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TRENDS AND APPROACHES IN THE MANAGEMENT OF VIRTUAL ENTERPRISES

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Abstract: *The paper presents some trends and approaches in the management of virtual enterprises, by using intelligent multi-agents systems. The trends are presented under impact of new information and communication technologies (ICT) on the development of the world economy, as knowledge based economy, or digital economy. The VE concept is considered one of the business models developed in last years under the influence of the globalisation on manufacturing and competition. Mainly, are underlined the trends in approaching manufacturing and new business models, particularly VE, and some of the problems and solutions in the management of this kind of enterprises. For that, are presented automated negotiation methods for implementing the complex business process of coordination, strategies, and partner selection in the VE, using the integration of multi-agent platform with an expert system shell, and rules based language.*

Key words: *virtual enterprise, multi-agent systems, negotiation methods, agent platform.*

1. INTRODUCTION

The virtual organizations paradigm is finding its way also in manufacturing industry under the name of Virtual Enterprise (**VE**) [1]. Globalization and new economy, as Knowledge based economy, characterized by very fast and continuous changes, new ICT and environment or working conditions regulations, improved standard for quality, are forcing manufacturing companies to adopt new organizational and production paradigms, involving cooperation among networked entities [2]. The main trends in research and development are focused on models, protocols, and mechanisms to support the collaboration of pre-existing heterogeneous and autonomous entities in distributed environments, as organizations and people. In order to leverage the potential benefits of the VE, there is a need for flexible and generic infrastructures and technologies to support the creation, operation, and dissolution of VE [3]. Some of the main trends in the attempts to develop this infrastructure include:

- **Layer-based frameworks**, which add a cooperation or coordination layer to the existing ICT platforms of the enterprises, to support the basic information and knowledge exchange and coordination needs in VE.
- **Agent-based framework**, as approaches that represent enterprises as **agents**, and the inter-enterprise cooperation or coordination as interactions in a distributed multi-agent system.
- **Service-market frameworks**, as model and possibility of enterprises to offer "portable services" to or from service directories, founded on the market (as e-market).

Setting up an infrastructure for VE, still requires large engineering efforts, which represents a major obstacle for the implementation of this new organizational paradigm. One important aspect in the VE creation and operation is the specification of the tasks necessary to achieve VE business goals. The activities carried out by a company are usually organized in group of inter-related activities called processes/business processes (BP) that can be seen as a set of activities, rules and constraints specifying the step that must be taken, and the conditions than must be satisfied, in order to accomplish a given goals. When a BP is executed by VE, parts of the decomposition of this BP (as sub-processes) are assigned to different enterprises, what makes BP a **distributed business process (DBP)**.

2. NEW BUSINESS MODELS

The term business model is used to describe the method of doing business by which a company can generate revenue, *i.e.* position in the value chain, targeted customers/market segment, products and services, competitive strategy for achieving a sustainable competitive advantage. It involves both strategies (what business intends to do) as well as implementation (how the business will carry out its plans). In the model for VE, a business serves as the front-end for a grid of relationships between itself and various suppliers of services and goods as presented in Fig. 1, where *A, B, C* and *D* are services and P_1, P_2, and P_3 are product offered on e-market.

A virtual organization is a collection of geographically distributed, functionally and/or culturally diverse entities that are linked by electronic forms of communication and rely on bilateral, dynamic relationships for coordination.

This new model create effective ways for enterprises included in VE to interact with their business partners through e-market, enabling collaboration at every level in the value chain, with all members benefiting from shared business processes and shared information or knowledge. In this model there are ability to allocate dynamically the work (jobs, tasks etc.) across people or groups, depending on workload demands, creating the possibility for some entities to participate in several VE

