The Agent-Based Virtual Enterprise

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A virtual enterprise is composed of distributed, heterogeneous and autonomous components and therefore, could be mapped into a multi-agent system (MAS). Moreover, the coordination and distributed problem solving that arise in a VE can be solved by MAS technology. The paper presents a generic agent-based model of a virtual enterprise, and highlights the main advantages and disadvantages of such a model.

Introduction

The Internet is becoming an important channel for retail commerce as well as business-to-business transactions. In this context, a new paradigm appeared in the last years, the virtual enterprise, a promising alternative to the traditional enterprise model. The virtual enterprise (VE) is a temporary alliance of enterprises that come together to share skills or core competencies and resources in order to better respond to business opportunities, and whose cooperation is supported by computer networks. The key elements of a virtual enterprise are cooperation and networking. Actually, a virtual enterprise can be described as a network of cooperating enterprises. The VE paradigm challenges the way companies are organized and managed, and is suitable for Small and Medium size Enterprises (SMEs). A virtual enterprise is composed of distributed, heterogeneous and autonomous components and therefore, can be mapped into a multi-agent system (MAS). Moreover, the coordination and distributed problem solving that arise in a VE can be solved by MAS technology. The paper presents a generic agent-based model of the virtual enterprise, and highlights the main advantages and disadvantages of such a model. Possible applications are also discussed.

The virtual enterprise

The virtual enterprise concept has no unified definition, still, the most common one is given in [1]: "A virtual enterprise is a temporary alliance of enterprises that come together to share skills or core competencies and resources in order to better respond to business opportunities, and whose cooperation is supported by computer networks."

The fundamental characteristics of a virtual enterprise are the networking and cooperation. Some related terms are *extended enterprise*, *virtual organization* and *networked organization*. An extended enterprise is an organization that extends its boundaries to some or all of its suppliers. A virtual organization comprises a network of organizations that share resources and skills in order to achieve its goal. The most general term, networking organization, refers to any group of organizations inter-connected by a computer network, that does not necessarily share resources or skills and who might have different goals.

The life cycle of a virtual enterprise has four stages: creation, operation, evolution and dissolution. They are represented in figure 1.

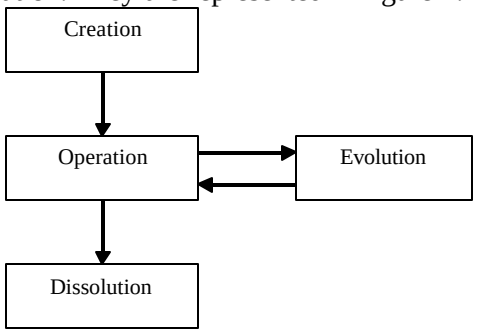

Fig. 1. The life cycle phases of a virtual enterprise

The main activities that are done during the first stage, the creation of the virtual enterprise, are: partner's search and selection, negotiation of the contract, definition of access rights and sharing level, infrastructure definition, etc.

The operation of the virtual enterprise is the phase when the business activities are performed in order to achieve the common goal. Several functionalities must be provided: information sharing and visibility rights support, secure data exchange mechanisms, orders management, distributed and dynamic planning and scheduling, coordination mechanisms, etc.

The operation of the virtual enterprise includes the evolution of it, mainly due to the unpredictable events that may occur on the market and inside the enterprise. For example, an unpredictable goal could be the change of the business goal, the temporary incapacity of a partner. Such events may lead to the change of the partner roles or to the replacement of a partner.

When the goal of the virtual enterprise was achieved the last stage, the dissolution of the virtual enterprise, is initiated.

Each enterprise of a virtual enterprise may play different roles during its life cycle. The main roles, presented in figure 2, are: the *coordinator*, *member*, *network directory node*, and *broker*.

