Implementing Virtual Enterprises Using AGORA Multi-agent System

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Abstract. In this paper, we describe how the AGORA multi-agent architecture is used to support Virtual Enterprises(VE). Software agents represent the partners of a VE, who collaborate to achieve the goals of the VE. We consider the formation of a VE within the context of an electronic market place, where a number of interested parties compete to become a partner in the VE.

1 Introduction

In this paper, we describe how the AGORA multi-agent architecture can be used to support Virtual Enterprises (VE). We have focused on understanding how a VE is formed and, in particular, how the partners of a VE are selected. We try to analyse this scenario in the form of an Agent Interaction Protocol (AIP) and then discuss how the AGORA multi-agent architecrure can be used to support this process.

Our working definition of a VE is: *a team of partners that collaborate to achieve a specific goal*. The partners may be human beings, organisations or software agents. We believe that software agents, hereafter referred to as agents, are a suitable means of representing the partners of a VE. One important reason is that by representing the partners of a VE as agents and by delegating agents to look for the next VE and conduct the negotiation on behalf of the partners, the partners would then have the time to do the actual work required in the current VE.

AGORA is an agent infrastructure that supports the implementation of software agents and market places. We have used AGORA to support the formation of a VE, within the context of an electronic market place, (e.g. [6]). We focus on representing the goals and the capabilities of the partners that are interested in joining the VE and how they are matched to the requirements of the VE.

Our work is related to the following researches. [3], uses electronic market and auctions to select the VE partners. The selection process is to match VE goals(or subgoals) within the different enterprises. E-institutions [2], an institutionalized electonic organisation to design and construct agent societies, uses the idea of changing states by means of agent interactions which is similar to what we use in AGORA.

2 AGORA Multi-agent System

The AGORA system, [5] consists of *agora nodes* and *registered agents*. An *agora node* is a cooperative node which facilitates communication, coordination and negotiation among the agents. When an agora node is created, two default agents, *agora manager* and *negotiator*, are created and connected to the agora node automatically. A standard agora manager implements general management functions such as the registration of agents and matchmaking. The negotiator controls the negotiation process and protocol.

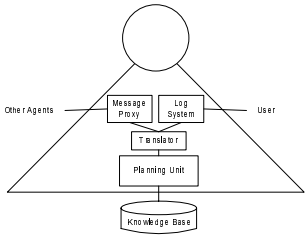


Fig. 1. Structure of an Agent

The structure of a single agent, either a default agent or a registered agent is illustrated in Figure 1. An agent uses the *Message Proxy* and the *Log System* to interact with the outside world. It communicates with other agents using FIPA ACL [1] and the messages are sent and received through the Message Proxy.

The *Log System* is the interaction channel between the agent and its owner, usually a human being. First, the user is able to monitor the executing status of an agent through the Log System. Second, the agent should be able to get instructions from the user at runtime. This is important for VE applications because, in many cases, the final decision is made by the user and not by the software agent.

AGORA uses a Prolog engine to implement the agent's knowledge base. The internal presentation of messages and rules is in Prolog. In order to integrate the FIPA message with the Prolog knowledge base, a *Translator* between FIPA messages and Prolog terms is provided.

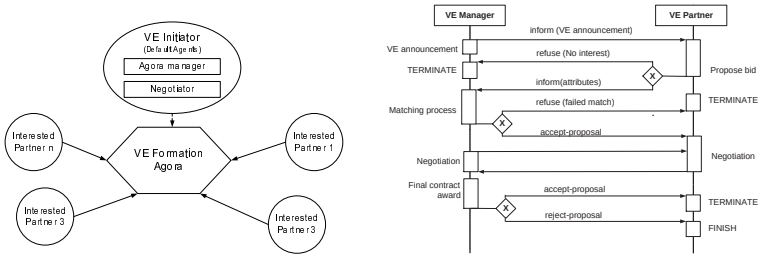
We consider the *Planning Unit* as a finite state machine so that the agent's next action is determined deductively by the current state and the rules stored in the agent's *Knowledge Base*. The action is in the form of a message that the agent sends to others. Part of the state information is perceived from the messages the agent has received.

3 Forming Virtual Enterprises Using AGORA

3.1 Virtual Enterprises in AGORA

Figure 2(a) shows the formation stage of the lifecycle of a VE within the context of AGORA. An agora node, VE Formation Agora, is created by the person

that wants to form the VE, the *VE Initiator*. When the VE Formation Agora node is created, the default agents are also created. The other agents that are registered at this Agora node can bid to become partners of the VE, *Interested Partners*. During the process of the formation of the VE, a partner evolves from an interested partner to someone who is actually a part of the VE. Interested Partners who meet the requirements of the VE are *Potential Partners* and a contract is negotiated with them before they become the partners of the VE.



(a) The AGORA Mulit-agent Architecture

(b) Agent Interaction Protocol

Fig. 2. The VE Model in AGORA

The VE formation Agora node will provide the necessary support for the matching and negotiation processes during the formation of the VE. If two Interested Partners need to interact, they can create another Agora node and acquire the required support from the Agora node.

3.2 Agent Interaction Protocol

The interaction between the VE Initiator and the VE partners can be represented using an AIP, as shown in Figure 2(b). In this paper, we describe the main steps in the formation process.

The first step is the **announcement of the VE** where the VE Initiator sends a message to all the agents registered at the VE formation Agora node to invite them to propose a bid. The VE announcement contains the main goal of the VE, the roles that are required for the VE and the requirements for the roles. We consider the goal structure as a simple tree structure where a goal can have one or more subgoals. Each subgoal is achieved by a set of activities which are perfomed by roles. Interested Partners then bid for roles. They send the proposals containing their goals and their capabilities, to become partners in the VE.

The second step is **matching the agents to the roles**. First, the goals of the Interested Partner are matched against the subgoals that corresponds to the roles to ensure that the goals are aligned. Then, the capabilities of the Interested Partners, which are described as a set of attributes, are matched against the requirements. The matching process itself consists of several subprocesses; e.g. matching the skills, availability and the costs.

The third step is **negotiation**, where the VE Initiator negotiates with the Potential Partners to agree upon the terms of the contract. The negotiation can

be based upon a number of attributes such as the skills, the availability of the partner and the cost.

The final step is **awarding the contract**. After the negotiation, the VE Initiator selects a team of partners for the VE and signs a contract.

4 Conclusions

AGORA provides the basic infrastructure for supporting a VE, based on the idea of an electronic market place. The VE is specified by its goal(s), a set of roles and the requirements for the roles. The agents that bid to become the partners of the VE are represented by their goals and a set of attributes and values. AGORA provides a default implementation for all its components including agent communication and the matching capabilities. Furthermore, the matching rules and negotiation protocols can be easily customised by the user as needed.

In this paper, we have not addressed issues such as trust and commitment of the partners. We plan to enhance our model to address such issues and we believe that we can draw from the research done in these areas (e.g. [4]). The next step in our research will be to complete the model of the VE and to implement a detailed AIP.

5 Acknowledgements

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