SEMANTIC SUPPORT FOR AUTOMATED NEGOTIATION WITH ALLIANCES

Stanislav Pokraev[1], Zlatko Zlatev[2], Rogier Brussee[1], Pascal van Eck[2]
[1]*Telematica Instituut, P.O.Box 589, 7500 AN, Enschede, The Netherland*
Email: {stanislav.pokraev, rogier.brussee}@telin.nl
[2] *Centre for Telematics and Information Technology,*
University of Twente, P.O. Box 217, 7500 AE, Enschede,The Netherlands
Email: {zlatko, vaneck}@cs.utwente.nl

Keywords: Automated negotiation, Alliances, Ontology, Semantics, OWL, Agents, e-Commerce

Abstract: Companies can form alliances on the Internet to aggregate buying or selling power and create value. More concretely, together resources are shared or new possibilities are exploited that cannot be exploited individually. Most alliances are formed as a result of a negotiation process between the companies that form an alliance. This paper proposes a software framework that enables automated negotiation between alliances. Our framework allows for the semantic description of negotiation objects and their attributes, and provides a mean for the exchange of negotiation messages unambiguously interpretable by all parties involved. The proposed framework supports ad-hoc alliances by allowing parties with a common interest to negotiate on the proposal they want to make to other market participants first.

1. INTRODUCTION

The Internet provides opportunities to create value by forming alliances to aggregate buying or selling power. More specific, companies form alliances either to share current resources and competences or to exploit new possibilities. The motives for forming alliances are diverse. Alliances are either formed by co-option of competitors or by providers of complementary products or services to reduce cost and improve customer offerings. Others allow each partner to concentrate on activities that best match their resources and competences or to learn from the other partners and develop competences that may be more widely exploited..

Kaplan and Sawhney (2000) have investigated alliances in their appearance as so-called 'e-hubs': B2B marketplaces that aggregate or match buyers or sellers. E-hubs can be neutral third parties, or buyer or seller biased. In their paper, Kaplan and Sawhney indicate which model - aggregation or matching, biased or neutral - works best in a specific market setting.

In our paper, we develop a software framework for the dynamic aggregation of buyers and/or sellers in an electronic market. The framework provides an architecture for automated negotiation between alliances. The framework relies entirely on the use of ontologies as a mean of formally representating the knowledge on a particular domain of interest. This provides clear semantics and represents shared understanding of the issues being negotiated on. Common understanding of the market, knowledge of the assets that the potential partners are ready to commit as well as shared expectations is a crucial prerequisite for choosing the right form of alliance or the discovery of the pitfalls in time.

2. SEMANTIC DESCRIPTIONS

Present e-commerce applications extend over the boundaries of an enterprise. New business scenarios include advertising of services or products on the Internet, matchmaking of sellers and buyers, negotiation with potential partners, etc. These scenarios presume the use of information outside its original context where it tends to lose its semantics. It is therefore widely believed that semantically richer descriptions are needed for tasks such as service and request matchmaking, negotiation, contracting and contract enactment.

Ontologies will play a crucial part in facilitating the sharing of information between communities, both of people and of software agents. To support the use of ontologies, a number of representational formats have been proposed, including RDF Schema (re: RDF Vocabulary Description Language), the

Ontology Interchange Language (OIL) (re: Ontology Inference Layer) and the DARPA Agent Markup Language (DAML) (re: DARPA Agent Markup Language). These last two have been unified to form DAML+OIL (DAML+OIL, 2001), which is the basis of the ontology web language (OWL) (re: Web Ontology Language). The OWL language is now a W3C standard for ontology and metadata representation. OWL exploits existing web standards such as XML, RDF and RDFS and adds primitives of object oriented and frame based systems, as well as the formal thoroughness of description logic. Its formal and rational basis provides powerful means for knowledge representation and reasoning services that are essential in the negotiation process.

3. NEGOTIATION AND ALLIANCES

Negotiation is a process whereby different entities reach an agreement on joint future behaviour. The need for negotiation arises when more than one entity (actor) has overlapping interests. The entities communicate their expectations about a potential mutually acceptable agreement. The result of the negotiation process is an agreement to which actors commit themselves for a certain future course of action.

Negotiation is usually decomposed into the following elements: *negotiation objects*, *negotiation protocols* and *negotiation strategy* (Jennings et al., 2001). Because the third element is considered private for every actor (Bartolini & Preist, 2001), we will discuss the first two ones only. The *negotiation object*, represents the subject (product or service) the participants negotiate on. The *negotiation protocol*, represents the rules that govern the negotiation process.

