Virtual Enterprises: Challenges in Selecting and Integrating Computational and Human Resources

Sobah Abbas Petersen
Dept. of Computer & Information Systems
Norwegian University of Science & Technology
Trondheim, Norway
Tel: +47 73 59 74 10
sap@idi.ntnu.no

Jinghai Rao
Dept. of Computer & Information Systems
Norwegian University of Science & Technology
Trondheim, Norway
Tel: +47 73 59 44 80
Jinghai.Rao@idi.ntnu.no

Amund Tveit
Dept. of Computer & Information Systems
Norwegian University of Science & Technology
Trondheim, Norway
Amund.Tveit@idi.ntnu.no

ABSTRACT
This paper considers agent-based support of Virtual Enterprises within the context of an electronic market and in terms of web services. The current initiatives in these areas of work consider a VE as consisting of computational resources only and not as a combination of computational and human resources. Based on this observation, this paper outlines some of the challenges that arise in supporting Virtual Enterprises.

Keywords
Virtual Enterprise, Agents, Electronic Markets, Web Services.

1. INTRODUCTION
Recent advances in communication and distributed information technologies have changed the way that business is conducted. Enabled by technologies such as software agents and Electronic Commerce, enterprises have gone beyond the geographical and sociocultural boundaries and have become entities that not only compete in the global market, but also draw their resources from an international market. The trend of outsourcing seems to be replaced by strategic alliances, where enterprises or individuals work together towards a common goal and share their responsibilities as well as their profits. Today, businesses advertise globally for their resources and organisations no longer require their employees to be co-located to perform their work. The global search and selection of resources impose additional challenges that require new ways of dealing with them. The concept of a Virtual Enterprise (VE) has evolved as a means of meeting these challenges.

There have been several attempts at defining VEs from different research communities and there are several definitions of the concept. A review of these definitions is available from [13]. The main characteristics of VEs are as follows:

- Temporary network of independent enterprises or individuals
- Collaboration among the partners
- Goal-oriented
- Commitment-based
- Shares skills, costs, profits, risks and markets
- Geographically distributed
- Exists for a limited amount of time

We consider a VE as a scenario that emerges in a world where individual entities (people, software agents or business enterprises) come together as a team to achieve a specific goal. These individual entities represent the *partners* of the VE and they cooperate to achieve a set of goals and then move on to join another VE. VEs do not have a rigid, permanent organisational framework. Rather, it is a *team of partners* that have common goals and are committed to fulfilling these goals.

2. VEs AND RELATED TECHNOLOGIES
Based on the characteristics of VEs stated above, there is a strong motivation to use agents as the technology for modeling and realising VEs. In a VE, the cooperating entities are the partners of the VE and therefore it is natural to use agents to represent the partners. The short lifespan of the VE means that the partners that participate in one VE may also be negotiating on a contract with another VE. By delegating agents to do this job, the partners have the time to do the actual work required in the VE. The ability to delegate responsibilities to agents and agents being reusable components makes them a suitable means of representing the partners in a VE.

Agents have been used to model various aspects of VEs. For example, in [3], agents were used to represent the different entities in a distributed supply chain (e.g. supplier); in [5] and [12], agents are used to represent an independent organisation and they view a VE as an aggregation of independent organisations that are connected via the Internet and use the idea of an electronic market place; in [10], the notion of commitments is used to manage the autonomy of an agent in a VE. In [18], a framework for finding the right agent for an organisation in cyberspace is described. Their work focuses on enabling software developers to build large-scale agent organisations in cyberspace.

The domain of VEs has been considered in other contexts too. For example, Grid computing has been described as "coordinated resource sharing in dynamic, multi-institutional virtual organizations" [6]. The main goal for grid computing has been to support large-scale scientific computing. However, lately there has been an increasing emphasis on the support of more generic large-scale services (e.g. utilizing the web services and the Semantic Web technologies in Grid applications [11]). The most interesting contribution from Grid Computing will be the support for very large-scale distributed applications, e.g. using the standardized Globus middleware.

Selecting the agents that represent the partners of a VE can be considered as selecting the services that are provided by the agents. (See Figure 2.) There are several web service initiatives that are significant to the domain of VEs. XML is currently the leading technology for specifying web service interfaces and registration. The most significant initiatives include the Universal Description, Discovery and Integration (UDDI) [20]; the XML-based Web Service Description Language (WSDL) [21] and DAML-S, a DAML (DARPA Agent Modelling Language) based semantic markup of Web services [2]. Other initiatives include the development of web service systems or frameworks. For example, [14] proposes a model that matches services between the customer and the supplier based on the dynamic evaluation of specific business rules. In [7], a framework for the representation, discovery and composition of web services for e-market places are discussed.

