasks are allocated optimally to the available resources and to arrange their production by automatically optimise the usage of these resources. It is necessary to assure that exceptions are efficiently and timely handled to damp down perturbations.
- Semantic interoperability: to create a semantic repository where terms, their definitions and linguistic translations are collected in order to facilitate document transformation and contents translation.
- Trust building: customers and suppliers must feel confident that their transactions will not be intercepted or modified, that both sellers and buyers own the identity they claim, and that the transaction mechanisms are available, secure and legal.
- Technical issues: the platform must be perceived by companies as ready-to-use solution, and accessible by a simple web browser etc..

In the point of architectural view, the E-best platform proposes three interlinked software environments (presented by Figure 1) specifically conceived for networked small companies, supported by advanced suite of ICT services and applications [8]:

- Ecosystem shaping - offers the functions that every association can employ to promote the constitution and characterize new company clusters, and improve their image over time, out of the ecosystem of its members.
- Collaboration framework - offers the functions that the single cluster can use to seize business opportunities, possibly identified by the association, and to prepare itself by designing the corresponding distributed processes.
- Operational framework - provides customers, companies and company clusters with a suite of operational functions enabling them to communicate, plan the distributed processes and schedule the internal resources.

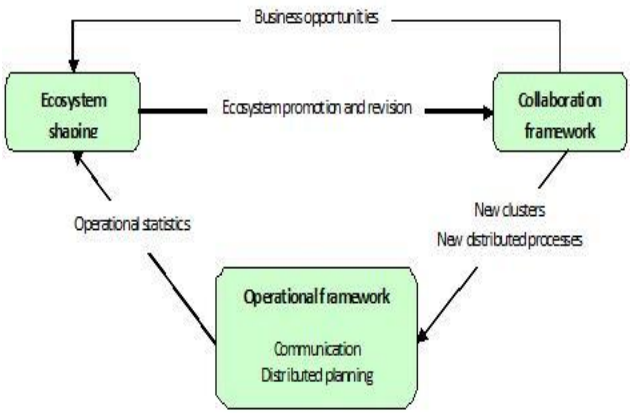

Figure 1 The eBEST platform [10]

In the point of operational view, these requirements demand the creation of a transparent communication framework and a traceable collaboration framework including workflow management and process management tools. This transparency of documents and processes is ensured by ontological approach.

A. Communication between ecosystems

To ensure an effective communication among the players of supply chain it is necessary to provide visible company profiles (in Company node), overall view about ecosystems (in Ecosystem node), documents with semantic contents related to the process elements (in Semantic node).

The following picture illustrates a general eBest environment with different ecosystems and configurations [11].

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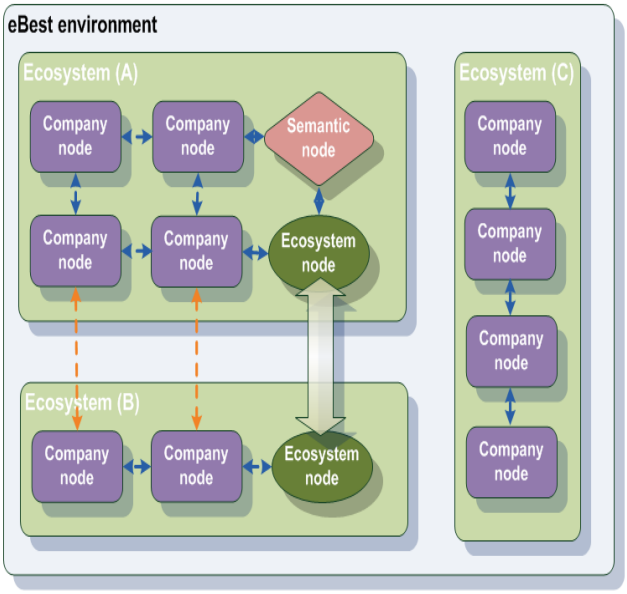

Figure 2. eBest environment

The functions of these nodes are the next ones:

- Semantic node functions. The eBest platform is asked to facilitate the business communications within an European context, hence it is necessary to pay a relevant attention to the linguistic and semantic issues.
- Ecosystem node functions. When many companies cope with each other, it is important to provide an unified view on their profiles and offers. Hence, this set of functions is mainly addressed to improve the ecosystem visibility and its capability of attracting potential new customers.
- Company node functions. This set of functions is conceived to let the companies interact with each other within an ecosystem.

Semantic node functions

The Semantic Node architecture is depicted by Figure 3 [11].

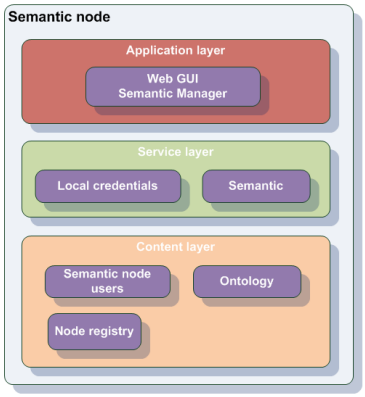

Figure 3. Semantic Node architecture

Content Layer handles users and roles having access to the semantic node, ontology information shared by all the nodes within the same ecosystem: business documents structure, terms translations, service taxonomy and information of nodes belonging to the same ecosystem.

