Intelligence Integration in Distributed Knowledge Management

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Chapter III
A Formal Analysis of Virtual Enterprise Creation and Operation

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ABSTRACT

This chapter introduces a formal model of virtual enterprises, as well as an analysis of their creation and operation. It is argued that virtual enterprises offer a promising approach to promote both innovations and collaboration between companies. A framework of integrated ICT-tools, called Plug and Play Business, which support innovators in turning their ideas into businesses by dynamically forming virtual enterprises, is also formally specified. Furthermore, issues regarding the implementation of this framework are discussed and some useful technologies are identified.

INTRODUCTION

Innovations are important to create both private and social values, including economic growth and employment opportunities. From an innovator's perspective, there are some common obstacles for realizing the potential of innovations such as shortage of time to spend on commercialization activities, lack of business knowledge, underdeveloped business network and limited financial resources (Tidd, Bessant, & Pavitt, 2005). Thus, the innovator requires support to develop the innovation into business, something often seen as the specific role of the entrepreneur, which is to search, discover, evaluate opportunities and marshal the financial resources necessary, among other things (Leibenstein, 1968). Playing the role of an innovator or entrepreneur in the networked

economy requires a global outlook. New trade and production patterns, as well as the emergence of new markets point toward a more efficient use of global resources. Information and communications technology (ICT) already plays an important role as a facilitator in this development. We believe that better economic growth can be achieved when the innovator and the entrepreneur can compete and collaborate in order to solve problems on a global market place.

In realizing innovations, small and medium sized enterprises (SME) are particularly important. In response to fast changing market conditions, most enterprises and especially the SMEs need ICT-infrastructures that consider their size as well as high specialization and flexibility. While allowing them to maintain their business independence, ICT-based innovation support should help SMEs reach new markets and expand their businesses (Cardoso & Oliveira, 2005). On this topic, one promising approach for SMEs is to participate in computer-supported collaborative networks that will act as breeding environments for the formation of dynamic virtual enterprises (cf. Ecolead, 2008).

The vision of Virtual Enterprises, or more generally Collaborative Networks, is constituted by a variety of entities (e.g., organizations and people) that are largely autonomous, geographically distributed and heterogeneous in terms of their operating environment, culture, social capital and goals (Camarinha-Matos & Afsarmanesh, 2006). The idea of participating in highly dynamic coalitions of enterprises that are formed according to the needs and opportunities of the market, as well as remaining operational as long as these opportunities persist, put forward a number of potential benefits, some of which are related to agility, innovation management, resource optimization and the adoption of complementary roles based on core competencies (Camarinha-Matos & Afsarmanesh, 2003).

The lack of appropriate theoretic definitions and formal models has been argued to be one of the main weaknesses in the area of collaborative networks and virtual enterprises (Camarinha-Matos & Afsarmanesh, 2003, 2005, 2006). In fact, D'Atri and Motro (2007, p. 21) point out that "while the essential principles of virtual enterprises are mostly agreed upon, a formal model of virtual enterprises has been curiously missing." In this article, we provide a formal model of virtual enterprises and their most crucial tasks. We also propose a formal framework of integrated ICT-support intended to enable secure and agile virtual enterprise creation and operation. We call this framework Plug and Play Business (Davidsson et al., 2006).

In the next section, we provide a formal description of the concept of virtual enterprise followed by a formal analysis of Plug and Play Business. Next, we discuss the usefulness of emerging technology trends relevant for the implementation of Plug and Play Business software. In the end, we present some conclusions and ideas for future work.

PROBLEM DESCRIPTION

The concept of virtual enterprise (see Figure 1) has been applied to many forms of collaborative business relations, like outsourcing, supply chains or temporary consortiums. As is emphasized by Camarinha-Matos and Afsarmanesh (2005), it is important for the companies in a virtual enterprise to share data and information, and to communicate with each other efficiently and securely. A virtual enterprise is typically defined as "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" (Camarinha-Matos & Afsarmanesh, 2005, p. 440). We can describe a virtual enterprise a as a tuple:

