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A Negotiation Protocol Framework for WS-Agreement

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Abstract. The Web Services Agreement specification defines a format and an establishment protocol for Service Level Agreements for Service Oriented Architectures. The current draft's simple request-response protocol for agreement creation only addresses bilateral offer exchanges. This paper proposes a framework augmenting this WS-Agreement to enable negotiations according to a variety of - more advanced - negotiation protocols. A meta-protocol is presented to exchange information on supported negotiation protocols, agree on a protocol and then execute the negotiation protocol itself. The meta-protocol is based on a comprehensive set of parameters describing the negotiation protocol to be conducted. With this framework a variety of bilateral and multilateral negotiation protocol definitions can be created, communicated to participating software agents and subsequently conducted, all resulting in valid Web Services Agreements.

1 Introduction

Service Level Agreements (SLA) represent qualitative guarantees placed on service invocations within a service oriented environment. Service consumers benefit from these guarantees because they make non-functional properties of service predictability. On the other hand, SLAs enable service capacity management for service providers. By employing SLAs, a robust service oriented architectures can be realised, even across company boundaries. To support broad application, standards for the structure of agreement documents as well as a standard process to establish and monitor them are required. Such protocols are particularly important if the agreement creation is to be executed automatically.

The Web Services Agreement (WS-Agreement) specification is a standardization effort conducted by the Open Grid Forum (OGF) in order to facilitate creation and monitoring of SLAs [1]. This standard defines an XML-based structural definition of SLA documents, a simple request-response protocol for agreement creation as well as corresponding interfaces for agreement creation and monitoring. A WS-Agreement specifies functional properties and qualitative service level guarantees in a detailed way in a set of terms.

However, the proposed agreement creation process is restricted to a simple request-response protocol: one party (agreement initiator) creates an agreement document, possibly based on an agreement template, and proposes it to the other party (agreement responder). The agreement responder evaluates the offered agreement and assesses its resource situation before accepting or rejecting the offer. This protocol does not enable advanced negotiations formats such as auction, involving numerous parties in different roles. Enabling a variety of negotiation protocols would result in wider applicability of WS-Agreement for more demanding allocation problems.

The incorporation of different negotiation protocols into the agreement creation process of WS-Agreement poses several problems: First, such protocols must be integrated seamlessly in the overall WS-Agreement protocol to enable subsequent agreement monitoring, as defined in the WS-Agreement specification. Furthermore, in an automated negotiation, all participating components - here referred to as agents - must be aware of all rules and constraints concerning the negotiation protocol. Finally, a corresponding infrastructure of role definitions, interfaces and methods has to be presented to facilitate the actual negotiations.

To supply the negotiating agents with the necessary information to participate in the actual negotiation protocol a fixed, well known set of negotiation protocol definitions could be specified. During the actual negotiation the corresponding protocol description is simply referenced. However, this limits the set of available negotiation protocols to a predefined, finite set.

In the framework proposed in this paper, we define a meta-language for negotiation protocols. Using such a meta-language a multitude of specific negotiation protocols can be defined using a well-defined set of attributes and parameters. These protocol definitions have to be distributed to all prospective negotiators before the actual negotiation to inform them with protocol has been chosen. Furthermore, we propose a negotiation meta-protocol to distribute the negotiation definitions to all prospective negotiators and choose a negotiation protocol. Finally we define a generic negotiation protocol that is able to support all specific negotiation protocols that can be described with the presented negotiation attributes as extension to basic WS-Agreement offers.

2 Basic Definitions and Data Structures

Before describing the exchange and negotiation protocols this section will give a short overview on the basic concepts and data structures used in the negotiation framework subsequently.

2.1 Negotiation Protocol Definition

This framework supports a multitude of different negotiation protocols, like various auction types or one-on-one bargaining protocols. Each negotiation protocol that is to be conducted fully automated in multi-agent systems has to be exhaustively described. Only by providing a complete and machine-processable

process description its correct application in automated distributed systems can be guaranteed. In order to enable such an protocol description a set of negotiation attributes have been identified as a basis for this framework, as described in the next subsections.

Theoretical Background To specify a comprehensive set of negotiation attributes this framework employs negotiation taxonomies originating in e-commerce research and economics. These taxonomies (e. g. [2], [3]) present a set of parameters that allow for detailed description of specific negotiation protocols. For this framework the existing taxonomies were integrated and consolidated in order to derive a set of attributes and corresponding domains suitable for definition of automated SLA negotiations among software agents.

Negotiation Attributes For this framework the following attribute categories were identified:

- General Negotiation Process: Basic negotiation parameters like start, termination or negotiation rounds.
- Negotiation Context: Negotiation configuration in terms of involved roles and agents.
- Negotiated Issues: SLA terms to be negotiated in the corresponding negotiation.
- Offer Submission: Rules concerning the bidding process, like when an offer can be posed or what constraint it has to satisfy.
- Offer Allocation: Matchmaking rules for the negotiation.
- Information Processing: Rules defining which information about the current negotiation and bidding history is available to which agent(s).