Alliances are groups of business actors formed to make collective use of resources or possibilities. The process of forming an alliance can include negotiation. An alliance can last for the duration of a single deal or it can last for many deals. We are interested in alliances formed to take part in a single negotiation agreement which we will call ad-hoc alliances.

Down below in this section we will discuss the problems of automating the process encountered by the participants of a negotiation process, which motivate the approach proposed in this paper.

Problem one: ***lack of common understanding***. A negotiation process is an exchange of messages. The messages are created by different actors and therefore (potentially) different meaning is given to the concepts used in them. The problem is the *lack of common understanding* of issues being discussed and the meaning of the exchanged messages. In our approach, we present a solution for this problem using ontologies.

Problem two: ***lack of common understanding of the protocol.*** Participants in a negotiation process should have a *common understanding* not only of the negotiation issues but also *of the protocol* they have to follow. One approach to this problem is to use a formal description of the negotiation protocol. Giving formal semantics to the negotiation protocol is an issue that we want to address in future work. In our current approach, we present a partial solution to this problem.

Problem three: ***loose connection among participants.*** In a many-to-many negotiation, participants have the possibility to form alliances. If the shared interests are only temporary, there is a *loose connection among participants* and the alliance is not stable. Therefore, it is not possible to treat the alliance as one participant and simplify the negotiation. We propose a solution that allows the formation of ad-hoc alliances.

Problem four: ***negotiation within an alliance.*** Apart from the problems in negotiating between alliances, there is a problem of similar complexity in forming the alliance. *Alliance formation requires negotiation*. We look at the alliance formation process as a separate negotiation process. The result of an alliance formation is a mutually agreed proposal that the alliance commits to. In our approach, we propose a separate negotiation process to form the alliance.

4. OUR APPROACH

C. Bartolini, C. Preist and N. Jennings (2002) present an abstraction of a negotiation process. The main concepts of the process are the following: To negotiate with one another, parties must have a common understanding of the different parameters of the negotiation (e.g. price, quantity, delivery terms, etc.). The negotiation process consists of exchanging proposals representing the agreements currently acceptable to the sending party involved. The submitted proposal should be valid with respect to the restrictions defined and it should be submitted according to the set of rules governing the negotiation.

In our approach, we extend the framework of Bartolini et al. by (1) semantic annotation of negotiated issues and messages and (2) providing means for ad-hoc alliances. Our approach investigates the use of OWL for describing the

negotiation objects and messages by the means of an upper negotiation ontology. The proposed formal semantic descriptions are a solution to the problem of common understanding over the negotiated matter (see section 4.1). Next, the proposed negotiation ontology defines the structure of the exchanged negotiation messages (see section 4.2). This solves only part of problem two (section 3), that is, giving a meaning to the messages. We present a partial solution to the rest of the problem - a two-step iterative exchange of negotiation proposals. Furthermore, our approach allows the negotiating parties to form ad-hoc alliances (see section 4.3 and 4.4). Actors that cannot satisfy the request as a whole, can join an ad-hoc alliance and contribute to the assembly of the requested package of services or products. Finally, we enable negotiation within an alliance by providing the means for negotiation over a joint proposal among the allied actors (see section 4.4). The following sections give more insight into our approach.

4.1 Negotiation objects

The process of negotiation requires that all parties involved have a common understanding about the negotiation issues (e.g. objects and their parameters). Furthermore, support for reasoning is necessary to ensure the validity of the proposals (for instance to test whether two negotiation issues are non-contradictory) or to derive implied relations between negotiation objects. Finally, a particular negotiation strategy might need to compute the concept hierarchy. Information about which concept is a specialization of another and which concepts are synonyms can be used to support the decision-making process.

To provide the desired functionality described above, we propose the usage of ontologies to describe the negotiation objects. This section gives an idea of how this can be done using the OWL language.

An ontology consists of object descriptions and their properties. To describe objects we first need to describe object types. This is done by defining general classes (using *owl:Class*). If we need to specify that a certain type is a subtype of another we use the *rdfs:subClassOf* property. Once defined, the object classes are used to describe the objects (e.g. a1 is *rdf:type* of class A). OWL uses properties to relate individuals to each other. Properties allow introducing associated object characteristics, such as *color* or *weight*. To limit the kinds of individuals that can fill a certain property, OWL allows for stating the property's range (using *rdfs:range* property). This mechanism allows new classes to be created by restricting the properties of the existing ones (e.g. all objects from class *Wines* that have property *color* restricted to value *red* define the new subclass of *Red wines*).