$ve = \langle A, R, AR, CI, S, G \rangle$

where

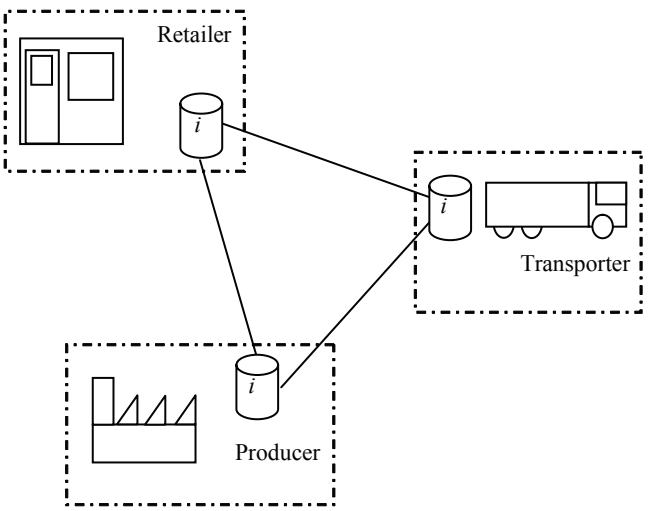
- $A = \{a_1, ..., a_n\}$ is the set of actors (typically enterprises) in *ve*. An actor can be described as a tuple:

  $a_i = \langle I_i, T_i, C_i, G_i \rangle$

  Where I_i are the relevant information systems needed in *vei*, T_i is the set of resources of the actor, C_i is the set of core competencies of the actor and G_i is the set of individual goals of the actor.
- $R_i = \{r_1, ..., r_m\}$ is the set of roles that the actors can play in the *vei*. Each actor in the virtual enterprise can play one or more roles, for example, innovator or supplier/provider of for example, goods, services, expertise, and so forth. The choice of role depends on the virtual enterprise goal(s), the actor's core competencies, resources and individual business goals.
- AR is a set of triples $\langle a_k, r_j, O_j^k \rangle$ where $a_k \in A$ and $r_j \in R$ that is, the actors and their roles in the virtual enterprise and the set of obligations, O_j^k, that is associated with the actor's role in the virtual enterprise.
- CI is a set of communication infrastructures needed for operating the virtual enterprise.
- S is a set of states of affairs that hold at each time in *ve*.
- G is a set of goals of the virtual enterprise that is derived from the business opportunities that motivate the initiation of the virtual enterprise.

According to literature (cf. Camarinha-Matos & Afsarmanesh, 2006), there are two critical stages in the lifecycle of collaborative networks and virtual enterprises when transforming the enterprise from a business opportunity to a successful business collaboration. These stages are the creation and the operation phases. For reasons of completeness, we add the phase of virtual enterprise definition, in which the preconditions for the creation phase are specified.

Figure 1. An example of a virtual enterprise including a communication infrastructure connecting three actors (where each actor is a company that consists of the information resource (i) and the spe-cial skill or competence required in the cooperation) collaborating in the roles of transporter, retailer, and producer



Virtual Enterprise Definition

In the definition process, the business opportunity is described in terms of roles and goals of the virtual enterprise. This process emanates from the detection of a business opportunity and results in a set of goals, *G* and roles, *R*, which are necessary for the fulfillment of the virtual enterprise.

Virtual Enterprise Creation

During the creation process, the virtual enterprise is formed. Given the set of goals and roles specified in the definition phase, the virtual enterprise initiator determines the set of actors, *A*, maps the actors to the roles, *AR*, and selects the communication infrastructures, *CI*, to be used in the virtual enterprise. The creation process is thus initiated when a set of goals and roles for the virtual enterprise has been specified and it is terminated when an agreement concerning the actors, their roles and the communication infrastructures in the virtual enterprise has been reached.

Virtual Enterprise Operation

When an agreement concerning the roles and obligations in the virtual enterprise has been reached, the operation phase can be initiated. We regard operation as a process that, given a set of actors, their roles and a set of communication infrastructures, fulfills the goals, *G*, of the virtual enterprise. Operation is initiated when the communication infrastructures are in place to support the actors in their roles to reach the agreed goals and it is terminated when the goals of the virtual enterprise are fulfilled. Note that virtual enterprise operation may include both multilateral and resource-sharing collaboration.