We believe that an important requirement has been overlooked in the current agent-based applications as well as the initiatives in the area of web services. The current applications do not consider **the partners of a VE as a combination of entities – agents, human beings and business enterprises**. The partners are considered as consisting of computational resources only and not as a combination of computational and human resources. We believe that the concept of a VE can only be fully supported by considering scenarios where the partners of the VE are a combination of entities and by providing support to represent, select and integrate a combination of these resources.

In the remaining sections, we focus on VEs where the partners are a combination of entities and outline a set of challenges faced by VEs. The rest of the paper is organised as follows: Section 3 describes a VE within the context of an electronic market and web services; Section 4 describes briefly the issues facing VEs with a combination of human and agent partners; Section 5 outlines a list of challenges and Section 6 summarises the paper.

3. VE FORMATION

The lifecycle of a VE can be analysed using ideas from enterprise modeling and enterprise reference architectures, e.g. GERAM (Generic Enterprise Reference Architecture and Methodology [9]). Figure 1 shows the formation stage of a VE within a lifecycle context. Before a VE is formed, it's concepts and goals have to be defined. The requirements from the customer sets the requirements for the VE team and in order for the VE to be able to deliver to its customer, the right team has to be formed. This implies that the success of the VE is strongly dependent on the commitment, the performance and the delivery capabilities of its partners. Hence, the selection of the partners of the VE becomes a crucial part of the lifecycle of the VE. Also, due to the limited lifetime of a VE, they need to be formed very quickly in order to meet the deadlines of the goals and there is a need to form VEs often.

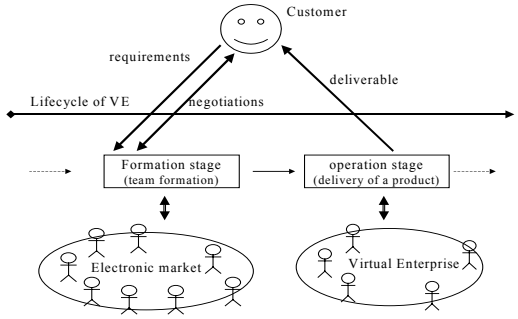


Figure 1 A Lifecycle-oriented view of VEs

During the formation stage of the lifecycle, electronic billboards and market places can be used to facilitate initial contact among the partners. A person or enterprise intending to form a VE, *VE Initiator*, may announce the VE and invite parties to bid to become partners of the VE. The parties that submit a bid can be assumed to be self-interested (profit maximizing), competitive and cooperative. In this case, they will bid and negotiate to become a partner of the VE and the best one(s) will win the contract. If we consider the VE scenario as an electronic market place, we can identify the following entities:

- The VE context is the *electronic market.*
- The *trading agents* are the partners who bid to be a part of the VE and a VE Initiator (or a customer) that is initiating the VE.
- The *goods or services* that are traded which is the ability for a partner to meet the VEs requirements (a combination of several factors such as the services they provide, skills, cost and the time of availability).
- The *transactions* are the contracts that are signed between the VE Initiator and the partner agents to deliver a specific service for a specific price within a specific time.

Figure 2 shows a web services-oriented view of a VE, where the partners of the VE provide services to or consume services from each other within an electronic market. Partner B provides the service M and Partner D provides the service O. Partner C consumes service O and Partner D consumes service L. Service L is a composite service which is an integration of services provided by both Partners B and C. In this case, the VE is composed of Partners B, C and D and the services L, M, N and O. These services may be based on computational or human resources. In such a situation, the description of the VE will be in terms of

these services and the selection of the partners for the VE will be based on the services that they provide.