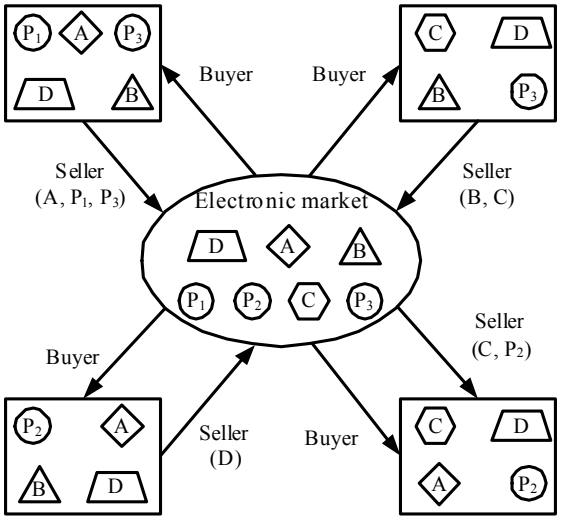

Fig. 1. Services oriented model for VE.

simultaneously. We can define a VE as business model based on outsourcing, in which different independent companies cooperate, by using new ICT, for providing better services or products than that which could be provided by each single company.

The configuration of the VE service or product design and manufacturing process is faster and flexible than in traditional business models, because cooperation can be established ad-hoc. This is relevant especially for SMEs, due to their reduced size, high specialization and flexibility, the ability to adapt to a constantly changing markets, by organizing themselves in strategic partnerships, and by reaching otherwise unreachable markets and to take the advantage of economies of scale. Furthermore, many large companies are isolating parts of their businesses, making them autonomous in order to increase the overall flexibility and achieve greater performances. The **VE business model** is that of a **virtual intermediary**, that creates benefits and value for a community of business partners, by reducing transaction cost and spreading those benefits (savings and efficiencies) among all partners. The benefits are possible because each participant has the ability to interact with multiple business partners, to function as both a buyer and a seller, to complete business transactions and to manage complex business processes entirely via the Internet and e-market, as shown in Fig. 1.

3. VIRTUAL ENTERPRISES AND THE PROBLEMS OF MANAGEMENT AND ENGINEERING

The VE management, called also meta-management [4], has two distinct characteristics, apart from the traditional management:

- **first**, is the requirement to set clear objectives and explicit goals, easy to be shared by all partners in the virtual organization;
- **second**, is that the central part of meta-management is the maintenance of the temporary partnerships within virtual organization.

From the information system perspective, the management and engineering of a VE implies applications integration and interoperability, systemic coordination of the traditional business functions, and effective way for cooperation across organizational boundaries. Management of VE consists in the management of business processes taking place among the VE members. The engineering of VE means to design, to validate, and to deploy a comprehensive set of tools and methods to support the achievement of VE concept. These tools and method derive from an integrated enterprise management model, and enable the formation, operation, and dissolution of VE.

The essence of a VE is its limited time span and its capacity to dynamically switch among different inter-organizational relationships, based on changing opportunities in the market. Therefore, their models and management tools must emphasize the dynamic aspects; have to be able to depict the changes of attributes over the time and to differentiate behavioural patterns.

Life-cycle theory and models is a useful tool for studying and explaining the particular organizational behaviour during its evolution in time. A life-cycle model describes the key phases and activities required during the existence of VE: **creation**, **operation**, **reconfiguration**, and **dissolution**. In each of these four phases, decision processes, such as partner evaluation and selection, exception handling, operation redesign and partner decommission, are involved.

Most of the approaches for the definition and analysis of the activities in the VE life-cycle phases, are **goal oriented** or **role based**. Virtual enterprise methodology (VEM) are goal oriented [11]. According to VEM, the specific management activities required in the creation phase are: customer requirements analysis, partner selection, VE Work Breakdown Structure (WBS) creation, set-up of the VE infrastructure. The WBS represents the decomposition of the VE's product into deliverables and the accompanying partner selection, i.e. which partner is responsible for which deliverable. For the operation phase the following activities are defined: planning, scheduling (each partner makes more detailed scheduling of its tasks in accordance with its other activities, and decides what parts to subcontract), and VE operation monitoring.

