THE ADVANTAGES OF USING A COLLABORATIVE INFRASTRUCTURE IN VIRTUAL ENTERPRISES

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Abstract
The purpose of this work is to provide a collaboration support for small and medium enterprises which cannot or do not want to fulfill a major contract alone. In that case, in order to better meet a higher external demand, the managers are willing to subcontract parts of their contracts even to competitors.
This approach is illustrated by a business-to-business interaction, being proposed a sample scenario where partners are autonomous gas stations grouped in a virtual enterprise (VE). In such a VE, we present a schematic example of a collaboration process using negotiation and coordination mechanisms that we proposed in this paper.

***Keywords**: SME, B2B interaction, subcontracting, cooperation, collaboration.*

1. Introduction

Recent advances in the information technology have made possible the development of a new type of organization, the virtual organization. Taking into account the connection between the new communication technologies and the relationships between the industrial organizations, two main directions are distinguished. The first direction considers the Internet and the Informatics as being the main technologies that facilitate the communication between persons. The second direction, more visionary, is focused not only on the communication but mainly on the modalities that allow the information technologies to coordinate in an efficient fashion and with minimal effort requirements the activities of individuals.

Related to the second direction, the concept of "Virtual Enterprise (VE)" or "Network of Enterprises" has emerged to identify the situation when several independent companies decided to collaborate and establish a virtual organization with the goal of increasing their profits. Camarinha-Matos defines the concept of VE as follows: "A *Virtual Enterprise (VE)* is a temporary alliance of enterprises that come together to share skills and resources in order to better respond to business opportunities and whose cooperation is supported by computer networks"[1].

Given this general context, the objective of the present paper is to develop a conceptual framework and the associated informational infrastructure that are necessary to facilitate the collaboration activities and, in particular, the negotiations between independent organizations that participate in a virtual alliance.

The starting point in the development of this work was the goal to support small and medium enterprises that are not able or are not willing to perform alone a large contract since in this situation the association in a virtual alliance provides the opportunity to subcontract the tasks of the contract to other partners within the alliance. To achieve this goal, research was dedicated to the development of a model to coordinate the negotiations that take place within an inter-organizational alliance. Our research was focused on the topics of virtual alliances, automation of the negotiations and of coordination aimed to provide the mechanisms for coordinating the negotiations that take place among autonomous enterprises that are grouped in a virtual alliance.

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[1] Camarinha-Matos L.M. and Afsarmanesh H.,(2004), *Collaborative Networked Organizations,* Kluwer Academic Publisher Boston.

Assuming that the nature of the roles that may be played in a negotiation are similar in multiple approaches, the number of participants involved at the same time in the same negotiation is considerably different.

Depending on the number of participants involved in a negotiation, we may distinguish various negotiation types: *bilateral negotiation (one-to-one)*; *one-to-many negotiation; many-to-many negotiation*.

Taking into account the complexity of the negotiations modeled by multi-agent system, we can state that to conduct in an efficient fashion one or many negotiations that involve a large number of participants and to properly account for all negotiation dimensions, it is necessary to develop a coordination process that is defined outside of the specific constraints of a given decision mechanism or communication protocol.

The negotiation process was exemplified by scenarios tight together by a virtual alliance of the autonomous gas stations. Typically, these are competing companies. However, to satisfy the demands that go beyond the vicinity of a single gas station and to better accommodate the market requirements, they must enter in an alliance and must cooperate to achieve common tasks. The type of alliance that we use to define their association emphasizes that each participant to this alliance is completely autonomous i.e., it is responsible of its own amount of work and the management of its resources. The manager of a gas station wants to have a complete decision-making power over the administration of his contracts, resources, budget and clients. At the same time, the manager attempts to cooperate with other gas stations to accomplish the global task at hand only through a minimal exchange of information. This exchange is minimal in the sense that the manager is in charge and has the ability to select the information exchanged.

