Using Agents to Support the Selection of Virtual Enterprise Teams

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ABSTRACT

Virtual Enterprises are dynamically constituted by individual entities that come together as a team to achieve specific goals. This dynamic nature imposes strong demands on the formation of the Virtual Enterprise since the capability of effectively putting together the best team of individuals is key to the success of the Virtual Enterprise itself. In this paper, we propose an agent-based model to support the formation of Virtual Enterprises. In our approach, each individual entity is represented by an agent who, in the context of an electronic market place, competes to become partners of a VE. The paper describes the attributes of the agents that are required and the issues facing the selection of the partners. In particular, it stresses the need to select partners by considering not the individual entities alone, but also how they can contribute to the desired *team of partners*.

KEYWORDS

Virtual Enterprise, Team Formation and Electronic Markets

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. The concept of a Virtual Enterprise (VE) has emerged as a means of dealing with this new type of alliance.

A VE can be described as a scenario that emerges in a world where individual entities, human beings, software agents or organisations, come together as a team to achieve a specific goal. There have been several attempts at defining VEs from different research communities and there are several definitions of the concept as summarized in [15]. VEs can be characterised as a network of independent (heterogeneous) individuals or enterprises [10]. VEs exist for a limited amount of time, [7], [14]. The entities that constitute the VE are the partners of the VE. The partners collaborate among themselves [5], are goal-oriented [16], commitment-based [11] and share their skills, costs, profits, risks and markets [4].

The partners 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, they are a *team of partners* that have common goals and are committed to fulfilling these goals. Thus, the success of the VE is strongly dependent on the commitment, the performance and the delivery capabilities of its partners. In this paper, we consider VEs where the partners are human beings.

One of the most important stages in the lifecycle of the VE is the formation of the VE. Since VEs have a limited lifetime, 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. An important part of the formation of the VE is the selection of its partners. They are selected on the basis of their ability to fulfil the requirements of the VE. Since all the partners have to work as a team, these requirements must address not only the individual partners of the VE, but also how the partners fit into a team. When selecting a team of partners from a global resource pool, how can we determine the *best team*? What is *best* in this situation? In order to be able to define this, we need to have answers to questions such as what do we require from the partners? What are the attributes we're looking for in the partners? How can we judge each partner or a team of partners? How can we compare two partners or two teams of partners?

Some of the above information may not be available apriori or may evolve during the selection of the partners. Another issue in defining some of the above information is the fact that partners are human resources. While the capabilities of a human being can be expressed in quantitative terms, not all aspects of their behaviour, in particular their cooperative behaviour can be expressed so clearly. This makes it harder to express the attributes of the desired partner and the desired team in clear unambiguous terms.

It is also important to bear in mind that the formation of the VE is one of several phases in the life cycle of the VE. The lifecycle of a VE can be analysed using ideas from Enterprise Modelling and Enterprise Reference Architectures (e.g. GERAM, Generic Enterprise Reference Architecture and Modelling, [12]).

Fig. 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. During the formation stage of a VE, the individual entities compete and negotiate to become the partners of the VE. When the VE is formed, the partners that have been selected constitute the VE and work together to deliver to the customer.

