

Multi-Agent Systems in the formation of Dynamic Virtual Enterprises.

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Abstract

New Information and Communication Technologies are creating the new context companies and organizations are doing business today. In this new situation, success and excellence are achieved through effective knowledge management, the main source of wealth generation. Consequently, new organizational structures, more flexible and intelligent, are required. Among the newly suggested answers, the paradigm of Dynamic Virtual Enterprise has acquired a great importance for authors and researchers.

In this paper we present some of the main characteristics of the DVE. Besides, we seek to contribute to its improvement proposing an agent-based model to support the necessary processes in the selection of the DVE partners in the stages of formation and reconfiguration. Such a model will allow us to create tools to provide automated support in the creation and operation of the Dynamic Virtual Enterprise.*

Keywords: *Dynamic Virtual Enterprises, Partner Selection, Multi-Agent Sistem, JADE*

1. Introduction

New Information and Communication Technologies (ICT) are changing the world. In this new situation, success and excellence are achieved thank to an *effective knowledge management* (i.e. the effective creation, storage, transformation and use of information), the main source of wealth. Therefore, new organizational structures, more flexible and intelligent, are required (Sanz *et al*, 2005).

In answer to the ever-growing management necessities new concepts, methods and organizational structures have appeared throughout last decades. Among them, the paradigm of Dynamic Virtual Enterprise (DVE) has recently acquired a great importance among research community. The DVE is an organizational structure able to respond to the necessities of current markets better than other traditional structures due to its adaptability and an intensive use of information technologies.

In this paper we first present some of the main characteristics of the DVE, as well as certain necessary elements to develop such paradigm as, for example, Multi-Agent Systems (MAS). Next, we propose an agent-based model to support the processes involved in the selection of

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the DVE partners. Such a model will allow us to create tools to provide automated support in the creation and operation of the DVE.

However, in order to understand the DVE, we first need to explore the context in which arises and develops itself i.e., the environment in which current managerial organizations develop their activity.

1.1. The New Managerial Environments

In the second half of the 20th century, human society has suffered an extraordinary transformation, and business can not ignore its impact. Quickly changing political, economic, commercial, technological, and human environments have created new scenarios companies have to face.

Events such as the amplification of the European Union, free trade agreements, etc., have developed wider and more liberal markets creating new and important opportunities (Cuesta, 1998). Markets are more and more global and, of course, competition is continually increasing.

On the other hand, developed economies show a concerning problem: employment destruction. At world-wide level the creation of employment has moved from the more developed countries to the less developed ones where the conditions to establish new productive centers are usually more favorable and labor costs smaller.

Traditional markets, mainly in developed countries, are very mature and saturated i.e, with a very limited potential growth. As consequence, in current markets the business opportunities appear in precise moments, in different geographical regions and for brief periods of time.

Market maturity has also effects on consumer behavior. Companies must face clients with different necessities which demand from our products those expectations we have woken up in them. Therefore, in order to compete in this new complex environment, it is necessary to know the customers' necessities to make customized offers. How can we do that? The answer lies in the *communication* i.e. communication is the best guarantee to offer customers products and services meeting their needs with optimizing costs. This obviously requires the appropriate communication systems.

Communication, the main source of business opportunities, has been favored and facilitated by the impressive developments in information technologies. ICT influences in every aspect of daily economic life and in the organization and management of companies (Comisión de las Comunidades Europeas, 2001). The accelerated increase of productivity, and consequently of the competitiveness of companies, is related to the advances in ICT.

Communication technology facilitates the adoption of innovations and reforms in the enterprise system, modifies the conditions of competition and configuration of markets, impacts the structure and the vital cycle of companies, etc.. Current infrastructures allow for the integration of different components, structurally and geographically dispersed, by means of an efficient information sharing and communication.

Finally, companies are open systems where people is working in different links of the value chain. So we can find diverse organizations (suppliers, manufacturers, dealers, etc. and, of

course, the client) collaborating under *partnership* relations rather than in accords of the obsolete client-supplier concept. For these reasons, the traditional vertical integration must be replaced with the *horizontal process* concept (i.e. reduction of the hierarchical levels) and understand the company as an open and global system (Porter's value chain), in which suppliers, clients, and even competitors, are integrated as a whole.

An organizational and structural answer to these challenges can be found in the DVE concept we discuss below.

2. Dynamic Virtual Enterprises

The paradigm of the Virtual Enterprise represents a major area of research and technological development for industrial enterprises and an important area of application for web-based cooperative environments. We can say that the VE concept is one of the most important ways to increase the agility and competitiveness of manufacturing enterprises.

The VE attracts increasing attention from both the academic and industrial communities. Many worldwide programs and projects are being performed to propagate and implement the VE concept. Many terms and definitions have been proposed for VE, but so far, there is no an unified definition.