When a purchasing request reaches a gas station, the manager analyses it to understand if it can be accepted, taking into account job schedules and resources availability. If the manager accepts the purchasing request, he may decide to perform the job locally or to partially subcontract it, given the gas station resource availability and technical capabilities. If the manager decides to subcontract a job, he starts a negotiation within the collaborative infrastructure with selected participants. In case that the negotiation results in an agreement, a contract is settled between the subcontractor and the contractor gas station, which defines the business process outsourcing jobs and a set of obligation relations among participants[2].

The gas station alliance scenario shows a typical example of the SME virtual alliances where partner organizations may be in competition with each other, but may want to cooperate in order to be globally more responsive to market demand.

The collaborative infrastructure, that we describe, should flexibly support negotiation processes respecting the autonomy of the partners.

We are starting with a presentation in Section 2 of a VE life cycle model. Then, we are briefly describing in Section 3 the architecture of the collaboration system in which the interactions take place.

The main objective of this paper is to propose a collaboration framework in a dynamical system with autonomous organizations. In Section 4 we define the Coordination Components that manage different negotiations which may take place simultaneously.

In Section 5 we present how the structure of the negotiation process can be used by describing a particular case of negotiation. Finally, Section 6 concludes this paper.

[2] Singh M.P., (1997) *Commitments among autonomous agents in information-rich environments*. In Proceedings of the 8th European Workshop on Modelling Autonomous Agents in a Multi-Agent World (MAAMAW), pp. 141–155

2. The main steps of the Virtual Enterprise life cycle

The life cycle of virtual enterprise is classified into six phases. The relevance in different phases is shown in Figure 1 and the statement for each phase is given as follows:

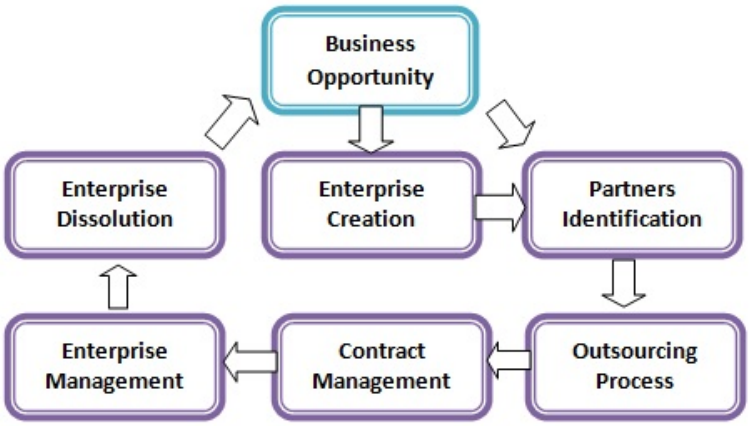

Figure 1. Life-cycle of a virtual enterprise

a) VE creation

When a business opportunity is detected, there is a need to plan and create the VE, identify partners, establish the contract or cooperation agreement among partners, in order to manage the processes of the VE.

b) Partners search and selection

The selection of business partners is a very important and critical activity in the operation of a company. Partners search can be based on a number of different information sources, being private, public, or independent. The enterprise's private suppliers' list is a data repository that contains information about the companies that have had commercial relationships with this enterprise. This information composes an *Internal Suppliers Directory (ISD)*. External sources include directories maintained by industrial associations, commerce chambers, or Internet services. This information composes the *External Suppliers Directory (ESD)*. Another emerging solution is the creation of clusters of enterprises that agreed to cooperate and whose skills and available resources are registered in a common *SME Cluster Directory* (CD).

c) Outsourcing of tasks within a VE

In this stage of a VE life cycle, we can assume that a gas station company receives a customer demand. In this respect, the Manager of this company may negotiate the outsourcing of a schedule tasks that cannot perform locally with multiple partners of selected gas station companies, geographically distributed. The Manager can select the partners of the negotiation among the database possible partners according to their declared resources and the knowledge he has about them.

The outcome of a negotiation can be "success" (the task was fully outsourced), "failure" (no outsourcing agreement could be reached) or "partial" (only part of the task could be outsourced).

d) Contract management in the VE

In case the negotiation process ends in a successful, a contract is established between the outsourcing company and the insourcing ones. The contract is a complex object, which is based of trust in this coordination mechanism. Moreover, it contains a set of specific rules, such as penalties, expressing obligation relations between the participants.