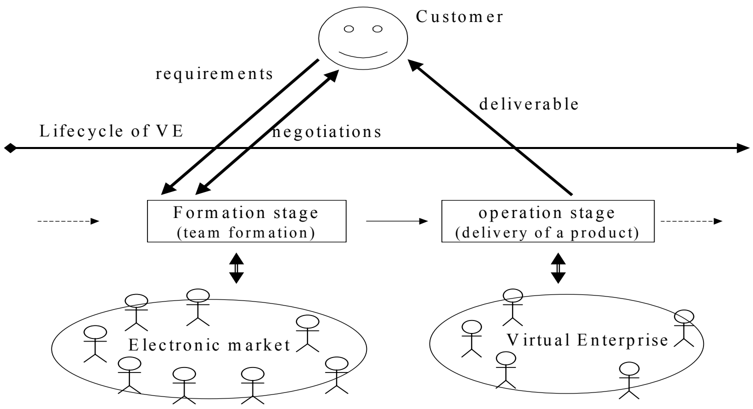

Fig. 1. Formation of a VE from a lifecycle perspective

We have chosen agents as the solution technology for our work, where software agents (hereafter referred to as agents) represent the partners of a VE. The distributed nature of agents does not require the co-location of the partners of a VE. 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. Another important aspect of using agents is that ideas from e-commerce and electronic market places have been considered as a suitable means of supporting advanced inter-organisational relationships and bringing together individual entities that want to form a VE [18]. In this respect, the agents can operate within the context of an electronic market during the formation stage of the VE, as illustrated in Fig. 1.

This paper considers a VE where individual entities compete to become partners of a VE. The partners of the VE are represented by software agents. The formation of the VE is supported by providing decision support to select the best team of partners for a specific VE. We discuss the issues faced in the selection of the partners. We also propose that the selection of partners by considering individual partners alone does not necessarily result in the best *team* of partners for the VE and we describe an example of selecting the partners for a VE. The remainder of this paper is organised as follows: Section 2 describes an agent-based model for the VE, the agents and their attributes in detail; Section 3 describes the process of selecting a team of partners for the VE; Section 4 describes an example of the formation of a VE; Section 5 reviews some of the literature that is related to this work and Section 6 discusses the conclusions and the work that is planned for the future.

2. Model Overview and Agent Attributes

In order to support the rapid formation of VEs, a model that describes the complete VE in terms of its entities and the relationships among them is important. An agent-based model for VEs is proposed in [16]. Fig. 2 shows the different entities that are in the model and their relationships. A VE has a *goal* (or a set of goals) that is/are achieved by a set of *activities* that are performed by *roles* which are filled by *agents*. A role requires a certain set of *skills*. The agent that fills the role meets the skills requirement. The entities in the model are described using attributes; the relationships among the entities are represented using predicate calculus and a set of rules represent how they can be used. One of the strengths of this model is the fact that the entities are not only described by how they relate to or depend on each other, but also by considering the internal contents of them in terms of attributes.

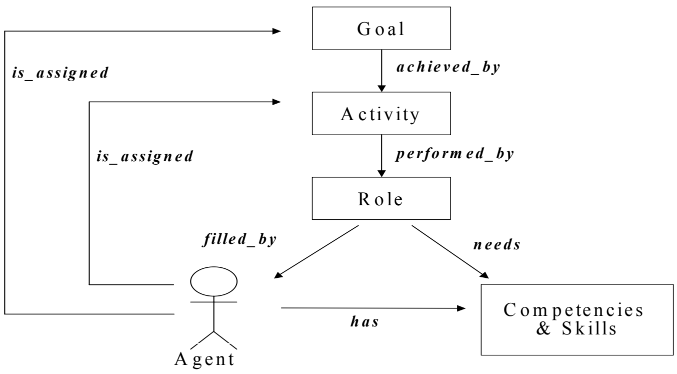

Fig. 2. VE Model Overview & Scenario

In this paper, we focus on the contents of the model that are relevant for the formation of a VE. However, it is important to consider the complete model to be able to understand how the different entities affect one another. For example, how does the selection of a particular agent affect the goals of the VE? Such a question can only be answered if we see the link from the agent to the goals of the VE. A complete model is also helpful in determining the kind of information that is flowing among the different entities. This in turn helps in designing the agents and the communication and collaboration among the agents.

The agents can be classified as *VE Intiator* (who may also be the customer), who takes the initiative to form the VE and *Partner* (who may also be the VE Initiator), who are the people that form the VE. A Partner evolves from someone that is interested in becoming a part of the VE to someone who is actually a part of the VE. During the formation of a VE, the partners go through the following stages (see Fig. 3 for an illustration of these stages):

- Interested Partner – one that is interested in becoming a part of the VE and submits a bid for the work.