On Requirements of ICT-Tools that Support Virtual Enterprises

It is clear that the vision of virtual enterprises can be realized with the help of ICT. We will therefore specify a set of quality attributes (i.e., nonfunctional requirements) for such a framework of ICT-tools. Based on interviews with SMEs and on previous work by, for example, Camarinha-Matos and Afsarmanesh (2003, 2005), we believe that the following quality attributes are important:

- **Scalability.** Some virtual enterprises may be large in that the number of involved companies can be large, whereas some virtual enterprises may be small in that the number of involved companies can be small. Hence, ICT-solutions must be scalable to the shifting number of enterprises within the virtual enterprises.
- **Flexibility.** Being adaptable or variable is important due to the heterogeneity of companies (especially given that SMEs belong to the target group of virtual enterprises), relationships and actors in a virtual enterprise. Hence, software must be flexible to the varying needs of the intended virtual enterprise organizations.
- **Performance.** Although there may not be many hard real-time requirements for such a software to meet, response times and other delays must be kept on reasonable levels.
- **Cost.** High costs associated with joining and participating in a collaboration alliance is considered an obstacle for any growing network (Shapiro & Varian, 1999). Some of the envisioned benefits of virtual enterprises are low preparation and transactions costs as well as decreased time to market.
- **Usability.** A user-friendly interface is crucial in order to get interaction from the humans involved in the chain of collaboration.
- **Security.** The prevention and detection of unauthorized actions is a key feature if trust

is to be established among the parties in a virtual enterprise.

PLUG AND PLAY BUSINESS

The concept of Plug and Play Business (Davidsson et al., 2006; Jacobsson & Davidsson, 2006) relies on an integrated set of ICT-tools that support innovators in turning their ideas into businesses by forming virtual enterprises for interorganizational and interoperable collaboration. We envision Plug and Play Business as a software framework that helps companies, SMEs in particular, in realizing innovations and thus developing their business potential.

After having deployed the Plug and Play Business software, companies are connected to a networked community where all participants share one common goal; namely to increase business. In that way, the purpose of Plug and Play Business is to stimulate the realization of innovations without interfering with the individual goals of the Plug and Play Business companies. Together with the autonomy, heterogeneity and possibly conflicting goals of the involved parties of a Plug and Play Business community, this requires ICT-solutions that are able to handle dynamically evolving and distributed business partnerships and processes that cross the borders of various enterprises. Thus, the interoperability between the information systems of the involved enterprises belongs to the technological core of the concept of Plug and Play Business.

In addition to the concept of virtual enterprises, another important concept for implementing Plug and Play Business is Internet communities. Enterprises dynamically join a Plug and Play Business community by installing and running the Plug and Play Business software and by describing and validating the resources of the enterprise, for example, production capacity, distribution network, intellectual capital, and so forth. The community is dynamic in the sense that enterprises may (in principle) join and leave the community at any time. To enhance security, a gate-keeper facility that regulates the entering and leaving of the community is included in the community. Formally, a Plug and Play Business community, p, can be described as a tuple:

$$p = \langle A, R, VE, S, l, CI, gk \rangle$$

where

- $A = \{a_1, ..., a_n\}$ is the set of actors (typically enterprises) in the community. An actor in the Plug and Play Business community can be described as a tuple:

  $$a_i = \langle I_i, T_i, C_i, G_i, h_i, b_i \rangle$$

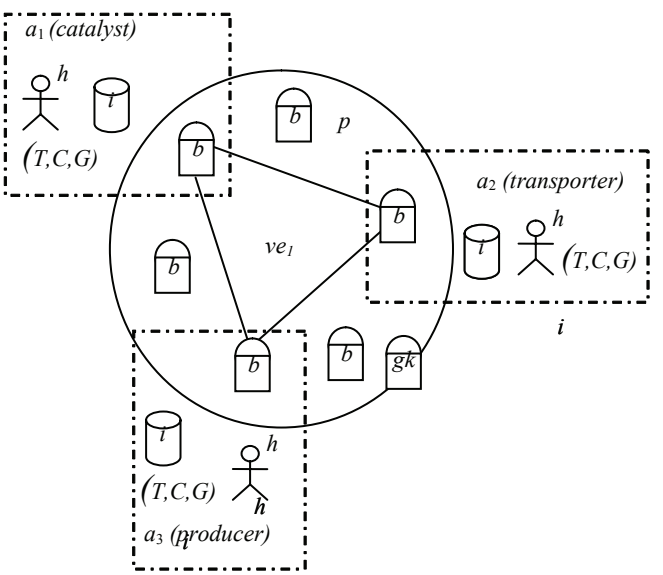
  Compared to the definition of actors in virtual enterprises, we add h_i, which is the person representing the actor/enterprise and b_i, which is the Plug and Play Business client software (an intelligent agent supporting the (agent) communication language, l_i) acting on behalf of the actor/enterprise.
- $R = \{r_1, ..., r_m\}$ is the set of roles that the actors can play,
- $VE = \{ve, ..., ve1\}$ is the set of virtual enterprises currently active in the community,
- S is a set of states of affairs that hold at any time in p,
- l is the agent communication language used by the agents B. We will assume that l includes a set of relevant interaction protocols, a set of relevant ontologies and possibly other things necessary to perform useful communication,
- CI is a set of communication infrastructures needed for operating the community, and
- gk is the gate-keeper facility that regulates the entering (and leaving) of actors to (and from) the community. In order to become a member of p there is a set of criteria that must be fulfilled, for example, corporate identi-