In case of failure of a partner, the Manager will have to supervise if the obligations are honored (for example to oblige the partner to finish his work or to set penalties) and to modify the business process renegotiating parts of the work that have not been realized.

e) Management of the VE

A VE is a dynamic entity in which a new company may join or leave it. Members may need to leave for many reasons, when they change their activity or when they don't want any more to collaborate with the partners of the VE. In case of departure from the VE, the leaving partner may either notify all the partners. It also may leave without giving any information. The departure of a partner from the VE will have an important impact on ongoing contracts especially when this partner is an insourcer of an important amount of task.

f) VE dissolution - after stopping the execution of the business processes.

3. The Collaborative Infrastructure

The main objective of this software infrastructure is to support collaborating activities in virtual enterprises. In VE partners are autonomous companies with the same object of activity, geographically distributed.

Taking into consideration, the constraints imposed by the autonomy of participants within VE, the only way to share information and resources is the negotiation process.

Figure 2 shows the architecture of the collaborative system:

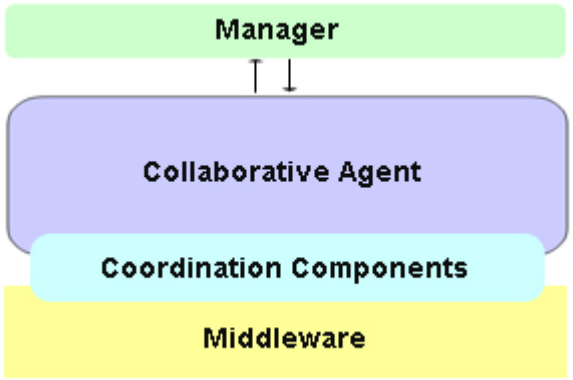

Figure 2. The architecture of the collaborative system

This infrastructure is structured in four main layers[3]: Manager, Collaborative Agent, Coordination Components and Middleware. A first layer is dedicated to the Manager of each organization of the alliance. A second layer is dedicated to the Collaborative Agent who assists its gas station manager at a global level (negotiations with different participants on different jobs) and at a specific level (negotiation on the same job with different participants) by coordinating itself with the Collaborative Agents of the other partners through the fourth layer, Middleware[4]. The third layer,

[3] Cretan A., Coutinho C., Bratu B. and Jardim-Goncalves R., (2011), *A Framework for Sustainable Interoperability of Negotiation Processes*. Paper submitted to INCOM'12 14th IFAC Symposium on Information Control Problems in Manufacturing.

[4] Bamford J.D., Gomes-Casseres B., and Robinson M.S., (2003), *Mastering Alliance Strategy: A Comprehensive Guide to Design, Management and Organization*. San Francisco: Jossey-Bass, pp. 27-38

Coordination Components, manages the coordination constraints among different negotiations which take place simultaneously.

A Collaborative Agent aims at managing the negotiations in which its own gas station is involved (e.g. as initiator or participant) with different partners of the alliance.

Each negotiation is organized in three main steps: initialization; refinement of the job under negotiation and closing[5]. The initialization step allows to define what has to be negotiated (Negotiation Object) and how (Negotiation Framework)[6]. A selection of negotiation participants can be made using history on passed negotiation, available locally or provided by the negotiation infrastructure[7]. In the refinement step, participants exchange proposals on the negotiation object trying to satisfy their constraints[8]. The manager may participate in the definition and evolution of negotiation frameworks and objects[9]. Decisions are taken by the manager, assisted by his Collaborative Agent[10]. For each negotiation, a Collaborative Agent manages one or more negotiation objects, one framework and the negotiation status. A manager can specify some global parameters: duration; maximum number of messages to be exchanged; maximum number of candidates to be considered in the negotiation and involved in the contract; tactics; protocols for the Collaborative Agent interactions with the manager and with the other Collaborative Agents [11].