- Potential Partner – one that is considered for the VE and a contract is negotiated.
- VE Partner – one that is selected as part of the VE team after a process of negotiation.

The agents are described by a set of attributes and these attributes form the basis for the evaluation of the agent as a partner in the VE and during the selection of the VE team. We do not consider the complete model of the agent. Rather, we consider the attributes that are required for the agents to propose a bid and negotiate to become a partner in the VE. An agent representing the VE Initiator is described by the attributes shown in Table 1.

Table 1. Attributes of the VE Initiator

Attribute	*Description*
Goal(s)	The VE's goal(s)
Availability	The time frame that the partners are required for, i.e. the time frame for the VE.
VE requirements	The skills and other information that are required by the VE and the constraints on these attributes.
Deadline	Bid closing date

An agent representing a VE Partner is described by multiple attributes, some of which may in turn be described by a set of attributes themselves, e.g. a particular skill of an agent. Each attribute is weighted to calculate a utility value that is used in the selection process. Table 2 shows the set of attributes describing an agent representing a VE partner.

Table 2. Attributes of a VE Partner

Attribute	*Description*
Goal(s)	The partner's goal(s)
Availability	The time period that the partner is available to do the work.
Skill(s)	Something that the partner can do, e.g. java programming
No. of skills	The no. of things that the partner can do.
Cost per hour	How much the partner expects to be paid for each hour of work.
Total no. of hours	The total no. of hours that the partner takes to perform the job.
Performance rating	Indication of how efficient the person is at performing a specific task.
Level of commitment	How committed the partner is at doing the work.
Risk	The risk(s) involved in including a partner in the VE.

The skills of a VE Partner (or an agent) are described as a set of multiple attributes that have constraints. Each agent may have one or more skills, each of which can be described by the attributes skill, (e.g. java programming), no. of years of experience, (e.g. 2) and skill rating, (e.g. [1-10]). Examples of some constraints for these attributes are the minimum no. of years of experience that is required for a skill or the lowest acceptable level of skill rating for a skill.

Some of the attributes given in Table 2 are not easy to represent in quantitative terms (e.g. commitment). In order to be able to create a quantitative model that can be used in multi-attribute negotiations, we have tried to come up with a quantitative value for the attributes. We have detailed some of the attributes as follows:

- *Availability* – the time period that the partner is available. The availability of a partner is matched against the time that the VE Initiator needs a VE team. This value is constrained by a start date and an end date.
- *The total cost of having a partner* – the total cost charged for doing the job (total no. of hours * the charge per hour).
- *Level of commitment* – is measured in terms of a "commitment breaking cost" which is the cost that the partner must pay to the VE if the partner breaks the commitment before the goals of the VE are achieved. Thus, the higher this value is, the more preferable for the VE. We have expressed this as a percentage of the total cost. (In reality, this may not be so rigid as the commitment breaking cost may be a function of the status of the activity as well.)
- *Risk* – the risk of having a partner is simplified as (the total cost of having a partner – the commitment breaking cost). Thus the higher the commitment breaking cost, the lower the risk.

3. Selection of VE Partners

3.1 Selection Process

Fig. 3 gives an overview of the selection process. The first subprocess "align goals" is to check if the goals of the VE and the goals of the partner are aligned. If this is true, the partners now becomes Interested Partners and their skills and availability are matched against the requirements of the VE in the subprocess "match skills and availability". The skills are matched by conducting a string match. The Interested Partners are now Potential Partners and their individual bids are evaluated and ranked in the subprocess "Individual bid evaluation". The best set of partners selected by considering individual bids may not necessarily be the best team. (We discuss this further in Section 3.4.) Therefore, a fourth subprocess, "Select team", is included where the Potential Partners are considered as a team during the selection.

The first 3 subprocesses consider individual partners while the fourth subprocess considers a team of partners and the evaluation is conducted based on different criteria.