The expressive power and the formal rigor of OWL allows negotiation objects to be described in unambiguous way and therefore understood by all the participants in a negotiation process. Its basis for reasoning services provides a powerful mean to check the validity of a proposal or to infer implicit knowledge.

4.2 Negotiation messages

The process of negotiation in general is the iterative exchange of negotiation proposals until agreement is reached. Agreement is reached when the response of a proposal is an identical proposal or when one party repeats his proposal a second time in a row.

The proposed message structure is inspired by the work of Jennings et al. (Jennings et al., 2001) and Bartolini and Preist (Bartolini & Preist, 2001). Bartolini and Preist's messages are based on the instantiation of a template message, which is the proposal sent to the opponent. Jennings et al. see the negotiation objects as a collection of negotiation issues. We combine these two approaches and propose the message structure as shown in Figure 1.

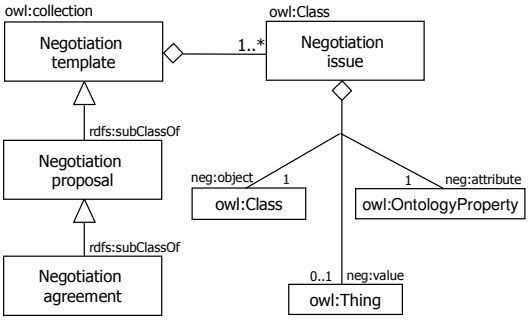

Figure 1: Negotiation message

Prior to any negotiation, participants must agree on the structure of the negotiation proposal, which is defined by the *Negotiation template* (see Figure 1). The Negotiation template specifies that every valid negotiation proposal is a collection of *Negotiation issues*. The Negotiation issue specifies the negotiation *object*, an *attribute* of a negotiation object and the *value* of that attribute. The Negotiation template does not prescribe the number of Negotiation issues, which allows parties to change the structure of the proposal during the negotiation process. The Negotiation template is a

blank proposal, i.e. neither attributes nor values are specified. Nevertheless, the Negotiation template does not forbid such specification. Its role is to 'reserve' space for participants to make their concrete proposals. The *Negotiation proposal* is a subclass of the Negotiation template. The Negotiation proposal follows the structure of the Negotiation template and the Negotiation issues are fully specified. By fully specified, we understand that to every negotiation object attribute there is a corresponding value. Once accepted, a Negotiation proposal becomes a *Negotiation agreement*.

4.3 Ad-hoc alliances

When businesses enter a negotiation process they usually have expectations that do not match exactly. Requestors ask for a complex product or service that cannot be fulfilled by any party. Conversely, providers may offer large discounts but for a quantity that no one can handle separately. Businesses deal with such problems by forming alliances. Alliances are formed by an additional negotiation among the future partners. In our approach, we provide a means for forming alliances. We call them *ad-hoc alliances*, because they are formed dynamically in the beginning of the negotiation process and disappear after an agreement is reached.

The main components that conduct the negotiation process in our framework are *negotiation host* and *ad-hoc alliance host* (see Figure 2). The negotiation host provides a medium for negotiation among single business parties and potential ad-hoc alliances. The ad-hoc alliance host represents the ad-hoc alliance in the negotiation process that takes place in the negotiation host. The ad-hoc alliance host provides allied parties with medium for negotiation of a common strategy. The ad-hoc alliance host represents an ad-hoc alliance in the negotiation process, which takes place in the negotiation host. Both the ad-hoc alliance host and the negotiation host have the same internal structure (discussed in details in the next section). These hosts have components (discussed in section 5.1) responsible for admission of participants, validation of proposals, enforcement of the protocol and the update of negotiation information. What makes them different is the template they use in the course of the negotiation process. The ad-hoc alliances are formed by sending invitations from the ad-hoc alliance host to the matched service or product providers. They can join the ad-hoc alliance by responding to these invitations.

4.4 Negotiation process

In our work, we adopt the approach proposed by Bartolini, Preist and Jennings (2002) and extend it further with a new concept of ad-hoc negotiation host. We propose a two-step negotiation process (Figure 2). The first step is negotiation among allied parties about their joint proposal to their opponent. The second step takes place in the negotiation host where parties negotiate over the joint proposal made by the ad-hoc alliance. We discuss our approach in details below.