4. Coordination Components

In order to handle the complex types of negotiation scenarios, we propose five different components[12]:

- *Subcontracting* (resp. *Contracting*) for subcontracting jobs by exchanging proposals among participants known from the beginning;
- *Block* component for assuring that a task is entirely subcontracted by the single partner;
- *Divide* component manages the propagation of constraints among several slots, negotiated in parallel and issued from the split of a single job;
- *Broker*: a component automating the process of selection of possible partners to start the negotiation;
- *Transport* component implements a coordination mechanism between two ongoing negotiations in order to find and synchronize on the common transport of both tasks.

These components are able to evaluate the received proposals and, further, if these are valid, the components will be able to reply with new proposals constructed based on their particular coordination constraints[13].

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[5] Sycara K., (1991), *Problem restructuring in negotiation*, in Management Science, 37(10), pp.24-32.

[6] Smith R., and Davis R., (1981), *Framework for cooperation in distributed problem solving*. IEEE Transactions on Systems, Man and Cybernetics, SMC-11, pp. 42-57.

[7] Zhang X. and Lesser V., (2002), *Multi-linked negotiation in multi-agent systems*. In Proc. of AAMAS, Bologna, pp. 1207 – 1214.

[8] Barbuceanu M. and Wai-Kau Lo, (2003), *Multi-attribute Utility Theoretic Negotiation for Electronic Commerce*. In AMEC III, LNAI, pp. 15-30.

[9] Keeny R. and Raiffa H., (1976), *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. JohnWilley & Sons.

[10] Bui V. and Kowalczyk R., *On constraint-based reasoning in e-negotiation agents*. In AMEC III, LNAI 2003, pp. 31-46.

[11] Faratin P., (2000), *Automated service negotiation between autonomous computational agent*. Ph. D. Thesis, Department of Electronic Engineering Queen Mary & West-field College.

[12] Cretan A., Coutinho C., Bratu B. and Jardim-Goncalves R., (2011), *A Framework for Sustainable Interoperability of Negotiation Processes*. Paper submitted to INCOM'12 14th IFAC Symposium on Information Control Problems in Manufacturing.

[13] Vercouter, L., (2000), *A distributed approach to design open multi-agent system*. In 2nd Int. Workshop Engineering Societies in the Agents' World (ESAW), pp. 32-49.

From our point of view the coordination problems managing the constraints between several negotiations can be divided into two distinct classes of components:

Coordination components in closed environment**:** components that build their images on the negotiation in progress and manage the coordination constraints according to information extracted only from their current negotiation graph (*Subcontracting, Contracting, Block, Divide)*;

Coordination components in opened environment: components that also build their images on the negotiation in progress but they manage the coordination constraints according to available information in data structures representing certain characteristics of other negotiations currently ongoing into the system (*Broker, Transport)*.

Following the descriptions of these components we can state that unlike the components in closed environment (*Subcontracting, Contracting, Block, Divide)* that manage the coordination constraints of a single negotiation at a time, the components in opened environment (*Broker, Transport)* allow the coordination of constraints among several different negotiations in parallel[14].

The novelty degree of this software architecture resides in the fact that it is structured on four levels, each level approaching a particular aspect of the negotiation process. Thus, as opposed to classical architectures which achieve only a limited coordination of proposal exchanges which take place during the same negotiation, the proposed architecture allows approaching complex cases of negotiation coordination. This aspect has been accomplished through the introduction of coordination components level, which allows administrating all simultaneous negotiations in which an alliance partner can be involved.

The coordination components have two main functions such as: i) they mediate the transition between the negotiation image at the Collaboration Agent level and the image at the Middleware level; ii) they allow implementing various types of appropriate behavior in particular cases of negotiation. Thus we can say that each component corresponding to a particular negotiation type.

Following the descriptions of this infrastructure we can state that we developed a framework to describe a negotiation among the participants to a virtual enterprise. To achieve a generic coordination framework, nonselective and flexible, we found necessary to first develop the structure of the negotiation process that helps us to describe the negotiation in order to establish the general environment where the participants may negotiate. To develop this structure, we proposed a succession of phases that are specific to different stages of negotiation (initialization, negotiation, contract adoption) that provided a formal description of the negotiation process.