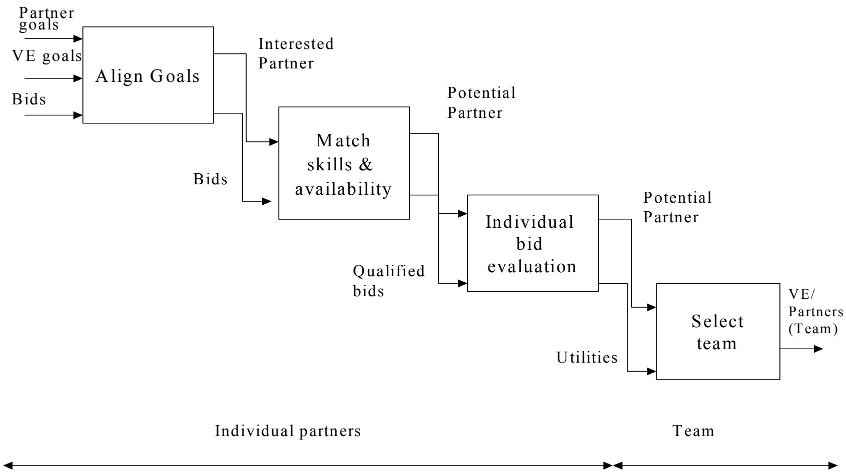

Fig. 3. Selecting partners for a VE

3.2 Communication

Fig. 4 shows the communication that takes place between the VE Initiator and the Partners. The VE is announced by inviting Interested Partners to bid and the announcement contains the following information:

- The goals of the VE
- The skills that are required for the VE
- The time frame for the VE
- The deadline for the response to the announcement

The Interested Partners respond to the announcement by sending in a bid, which contains the following information:

- The goals of the partner
- List of attributes and their values (the attributes include the skills of the partner)

The bids are qualified if the goals are aligned and a minimum no. of skills are matched. Skills that do not match are ignored. The bids that are disqualified are informed of their failure to qualify and the VE Initiator then prepares to negotiate with the partners that submitted bids that qualified; i.e. the Potential Partners.

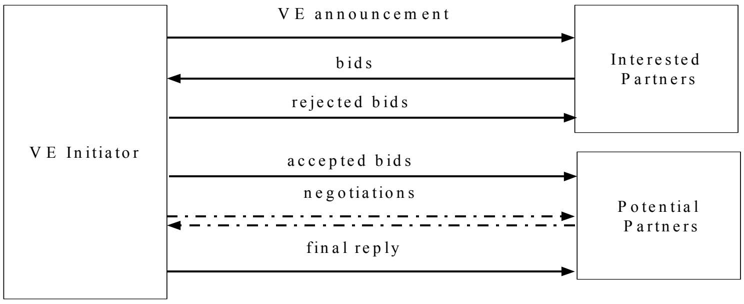

Fig. 4. Communication during the formation of a VE

In addition to the above information, both the announcement and the bid will carry the name, identification and address of the sender and receiver agents. But since we're not considering a specific implementation of a multi-agent architecture, the details of this information have been left out.

3.3 Bid Evaluation

The bids are evaluated using a multi-attribute utility function. For each qualifying bid, the attribute values are checked to see if they meet the constraints. If the values do not meet the constraints, then they are assigned the value zero. Each attribute is weighted and the utility function is as follows:

$$\text{Utility Value} = \Sigma(\text{attribute value} * \text{weight})$$

Since the values may span a wide range, the values are normalised before the calculation. The utility values are calculated for all the qualified bids and the values are ranked, where the highest utility value is at the top. This list is then submitted to the VE Initiator. The VE Initiator can then choose the best (highest ranked) Potential Partners for the VE or s/he can choose to negotiate with the Potential Partners for a better bid. Instead of selecting a number of highest ranked Potential Partners, the VE Initiator can also choose the best team for the VE.

The evaluation is based on the set of attribute values that are included in the utility function and the weights that are assigned to them. The utility function can be changed by choosing a different set of attributes and/or by changing the weightings that are assigned to the attributes.