The primary goal of the eBest semantic repository is to provide a unique location where terms, definitions and linguistic translations are collected. Ontologies represent the building blocks of the eBest solution since static contents shared among the eBest nodes become defined. The ontologies information must be prepared before the eBest platform is deployed and any further change actually represents a platform update. Hence, ontologies shall be considered almost static objects, whose changes must be undertaken with care. eBest is based on three ontologies:

- Business document ontology. It defines which business documents are managed within the ecosystem and their specific data structures.
- Localization ontology. It defines the labels, with their relevant translations, addressed to feed the eBest application user interfaces.
- Offer taxonomy. It defines a hierarchy of terms conceived for the company offer classification. The offer taxonomy should take into account the trade-off between a wide taxonomy (very detailed classification with sparse samples) and a reduced taxonomy (generic classification with dense samples). Each taxonomy term is composed by a label and a definition.

Differently from ontologies, the catalogue vocabulary is a repository of terms that companies dynamically feed with the terms and definitions used to characterize their offers.

Service Layer provides user authentication and authorization function, terms translation management functions, the access to the catalogue vocabulary terms, published by companies, by means of distributed queries, the access to ontology items, and the download of ontology modules for being embedded in the eBest binary distributions.

Application Layer deals with translating terms, updating translations and browsing the ontology structures and term lists.

This node is responsible for feeding all platforms with semantic documents to foster effective and transparent communication, and to realize semantic interoperability.

B. *Communication through the operational process*

In the operational framework, the ontological support of the processes is to facilitate the exchange variety of documents through the supply chain. The next table consists of the main activities of the supply chain management and ontology elements related to them [14]. These elements are provided by the Semantic Node.

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TABLE I. ONTOLOGY CONCEPTS RELATED TO SUPPLY CHAIN MANAGEMENT PROCESSES

Process description	*Ontology concepts*
Network planning It is handled in ecosystem shaping.	Company
Sourcing It is based catalogues which are divided offer and demand parts. Besides of the Catalogue of provided/requested services or goods, where the product families can be described by terms, attachments and parameters. Company profile specifies additional metadata about the company which can be used to filter out results of the search of prospective customers.	Company, Service, Parameter, Term, Attachment
Ordering Negotiation phase is implemented using Quotation concept, which is used to initiate ordering by Customer. Quotation consists of Configurations, which specifies the properties of the requested services or goods and conditions for payment and delivery time. Seller can simply confirm receipt of the Quotation and Customer can confirm unchanged Quotation by Purchase Order concept. Proposed changes to Quotation by the Seller are accomplished by direct modification of the Quotation where the Seller can indicate changed conditions or parameters.	Quotation, Order, Configuration, Parameter, Term, Attachment
Fulfilment In the current proposal, only proactive Despatch advice send from the Seller to the Customer is supported. Additionally Seller can send Order Progress concept where communicates order status and progress.	Dispatch Advice
Billing All invoicing types (prepayment invoice, pro-forma invoice and normal invoice) are implemented using the same Invoice concept.	Invoice
Maintenance Technical assistance or maintenance contracts are service contracts whose main feature is continuity over time. These contracts establishes cases, conditions, methods, times and costs of the activities that the Supplier is engaged to perform for guaranteeing the correct operation of a certain product or service as well as its repair or recovery after a fault.	Contract, Intervention call, Intervention report

These ontology concepts have a crucial role in their related processes. They carry unambiguous information for executing the ecosystem shaping and operational processes without any perturbations. Therefore, they ensure the visibility of companies and catalogues, and the transparent communication and cooperation. So they contribute the trust building among companies.

C. Collaboration framework

The Collaboration Framework of the eBEST architecture serves as a shared environment for business ecosystem members, where member companies can cooperate on collective activity like tender management, event organisation, marketing and other areas of common interest. In order to fulfil this requirement, the ecosystems need a workflow management solution that can be freely customized for their specific needs. We have developed a process definition scheme and the actual software implementation for automated generation of collaboration workflow management [20].

The objective of this section is to present the technological innovation achieved during the development of the eBEST Collaboration Framework responsible for realizing the common environment for SMEs connected through a business cluster (business ecosystem) [20]. The theoretical focus is given to the experience derived from the creation of conceptual models, process model representation by ontology definition, and turning the process ontology output into workflow supporting application. The eBEST project ensured a practical framework for this transition, but the overall goal is to conceive a general implementation pattern. The building blocks of the proposed architecture are well-founded ideas, the innovation lies in utilizing them in a coherent theoretical and architectural framework.

We have defined an ontology based annotation scheme for planning collaborative business processes at a conceptual level that can be designed by non-IT personnel [20]. The annotation scheme is an extension of the OWL (Web Ontology Language), that determines the structure and attributes of the workflow processes defined by business process modelling.