The advantage of this structure of the negotiation process consists on the fact that it allows a proper identification of the elements that constitute the object of coordination, of the dependencies that are possible among the existing negotiations within the VE, as well as the modality to manage these negotiations at the level of the coordination components.

5. The structure of the negotiation process

According to our approach regarding the negotiation, the participants to a negotiation may propose offers and each participant may decide in an autonomous manner to stop a negotiation either by accepting or by rejecting the offer received. Also, depending on its role in a negotiation, a participant may invite new participants to the negotiation.

In order to illustrate this approach, we present a schematic example of a negotiation process using negotiation and coordination mechanisms that we proposed in this paper.

Negotiation process that we present in Figure 3 is divided into five parts (initialization, choice of tactics, choice of partners, negotiation and contract adoption).

Initialization. The Manager initiates a subcontracting of a task, defining and communicating to the Collaborative Agent the properties and the constraints of the negotiation object and the negotiation framework. The negotiation process begins by creating an instance of the component

[14] Muller H., (1996), *Negotiation principles.* Foundations of Distributed Artificial Intelligence.

Subcontracting. This instance will initiate other stages of negotiation, based on constraints provided by the Manager: the invitation of the coordination components (*Contracting*, *Broker*, etc.). Moreover, this instance will conduct negotiations in terms of construction and evaluation of proposals for subcontracting proposed task.

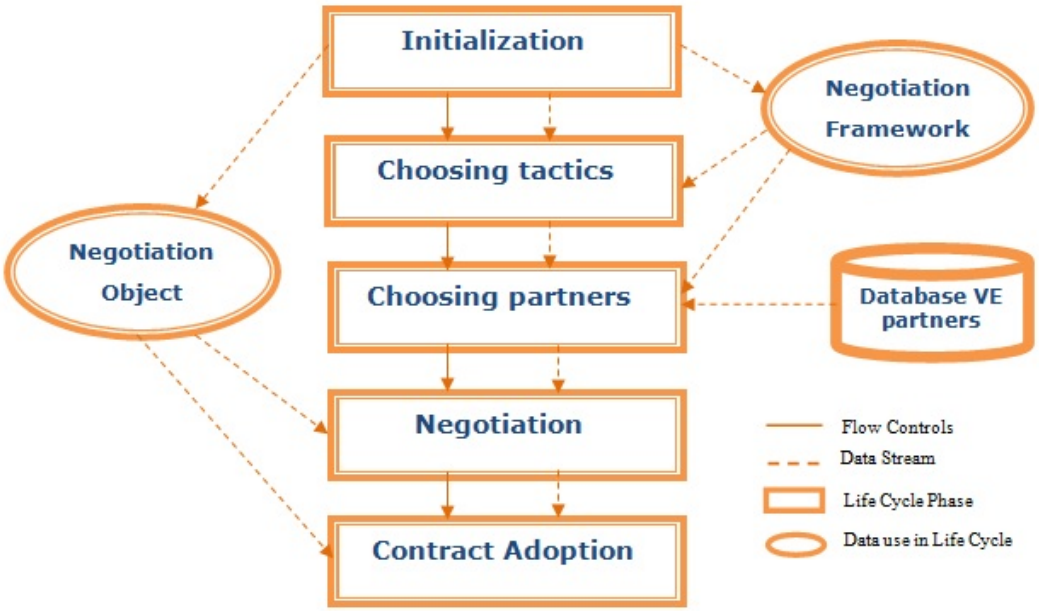

Figure 3 – The structure of the negotiation process

Choosing tactics. Using the tactics of negotiation specified in the negotiation framework, the coordination is decomposed into several coordination schemes. We considered three tactics that correspond to three coordination schemes: Block, Divide and Transport.

Choosing partners. We have two choices of partners:

- among known partners – The Manager who initiating the outsourcing can specify any constraints on the set of possible alliance contractors. To do this, the manager uses the description of the job that follow to be subcontracted and also the database alliance partners and/or the different adhesion contracts which they signed[15];
- among unknown partners - in this case, the entire research activity of the potential partners is managed by the infrastructure through Broker component.