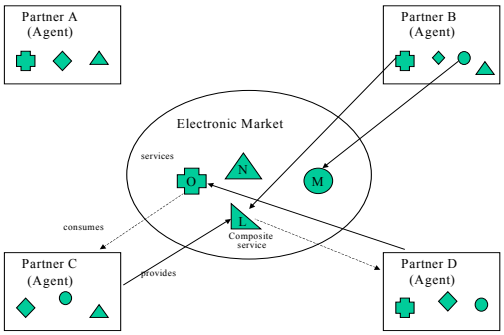


Figure 2 Web services-oriented view of VEs

4. HUMANS, AGENTS AND WEB SERVICES

The combination of human beings and agents as partners of a VE introduces a number of issues that must be addressed and resolved in order to fully support the formation and the operation of a VE. The human beings are represented by agents during the formation process and thus the agents that represent them must reflect the characteristics of a human being that are relevant to a VE. Some of these characteristics are harder to represent than others. For example, the commitment and reliability of a person is not easy to convert to a quantitative value. How do we represent characteristics such as the style of management preferred by a person or the level of empowerment s/he is used to? In addition to these individual characteristics, we also need to consider the characteristics of an individual that are relevant for a team. This requires an understanding of team dynamics and how the individuals affect the team dynamics. How does the combination of human beings and agents affect the team dynamics? Another important issue is the level of autonomy given to an agent. Since agents are representing human beings and conducting sophisticated negotiations on their behalf to support the decision making process, the level of autonomy must be adjustable [15].

In a web services-oriented view of the VE, it is important to consider the partners of a VE as service providers and consumers. Although web services have been widely discussed, their definition is still vague. (e.g. [8] and [17].) However, from a wider point of view, the term web services denotes an abstraction of a set of computational and/or physical activities intended to fulfill a class of customer needs or business requirements, [4]. We consider a web service as a functionality which has an interface that can be discovered and accessed through the web. The service can be fulfilled by either a human resource or a computational resource (agent). An example of a service fulfilled by a human resource could be the logistics in the VE. Web services that refer to human resources are, in general, more difficult to define, retrieve and execute than the web services that refer to computational resources.

5. CHALLENGES

In this section, we consider the main challenges in supporting the formation of VEs. We consider the challenges in the light of work that is being done in the area of web services.

1. The first challenge is to **support the heterogeneity** of the agents that represent the partners of a VE. The global setting for a VE means that the different agents are designed and developed by different sources. The arena (e.g. a market place) for the agents to meet to compete for VE partnership must be accessible (easy to find and register) to all agents that want to participate. This requires a universal catalogue of agents and a set of protocols to define agents. The Agentcities initiative is a step towards meeting this challenge, [19]. In addition to the heterogeneity of the agents themselves, the services provided and consumed by these agents may be combinations of different types, e.g. computational and human. Most researchers just consider the services as a computational resource.
2. Current **representation languages are not sufficient** to capture the semantics of the VE and the structure of the services that compose it. This challenge arises due to the varied nature of the partners of the VE, where the partners could be a team of human beings, enterprises, agents or a combination of these. The input and output parameters for defining the services are not sufficient to describe all the services, especially those that are related to human resources. For example, the Polymorphic Process Model (PPM) defines a placeholder activity for dynamic selection and composition of services. A placeholder activity is an abstract activity replaced at runtime with a concrete service activity that has the same input and output data as the defined placeholder, [16].
3. Selecting of services is based on **attribute matching and not semantic matching**. While the issues faced by the description, integration and execution of computational resource-based services are only partly resolved, these issues become more complicated and challenging when we combine computational and human resources. Attribute matching is not enough to meet the requirements for resource matching and selection in a VE. An improvement to the current situation is proposed by [7], as a model using a type tree (ontology) to organize relationships and levels of concepts that could be used for matching. This helps deal with semantic conflicts, but not matching services that are represented by different ontologies.
4. The formation of the VE is the composition of the VE team, which can be seen as the **integration of the services** that have been selected. Current trend is to use workflow models for the definition of the control flow and data flow among the services [4]. However, considering the heterogeneity of the VE services, the traditional workflow systems are not very effective in addressing the needs of composite services among the heterogeneous partners. One challenge is the need to harmonize the different workflow models, processes and the representation formats. Another challenge is the

invocation and interaction of the services within a VE. Currently, several glue methods that could invoke the computational services sequentially and transfer the output of one service as input to another service are available, e.g. [1]. However, additional research is still needed on the interaction between human resources and computational resources.

6. SUMMARY

In this paper, we have identified an important requirement that has been overlooked in the current agent-based applications of VEs and web service initiatives. Current efforts consider a VE as consisting of computational resources and not as a combination of computational and human resources. Based on this observation, we have outlined a list of challenges that are faced by VEs.

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