RBVO Formation Protocol

Jiří Vokřínek, Jiří Bíba, Jiří Hodík, Jaromír Vybíhal, and Přemysl Volf

Gerstner Laboratory, Department of Cybernetics

Czech Technical University in Prague

Technická 2, 166 27 Prague, Czech Republic

`{vokrinek/biba/hodik/vybihj1/volf}@labe.felk.cvut.cz`

Abstract

The proposed protocol has been designed to support a flexible formation of Request-based Virtual Organizations with an emphasis on reflecting the conditions of real competitive environments. It supports automated or semi-automated negotiations mainly in the creation part of a Virtual Organization life cycle and accounts for a use of Service Level Agreements. The protocol consists of three phases: (i) potential partner search, (ii) negotiation of SLAs and RBVO establishment, and (iii) RBVO execution and dissolution. The protocol is based on FIPA standards.

1. Introduction

A formation of a Virtual Organization (VO) is based on a negotiation between independent partners willing to cooperate. Individual enterprises (mostly SMEs) are motivated to join the Virtual Organization to increase their business opportunities and to be able to participate on larger scale jobs.

The Virtual Organizations naturally operate in a competitive environment [1]. Every partner follows its own goals and maximizes its utility function. Individual utility functions may use different metrics and they are usually hidden to the others. The standardized protocols for agent contracting are insufficient for bargaining over contracts in such environment as the related negotiation mechanisms do not account for it.

A Virtual Organization establishment is based on an agreement on a cooperation of individual partners. The concept of *social commitments* was introduced by Wooldridge and Jennings in [9]. This concept may be applicable in some VO domain, but it does not address the problem of unilaterally advantageous dropping of commitments. In most of VO domains an explicit employment of rewards and penalties is needed as a clear qualification of utilities that a partner gains or looses. A concept of such explicit utility evaluation is then a part of commitments; a party providing a service commits not only to perform appropriate actions (in order to gain the promised utility which introduces its motivation), but to provide a compensation if it fails (e.g. a compensation of the profit lost to the other party). The most complete approach to the commitments in the competitive environment has been presented by Sandholm and Lesser [5] as *leveled commitment contracts* (LCC) which include an explicit utility evaluation in a form of a contract price and penalties. In order to provide a complete decision making mechanism, the authors applied several significant restrictions (e.g. the utility function needs to be identical for all participants, opportunity-cost business probability function for every agent is a common knowledge, etc.). These assumptions are quite limiting [1] and basically prevent a direct deployment of LCC in a real application. Nevertheless, LCC introduce a basis for notion of commitments in competitive environments.

This paper concentrates on a negotiation protocol for formation of Request-based Virtual Organizations, designed with an emphasis on reflecting the conditions of real competitive environments.

2. Theoretical Background

The concept of Request-based Virtual Organizations (RBVO) defined by Roberts in [4] comprise a cluster of partnering organizations that have totally replaced their vertical integration into a virtual one. The RBVOs are short-living entities that are formed to respond to business opportunities offered in electronic commerce. The RBVO concept refers to a dynamic multinational cluster of ERP/CRM value chain actors. RBVOs operations stands on predefined Service Level Agreements (SLAs). The organization and functioning of RBVOs' activities is ensured by a community of intelligent agents that automate procedures and operations of RBVOs [3]. The agents serve as assistants for human decision makers; in the agent system each participating SME is represented by its agent which is able to un-

dertake automated decision making on behalf of the SME or it enables a user to interact with the system on behalf of the SME. Every time when we refer to VO in the text, it is applicable also to RBVO.

2.1. VO life cycle

The VO life cycle and its phases have been described many times in previous works (e.g. [2]). The basic phases, which are included or extended in most of definitions, are *(i)* creation, *(ii)* operation, and *(iii)* dissolution. The creation phase includes all activities related to discovering a business opportunity and VO team formation. The operation phase includes value-adding processes of the VO and operative management of the VO. The dissolution phase finalizes the life cycle of the VO.

2.2. Service Level Agreements

A Service Level Agreement (SLA) introduces a formalization of a business relationship (or a part of a business relationship) between two parties (most often between a provider and a customer) that is a key concept for service management [7]. Usually it specifies a delivery of products or services for certain price, meeting specified deadlines, quality requirements together with financial guarantees and other contract terms. It may concern continuous, discrete or one-shot service/goods deliveries. For RBVO it represents a description of work flows, schedules, resource allocations, participant roles, prices, sanctions, guarantees, legacy-related and other contract management and coordination issues. The SLA introduces a consistent (possibly reduced) electronic form of the contract signed by contract parties as a paper document (the reduction may concern mainly non-technical/financial parts), expressed in a machine-readable language (most often in XML that is nowadays considered as an interoperable business information exchange format).

