

A TWO-TIERED MODEL OF NEGOTIATION BASED ON WEB SERVICE AGREEMENTS

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Abstract

This paper presents a generic model for document-based mediated resource negotiation. Document-based due to the use of Web Service Agreements. The information types included in the Web Service Agreement structure have been extended to include the accept phase of negotiation. This model of mediated negotiation respects the autonomy of both individual provider agents and consumer agents: consumer agents negotiate with multiple mediator agents; mediator agents negotiate with virtual organisations that represent multiple provider agents. This model has been implemented and tested in the AgentScape framework for resource management.

1 Introduction

Negotiation is one of the basic patterns of communication: mediation, bargaining, conflict resolution, trading, to name a few. Some even claim that negotiation is the heart of all communication [3]. Negotiation is, in fact, a process with two or more interdependent participants each with their own possibly incompatible goals. During a negotiation process alternatives are investigated, of which one may be chosen as the mutually acceptable outcome [13]. Weigand et al. distinguish a number of different types of negotiation: norm-oriented, goal-oriented and document-oriented, each with their own specific characteristics. Electronic negotiation often focuses on only a small part of the complete negotiation process, namely on the phase of bargaining. Bargaining entails finding a compromise between the established preferences of the participants. Examples of these electronic negotiations can be found in implementations of application-oriented multi-agent negotiation systems presented by Brazier et al. [2] in which a system was designed to support load balancing of electricity use. In this model customer agents represent groups of resources and utility agents represent the providers. A similar example of an agent based approach to energy resource management is described by Jones and James [4].

Electronic negotiation models can be classified by the characteristics of the negotiation space for which the models are best suited [5]. The most defining characteristics are the negotiation domain, the negotiation interactions, and negotiation environment.

A *negotiation domain* can be defined by the issues that are central to the negotiation: During negotiation, either a single item can be negotiated (single-issue negotiation), or multiple (possibly related) items can be negotiated (multiple-issue negotiation). The languages with which items are expressed often differs considerably. The most simple cases are those where the items are commodities that can be identified through a unique number and the price is the only negotiation issue. The language only has to express pairs of integers denoting identifiers and prices. In the type of negotiation addressed in this paper, this suffices. On the other extreme negotiate complex contracts can be negotiated with many conditions. An example of a language for electronic contracts

has been proposed by Tan and Thoen [12]: a very powerful language that allows for many issues to be negotiated. Types of *negotiation interactions* can be defined by the number of participating entities in a negotiation process: one-to-one, one-to-many, and many-many negotiation are the standard types that are distinguished. Finally, a *negotiation environment* is of importance. An environment can be static or dynamic, with respect to the participants and the items negotiated.

This paper presents a generic model for mediated resource negotiation using Web Service Agreements. The format of the Web Service Agreements provides a template with which interaction is structured. As a result the model presented in this paper is document-based, focusing explicitly on the interaction between participants. The model specifies the interaction needed for multiple-issue negotiation, as the negotiation document can contain descriptions of multiple resources. The negotiation is one-to-many, as consumers can enter into negotiations with multiple mediators, and a mediator can negotiate with multiple resource managers. The environment is dynamic, as available resources change continuously, and negotiation participants also change over time.

The underlying aspects of the model for mediated negotiation are presented in the following sections: the basic negotiation framework, the negotiation process, negotiation language, and the negotiation protocol.

2 The basic negotiation framework

2.1 Participants

The framework distinguishes a number of participants: consumers, mediators and resource providers. Resource providers are grouped together in dynamic virtual organisations.

Both consumers and resource providers are modeled abstractly, i.e. the model defines interface elements and interactions between participants, no internal modeling is given. The domain of energy management as described in [4] is used to illustrate our approach.

2.1.1 Resource Provider Agent

A resource provider agent (RPA) represents the provider/owner of resources in negotiations with a mediator. For each resource, access and usage policies are defined by the provider/owner. These policies are implemented and enforced by the RPA. The RPA is responsible for implementing its own local management policies.

In the energy management domain, RPAs represent energy generating devices (wind generators, photo-voltaic arrays, etc.). These RPAs are responsible for applying local policies regarding the use of the generated energy. One RPA may represent a single device or a group of devices, such as for example a group of wind turbines at a specific location. Access and usage policies describe in which order individual turbines are used to generate energy by whom, if the demand for energy increases.