fication number must be declared, the roles the actor is willing to play should be stated and information systems must be specified. Thus, some of the aims of the gate-keeper are to ensure that this type of information is available to the Plug and Play Business community and to verify the identity of the actors. Possibly, the gate-keeper may also be equipped with capabilities of handling different levels of memberships with different sets of norms in order to cope with the varying needs of potential participants and members. The gate-keeper could also inform the potential member about general rules that hold in the community and require the potential member to comply with them.

Note that all these entities change dynamically, but with different frequency. New virtual enterprises may be formed (and dissolved) relatively frequently, actors enter and leave the community every now and then, and new roles may be added although this is not expected to happen often. In Figure 2, we illustrate an example of a Plug and Play Business community.

In Plug and Play Business, the interactions between participants in the community as well as in the virtual enterprises are role-based. Each actor plays one or more roles, for example, innovator, raw material producer, transporter, product designer, logistics provider, marketer, financier, retailer, and so forth. The choice of role depends on the company's core competencies and business intentions. An important role in the life cycle of businesses is the entrepreneur and we make a distinction between this role and that of the innovator. One of the main purposes of Plug and Play Business is to automate as much of the entrepreneurial role as possible, thus increasing the probability of turning an innovative idea into a business.

Figure 2. An example of a Plug and Play Business community (p) where i is the relevant information systems needed in the virtual enterprise (ve1), T is the resources of the actor/enterprise, C is the core competencies of the actor/enterprise, G is the goals of the actor/enterprise, gk is the gate-keeper, h is the person representing the actor/enterprise, and b is the Plug and Play Business client. The figure also contains three examples of roles played by the actors (a)



Virtual Enterprise Definition

In the virtual enterprise definition phase, a member of the Plug and Play Business community, typically an innovator, may at any time initiate an attempt to form a collaborative coalition between the members. This process may be viewed analogous to crystallization, where a catalyst (innovator) initiates a process resulting in a precise form of collaboration, that is, the formation of a virtual enterprise. The main role of the entrepreneur, which to a large extent is automated by the Plug and Play Business software, is to drive this process. It may be a more or less elaborate process starting with just a seed of an innovative idea without any predefined business structure, or it may be a full-fledged business idea with well-defined needs to be met by potential collaborators. In this phase, the catalyst, Ω, where $\Omega \in A$, describes the business opportunity in terms of goals, G and roles, R, of the virtual enterprise. Because this is a highly complex task, $h\Omega$ will be the main contributor, whereas $b\Omega$ primarily will provide structural support.

Virtual Enterprise Creation

The virtual enterprise creation phase (where crystallization takes place) consists of three subtasks and is initiated by a catalyst. We have identified the following functions as helpful in forming a successful collaborative coalition.