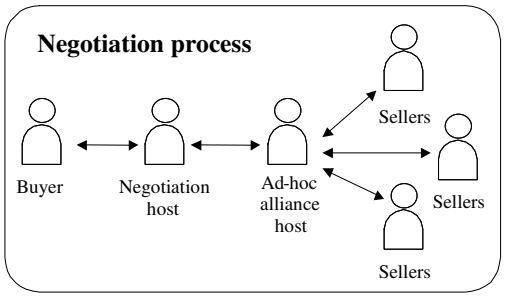

Figure 2: Negotiation process

Sellers register their service or product advertisements. The validity of the advertisement is checked and if it is valid, sellers are notified that the process of registration has been successful. When a buyer wants to search for a service or product, he creates a request – a virtual description of the package of products or services he wants to have – and files it. If the request is valid, the buyer is notified that the registration has been successful and the request is matched with the registered advertisements.

In case of a partial or complete match, an ad-hoc alliance host is created and all matched sellers are invited to join in. In this way, the ad-hoc alliance host serves as a forward aggregator in the terminology of Kaplan and Sawhney (2000). At the same time, a negotiation host is created, connected to the ad-hoc alliance host and the buyer is invited to join in. To be admitted to the negotiation process, sellers must accept an ad-hoc alliance negotiation template proposed by the ad-hoc alliance host and conversely, the buyer must accept a negotiation template proposed by the negotiation host. Both negotiation templates are dynamically created and specify the parameters of the negotiation (e.g. product types, prices, delivery dates, etc) taking into account the buyer's request. Additionally, a new negotiation issue is added to the ad-hoc alliance negotiation template – the direction that all sellers want to give to the buyer. When the participants are admitted, the negotiation process begins at the ad-

hoc alliance host. Once all sellers agree on the proposal they want to make to the buyer, the ad-hoc alliance host sends this proposal to the negotiation host. The buyer then agrees or makes a new proposal that is sent back to the ad-hoc alliance negotiation host.

5. ARCHITECTURE

This section presents an architecture that realizes our approach. We define the main components and describe the interactions among them. The architecture is depicted in Figure 3.

5.1 Components

The *communication layer* is responsible for providing the means for communication between the components representing participants and the system components. It provides secure and reliable communication, while hiding the complexity of the underlying network protocols.

The *participant*'s *component* represents a requestor or provider of a product or service. It contains facts and rules that represent the negotiation strategy of the involved party and uses a reasoning engine to carry out the negotiation process.

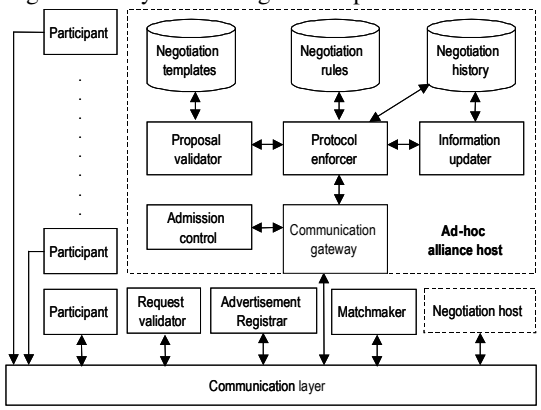

Figure 3: Architecture

The *advertisement registrar* is a component responsible for registering a particular service or product description. This component communicates with a *request validator component* to check whether a particular request or advertisement is valid and if so, it registers the request in its advertisement database.

The *request validator component* is responsible for checking whether an advertisement or request contains instances of agreed upon, domain-specific concepts.

The *matchmaker component* is responsible for matching requests with product or service advertisements. Initially, it uses the *request validator component* to check whether the issued request is valid. If so, the matchmaker uses its reasoning engine to match facts of the request with the facts of the registered advertisements. If there is no advertisement that completely satisfies the request, the component tries to find advertisements whose combination complies with the request. If any, the matchmaker creates an *ad-hoc alliance host* and initializes its *admission control component* to accept only participants associated with the matched advertisements. In addition it creates a *negotiation host* and initializes its *admission control component* to accept only the requestor and the ad-hoc alliance host.