2.1.2 Mediator Agent

A mediator agent represents a virtual organisation in negotiations with consumer agents. A mediator agent takes care that a negotiation that essentially might be between multiple resources and multiple customers, is split up into two one-to-many negotiations. In this case the mediator is seen as representing a virtual organisation containing many resource providers. It could also be a virtual consumer organisation representing a group of consumers (think e.g. of a central purchasing department for a large organisation).

A *virtual organisation* is an abstract representation of a number of RPAs. Each virtual organisation has its own management policies spanning the RPAs involved. A mediator agent is responsible for the implementation of these organisation-wide management policies. To this purpose a mediator aggregates relevant negotiation information from the RPAs within the virtual organisation.

In the distributed energy management example, an example of a virtual organisation is one that represents turbines from different companies located in the vicinity of a city. Another example is that of multiple fields of wind turbines in a specific geographical area owned by the same company.

A mediator agent represents a wind turbine company, or city council, and implements domain-wide energy management policies, describing how aggregated resources should be used. An example

of a policy on this level is a policy defining the maximum number of wind turbines which may be active at specific times.

2.2 Consumer Agent

A consumer agent contacts one or more mediators of virtual organisations to initiate negotiation, aiming to acquire an offer which they can accept: an offer that fulfills their needs/requirements. Their initial statement of interest expresses their needs.

In the example, consumers agents represent devices requiring energy (air conditioning, refrigerators, heating equipment, etc.). Consumers can represent single devices, or larger groups of devices such as all devices in a building, or similar devices distributed over a larger area, with for example similar energy requirements. They may express their needs to one or more mediators to discover their options.

2.3 Negotiation model

The agents introduced above are depicted in figure 1. Consumer Agents (C) negotiate with mediator agents (M). The mediator agents negotiate with resource provider agents (RP). The result of the negotiation sequence is an agreement between a consumer and a mediator, specifying the resource usage conditions agreed. After activation of this agreement, the RPAs are responsible for ensuring that the agreement is fulfilled. The negotiation interactions between the agents are document based. Documents representing (partial) agreements are exchanged and manipulated, ultimately resulting in a final agreement document.

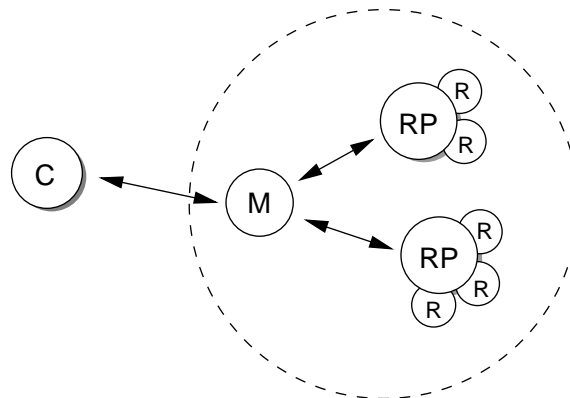


Figure 1: Negotiation model overview.

3 Negotiation process

The negotiation process used between agents in the above framework is based on Web Service Agreement specifications. Below first a description of Web Service Agreement Specifications is provided followed by a description of their use in our framework.

3.1 Web Service Agreement specification

The Web Service Agreement specification (WSA) [1] describes a negotiation-based approach for accessing web services. To obtain access to and use a web service, a negotiation cycle takes place between a web service provider and a web service consumer. The resulting agreement specifies the conditions under which the service can/may be used by a consumer.

The specification has been designed specifically for web services, and defines a negotiation language and protocol. The negotiation functionality is encapsulated in web services: the WSA specification includes proposed negotiation interfaces in the form of web service port type definitions.

The specification also describes how WSA functionality can be embedded into existing service architectures. The model recognizes two layers: A *service layer*, being the actual service subject to agreement based management; An *agreement layer*, implementing the agreement-based negotiation functionality. The agreement layer consists of an *agreement factory*, exposing an interface allowing the requesting of templates, and the creation of agreements. Upon creation of an agreement, an *agreement service* is instantiated, implementing the actual agreement and exposing agreement life cycle operations.