With these attributes a multitude of 1:1 and 1:n negotiation protocols can be defined as detailed as is necessary for automated execution. For a more detailed description of the identified attributes, see [4].

Negotiation Types and Instances For the remaining paper negotiation types and instances will be distinguished. A negotiation type describes a general class of negotiations and defines their common attributes and elements. A negotiation instance, however, stands for one particular negotiation of some type. For example, a negotiation type can define, that there is one agent involved not allowed to post offers, whereas on the other side n agents can participate posting offers, in which every offer has to succeed the last posted offer by some amount and so on. This roughly describes the class of auctions. One particular negotiation instance of this negotiation type represents one particular auction conducted at some particular point in time.

Hence, a negotiation instance defines only instance specific data, like an identifier, a reference to this negotiation's type or the involved agents, while a negotiation type specifies the remaining attributes of a negotiation as identified within the presented categories.

In order to supply the negotiating agents with the required information about negotiation types and instances two Extensible Markup Language (XML) document descriptions (formalised as XML-Schema documents) for each of these concepts were defined. These documents will be used within the actual negotiation protocols as described in the following sections. These XML-Schema documents are presented in [4].

2.2 Negotiation Process Description

This subsection will describe the abstract architecture of a negotiation process by relating the involved documents and roles.

Abstract Architecture of Negotiation Documents The main negotiation object is a WS-Agreement template with its corresponding creation constraints as defined in the current WS-Agreement specification. Since this framework augments the current specification with possibilities to negotiate over a WS-Agreement this fundamental data structure is adopted for the (partial) definition of some service(s) to be negotiated. The creation constraints as part of this template are also used in this approach to give syntactical restrictions on the elements still to be filled out or altered during the negotiation.

The negotiation type document as sketched in the previous section refers to the WS-Agreement template the negotiation is defined upon for specifying the negotiated issues. Given its content the Negotiation Type document defines which terms of a WS-Agreement can be negotiated and how to do so.

A concrete negotiation is represented by a negotiation instance document as already hinted. This document refers to the negotiation's type, its participants and specifies a unique identifier.

Finally, the result of the complete negotiation protocol is a valid WS-Agreement document satisfying the creation constraints as defined in the initial WS-Agreement referenced in the negotiation type document.

Roles In order to describe the involved parties in a negotiation process three distinct roles are introduced for this framework: Negotiation Participant, Negotiation Coordinator and Information Service. Since this framework is employed in service oriented environments each of these roles offers some functionality as a service to the other agents involved in the negotiation, therefore providing a corresponding interface.

In such a negotiation process the Negotiation Participants represent regular agents participating in the initial negotiation meta-protocol (used to distribute the negotiation documents to the prospective negotiators) and the negotiation process itself. Therefore the respective interface offers methods used in the exchange and the negotiation process.

The Negotiation Coordinator is a logically centralised instance which handles admission of agents to a given negotiation as well as (re)distribution of the negotiation documents to the prospective negotiators. Hence, the coordinator

interface offers methods for querying instance and type documents or methods used for joining a concrete negotiation.

The information distribution during the actual negotiation is administrated by the Information Service. This service offers information about the current status of a negotiation (for example the currently highest bid) or about the offer history to the negotiators.

Employing the presented roles and data structures the next sections will introduce the negotiation meta-protocol for negotiation data and the negotiation protocol subsequently.

3 Negotiation Meta-Protocol

This paper proposes a framework supporting the complete agreement creation process. As depicted in the following figure this creation process as defined in this work is divided into three distinct phases: first the negotiation protocol definition has to be distributed to all prospective negotiators as described in this section. Subsequently the actual negotiation process takes place, according to the rules defined and distributed in the previous phase. Finally in the agreement acceptance phase one offered agreement is accepted by one of the participants to terminate the negotiation.

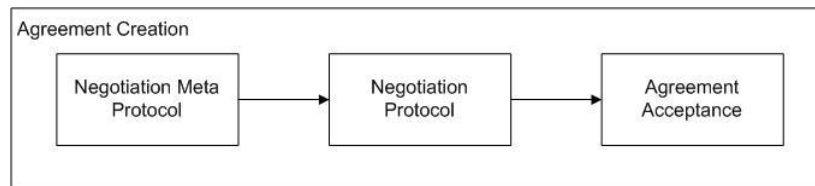


Fig. 1. Agreement Creation Process

To enable automated SLA negotiations in service oriented environments the negotiation meta-protocol for the negotiation documents as well as the negotiation protocol will be defined in terms of method invocation sequences on the services offered by the three involved roles.

