REQUIREMENTS FOR AN AGENT-BASED APPROACH TO SUPPORT VIRTUAL ENTERPRISES

Sobah Abbas Petersen¹, Geir J. Husøy², Edgar Karlsen², Mihhail Matskin³

¹ Dept. of Computer and Information Science, Norwegian University of Science and Technology, Trondheim, NORWAY, Email: sap@idi.ntnu.no

² The Organisation Development Alliance AS, Akersgaten 43, 0158 Oslo, NORWAY
Email: {geir.johan.husoy,edgar.karlsen}@oda.as

³ Dept. of Microelectronics and Information Technology, Royal Institute of Technology, SE-164 40 Kista, SWEDEN, Email: misha@imit.kth.se

In this paper, we present the requirements for an agent-based approach to support the formation of Virtual Enterprises by analysing the approach using two industrial case studies. We believe that there are two important aspects of selecting the partners for a Virtual Enterprise; (i) matching the correct partner to the requirements, and (ii) the process in which the partners are evaluated and selected. Our analysis showed that the system must provide support for a language to represent the capabilities of the partner, the evaluation of different kinds of partners, flexibility in defining the evaluation criteria, the selection process and the negotiation process.

1. INTRODUCTION

A Virtual Enterprise (VE) can be considered as a scenario where a number of entities (organisations, software agents or human beings) collaborate to achieve a specific goal. There are several types of VEs, e.g. a consortium for one-of-a-kind manufacturing or a project group to take advantage of a particular market situation, [1]. The success of a VE is dependent on the performance of its partners. Hence, the formation of the VE and the selection of the partners for the VE is an important process in the lifecycle of a VE, [3].

In this paper, we analyse an agent-based approach to support the formation of VEs using 2 case studies. Our approach is aimed towards supporting the decision making process for human beings or organisations during the formation of VEs. We believe that software agents, hereafter referred to as agents, are a suitable means of representing the partners of a VE. Agents, by definition are able to support sophisticated interactions such as negotiations, [7]. By delegating the agents to conduct the negotiation on behalf of the partners, the partners could then have the time to do the actual work required in the current VE. We believe that there are two important steps in selecting the partners of the VE; (i) how well the partners meet the requirements of the VE and (ii) the process in which they are selected.

We describe the agent-based approach by using a simple hypothetical example of a VE, where we consider the roles of the VE, the requirements for the roles, the attributes of the agents and the selection process. In order to provide the right kind of support for the numerous VEs in the industrial world, we believe that such an approach must be applied to real situations. It is only through such evaluations that we will be able to obtain a true indication of the strengths and weaknesses of the approach and the requirements for such an approach.

In this paper, we present the requirements of an agent-based system to support the formation of VEs based on 2 industrial case studies. The remainder of this paper is organised as follows: Section 2 describes our agent-based approach, Section 3 describes the ODA model, section 4 describes the 2 cases, Section 5 describes the analysis of our approach using the cases, Section 6 presents the set of requirements based on the analysis, Section 7 discusses the work related to this and Section 8 discusses the conclusions.

2. THE AGENT-BASED APPROACH

Before a VE is formed, its concepts and goals have to be defined. The requirements from the customer sets the requirements for the VE partners and in order for the VE to be able to deliver to its customer, the right team of partners has to be formed. In developing the agent-based approach, the first step was to develop an agent-based model for a VE. The model can be used to define the goals, the activities and the roles that are required for the VE. Agents that meet the requirements for the roles can fill the roles. A detailed description of the model is available from [9]. Developing a model of the VE can be summarised as identifying the roles of the VE, the requirements for the roles and the attributes of the partners. The second step was to use the model to select the best team of partners. The selection process includes the alignment of the partners' goals with the goals of the VE and matching their attributes to the requirements for the roles.

Consider a VE formed to design the Internet homepage for a company. A *VE Initiator*, who decides to form a VE to perform this job, looks for 2 partners with the relevant programming skills. IP-A, IP-B, IP-C and IP-D are *Interested Partners* (ones that are interested in joining the VE) and they bid to become a partner in the VE. Each of these Interested Partners can be represented by an agent, which has a set of attributes that describes its skills and capabilities. Similarly, the VE Initiator can also be represented by an agent, which is described by a set of requirements for the partners' skills and capabilities.

The selection criteria can be based on a set of attributes of the Interested Partners and how well these attributes match the requirements. The attributes that we considered, based on industrial experience and literature, are the partner's goal(s), the time period that the partner is available to do the work, the specific skills of the partner, the cost of having the partner (based on the total no. of hours and the cost per hour), the performance rating which is an indication of how efficient the partner is at performing a task, the commitment of the partner to do the work and the risk(s) involved in including the partner in the VE. In addition, the selection of the best team can be considered using the total cost of the partners in a team and the total risk of having the partners in the team.