The main objective of a VE is to allow a number of organizations, physically distributed, to rapidly develop a common working environment using electronic means and systems to manage a collection of resources provided by the participating organizations toward the attainment of common goals. Because each partner brings his strength or core competence to the consortium, the success of the project depends on all co-operating as a single unit (Sanz, 2004).

We can identify two well-defined categories of the VE, namely the Static VE (SVE) and the Dynamic VE or DVE (Ouzounis, 2001):

- ✓ In the SVE a set of business partners is linked together in a static and fixed way. The business relationships among the partners are pre-defined, fixed and customized among the partners.
- ✓ In the Dynamic one a set of business partners is linked dynamically, on-demand, and according to the customers' requirements, by deploying a core business marketplace. The entities do not have fixed business relationships and thus, the DVE changes continuously adapting to market.

The main advantage of the dynamic virtual enterprise is its ability to link the most suitable supplier of each individual service to deliver a customer specific solution. Additionally, the DVE provides the ability to recognize, rapidly react and cope with the unpredictable changes in the environment in order to achieve better responses to opportunities, shorter time-to-market, and higher quality with less investment. The DVE is an agile corporation.

The DVE allows enterprises to participate in competitive business opportunities and new markets. By this way, SME will be able to achieve critical mass and appear in the market with a larger visible size. The DVE is, necessarily, the foremost way SME have to survive at the present time and in the future.

From business point of view it is obvious that the dynamic and agile VE is a significant improvement over the SVE and is more able to take full advantage of the open, global, opportunities offered by Internet and the global economy. However, from technical point of view, the required technical solutions are more complex.

The employment of the multi-agent systems paradigm, flexible content description languages, like XML, platform independent programming languages, like Java, intelligent Web Services, etc., can provide the starting point for the creation of these required solutions, i.e. a new generation of open, flexible, autonomous and distributed business process management systems for dynamic virtual enterprises.

3. Partner Selection using Agents

3.1. Agents in the DVE

Basically, an agent is software that exhibits autonomy, co-operation, intelligence and mobility. It acts typically on behalf of an user or a process in a goal-oriented manner enabling task automation (i.e. they operate proactively in pursuit of their goals).

Agents operate rather autonomously of the user (they are often event or time triggered), and may communicate with the user, system resources or other agents to perform their tasks. Through communication, agents may co-operate with other agents to carry out tasks or to achieve goals beyond the capability of a single agent (Araúzo, 2003).

The agent's intelligence is based on its ability to solve problems using a wide range of reasoning techniques and learning mechanisms. Furthermore, agents may be mobile, i.e. they may move from one system to another to access remote resources or even meet other agents and co-operate with them. Agent platforms provide the supporting software infrastructure needed to manage and execute agent-based applications (Camarinha-Matos, 2001).

From the academic community there is a strong stimulus to use agents as the technology for modeling and creating real DVE. So long as a DVE is composed of distributed, heterogeneous and autonomous components (i.e. the DVE partners) agents are the natural way to represent them.

Dynamic VE has a limited lifetime. Thus, they need to be formed very quickly in order to meet the deadlines of the goals, and there is a need to form it very often. An important element of the formation stage is the partner selection. The partners are selected according to the ability to fulfill the dynamic VE's requirements. This partner selection shows negotiation necessities widely studied in MAS (Camarinha-Matos, 2002).

The short lifespan of the DVE also means that the partners who participate in a DVE may also be simultaneously negotiating contracts with other DVE. By delegating agents to do this job, the partners have time to do the required work.

3.2. The DVE Life-Cycle and the Role of "Making Virtual"

A dynamic virtual company can evolve through six different phases throughout its existence: identification, formation, design, operation, reconfiguration and dissolution phase (Davidrajuh y Deng, 2000; Kanet *et al*, 1999). Figure 1 depicts all of these phases in a view.