The negotiation meta-protocol describes the process of distributing the necessary information about a negotiation protocol to the agents wanting to participate in it. This is done by distributing the already mentioned negotiation type and instance documents to the respective agents.

3.1 Involved Roles and Corresponding Interfaces

In this subsection the roles and corresponding interfaces involved in the exchange process will shortly be described. For detailed method description and the corresponding WSDL documents see [4].

The central instance in such an exchange process represents the Negotiation Coordinator that provides these documents. The corresponding interface offers a set of query methods, used for requesting available negotiation type and instance documents, as well as a method for joining a particular negotiation. Also additional functionality for proposing or publishing negotiation documents is offered to the participants.

The Negotiation Participant role is present in the exchange and the negotiation protocol. For the exchange process the corresponding interface offers methods to propose negotiation instances, to allow Negotiation Coordinators to actively distribute such documents, as well as functionality to update negotiation instance data. This is invoked by the Negotiation Coordinator to notify the participant of changed negotiation data, like newly joined agents.

Using these methods some basic protocol components for the exchange process can be defined as described in the next subsection.

3.2 Protocol Components

In order to define the negotiation meta-protocol for negotiation data only three basic protocol components have to be specified. More sophisticated negotiation meta-protocols can be defined by combining these basic elements. These three fundamental protocol components correspond to three scenarios possible within the negotiation meta-protocol: request for negotiation documents, proposal of negotiation documents and mediated exchange process.

Request for negotiation documents depicts the process of one agent requesting negotiation type or instance documents from the respective Negotiation Coordinator. An agent can query negotiation instances and subsequently join if desired or it can request negotiation types, create an instance document itself and propose it to the coordinator for further processing.

Proposal of negotiation documents represents the process of actively proposing some instance document to a prospective participant or coordinator. As just described this protocol component regularly follows a request for negotiation types in order to propose the newly created instance to the coordinating agent.

Mediated exchange processes offer publish/subscribe functionality to the participants. Agents can publish negotiation instances at some Negotiation Coordinator (which does not have to act as coordinator for the remaining exchange process, but only as publication server) to make it available to a larger community of prospective negotiation participants. This way a distributed system of negotiation look-up servers can be created, as sketched in [4].

By combining these three basic protocol components a multitude of different exchange processes can be specified, all resulting in distributing the information, needed to participate in a particular negotiation, to all prospective participants.

4 Negotiation Protocol

After supplying all negotiation participants with the negotiation type and instance documents the actual negotiation can start. The protocol governing this process is described in this section.

In general, we describe every negotiation as a bidding process. Each party involved in a negotiation offers an agreement to the other party concerning the issues subject to the negotiation that is currently acceptable for them. Then the other party assesses the offered agreement and generates a counter-offer, accepts the offer or rejects it and terminates the negotiation. This way the two parties involved move from a conflict situation concerning some (logical) resource(s) to a consensus represented by the resulting agreement. Since SLA scenarios only exhibit two logical positions actively involved in a negotiation, the service providers and consumers, only such two-sided negotiation protocols are considered in this paper.

Which agent involved in the bidding process can post offers and at which constraints are posted on the offer submission is defined within the negotiation type document, describing a distinct bidding process.

The Negotiation Participant interface offers methods to place offers, accept and reject agreements in order to conduct WS-Agreement negotiations. These methods allow the three actions resulting from a received offer as already mentioned above: generating counter offers, accepting the offered SLA, or rejecting it and terminating the negotiation. The Information Service role provides access to information on the current negotiation status or past offers.

The roles and interfaces presented for the negotiation protocol are capable of conducting any negotiation protocol describable with the attributes identified before.

5 Conclusion

This paper proposes a comprehensive negotiation framework for WS-Agreement. Negotiation protocols can be specified in a description language and made available to parties interested in negotiations. Parties interested in negotiating an agreement first run the negotiation meta-protocol to establish which negotiation protocol is used. Subsequently, the protocol is executed, based on the WS-Agreement offer. Finally, after winner determination, acceptance and rejection is performed again according to the standard WS-Agreement protocol. With these two protocols fully automated WS-Agreement negotiations according to a variety of different negotiation protocols can be conducted in Web Service environments.

In future work, we will continue implementing and testing a variety of negotiation protocols and thus verify the expressiveness of the negotiation description language and the capabilities of the negotiation meta-protocol.

6 References

1. Andrieux, A. et al.: Web Services Agreement Specification Draft, Version 09/2005
2. Stroebel, M. and Weinhardt, C.: The Montreal Taxonomy for Electronic Negotiations, *Journal of Group Decision and Negotiation*(12): 143-164, 2003
3. Bartolini, C. et al.: A Software Framework for Automated Negotiation, *Software Engineering for Multi-Agent Systems III*: 213-235, 2005
4. Hudert, S.: A Proposal for a Web Services Agreement Protocol Framework, Technical Report, Bamberg University, October 2006