3. ODA MODEL

We have selected 2 cases where The Organisation Development Alliance AS (ODA), on behalf of a customer, evaluates a number of bids to select the best project team or the VE for a large scale project (ODA is the VE Initiator). ODA has developed a model to evaluate “integrated project teams”, a VE in which a group of partners that delivers to a customer and the customer work together for large scale projects. The evaluation method is focused on identifying potential risks and designing a project management strategy aimed at mitigating the risks. The ODA Model is based on understanding the preconditions for effective project execution. It identifies 3 main aspects that must be considered in the preparation and execution of evaluation; see **Figure 1**. The evaluation criteria are tailor-made to the scope of work and the customer contract and execution philosophy. The aim is to identify the team or VE with the best capabilities to execute the scope of work in question within the established framework. The main aspects of the ODA Model are, [2]:

1. **Incentives** - the risk and reward structure.
2. **Trust** - the ability and attitude to work in close co-operation.
3. **Authority** - the co-operation model, e.g. the type of alliance.

Figure 1: ODA Model and corresponding Evaluation Criteria

Based on this model, ODA has developed a set of criteria, for evaluating and selecting partners, which is tailor-made for each evaluation. (The details of defining the specific evaluation criteria from the ODA Model are beyond the scope of this paper.) The incentives, contract and execution philosophy must be established prior to the evaluation process. If a customer wants a closely integrated framework, the experience and attitude of the potential partner(s) to work integrated with the customer will be a critical evaluation criterion. The evaluation criteria can be broadly categorised as contract, social issues, and organisation, where each of these categories can be described in detail with a set of attributes that reflect the requirements for the partner. These 3 criteria can be described as follows:

1. **Contract** - corresponds to incentives, describes the suggested contractual model, which includes the details of execution of the work.
2. **Social Issues** - corresponds to trust, describes attitude towards working integrated.
3. **Organisation** - corresponds to authority, describes the project organisation, the proposed co-operation model and the individual and team competence.

4. DESCRIPTION OF THE CASES

An overview of the 2 cases is given in Table 1. Since our aim is to identify a general set of requirements, we have chosen 2 cases from 2 different application areas.

Table 1: Overview of the Cases

<i>Characteristics</i>	<i>Case 1</i>	<i>Case 2</i>
Industry/domain	Oil and gas	IT
Purpose	Increase production through water injection	Increase efficiency through new hardware and software support
Scale (\$)	300 million	35-40 million
Expected duration of the VE	4 years	3 years
Time taken for VE formation	4-6 weeks	4-6 weeks
No. of partners in VE	2	2
Kind of partners	Individual companies	Consortium
Specialisation of the skills in the VE (High, Medium, Low)	High	High
Complexity of the VE (High, Medium, Low)	High	High

4.1 Case 1

Case 1 is taken from a capital project in the oil and gas industry, with the objective to facilitate increased production through a new water injection platform and modifications to existing installations. The main focus of this evaluation is to select the partners that show most motivation to work with the customer, as a VE.

Selection Criteria: The selection criteria were categorised into 4 groups:

1. The proposed contractual framework between the partners of the VE and the VE and the customer. This included details about the execution of the work as well as issues such as the distribution of risks and profit.
2. The experience of the partner.
3. The organizational model of the VE and the skills and competencies of the individual members within each partner organisation.
4. Social issues or team and collaborative aspects which describe how the VE will solve a problem collaboratively (e.g. with the customer or sub-suppliers).

Selection Process: The selection process consisted of evaluating each interested partner against the requirements to select some potential partners. Then, they were called in for interviews and to a workshop to solve a problem collaboratively. A number of issues, such as price, incentives and bonuses, change of personnel, improvement of services, and other terms and conditions of the contract, were then negotiated upon before the final selection was done. An overview of the selection process is shown in Figure 2.

Figure 2: Case 1: Selection Process

4.2 Case 2

Case 2 is based on a project aiming to upgrade software and hardware to all personnel of a large government body represented in all main rural areas of the country. In this case, ODA had to select a single partner. However, the potential partners consisted of several sub-departments within one organisation.

Selection Criteria: The selection criteria were categorised into 3 groups:

1. Price – the price of the infrastructure, the total package delivered.
2. The complete system where the development of the system was considered. In addition to how well the system met the requirements, the planning, organisation of the delivery team and the execution of the development project were also considered.
3. The long-term maintenance contract.

Selection Process: The selection process is similar to that of Case 1. However, in this case, the main purpose of the negotiation process was to agree upon the contents of the tasks to be performed by the VE, for a particular price. Also, the type of information that the potential partner is requested to submit for verification is different from that of Case 1. This is related to both the different scope of work and execution model chosen by the customer, which leads to different criteria and instruction to bidders.

5. ANALYSIS

In this section, we analyse our agent-based approach with respect to the 2 cases. Based on this analysis, we present the limitations and strengths of our approach and discuss how it can be used to support ODA in their evaluation and partner selection processes.