Role based approaches are inspired by the Role Theory [5], for which the normative perspective consider an organization as a system of interactions among entities constrained by shared norms and expectations or prescriptions. According to these prescriptions, the entities in the organizations can occupy a number of positions and play the roles associated with these positions. A role is defined as a collection of obligations and rights related to a position. Interactions are determined by the relationships among the roles the different entities occupy, and the activities of a role are classified based on its obligations and rights (permissions or interdictions). In the ISO/ITU-T Standard for Open Distributed Processing (ODP), a general framework for modelling of distributed systems, the concept of role is defined as an "Identifier for behaviour", and a behaviour specification is a collection of actions with a set of constraints on when they may occur. Such an approach is adopted in defining the **management roles** of the VE, as following [6, 7]:

- **broker**, responsible for marketing the network competencies;

- **competence manager**, that brings partner competences together and communicates with customers;
- **project management**, responsible for order processing and engineering, keeping the time and budget constraints and for replacing a partner that does not perform satisfactorily;
- **network coach**, responsible for setting up and maintenance of the technical infrastructure and partner management;
- **auditor**, that is responsible for neutral financial control and assessment;
- **manager of in/out-sourcing**, responsible for coordination and communication with the project manager, for providing the technological know-how or knowledge, resources and its technology to the VE;
- **broker**, that initiates the VE and searches for partners;
- **coordinator**, as a regulator component for the VE activities.

In developing technological solutions to support the business issues associated with the various stages in the life-cycle of a dynamic VE, are identified and other significant roles (virtual industrial park site, market-marker, registered members, pre-certified companies) [8].

Given the role based approach, the agent system paradigm becomes very appropriate and attractive to be used, in dealing with the management functions of the system.

A role is defined as a set of **capabilities** and an **expected behaviour**. The capabilities consist in a set of **actions** that an agent playing such a role can perform to achieve its tasks. Given the dynamic and complex nature of the relationships among partners in a VE, the following research issues arouse:

- what should be the functionality, structure and focus area of the inter-enterprise interactions and in what amount would be affected the management system of the member companies;
- what should be the proportion between cooperation and competition among them.

The approach in this case is based on a layered model of the member enterprises and a hierarchical control structure, vertically integrated from the ICT point of view. The highest level, considered the **strategic level,** consists of the business process. The following is the **planning level**, where can be placed the activities represented by systems from Enterprise Resource Planning System (ERP System) class. Next is the **execution level**, where are placed the current **manufacturing execution** activities like: production scheduling, resource allocation, product and equipment tracking, production flow-monitoring, inventory and quality management, reporting to higher levels. Very important are the **needs of interaction** at the execution level, given the fact the VE is based mainly on the fast identification of the available resources, included services among partners, without the need to find opportunities on the market as usually happened.

Different other approaches are concentrated at the business process level and consider the specification of the tasks necessary to achieve the VE business goals. The business process is decomposed into a hierarchy of subprocesses and enterprise activities that are assigned to different enterprises, transforming it into a distributed business process (DBP). The appropriate coordination of these processes, taking place at different members of the VE, requires the supervision and coordination of the DBP at its various levels of decomposition, in the context where its definition refers to a set of autonomous, distributed, and heterogeneous entities that need to cooperate. Most of the researches develop extensions to the work flow paradigm in order to support flexible workflows and distributed planning and execution, or combine workflow with multi-agent approaches.

4. THE USE OF AGENTS IN THE MANAGEMENT OF VE

Agent technology has emerged as a paradigm for structuring, designing and building distributed software systems that involve complex interactions between autonomous components. While the object-oriented paradigm models the systems focusing on the structural, static characteristics of their components, which are defined through encapsulation and inheritance, the agent paradigm models the systems focusing on the underlining dynamics, defined by the interactions between their components. **Intelligent agents** are software entities which possess autonomy, intelligence, environmental awareness, and exhibit capabilities like: goal seeking behaviour, the ability to plan, reactive action and reflective reasoning. They can perform tasks in complex and dynamically changing environments. A **multi-agent system (**MAS**)** is a collection of software agents and a common interaction infrastructure which enable the implementation of several coordination mechanisms (collaboration or competition).