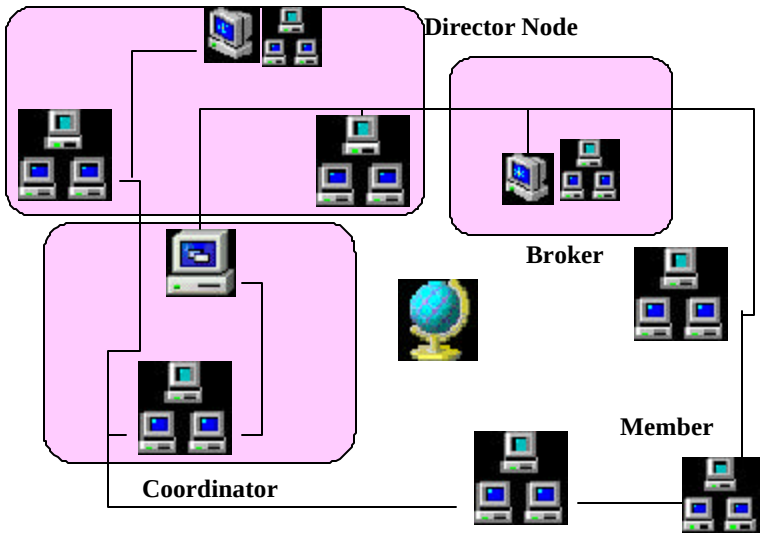

Fig. 2. Partners' roles

The *coordinator* is either a node specialized in coordination or an already existing partner who has this capability can play such a role.

A *member* of the virtual enterprise is an enterprise with different resources and skills that participate in the business process.

The *network directory node* can be one or more node in a network of enterprises (e.g. included in a wide area network such as Internet).

The *broker* is a company that initiates the creation of the virtual enterprise, plans the business process and searches for partners.

A typical application of the virtual enterprise paradigm is the industrial manufacturing, where several enterprises must cooperate in order to have a profitable business. Some particular businesses are shipbuilding, civil engineering, automotive industry, food industry, etc.

The agent-based virtual enterprise

When a business process is executed by a virtual enterprise, parts of the decomposition of the business process are assigned (distributed) to different enterprises. The multi-agent system approach provides solutions to inherently distributed problems, such as that of a virtual enterprise implementation. Agents in a multi-agent system are expected to coordinate by exchanging services and information, to be able to follow complex negotiation protocols, to agree on commitments and to perform other socially complex operations [2]. The infrastructure of MAS is a set of services, conventions and knowledge that support complex social interactions. Coordination and distributed problem solving are critical problems in the virtual enterprise management and they can be solved by a MAS approach. Each stage from the life cy-

cle of a virtual enterprise requires solving different tasks that are suitable for the MAS approach. Some obstacles in the implementation of a MAS solution are given by the lack of some important characteristics that are crucial factors in a real virtual enterprise: the robustness, the security mechanisms and virus protection, standards to support the interoperability, easy interface with the legacy systems.

Several federated architectures for MAS have been proposed in the literature [3]. Two of the most used are: the facilitator-based federation and the broker-based federation. In the facilitator-based approach several related agents are combined into a group, and the communication between agents takes place always through a specialized interface agent called Facilitator. In a broker-based approach, brokers are agents similar to facilitators but with some additional functions (monitoring and notification). Both approaches can be applied to an agent-based virtual enterprise implementation.

In figure 3 it is presented an example of generic agent-based virtual enterprise architecture.

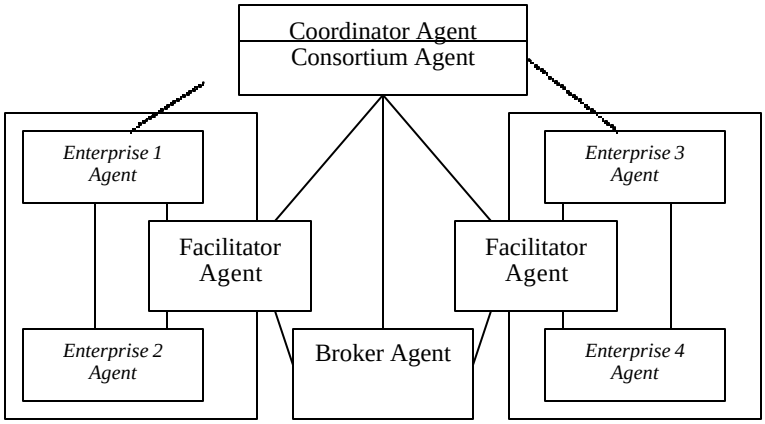

Fig. 3. The architecture of an agent-based virtual enterprise

The main types of agents that can appear in an agent-based virtual enterprise are:

1) *Enterprise-Agent* – represents a given enterprise, member of the virtual enterprise; it can interact with the consortium and facilitator agents.

2) *Broker-Agent* – represents a global system supervisor that acts as an interface between the system and the human broker; it can interact with the facilitator and consortium agents.