- **Finding.** To find candidates suitable for a potential virtual enterprise is an important function. This function primarily concerns the catalyst of the business idea to provide the requirements of the preferred abilities of the roles for the potential collaborating partners. The finding functionality may include the possibility both for search, based on specific needs specified by criteria, for example, type of products and business model, as well as for posting general needs or ideas that other members may suggest solutions or resources for. Further, Plug and Play Business software should provide the feature of suggesting actors for collaboration based on, for example, content-based recommendation and collaborative recommendations. The function of finding requires that Ω has a list of the roles that must be filled in order to get an operating virtual enterprise. This list is provided by $h\Omega$, that is, the person representing Ω in the definition phase. Then, for each of the roles, the task for $b\Omega$ is to find the set of candidate actors K where $K \subset A$ that are able to play the role.
- **Selection/Evaluation.** When a set of potential collaborators has been found they need to be evaluated. This requires support for using track records and potentially support for certification schemes of, for instance, the trustworthiness of the actors. Further, decision support for evaluating trade-offs between a number of characteristics are needed, for example, trade-offs between cost of product/service, cost of transportation and time to delivery of product/service. Which actors to choose for the creation of a virtual enterprise should be based on the evaluation and the estimated future value of collaboration potential with the other actors in the alliance. So, based on some evaluation criteria, the initiator of the virtual enterprise selects which candidate actors to start negotiating with. In the evaluation task, Ω should rank the actors in K according to a set of requirements Q_r where $Q_r = \{q_1, q_2, ...q_k\}$ (provided by $h\Omega$). Based on this, Ω selects the actors with the highest rank k where $k \in K$ for negotiating on terms for virtual enterprise operation.
- **Negotiation.** When the catalyst has selected actors for the necessary roles of the virtual enterprise, agreements between the actors with respect to their roles, their obligations,

the communication infrastructure and the goals of the virtual enterprise need to be settled. The Plug and Play Business software should provide support for different types of contracts of agreements including support for intellectual property rights. The goal of negotiation is to establish an agreement between Ω and k concerning k's set of obligations, O_k. These obligations should of course be consistent with the set of goals, G of the *ve* and the set of goals of G_k .

Virtual Enterprise Operation

When the creation phase is finished and a virtual enterprise is formed, the Plug and Play Business software should provide support also for the operation phase, that is, the collaboration between the parties of the virtual enterprise. This support may be on a quite shallow level, for example, transactions of information between actors. On a deeper level, the Plug and Play Business software should support and facilitate complex coordination and synchronization of activities. A wide range of information types needs to be transferred in an efficient way in order to reduce the administrational costs of the actors as well as reducing the risk of inaccuracy in information. The management of the virtual enterprise requires support for controlling the flow of activities between the involved actors. It concerns activities with potential long-term consequences (e.g., initiating product development) as well as regular business activities (e.g., decisions of production and distribution). With respect to the operation phase, Plug and Play Business software must support:

- **Information resource-sharing.** This is related to the content and purpose of the exchanged information with tasks ranging from administrative information exchange to complex operations planning. An example of a simple administrative task is ordering and invoicing, whereas a more complex task may concern making critical information available to the collaborating partners in order to improve operations by better and more efficient planning and scheduling, that is, resource optimization.
- **Multilateral collaboration.** The more parties involved in the collaboration, the more complex the solutions may be. The simplest case concerns cooperation between only two enterprises, whereas the general case involves a large number of enterprises collaborating with each other in different ways (many-to-many collaboration).

We separate between two levels of collaboration: administrational and operational. They are defined by the type of interaction protocols they support. Administrational collaboration includes only protocols using the "weaker" *performatives*, such as, *ask*, *tell*, *reply*, and so forth. Let us call this set of interaction protocols *IPW*. Operational collaboration supports protocols also using the *performatives* that actually manipulate the receiver's knowledge, such as, *insert*, where the sender requests the receiver to add the content of the message to its knowledge base, and *delete*, where the sender requests the receiver to delete the content of the message from its knowledge base. Let us call this set of interaction protocols *IPS*. Moreover, we make a distinction between bilateral and multilateral collaboration. Thus, we have four types of collaboration within the operation phase:

- Bilateral administrational collaboration between two actors a_i and a_j (where $a_i \in A$ and $a_j \in A$) in a virtual enterprise *ve* should support the use of a set of interaction protocols, IPW_{ij} where $IPW_{ij} \subset IPW$, between the two actors' information systems (i_i and i_j) and mediated by the actors' Plug and Play Business client software (b_i and b_j).
- Multilateral administrational collaboration between a set of actors A_u (where $A_u \subset A$

in a virtual enterprise *ve* should support the use of a set of interaction protocols, IPW_u where $IPW_u \subset IPW$, between all the actors' information systems and mediated by the actors' Plug and Play Business client software.