3.4. Team Selection

We believe that the concept of a team is an important point in forming a VE as the partners have to collaborate and work together as a team to achieve the goals of the VE. Therefore, we consider the selection of the team as a separate subprocess in the selection of the partners and consider the attributes of a team rather than the attributes of an individual in the utility function to determine the best team of partners.

The selection of the best team can be based on several criteria and the best team may not always be the team that consists of the highest ranked Potential Partners. For example, a VE may have constraints such as a total budget that the VE Initiator can pay its partners. There may be other such constraints. In the example in Section 4, we have considered the following attributes as the main factors determining the utility function for the selection of a team:

- The total cost of the partners in a team.
- The total risk of having the partners in the team.

Consider the situation where the VE is looking for a set of skills that several people possess and the variation of the level of the skill is not so high. In such a situation, the skills of the partner may not play such an important role in selecting the team, whereas the cost of hiring the people may play a bigger role. Another situation could be where we are looking for very specific skills and the degree of variation of the skill level is high. In such a situation, the skill of the partner may play a more significant role than in the previous situation. Therefore, in this situation, a higher weight might be put on the skills of the partner.

Due to the reasons explained above, we also believe that the attributes that define the best team for a VE cannot always be defined apriori and there is often a need to change or redefine the utility function to select a team during the selection process. Therefore, it becomes necessary to support this flexibility in defining the utility functions that are used in selecting both individual partners as well as the team of partners. This is one of the areas where we continue our research.

3.5. The role of Negotiation

Negotiations can take place in several places:

1. The VE Initiator negotiates with the Interested Partner on the initial bid (using the lowest values based on the bids from all the Interested Partners). This would mean that the ranking is done based on the last (best) offers made by the Interested Partners.
2. The VE Initiator negotiates with the Interested Partner on selected attribute values after the ranking. e.g. the highest ranked Potential Partners may not fulfil the cost constraint of the team. Thus, the VE Initiator may negotiate with the highest ranked (or all of the) Potential Partners to reduce their costs and risks.

Negotiations are based on a multiple set of attributes and the aim of the negotiation is to obtain a set of attribute values that are at a pareto optimum.

4. Example

Consider a VE formed to design the Internet homepage for a company, [3]. The VE Initiator is looking for 2 partners with the relevant programming skills. IP-A, IP-B, IP-C and IP-D are Interested Partners and they bid to become a part of the VE. The attributes and the values for each partner that are considered for the evaluation and the constraints and the weightings that are applied in the utility function are shown in Table 3.

Table 3. The attributes, their utilities and weightings

Attribute (Constraints), (Weightings)	***IP-A***	***IP-B***	***IP-C***	***IP-D***
Area of relevant skills (HTML, XML, Java), ()	Java, XML	HTML, XML	Java, XML, HTML	Cobol, HTML
For each skill:				
No.of years of experience (>=2), (50)	5,6	4,3	5,3,5	10,2
Skill rating (>=6), (50)	10,9	8,3	6,6,6	10,2
Performance rating (>=6), (30)	9	6	8	9
No. of relevant skills (>=2), (5)	2	2	3	1
Availability (calculated) (), (25)				
Start date (1.11.01), ()	1.10.2001	1.10.2001	1.10.2001	1.10.2001
End date (1.12.01), ()	1.1.2002	1.1.2002	1.1.2002	1.1.2002
% time available	100	80	50	100
Total Cost (calculated) (), (25)	48,000	38,400	36,000	40,000
Cost per hour (<NOK500), ()	300	300	450	250
Commitment breaking cost	50%	35%	35%	10%
Risk for the VE (calculated) (), (15)	24,000	24,960	23,400	36,000

In this example, we assume that the goals of the Interested Partners are aligned with the goals of the VE. So, the next step is to conduct the skills matching. This is done by matching the skills of the Partners against those that are required by the VE and then checking the no. of skills that are relevant. It can be seen that IP-D does not meet the minimum no. of skills that are required and will not be considered in the evaluation. The utility values are calculated using the following equation:

Utility Value for each partner = (skills_value*35%) + (cost_value*25%) + (risk_value*15%) + availability_value*25%)

By calculating the utility values for each partner, we get the following ranking:
IP-A: Utility = 101, IP-C: Utility = 94, IP-B: Utility = 68

Based on this evaluation, the VE Initiator could choose IP-A and IP-C to form the VE team. A team, however, is not necessarily based on the same kinds of attributes that were considered for the above ratings; i.e. the best team could be based on a different utility function. In this example, we have considered the combined cost of the team and the combined risk of the team as the factors defining the utility function for the team. The utility value for a team is calculated using the following equation:

Utility Value for a team = (total_cost_value*70%) + (total_risk_value*30)

Using the values and weightings shown in Table 4 to calculate the utility value for each combination of the team consisting of 2 partners, we get the highest utility value for the team consisting of IP-B and IP-C.

This simple example demonstrates that the highest ranked partners don't necessarily form the best team. Thus, it is important to support both these steps so that the VE Initiator has the possibility to select the best team. Supporting both these steps also demands the need for the flexibility to define a different utility function for teams.

Table 4. Attributes of teams for the VE

Team combination	*Total Cost (max. cost),(weighting=70)*	*Risk for the VE (max. risk),(weighting=(30)*	*Utility Values*
IP-A and IP-B	48,000 + 38,400 = 86,400	86,400 – (48,000*0.5 + 38,400*0.35) = 48,960	23
IP-A and IP-C	48,000 + 36,000 = 84,000	84,000 – (48,000*0.5 + 36,000*0.35) = 47,400	25
IP-B and IP-C	38,400 + 36,000 = 74,400	74,400 – (38,400*0.35 + 36,000*0.35) = 48,360	31

In this example, the two steps are shown in isolation and therefore, the ranking of the partners may appear to be redundant. However, given the variety of situations where the formation of a VE takes place, it is desirable that the system provides the VE Initiator with as much information as possible. It is then the responsibility of the VE Initiator to evaluate the information depending on the specific situation. Alternatively, it is possible to connect the two steps directly to include the ranking as a parameter in the utility function to determine the best team.

5. Related Work

An important contribution in modelling enterprises was made in [8], where a formal description of an enterprise was given. This work was later developed to describe how the structures of an enterprise could be linked to its behaviour, by using agents and ontologies [9]. Although this work does not address the particular concept of VEs, it provided the foundation for our model of a VE.

Agents have been used to support VEs in several applications. In [2], agents were used to represent the different entities in a distributed supply chain (e.g. supplier) and in [11], the notion of commitments is used to manage the autonomy of an agent in a VE. Mobile agents also have been applied to represent VEs. Examples of such applications are described in [1] and [21].

Of particular relevance to our work is the work done in representing VEs within the context of an electronic market. The AVE (Agents in Virtual Enterprises) project, described in [7], provides a description of how agents can be used in the formation of a VE. One of the main components of the system that was proposed is an electronic VE market, where different enterprises can announce and obtain various information. This approach was further developed as a multi-agent architecture in [14] with focus on the formation of the VE, where agents that represent the partners of a VE negotiate to become a part of the VE. The agents conduct a multi-attribute negotiation and have the ability to learn from past experiences. While this work considers a wider aspect of multi-agent systems, it does not describe a holistic model of the VE and does not address the aspect of a team formation explicitly.

The concept of a team is used in [23], which describes a framework for finding the right agent for an organisation in cyberspace. Their work focuses on enabling software developers to build large-scale agent organisations in cyberspace. The system provides a means of defining organisation roles and their requirements and matching agents that meet these requirements. More recently, there has been work done in immersing a team of agents within a human organisation [17]. The multi-agent system, RETSINA provides matchmaking capabilities that have been used to match a requester and a service provider, through a middle agent, [19]. These capabilities have been used in AgentStorm to form a team of agents that provide support to human beings, [20]. While these works deal with issues that are relevant to our model of the VE, they mainly address the possibility and capability of an individual to join a team and they do not consider the team as a whole, trying to optimize its composition. In this perspective they can be considered as complementary rather than alternative approaches to the one presented in this paper.