Once created and initialized, the ad-*hoc alliance host* sends an invitation to all admitted participants to submit their proposals. When a proposal is received, the *communication gateway* checks whether this proposal comes from an admitted participant. If so, it sends it to the *protocol enforcer*. The *protocol enforcer* checks the validity of the proposal with the negotiation template. Then it checks whether the proposal is submitted according to the negotiation rules. If all conditions are met, it uses the *information updater* to assert or retract the new facts from the proposal to the negotiation history database. Finally, it updates the negotiation template. Once this is done, the *protocol enforcer* sends the updated negotiation template to all participants and invites the next participant to place its proposal. After all participants reach an agreement on the offer they want to make to the requestor, the *ad-hoc alliance host* submits the agreement as a proposal to the negotiation host.

The *Negotiation host* repeats the structure of the *ad-hoc alliance host*. The same components enforce the rules of negotiation between the requestor and the ad-hoc alliance host.

6. RELATED WORK

Bartolini, C. Preist, C and Jennings, N. (2002) present a general negotiation protocol, which can be parameterized by different rules to implement a variety of negotiation mechanisms. However, this work does not provide support for multi-party negotiations. Moreover, the lack of a formal semantics of the negotiation objects and messages could lead to misinterpretation of the issues being discussed.

The work of Tamma, Wooldridge and Dickinson (2002) presents an approach to ontology-based automated negotiation. The approach complements the one presented in the previous paragraph in a sense that negotiation issues and protocol are described in terms of a shared ontology. This approach, as the previous one, does not address multi-party negotiation.

7. FUTURE WORK

A number of issues raised in this paper require further investigation. First, heterogeneous agents meet difficulties joining an unknown negotiation process because they need to know the protocol in advance. In order to allow agents to participate in arbitrary negotiations, the rules that govern a particular negotiation should be described by the means of formal semantics. This requires investigation of the possibility to use DAML-Rules (re: DAML Rules) for protocol description. Second, the proposed solution for alliances requires further refinements into the following directions: (1) support for more that one alliance, including buyers' and sellers' sides. This will allow negotiation between alliances and freedom for actors to choose the alliance that suits them best; (2) better support for actors inside an alliance for acceptance and execution of a shared negotiation strategy.

8. CONCLUSIONS

In this paper, we address the problems of semantic interoperability in existing systems for automated negotiation. More, we discuss the lack of support for alliances in a negotiation process. We use the description logic provided by OWL as a means for formal representation of agreed upon concepts and relations from a particular domain of interest. The OWL language also allows for complex reasoning, while exploiting existing web standards such as XML and RDF. Our work extends existing work in the field by proposing a more advanced negotiation template defined by means of OWL. Such a template can significantly improve the process of negotiation by removing the possible ambiguities. The latter is achieved by restricting the range of the attributes that a certain negotiation object may take. Furthermore, in our approach we introduce the notion of "ad-hoc alliance host" – a component that enables multiple parties to agree on a joint proposal when negotiating with other party or alliance.

ACKNOWLEDGMENTS

We would like to express our gratitude to prof. Roel Wieringa from the University of Twente for his comments and suggestions.
This work is partially funded by the WASP project (re: WASP).

REFERENCES

Bartolini, C. & Preist, C., 2001, A Framework for Automated Negotiation, *HPL-2001-90*, HP Laboratories Bristol

Bartolini, C., Preist, C. & Jennings, N., 2002, A Generic Software Framework for Auto-mated Negotiation, *http://www.hpl.hp.com/techreports/2002/HPL-2002-2.pdf*

DAML+OIL (March 2001) Reference Description, *http://www.w3.org/TR/daml+oil-reference*

DAML Rules, *http://www.daml.org/rules/*

DARPA Agent Markup Language (DAML), *http://www.daml.org/*

Jennings, N., Faratin, P., Lomuscio, A., Parsons, S., Sierra, C. & Wooldridge M. , 2001, Automated Negotiation: Prospects, Methods and Challenges, *Int Journal of Group Decision and Negotiation*, vol. 10, no. 2, pp. 199-215

Kaplan, S. & Sawhney, M., 2000, E-Hubs: The New B2B Marketplaces, *Harvard Business Review*, May-June

Ontology Inference Layer (OIL), *http://www.ontoknowledge.org/oil/*

RDF Vocabulary Description Language: RDF Schema, *http://www.w3.org/TR/rdf-schema/*

Tamma, V., Wooldridge, M., and Dickinson, I., 2002, An ontology based approach to automated negotiation, *Proceedings of the IV workshop on agent mediated electronic commerce*, AAMAS 02 conference, Bologna, Italy.

WASP project, http://wasp.freeband.nl/

Web Ontology Language (OWL), *http://www.w3.org/TR/owl-ref/*