3) *Facilitator-Agent* – represents a member or a group of members of the virtual enterprise that have a particular common competence; it can interact with the supervisor, consortium and enterprise agents.

4) *Consortium-Agent* – represents a temporary agent that is created in order to manage the process of generating a virtual enterprise alternative for a given business opportunity, based on bids received from the enterprise-agents.

Example of applications

The supply chain of a modern virtual enterprise is a world-wide network of suppliers, factories, warehouses, distributive centers and retailers through which raw materials are acquired, transformed into products, delivered to customers, serviced and enhanced. In order to operate efficiently, supply chain functions must work in a tightly coordinated manner. But the dynamics of the enterprise and of the world market make this difficult: customers change or cancel orders, materials do not arrive on time, production facilities fail, etc thus causing deviation from the business plan. In many cases these events require several agents to coordinate in order to revise plans, schedules or decisions. In the supply chain, the ability to enable timely dissemination of information, accurate coordination of decisions and management of actions among people and systems is what ultimately determines the efficient achievement of the virtual

enterprise goals and the viability of the enterprise on the world market. Therefore, a possible way to solve the problems is to organize the supply chain as a network of cooperating agents, each performing one or more supply chain functions, and each coordinating their actions with other agents. Figure 4 describes an example of a multi-level supply chain. In a supply chain the available resources are transformed to goods or products along some supply paths. Each operative unit of a retail supply chain represents a supplier, producer, broker, wholesaler, retailer, warehouse, distribution center, and branch or logistics service provider. In a multi-agent approach each operative unit could be implemented as an agent or a multi-agent system at a lower level.

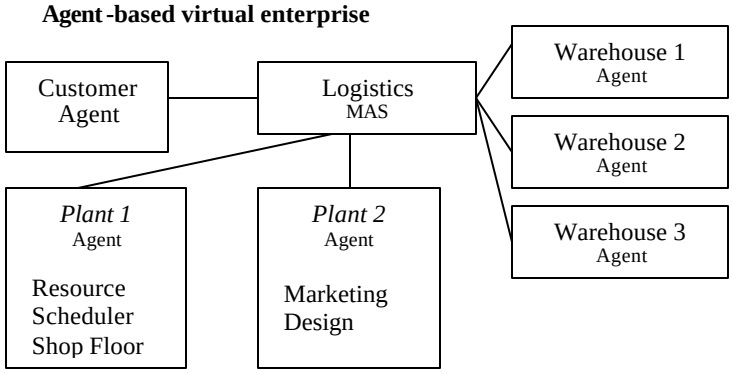

Fig. 4. Example of a multi-level supply chain

In [4] it is described an example of a mediator-based multi-agent architecture, MetaMorphII, that support enterprise integration and supply chain management. A manufacturing system is seen as a collection of subsystems, that can be multi-agent based as well, connected through special agents, named mediators. For example, each enterprise has at least one mediator agent, representing the administrative center of that enterprise. Partners, suppliers, and customers are connected through their mediators.

The TELE TRUCK system, presented in [5], can be applied to online dispatching in a logistics management node of a supply web, and uses telecommunication technologies (satellite, GPS, mobile phones). It has been demonstrated that a MAS approach is feasible to model an online dispatching system. The truck drivers, trucks, (semi)-trailers are autonomous entities with their own objectives, and only an appropriate group of these entities can perform together the transportation task. Thus the whole problem can be modeled as MAS. Each entity is an intelligent agent, and has its own plan, goal, and communication facilities in order to provide the resources for the transportation plans according to their role in the society.

Based on the proposed generic architecture we have modeled an agent-based virtual enterprise [6] for a cosmetics manufacturing company. The negotiation model that was adopted for the creation of the virtual enterprise, as well as for the contract negotiation is described in [7].

Conclusion

The virtual enterprise implementation could be made successfully by a MAS approach taking into account the issues that need to be addressed: the cooperation and coordination, distributed business process and support for autonomy as well as privacy, for example. The paper presented a generic agent-based virtual enterprise model that could be adapted and more deeply specified for a given application. Some applications were briefly discussed. The main limitations of the MAS approach are the robustness, the lack of some more efficient security mechanisms and standards that support interoperability, etc. Despite the fact that these limitations need further research, the results obtained so far,

make the MAS approach a feasible solution for the implementation of a successful virtual enterprise.

References

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