Contributions have been made by the DAI community to define teams and teamwork. Most of this work is based on agent theory and is aimed at providing support to the design of teams of agents. For example, a means of forming teams of agents at runtime is described in [24]. Here, a team is defined in terms of a joint plan and the execution of a joint plan. It also suggests some strategies for the formation of teams. Other models of teamwork include STEAM [22] and team formation by dialogue in [6]. These models are designed to support the automation of teamwork and use the notion of joint plans and plan execution and rely on tasks that are well-described apriori. In our model, we use the notion of activities, which is inspired more by the Enterprise Modelling community rather than the DAI community. The entity activity in our model is a higher-level concept that denotes some work that needs to be performed by the team. Since the objective of our work at this stage is not to automate these activities, we have not considered activities within the context of plan execution. We believe that the activities of a VE cannot always be described completely nor automated, partly because some of these activities are performed by human beings.

6. Conclusions

The main contribution of this paper lies in the description of a VE as a team of partners and how the potential partners of a VE can be represented by agents during the formation of the VE. The formation of the VE is supported by providing decision support to select the best team of partners for a specific VE. The paper describes in detail the attributes of the agents that are required and the issues facing the selection of the partners. It also proposes that the selection of partners by considering individual partners alone does not necessarily result in the best *team* of partners for the VE and illustrates this through a simple example.

The ideas presented in this paper have been implemented in JAVA. The implementation consists of a module that takes the attributes, their values, constraints and weightings and performs the bid evaluations. The output is a list of Potential Partners that are ranked according to the evaluation. Similarly, an evaluation for the best team is also conducted. This module is designed as a calculating mechanism that can be used within a multi-agent architecture. Our next step is to incorporate it into the AGORA multi-agent architecture, which is designed to support distributed working, [13]. Although we have chosen a particular multi-agent architecture, this module is designed such that it can be used by any architecture that is built around the concept of electronic markets.

Our main area of research will be in completing the model of the VE, in particular the attributes of the agents representing the VE and some of the “soft attributes” of an agent such as personality and management related ones, e.g. the style of management that a partner is used to or the level of empowerment that a partner works best at. We also need to address the cooperative and collaborative capabilities of a partner and how to represent them. Further enhancements of the model will be done based on industrial case studies.

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8. References

1. Ambroszkiewicz, S., Cetnarowicz, K. and Radko, B., Enterprise Formation Mechanisms based on Mobile Agents. In Holsten, A. et al. (eds.), *Proc. of the Workshop on Intelligent Agents in Information and Process Management*, KI'98, TZI-Bericht no.9-1998.
2. Barbuceanu, M. and Fox, M.S., The Information Agent: An infrastructure agent supporting collaborative enterprise architectures, In *Third Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises*, 1994.
3. Benes, L. D. and Meyer, M., GOPAMAN Multi-attribute Decision Making and Negotiation. *MSc Theses*, Norwegian University of Science & Technology, Trondheim, Norway, Dec. 2000.
4. Byrne, J. A., Brandt, R. and Port, O., *The Virtual Corporation*, Business Week, February 8, 1993, p. 36-40.
5. Childe, S. J., The Extended Enterprise - a Concept of Co-operation, *Production Planning & Contro*l, 1998, Vol.9, No.3, p. 320-327.
6. Dignum, F., Dunin-Keplicz, B. and Verbrugge, R., Agent Theory for Team Formation by Dialogue, *Intelligent Agents VII, Agent Theories Architecture and Language (ATAL2000)*, LNAI 1986, Castelfranchi, C. and Lesperance, Y. (eds.), 2000, p. 150-166.
7. Fischer, K., Muller, J. P., Heimig, I. and Scheer, A., Intelligent Agents in Virtual Enterprises, 1996. *Proc. of the First International Conference and Exhibition on The Practical Applications of Intelligent Agents and Multi-Agent Technology*, U.K.
8. Fox, M., Barbuceanu, M. and Gruninger, M., An Organisation Ontology for Enterprise Modelling: Preliminary Concepts for Linking Structures and Behaviour, *Computers in Industry*, Vol. 29, 1996, p. 123-134.
9. Fox, M. and Gruninger, M. Enterprise Modelling, *AI Magazine*, AAAI Press, Fall 1998, p. 109-121.
10. Jagdev, H. S. and Browne, J., The extended enterprise - a context for manufacturing, *Production Planning & Control*, 1998, Vol.9.No.3, p. 216-229.
11. Jain, A. K., Aparicio IV, M. and Singh, M. P., Agents for Process Coherence in Virtual Enterprises, in *Communications of the ACM*, March 1999, Vol. 42, No. 3, pp. 62-69.
12. IFIP-IFAC Task Force, GERAM: Generalised Enterprise Reference Architecture and Methodology, Version 1.6.2, available from http://www.cit.gu.edu.au/~bernus/
13. Matskin, M., Divitini, M. and Petersen, S. A., An Architecture for Multi-Agent Support in a Distributed Information Technology Application. *International Workshop on Intelligent Agents in Information and Process Management on the 22nd German Annual Conference*