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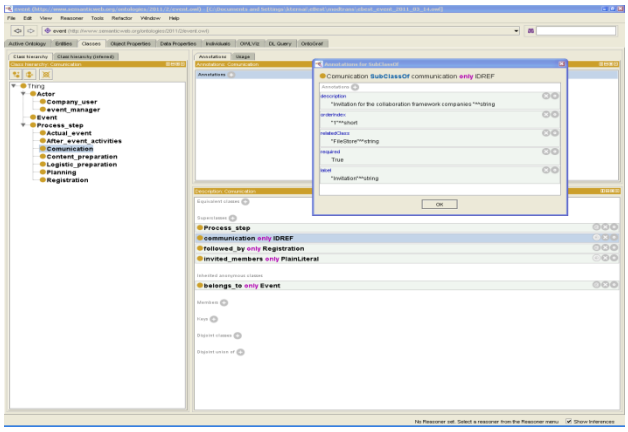

Figure 4. The event organisation process ontology in Protégé

We have developed the application framework which is able to interpret our workflow model and automatically generate the working software instance for workflow support [20].

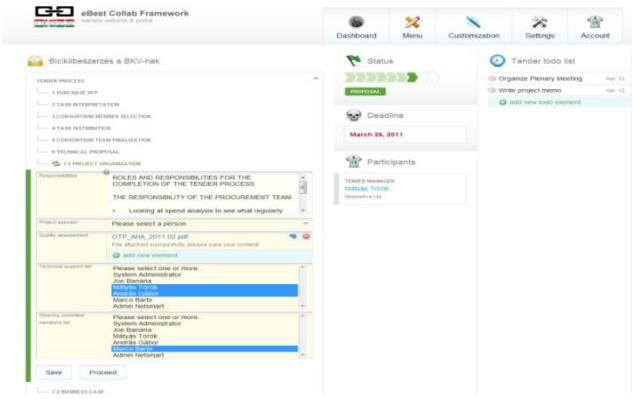

Figure 5. eBEST Collaboration Framework workflow interface [4]

We have validated the processes in real life circumstances with clusters utilizing the eBEST framework. The general idea is that business clusters themselves are empowered to design processes for their specific needs.

D. Validation of the approach

The performance of pilot experiments was foreseen to validate the eBEST approach. The relative software services with the twofold objective to demonstrate their effectiveness and collect hints for their best deployment to a wide population of the companies. The following table summarises the demo scenarios that were subject to experiment and grouped according to the eBEST components aiming to test.

TABLE II. PILOT SCENARIOS

Pilot	Ecosystem Shaping	Collaboration Portal	Operational Platform
SIRRIS, Belgium	X		
IDM-GAIA, Spain	X		
CCI KILKIS, Greece		X	
OKISZ, Hungary		X	
International		X	
TEL&CO, Italy			X
Fashion Contract, Italy			X
CEDEM, Italy			X
SCCI, Slovakia			X

The results from the pilot experiments are showed by the following although initial benefits:

- SME-AGs have the possibility to use a neutral and innovative support tool for shaping communities of potential partners as preliminary condition for their constitution as steady collaborative networks. This will impact on the competitiveness of networked companies and then on the survival and possible economic growth of entire ecosystems in the involved regions.
- Network leads have the possibility to achieve higher efficiency levels in coordinating the respective networks. The natural consequence is a stronger presence on the market and an increased trust in customers preferring direct and fast partnership with the lead SME on behalf of the entire network rather than managing dispersed relations with a number of individual suppliers.
- Network members have the possibility to collaborate with one or more networks or supply chains assuring fast responses to each of them without being affected by the need of adapting their legacy systems to the different leads. In other words they are finally in the condition to gain positions in the market according to their skills along with their reliability and collaboration efficiency.

In addition, the resulting collaboration framework and ICT platform have proved to be at the same time general enough for meeting the requirements of a variety of business ecosystem of service companies, and flexible enough to adapt to the single specific case.

IV. CONCLUSION AND FUTURE WORK

In this paper, an ontology-based Supply Chain Management platform was presented. The final product of the eBEST Framework is a software platform for SME clusters and associations, and the knowledge to use it at best in different operational conditions. The represented eBEST platform can provide several features with that SMEs can

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overcome the above-mentioned semantic barriers. The Ecosystem Shaping helps to find collaboration partners and to constitute clusters and improve their image which facilitates the preparation of processes. The workflow management built in the system provides an appropriate base to harmonize the processes. With the help of Operational Framework the companies can associate to each other through a supply chain and accomplish the promised goals. The visibility of companies and catalogues, the exchange of standardized semantic documents within the business processes are provided by ontological concepts in Semantic Node. In the Collaboration Framework an application built on ontology-based annotation scheme is responsible for automatically generating software instance of a new collaborative business process. These semantic applications support the realization of system requirements (like visibility, semantic interoperability, managing business process in transparent manner etc.) and foster collaboration and coordination among channel partners.

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