Negotiation. At this stage, during exchanges of proposals, the negotiation object evolves according to the constraints imposed by the manager on negotiated attributes of the subcontracting task. The final objective of the negotiation process is to build an Instantiated Negotiation Object from initial specification of negotiation object[16]. An Instantiated Negotiation Object is a negotiation object whose attributes have been accepted by the all partners. After that, this object will be used to establish a contract.

[15] Hurwitz, S.M., (1998) *Interoperable Infrastructures for Distributed Electronic Commerce*, http://www.atp.nist.gov/atp/98wpecc.htm

[16] Robinson W., and Volkov V., *Supporting the negotiation life cycle.* Communications of the ACM, 1998.

Contract Adoption. In the final negotiation phase, the negotiation properties are fixed values. In this case, the Collaborative Agent asks Manager to validate the result of negotiation and makes contact with other partners' agents.

Depending on the answers obtained, the Manager may decide to: i) to restart or to suspend negotiations; ii) to enable the contracting phase, which allows reaching an agreement[17].

The negotiation process involves several parties (for several bilateral negotiations), each having different criteria, constraints and preferences that determine their individual areas of interest[18]. Criteria, constraints and preferences of a participant are partially or totally unknown to the other participants. The job under negotiation is described as a multi-attribute object. Each attribute is related to local constraints and evaluation criteria, but also to global constraints drawing dependencies with other attributes[19].

In conclusion, the proposed architecture provides the following features:

- to define the negotiation process structure: participants, interaction protocol, negotiation protocol, tactics and coordination components, the negotiation object and the negotiation strategies;
- the modeling all negotiations for a gas station in the form of a set of bilateral negotiations, which the agent can operate independently;
- the modeling of the coordination among the negotiations based on a set of coordination components and the synchronization mechanisms at the middleware level.

Thus, we can say, that we have proposed an infrastructure that manages, in a decentralized manner, the coordination of multi-phase negotiations on a multi-attribute object and among a lot of participants.

6. Conclusions

The functioning of this kind of alliance suppose task achievement, which cannot be individual treated, by a single participant for better adjustment of the clients requirements.

The proposed infrastructure aims to help the different SMEs to fulfill their entire objectives by mediating the collaboration among the several organizations gathered into a virtual enterprise.

A specific feature that distinguishes the negotiation structure proposed in this work from the negotiations with imposed options (acceptance or denial) is that it allows the modification of the proposals through the addition of new information (new attributes) or through the modification of the initial values of certain attributes (for example, in the case of gas stations the gasoline price may be changed).

The business-to-business interaction context in which our activities take place forces us to model the unexpected and the dynamic aspects of this environment. An organization may participate in several parallel negotiations. Each negotiation may end with the acceptance of a contract that will automatically reduce the available resources and it will modify the context for the remaining negotiations.

In the current work we've described in our collaboration framework only the interactions with the goal to subcontract or contract a task. A negotiation process may end with a contract and in that case the supply schedule management and the well going of the contracted task are both parts of the outsourcing process.

In order to illustrate our approach we have used a sample scenario where distributed gas stations have been united into virtual enterprise. Take into consideration this scenario, one of the

[17] Ossowski S., (1999), *Coordination in Artificial Agent Societies*. Social Structure and its Implications for Autonomus Problem-Solving Agents, No. 1202, LNAI, Springer Verlag, pp.56-69.

[18] Schumacher M., (2001), *Objective coordination in multi-agent system engineering – design and implementation.* In Lecture Note in Artificial Intelligence, No. 2093, Springer Verlag, pp.72-88.

[19] Kraus S., (2001)*, Strategic negotiation in multi-agent environments.* MIT Press, pp.56-67.

principal objectives was related to the generic case and means that this proposed infrastructure can be used in other activity domains.

Regarding research perspective continuation, one first direction which can be mentioned is the negotiation process and the coordination process taking into consideration the contracts management process. In this way the coordination can administrate not only the dependence between the negotiations and the contracts which are formed and with execution dependences of those contracts.

Another perspective is to deliver to the user one instrument which allows him negotiation protocol definition according with the restrained negotiation interactions possibilities. Consequent, this will be a problem of coordination on which the infrastructure must solve on negotiation protocol administration and protocol build perspective.

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