on Artificial Intelligence in Bremen (KI-98), TZI-Bericht Nr. 9, Germany, 15-17 September, 1998, p. 47-58.
14. Oliveira, E. and Rocha, A. P., Agents' Advanced Features for Negotiation in Electronic Commerce and Virtual Organisation Formation Process*, European Perspectives on Agent Mediated Electronic Commerce*, Springer Verlag, June 2000.
15. Petersen, S. A., Extended and Virtual Enterprises – A Review of the Concepts, Technical Report 2/02, Dept. of Computer and Information Sciences, Norwegian University of Science & Technology, Trondheim, Norway, ISSN-NO:0802-6394, 2002.
16. Petersen, S. A., Gruninger, M., An Agent-based Model to Support the Formation of Virtual Enterprises, *International ICSC Symposium on Mobile Agents and Multi-agents in Virtual Organisations and E-Commerce (MAMA'2000)*, in Woolongong, Australia, 11-13 Dec. 2000.
17. Pynadath, D., Tambe, M., Arens, Y., Chalupsky, H., et. al., Electric Elves: Immersing an Agent Organisation in a Human Organisation, *Proceedings of the AAAI Fall Symposium on Socially Intelligent Agents --- the human in the loop*, 2000.
18. Rocha, A. P. and Oliveira, E., Electronic Commerce: a technological perspective, in *The Future of Internet*, March 1999.
19. Sycara, K., Lu, J., Klusch, M. and Widoff, S., Matchmaking Among Heterogeneous Agents on the Internet. *Proceedings AAAI Spring Symposium on Intelligent Agents in Cyberspace*, Stanford, USA, 1999.
20. Sycara, K. and Giampapa, J., AgentStorm, MURI: Integrating Intelligent Agents into Human Teams, 2000, available from http://www-2.cs.cmu.edu/~softagents/presentations/AgentStorm.ppt
21. Szirbik, N. B., Hammer, D. K., Goossenaerts, J. B. M. and Aerts, A. T. M., Mobile Agent Support for Tracking Products in Virtual Enterprises. *AGENT'99*, Seattle, USA, May 1999, Workshop Notes, ACM.
22. Tambe, M., Towards Flexible Teamwork, *Journal of Artificial Intelligence Research*, Vol. 7, 1997, p. 83-124
23. Tambe, M., Pynadath, D. and Chauvat, N., Building Dynamic Agent organizations in Cyberspace, *IEEE Internet Computing* (to appear).
24. Tidhar, G., Rao, A. S., Ljungberg, M., Kinny, D. and Sonenberg, E. A., Skills and Capabilities in Real-Time Team Formation, Technical Report, No. 7, Australian Artificial Intelligence Institute, 1992.