2.3. Protocols for VO Formation

Various mechanisms exist to achieve a mutual agreement among the partners concerning a mutually advantageous cooperation. Besides the other auction mechanisms, the most popular is probably the Contract-Net Protocol (CNP) which has been introduced by Smith [6]. Particularly the following protocol extending the CNP has been designed for competitive environments in which VOs mostly operate.

Competitive Contract Net Protocol (C-CNP) [8] is a FIPA-likeprotocol designed for flexible contracting in a competitive environment (e.g. E-commerce and Virtual Organizations) and aims at covering the whole contract life cycle, specifically: *(i)* contract conclusion phase, *(ii)* optional decommitment phase and *(iii)* contract termination phase. Not all the parties involved in a multi-round negotiation of commitments need to be addressed by call-for-proposals (CFP) messages. The protocol allows participants to impose their proposals (based third-party information) into an already running negotiation. The 1:N negotiation is held in a pairwise manner. During the execution phase any of the parties involved in pairwise commitments may attempt to decommit from the contract. The multi-round decommitment negotiation on conditions of dissolving the cooperation may end up either by backing off from the negotiation by the decommitting party (the contract returns back to normal) or by dropping the commitments under a payment of a penalty (the penalty may be fixed during the contract-conclusion negotiation or may remain opened and be adjusted in time). Finally, in the termination phase the results are evaluated with respect to the agreed commitments. Eventually, penalties for non-compliance with commitments are negotiated. The message content is assumed to describe the contract as a whole, i.e. full and explicit descriptions of commitments (i.e. not only a mere task assignment, but also resource allocation, quality of service, schedules, etc.), rewards and sanctions are provided (such message content may be e.g. an SLA). Thus, the negotiation is also assumed to be multi-attribute rather than single-attribute. The multi-round manner of the protocol allows multiple simultaneously running negotiations and as well as multi-level ordering of subsequent protocols (i.e. a participant of a C-CNP may become an initiator of another subsequent C-CNP negotiation, e.g. for outsourcing).

3. RBVO Formation Protocol

The RBVO formation protocol supports a contract negotiation on several levels. It consists of three phases: *(i)* search for potential partners (pre-negotiation of contract), *(ii)* negotiation of SLAs with selected partners and establishment of the RBVO (one partner or a small number of partners that cover required competencies together) and *(iii)* execution & dissolution of RBVO. The first two phases enable multi-round negotiations and they concern the creation phase of a RBVO life cycle. Both the coordinator and individual potential partners are allowed to withdraw from the negotiation for any reason. During the first two phases the final RBVO configuration is agreed together with related commitments (given by pairwise or multi-party SLAs) for all the parties. The final phase concerns the execution and termination phases of the RBVO life cycle.

A sequence diagram of the RBVO formation protocol is on Figure 1. The individual phases are described in detail
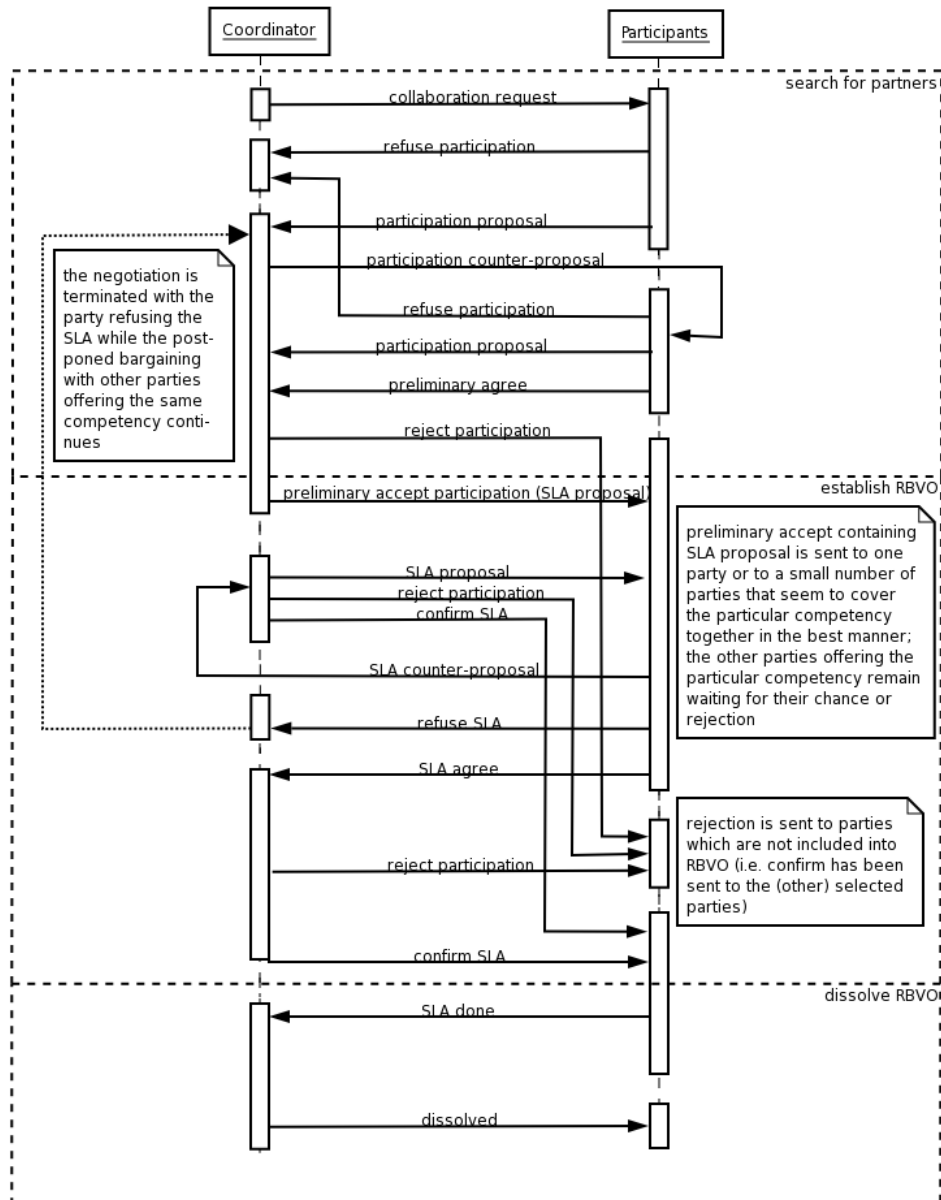
Figure 1. A sequence diagram of the RBVO formation protocol