- Bilateral operational collaboration between two actors a_i and a_j (where $a_i \in A$ and $a_j \in A$) in a virtual enterprise *ve* should support the use of a set of interaction protocols, IPS_{ij} where $IPS_{ij} \subset IPS$, between the two actors' information systems (i_i and i_j) and mediated by the actors' Plug and Play Business client software (b_i and b_j).
- Multilateral operational collaboration between a set of actors A_u (where $A_u \subset A$ in a virtual enterprise *ve* should support the use of a set of interaction protocols, IPS_u where $IPS_u \subset IPS$ between all the actors' information systems and mediated by the actors' Plug and Play Business client software.

Implementation Issues

Enhancing security and trust has been identified as a key issue in making virtual enterprises reach their potential (Camarinha-Matos & Afsarmanesh, 2005, 2006). One example of improving security is the gate-keeper facility that uses identification and authentication mechanisms regulates the entering (and leaving) of enterprises and registers them as members of the community. The gate-keeper can also inform the potential members about general rules that hold in the community and require the potential member to comply with them before being allowed to enter the Plug and Play Business community. Moreover, there may be a need for a surveillance mechanism that monitors the behavior of members in the community. The purpose of such a mechanism is to block unauthorized users and to detect and cope with malicious behavior, thereby incorporating security management into the Plug and Play Business software. A more detailed study on security analysis is provided by Jacobsson and Davidsson (2007).

One of the intended key advantages with Plug and Play Business software is to lower the costs of collaboration (including, e.g., preparation, transaction and search costs), which is particularly important in order to be accepted by SMEs. Another intended key advantage is the "plug'n'play" aspect, that is, the user-friendly interface of the software, which must be carefully considered in the software design. Response times and other delays must be kept on a reasonable level, thereby addressing performance requirements. The choice of system architecture is closely related to the system's performance in terms of a number of the previously mentioned attributes. Compared to a centralized architecture, a distributed architecture supports many of the quality attributes, for example, flexibility, scalability and dynamicity. Also, the risk of single point of failure and traffic bottlenecks may be avoided increasing the robustness of the system.

A decentralized paradigm such as peer-to-peer (P2P) may be preferable for the Plug and Play Business software because no central authority determines how the participants interact or coordinates them in order to accomplish some task. A P2P infrastructure self-configures and nodes can coordinate autonomously in order to search for resources, find actors and interact together. The heterogeneity of enterprises and relationships between the enterprises thereby have the potential to be maintained. P2P is a paradigm that allows the building of dynamic overlay networks and it can be used in order to realize an environment that manages a dynamic network of business relations. Dealing with business sensitive assets (e.g., innovators' knowledge), searching and retrieval of contents, as well as discovery, composition and invocation of new services, should be made secure and trustable. The P2P infrastructure realizes an environment in which every organization can make its knowledge and services available to other organizations keeping control over them.

In a P2P infrastructure, each organization can autonomously manage this task without having to delegate it to an external central authority that could be perceived as less trusted than the organization itself and should be the object of an external (to the collaborating network) agreement between all the involved organizations.

Related Work

Camarinha-Matos and Afsarmanesh (2003, p. 2) state that "there is a need for flexible and generic infrastructures to support the full life cycle of virtual enterprises, namely the phases of creation, operation and dissolution." We believe that the Plug and Play Business has the potential of constituting such an infrastructure. Moreover, they provide further motivation to our work by emphasizing the need for research on generic, interoperable, pervasive, free (low cost) and invisible (user-friendly) infrastructures that include methods for the creation of business (e.g., negotiation, methodologies for transforming existing organizations into a virtual enterprise-ready format) and business collaboration (e.g., coordinated and dynamic resource sharing, administration and management of distributed activities and risk management).

In recent years, a rich literature on the topic of collaborative networks and virtual enterprises has emerged. The concept of Plug and Play Business is similar to the concept of Virtual Breeding Environments as described by Camarinha-Matos and Afsarmanesh (2003, 2005). A virtual breeding environment represents an association or a cluster of organizations and their related supporting institutions that have both the potential and the will to cooperate with each other through the establishment of a "base" long-term cooperation agreement and interoperable infrastructure. When a business opportunity is identified by one member (acting as a broker similar to the catalyst within Plug and Play Business communities), a subset of these organizations can be selected, thus forming a virtual enterprise. Plug and Play Business is different from virtual breeding environments in that dynamic and temporary alliances can be formed within the community whenever a business opportunity is detected. Thus, Plug and Play Business also supports short-term collaboration. Another distinction is that Plug and Play Business emphasizes the importance of promoting innovations by automating as much as possible of the entrepreneurial role in the virtual enterprise, thereby promoting economic growth and employment.