5.1 Analysis of our Approach

We have used our agent-based approach to model the 2 cases, where we focused on representing the requirements for the partners and the attributes of the partners. We then tried to see how the sets of attributes and the ODA selection process compared with those that were used for our simple example. By reviewing our approach in the light of the 2 cases, we were able to identify the following:

- **Representation:** The ODA evaluation criteria are very rich and cannot be represented by quantitative or qualitative information only. Since the agents represent human beings or organisations, the attributes reflect characteristics of human beings and organisations such as commitment and responsibility. In addition, the team dynamics also has to be considered. In our approach, we have tried to represent the attributes as quantitative values, which, alone, do not capture the richness of the evaluation criteria or the semantics of the attributes.
- **Attributes:** ODA has a very rich set of attributes that consider the individual aspects as well as the team aspects. The attributes are categorized into several groups whereas, in our example, we have considered one set of attributes.
- **Selection Process:** In both the cases, goal alignment was considered implicitly, by assuming that the potential partners had proposed a bid because the goals are aligned. In our approach, since we define a VE as a goal-oriented entity, we consider goal alignment as an important aspect and, thus, ask the Interested

Partners to submit their goals. Both the cases have an explicit information verification process where they conducted interviews and workshops with the Potential Partners. Note that our simple example did not illustrate the aspect of negotiation, although to facilitate negotiation is one of the main aims of this approach.

- **Type of partner:** The cases show that the partners of a VE could be a coalition of partners (i.e. a VE themselves). See **Figure 3**. Our approach considers one level of partners only, thus, assuming that all partners are individuals.

Figure 3: Type of Partner

5.2 Support for ODA's Evaluation Process

Based on the analysis of our approach with respect to the cases, we identified that our approach cannot be used to conduct the complete evaluation and partner selection process for either of the cases. However, it can be used to provide some degree of support for ODA such as to conduct a coarse prequalification of the partners. This is particularly important where there are a number of potential partners. This would make ODA's process more efficient and cost effective. By supporting a percentage of the evaluation criteria, (e.g. a subset of the requirements and the attributes), our approach can contribute to reducing the cost of conducting the evaluation. Thus, it would be interesting to see how much of the process can be supported by our agent-based approach and this will be the next step in our analysis.

The ability to support multi-attribute negotiation is an advantage of this approach, although, in the 2 cases considered, it was not so simple to identify exactly when negotiation takes place and to find simple attributes that were negotiated upon.

6. REQUIREMENTS

The analysis of the cases identified some limitations of our approach. Based on this, we can summarise the overall requirements for an agent-based approach as shown below. The approach must provide support for:

1. **A language to represent the capabilities of the partners** - the user must be able to represent the capabilities of the partners for all situations where the partners may be human beings, organisations, software agents or VEs.
2. **Flexibility to define the set of attributes** - the user must be able to define the set of requirements and the attributes as required for any VE situation.
3. **Flexibility to define the selection process** - the user must be able to define the selection process, i.e. to define when goals are aligned, what is matched and which attributes are negotiated upon and when. There is no universal

selection process. Thus, there is a need to be able to support a variety of processes, which can be defined by the user.

4. **Evaluation of partners that are coalitions or VEs** – situations where the partners that bid are VEs themselves and where the individual members within a coalition must be considered during the evaluation. In such situations, there is a need to be able to look into the coalition as well as obtain a collective view of the coalition.
5. **Flexibility in negotiation** – The user must be able to define when a negotiation should take place during the selection process, between which entities and upon which set of attributes.

7. RELATED WORK

Agents have been used to support the formation of VEs in several applications, e.g. in [11], where the notion of a broker is used. Of particular relevance to our work are the VE formation scenarios considered within the context of an electronic market place, e.g. [8]. In [4], the selection of partners for a VE was considered in terms of Web Services, where the issue of representation was addressed. They propose some essential characteristics of a matchmaking engine.

Some high-level requirements for modelling a VE are given in [1], and a set of open challenges in the area of VEs is listed in [3]. One such challenge is to provide support for the complete lifecycle of the VE. In this paper, we have focussed on the formation phase only. However, our approach can be extended to cover the full lifecycle, [9].

8. DISCUSSION

In this paper, we have presented the requirements for an agent-based approach to support the formation of a VE. The requirements are derived by analysing the approach using 2 industrial case studies. The analysis is based on the attributes considered in the evaluation criteria and the selection process. In addition to the requirements, we also discuss the limitations and the strengths of the approach.

In order to meet the challenging requirements, there is a need to be able to represent the partners of a VE as best as possible. One aspect of this is to understand the kinds of attributes that should be represented by studying more industrial scenarios. The other aspect is representation itself; enterprise ontologies, (see [5] for a discussion), are a means of achieving this. Agent architectures that allow flexibility in defining the set of attributes, the selection processes and the negotiation scenario are required. Similarly, means of managing and adjusting the autonomy of agents is important, (e.g. [6] and [12]).

During the analysis process, we also identified that although the approach does not fully support the complex evaluation criteria that were used in both the cases, it can still provide some degree of support. The next phase in our work will be to conduct a more detailed analysis of the cases to obtain a better indication of how much of the VE formation process can be supported by our approach.

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