Characteristically, such systems are loosely coupled, with little or no global control, data are decentralized, execution is asynchronous and agents do not have all data or all methods available to achieve an objective. These characteristics justify why MAS technology is an appropriate paradigm for use in implementing VE management functions, and permits to achieve a VE coordination infrastructure that ensures the autonomy of operation of partner enterprises, secure separation of information and privacy protection among them.

Coordination has been defined as the process of managing dependencies between activities, or as a process in which the agents are engaged in order to achieve a coherent action of the MAS. The agent reasons about their local actions and the future actions of the other agents in the system. The general categories of MAS coordination mechanisms proposed in the literature are [9]: organizational structuring, contracting, planning, negotiation etc. Negotiation is considered a fundamental mechanism for managing inter-agent dependencies at the runtime, and implies an explicit exchange of information, often given in the form of structured messages. It can be used when the agents are self interested and when they are cooperative.

The Foundation for Intelligent Physical Agents (FIPA), as a standards organization, promotes agent-based tech nologies by providing a comprehensive set of specifications for generic agent technologies, both at the agent level and at the platform level (Fig. 2). At the platform level it specifies an abstract architecture for agent platforms and

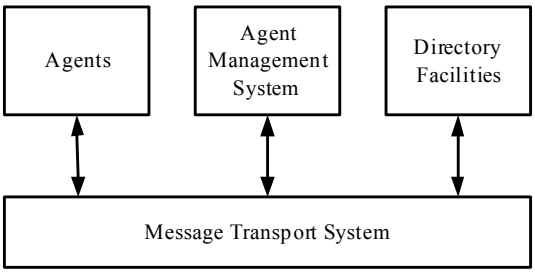

Fig. 2. FIPA reference model of the agents platform.

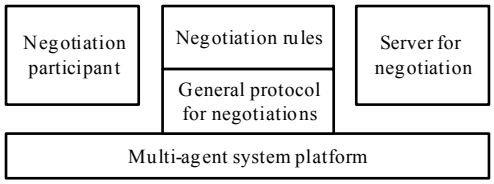

Fig. 3. The architecture of the negotiation system using a generic protocol.

services, using a model based on asynchronous message passing between agents. JADE (Java Agent DEvelopment Framework) is an implementation of these generic technologies and abstract architecture that provides the user with the following tools:

- a middleware platform and runtime support for specific agent services (agent for communication language, for message transport, life-cycle management, directories like yellow-pages etc.);
- a set of classes to support the implementation of user-defined agents, ontology and content languages.

Another fundamental element of a negotiation framework is the specification of the rules that govern the interaction among participants. These rules determine the valid (allowed) messages in each state of the negotiation. The formal specification of these conventions is called a **negotiation protocol** that includes the interaction protocol as well as other rules of the dialog (Fig. 3).

Interaction protocols are modelled using formal description techniques like FSM (Finite State Machines), Petri Nets, and, recently, agent-UML based modelling language (AUML). The rules are specified in a specific language, JEES (Java Expert System Shell) and executed by the rule engine embedded in the agent. Rules are executable pieces of declarative knowledge interpreted by an inference engine.

Using special software package (My Jess Behaviour) as interface between JADE and JESS, it is possible to create (write) JADE agents in the JESS scripting language, as is demonstrated in [3], for two agents: an Initiator role and a Responder role, implementing two different FIPA protocols: Request-Interaction and Propose-Interaction.

5. CONCLUSION

The Virtual Enterprise (VE) concept is one of the business models which exploit the new information and communication technologies and the trends of the new knowledge based economy.

To support the distributed business processes and the knowledge or resource sharing, required by the VE management, is recommended the use of multi-agent system concept, based on JADE platform and JESS scripter language, for creating the agents needed and used in the management of VE.

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