Plug and Play Business has some resemblance to the work described by Chituc and Azevedo (2005) in that dynamic collaboration processes for agile virtual enterprises are emphasized. However, their work excludes crucial aspects such as the dynamic creation of virtual enterprises and security management.

USEFUL TECHNOLOGIES

Technological support for the creation and operation phases of virtual enterprises is arising in many forms. Cardoso and Oliveira (2005, p. 1) state that "the most ambitious technologies intend to automate (part of) the process of creation and operation of virtual enterprises, mainly through multi-agent technology approaches, where each agent can represent each of the different enterprises." This is also the overall intention with Plug and Play Business software. Because agents are autonomous, can interact with other agents, and enable approaching distributed problems by means of negotiation and coordination capabilities, they are fit for the tasks within Plug and Play Business.

Based on the requirements and attributes mentioned previously, we hereby make a brief review of some relevant technologies (including multi-agent technologies) that are useful when developing Plug and Play Business software.

Finding, Evaluating and Selecting Potential Partners

The tasks of finding and evaluating (e.g., business partners) have been the object of a lot of research within the area of recommendation systems (cf. Adomavicius & Tuzhilin (2005)). Here, the main idea is to automate the process of "word-of-mouth" by which people recommend products or services to one another. Recommendation systems are usually classified based on how they are constructed into three categories:

- Content-based recommendation, which is based on previous interests of actors;
- Collaborative recommendation, which is based on preference of similar actors; and
- Hybrid recommendations, which is a combination of the two previous ones.

So far, recommendation systems have successfully been deployed primarily in consumer markets (see, for instance the collaborative filtering system at book dealer Amazon.com). As most existing recommendation systems are not developed for business-to-business applications, they generally exclude the negotiation process. Because recommendation systems are already deployed in large-scale consumer systems it can be assumed that they enable scalability, flexibility, usability and cost-efficiency. Thus, they may be a beneficial alternative to use when meeting the requirements of virtual enterprise creation; more specifically the finding and evaluation stages. Also, because they can take the history of a potential collaborator into account, they may also contribute to the enhancement of security and trust.

In the area of intelligent agents, middle agents or brokering agents have been used to locate other agents in an open environment like the Internet (Wiederhold, 1992; Wong & Sycara, 2000). Here, each agent in the community typically advertises its capabilities to some broker. These brokering agents may simply be match-makers or yellow page agents who match advertisements to requests for advertised capabilities. Brokering agent systems are able to cope quickly and robustly with a rapidly fluctuating agent population (Wooldridge, 2004), which indicates both a high level of flexibility, scalability, robustness and performance. This makes them appropriate to use in Plug and Play Business software.

Establishing an Agreement

There is a long tradition in the area of agent-based systems of studying how to reach agreements, for instance, using the Contract Net protocol (Smith, 1980) and computational auctions (Rosenschein & Zlotkin, 1994). Auctions are generally considered to be a useful technique for allocating resources to agents (Wooldridge, 2004), however, they are too simple for many settings as they are mainly concerned with the allocation of goods or resources. For more general settings, where agents must reach agreements on matters of mutual interest and including complex constraints, richer techniques for reaching agreements are required. Here, negotiation may be a promising alternative. Four different components are relevant for the Plug and Play Business setting:

- A negotiation set, which represents the space of possible obligations that agents can make;
- A protocol, which defines the legal obligations that the agents can make;
- A collection of strategies, one for each agent, which determines what obligations the enterprises will make; and
- A rule that determines when the negotiation is over and the deal has been closed.

Here, the concept of obligations is an important component in that it specifies the commitments that the members (or the agents acting on behalf of their owners) have against each other. Substantial work on obligations in normative

multiagent systems has been done (cf. the work by Boella and van der Torre (2004) and López y López, Luck and d'Inverno (2006)). In the area of electronic contracts, which are to be regarded as virtual representations of traditional contracts, that is, "formalizations of the behavior of a group of agents that jointly agree on a specific business activity" (Cardoso & Oliveira, 2005, p. 6). Electronic contracts usually have a set of identified roles to be fulfilled by the parties involved in the relation. Three types of norms are specified within a contract structure, namely obligation, permission or prohibition. Plug and Play Business software primarily adopts the concept of obligations, that is, that an agent (the Plug and Play Business software) has an obligation toward another agent to bring about a certain state of affairs (the goal(s) of the virtual enterprise) before a certain deadline. However, what more types of norms (e.g., permissions and prohibitions) and norm-enhancing mechanisms (e.g., promoter and defender functionality) that should be included in the definition of Plug and Play Business remains to be determined.