below:

- **Phase *(i)*: Search for Potential Partners**
  The first phase aims at a pre-negotiation of the contract conditions with eventual partners (equipped with required competencies) with respect to the ratings of their offers so that the number of partners selected for detailed negotiations of SLAs is reduced and the best candidates are chosen. The negotiation is started by sending a Collaboration Request (CR) in a call-for-proposals message. The CR describes decomposed tasks, respective competencies required for their accomplishment and constraints (e.g. geographical lo-

cation of a potential candidate, due dates, etc.). The coordinator and the candidates enter into a pairwise multi-round bargaining (in a propose/counter-propose manner) in which they try to agree on preliminary co-operation rules. Thus, the coordinator obtains several possible configurations of the resulting RBVO. The co-ordinator decides on the best configuration and sends the respective candidates preliminary-accept messages containing proposals of SLAs. The other candidates are not rejected immediately, but remain in the first phase of the bargaining process while the pre-selected candidates enter the second phase. The waiting candi-

dates may get their chances provided the coordinator fails to reach agreements on SLAs with some of the pre-selected candidates. The granularity of information in CRs is generally less fine than in case of SLAs (some of the attributes may be irrelevant to negotiate upon until the pre-agreement is reached). Both the coordinator and the candidates are allowed to terminate the negotiation for any reason by sending refuse-participation (candidates) or reject-participation (coordinator) messages.

- **Phase *(ii)*: Negotiation of SLAs and Establishment of the RBVO**
  The coordinator and the candidates pre-selected for the negotiation of detailed terms and conditions of the resulting SLAs try to reach final agreement reflecting various aspects like time schedules, qualitative parameters, prices, penalties, etc. The pairwise multi-round bargaining (again in a propose/counter-propose manner) may be terminated by any of the parties provided mutually advantageous compromise on contract conditions appears unreachable. In such case, some of the waiting candidates equipped with respective competency can be invited to the final negotiation by a preliminary accept message from the coordinator. As soon as all SLAs are finalized, confirm-SLA messages are send to the candidates and the RBVO is practically established. The waiting candidates that are not included into the RBVO receive reject-participation messages. The RBVO is created and the execution and termination phases of the RBVO life cycle can take place.

- **Phase *(iii)*: Execution and Dissolution of the RBVO**
  As soon as a participant accomplishes its tasks, it sends SLA-done message to the coordinator. The coordinator terminates the cooperation by confirming the dissolution of the RBVO.

4. Conclusion

The proposed protocol has been designed for Request-based Virtual Organization formation, but it is possible to deploy it to other domains of Virtual Organizations which employ the concept of Service Level Agreements. The protocol allows for reflecting the conditions of real competitive environments as well as a negotiation scalability and complexity and an support for a human-assisted negotiation.

The first phase of the protocol focuses on the multi-round pre-negotiation of the contract conditions between the partners. This phase is finished by a preliminary agreement or a participation refusing/rejection and can be fully or partially automated (agents negotiating on behalf of their owners). The second part is more business oriented and contains pairwise multi-round bargaining of the agreements. The result of this part is a set of SLAs or participation rejections. The third part is the focused on RBVO dissolution and doesn't offer any special terminating conditions (e.g. penalties, quality of service delivered, etc.).

A possible improvement of the presented RBVO formation protocol consists in adoption of features of the C-CNP protocol in its decommitment and termination phases. In fact, the proposed RBVO formation protocol can be used instead of contracting phase of the C-CNP.

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