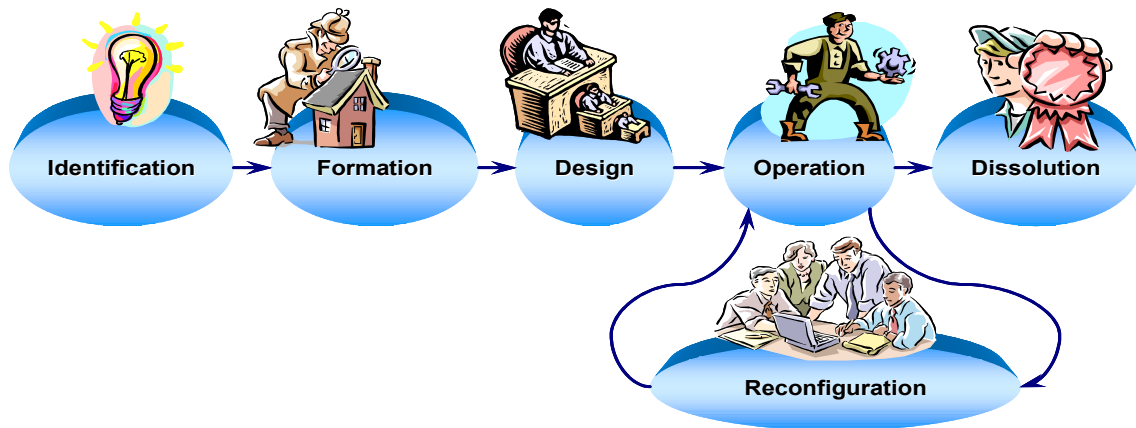


Figure 1. The DVE life cycle

Each component of this enterprises network must have previously passed through a virtualization process (i.e. a re-discovering of their *core business* processes). This process will allow it to become one of the best world-wide specialists in its specific activity, a previous requirement to become a perfect component of this organizational and structural concept.

After this virtualization process, the different organizations must define their core business process and those tasks that will have to be provided by other remote entities. Once its business processes have been defined, each entity must register itself in the Core Business Marketplace, *CBMp*. The supplies corresponding to each core process declare the terms and conditions under which those core processes will be offered to other entities.

In the following Figure 2 the virtualization and core business registration processes are shown.

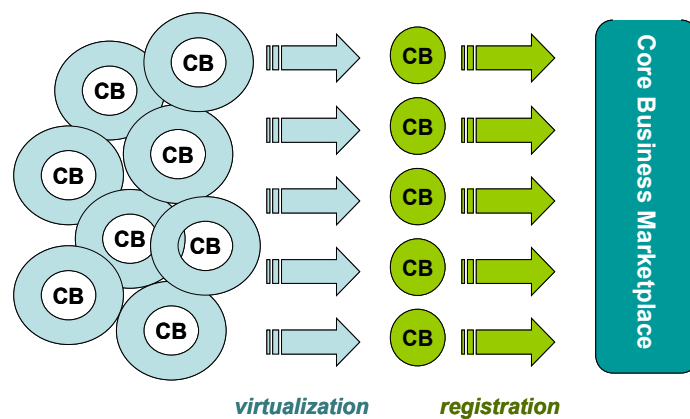


Figure 2. The virtualization and core business registration processes

3.3. The Selection Model

The key factor in the formation and management of a DVE is the selection of agile, competent and compatible partners. That selection can occur in two phases of the DVE life-cycle: during the formation and reconfiguration phases. For it, it will be necessary to resort to *CBMp*.

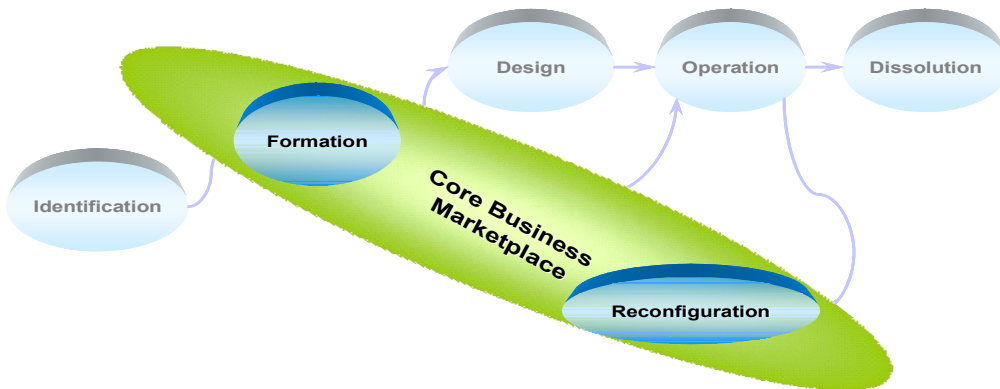


Figure 3. The importance of the Core Business Marketplace in the DVE life cycle.

It is crucial to reduce the duration of the selection process to quickly take advantage of business opportunities and avoid wasting resources. Therefore, we have developed an agent-based model based on the relationships among the principal actors of the selection process.

The different agents taking part in the selection process can be classified as:

- ✓ The *DVE Starter Agent, DSA*: takes the initiative to form the DVE throwing a necessity.
- ✓ The *DVE Partner Agents, DPA*: represent the members of the dynamic VE.
- ✓ The *Potential DVE Partner Agents, PDPA*: represent the entities that want to participate in the dynamic VE and have the ability to do it.
- ✓ The *Core Business Marketplace Agent, CBMpA*: is the agent that provides registration services for potential dynamic VE partners. Also provides the list of potential partners who can satisfy a specific necessity.

The relationships among these agents are depicted in Figures 4 and 5.