Agent-based auctions, negotiation protocols and electronic contracts may be sound technologies to enable the establishment of agreements within Plug and Play Business since intelligent agents can be designed to cope with individual goals and conflicting behavior (which certainly may occur in the Plug and Play Business community).

Operation

Several examinations on current state of the art technologies useful for building ICT-infrastructures with the purpose of business collaboration within virtual enterprises have been undertaken (cf. Camarinha-Matos & Afsarmanesh (1999, 2003, 2005)). Some common conclusions are that multi-agent technology constitutes a promising contributor to the development of support infrastructures and services. Also, Internet and Web technologies, such as Web services, represent a fast growing sector with large potential in interenterprise collaboration support. However, further support for multilateral collaboration is necessary. A number of other emerging technologies, for example, service-oriented architectures, the semantic Web and countless collections of software standards (cf. the ebXML framework) are likely to provide important contributions.

It seems that Microsoft's BizTalk Server is the most sophisticated solution for interenterprise collaboration widely available. BizTalk is based upon a central server through which all exchanged information passes, it uses XML and supports the main protocols for e-mail and http. However, BizTalk supports multilateral collaboration only to some extent and it is not fit for interoperable information resource sharing. Being a centralized proprietary client-server solution, it has several disadvantages, such as making the actors dependent of third party, being expensive and having possible risks for communication bottlenecks, thereby failing to meet requirements such as scalability, flexibility, robustness, cost and security.

Another possibility is to use computational auctions (Rosenschein & Zlotkin, 1994; Yamamoto, 2004). They can be used within the collaboration task as a method for dynamically solving resource allocation within the virtual enterprise. Possibly, auctions can also be deployed within multilateral administrational collaboration when allocating work tasks between partners of a virtual enterprise. However, as stated by Camarinha-Matos and Afsarmanesh (2005, p. 447) "publicly funded research should avoid approaches that are too biased by existing technologies."

We believe that there are some technologies that may be useful for the collaboration task within Plug and Play Business software. One promising alternative for multilateral collaboration is the use of decentralized intelligent agents. In previous work (Davidsson, Ramstedt, & Tornquist, 2005), we have described a general wrapper agent solution based on open source freeware that makes it

possible (in principle) for any business system to exchange (administrational) information with any other business system. In Carlsson, Davidsson, Jacobson, Johansson, and Persson (2005), we suggest further improvements to the wrapper agent technology by addressing security issues as well as an extended, possibly dynamic, set of involved companies and higher levels of cooperation (i.e., operational resource sharing).

CONCLUSION AND FUTURE WORK

One of the weaknesses in the area of virtual enterprises and collaborative networks is the lack of appropriate theoretic definitions, formal models and consistent modeling paradigms. The main contribution of this article is a formal model of virtual enterprise definition, creation and collaboration as well as their associated tasks. We have also formally described Plug and Play Business, which is a set of integrated ICT-tools that support innovators in turning their ideas into businesses by forming virtual enterprises for interorganizational and interoperable collaboration.

In approaching a technology platform for Plug and Play Business software, we have made an assessment of useful technologies and related work. Based on this review, we can conclude that some of the evaluated technologies may be used for the tasks of Plug and Play Business software. With respect to finding and evaluating partners for a virtual enterprise, recommendation systems show numerous fruitful examples that can be applied. For the process of establishing an agreement between the catalyst and the highest ranked actor in the evaluation process, the Contract Net protocol and broker agents may be promising alternatives. Relevant approaches for supporting virtual enterprise operation include Microsoft's BizTalk solution, wrapper agents and computational auctions.

The next step will mainly focus on further analyzing the components of the Plug and Play Business software and on refining the requirements that were only briefly discussed in this article. We will also continue to perfect the formal framework presented above. In particular, we will further develop the roles and different types of obligations in the Plug and Play Business community as well as in the virtual enterprises. We also intend to implement a proof of concept of the Plug and Play Business concept and to evaluate its viability.

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