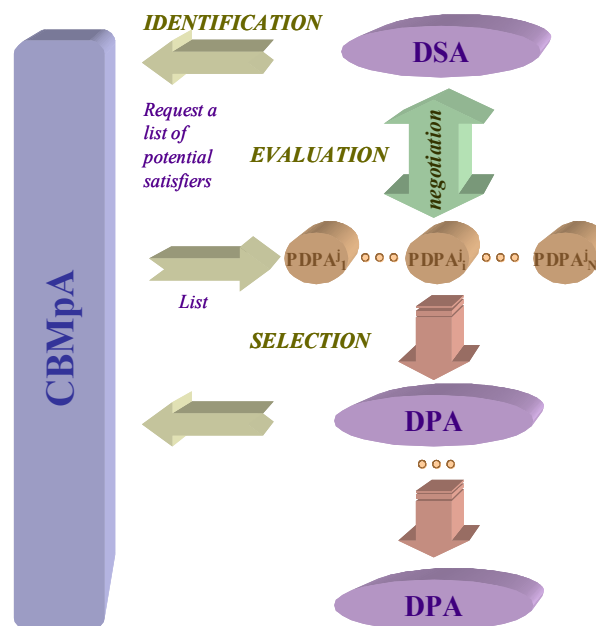


Figure 4. The relationships among the different agents of our model

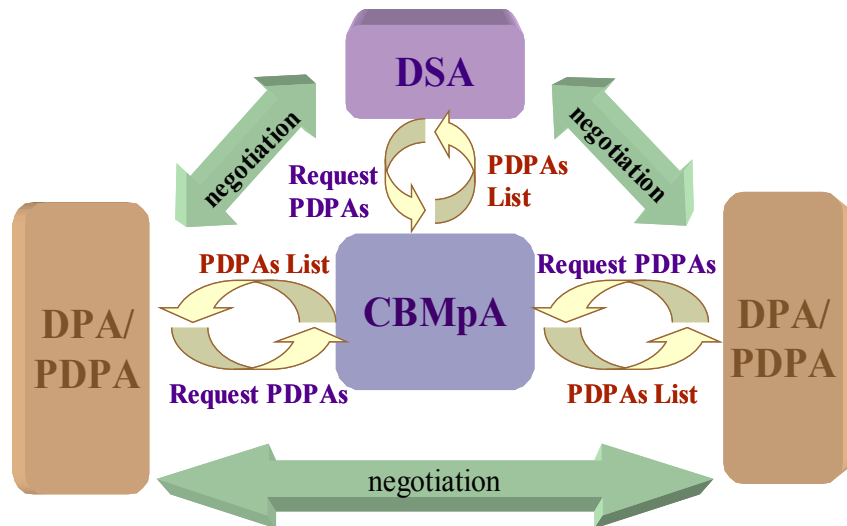


Figure 5. The relationships among the different agents of our model

Let us suppose that an entity locates a market opportunity (niche), which can be satisfied through its core business, or that a client requires from it the accomplishment of a certain service. If one of the sub-process of the main process (core process) must be provided by other domain, the suitable partner for this sub-process should be located. The DVE selection process has begun.

The departure point is the identification stage, where agent who represents the starter entity, DSA, conducts the marketplace agent, CBMpA, and asks for a list with all possible candidates who can satisfy the necessities. Upon request, the CBMpA informs the DSA about all the registered potential PDPA that can provide this specific service.

Once the DSA has located all the potential DVE partners, it negotiates with their agents, PDPA, dynamically in order to select the best one satisfying certain selection and negotiation criteria such as location, amount, price, etc., previously analysed. This is the evaluation stage. The evaluation stage ends when the best partner has been found and selected. The agreement will be described in terms of an electronic contract. In this moment, the potential DVE partner becomes a DVE partner, and its agent becomes DPA.

If this new DVE partner requires their non-nuclear processes to be implemented by other organizations, a similar procedure to the above described must be carried out so many times as necessary. The partner selection ends when all of necessary processes and sub-processes have been completed.

It is important to emphasize that the provision of the whole process is totally transparent to the customer. He has no knowledge of the existence of all involved entities. He only sees a customized service.

For the implementation of this model, we are using the JADE (Java Agent DEvelopment Framework) framework, version 3.3, which supports a seamless integration of two necessary technologies: agents and web services. For the design, creation and edition of the necessary ontologies we are working with Protégé, a free and open source ontology editor and knowledge-base framework (Protégé, 2005).

4. Conclusion

Throughout these pages we have been knowing the paradigm of DVE. It appears as the best form to confront the increasing complexity of changing environments. Nevertheless, it is still necessary to cross a long way until getting to see it like a reality in all the industrial scopes.

Our model looks for to improve one of the crucial processes for the success of a DVE: the selection of partners. Thanks to technologies like the MAS, Web services, XML, etc., the DVE will soon take the great step towards a massive use.

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