The interaction protocol is relatively straightforward: First, the initiator of a negotiation sequence requests available *templates* from the service provider. The initiator then selects a suitable template and uses this to create an *agreement offer*. This offer is sent to the service provider. If it is accepted, the provider creates an *agreement* based on the offer. The agreement is implemented, and returned to the initiator. During the time that the agreement is active, its status can be monitored, to determine if all elements of the agreement are still valid, or if violations of the agreement have occurred.

Although this negotiation scheme might be classified as norm-oriented [13], as there is a request for quotes and quotes phase, there are no obligations and authorizations derived. The negotiation process is primarily document-based, because the filling of the WSA is the primary driving force of the negotiation.

The specification defines negotiation document formats as XML-Schema specifications. Two document types are distinguished: Templates, and Agreements. Central to these document types are negotiation *terms*. In the negotiation language specification, resource descriptions are explicitly not modeled, and can be added to the specification according to the requirements of the application domain. The following sections will describe the document types in more detail.

3.1.1 Agreement document

An agreement (or agreement offer) consists of two main sections: a *context*, and *terms* section. The context section contains agreement meta-information. The terms section contains the actual agreement content. Two types of terms are distinguished: *Service Description Terms* (SDTs), and *Guarantee Terms* (GTs). SDTs define the actual services that the agreement is about. GTs define “*assurances to the service consumer on the service quality and/or resource availability offer by the service provider*”. Terms can be logically grouped using term compositors, allowing for the specification of several alternative term combinations in a single agreement document. Figure 2 gives an overview of an agreement document.

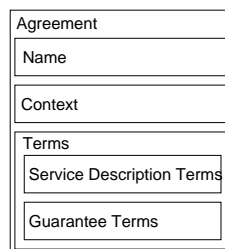


Figure 2: Conceptual overview of an agreement.

3.1.2 Template document

A template has a document structure similar to an agreement document, but with the addition of a *Creation Constraint* section, which can be used to define initial negotiation constraints on terms describe in the template. Figure 3 show an overview of a template document.

3.2 Negotiation Process using WSA specs

The WSA protocol has been used to structure interaction between the agents described above in section 2. The negotiation process itself consists of four main phases. Each phase can be associated with a negotiation document type.

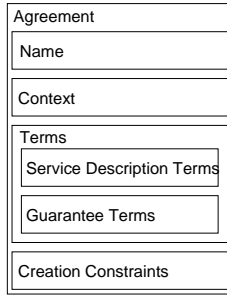


Figure 3: Conceptual overview of a template.

The first phase is the *advertisement phase*. In this phase, consumer agents inform the mediator agent of the types of resources they require. The mediator agent retrieves individual advertisements from individual resource provider agents in its virtual organisation in which the resources it can provide at this point in time are described in general terms, possibly combining options from different resource provider agents to create advertisements suitable for the consumer agent's needs.

In the *request phase*, consumer agents respond to the advertisements with a *lease request*. The request describes which resources a consumer agent wishes to access, under which conditions in accordance with the advertisement on which the request is based. The mediator agent translates the lease request into requests to the individual resource provider agents involved.

In the *offer phase*, resource provider agents analyze the lease requests received from the mediator agent, and create *lease offers*. These lease offers describe the conditions under which the resources can be made available to the consumer agent, based on current resource availability and policies. The offers are valid for a limited time-period. The mediator agent aggregates the offers into one or more domain offers, and returns these to the consumer agent.

In the *acceptance phase*, the consumer agent accepts one of the offers made by the mediator. The mediator agent translates this into acceptance of the individual lease offers made by the respective resource provider agents. This results in a *domain lease* document, which details the actual resources and conditions that are to be provided. The lease also specifies an expiration time for the lease. Extension of the lease needs to be re-negotiated by the consumer agent.

Although this negotiation model seems extremely simple it is nevertheless sufficient. In cases where the parties do not reach an agreement one of the parties might initiate an alternative request or offer and start the process over again. The model can be compared to the well-known Contract Net protocol [11]: At both the consumer level and the provider level of the negotiation model, a Contract Net-like interaction sequence takes place: lease requests can be compared to *calls for proposals*, lease offers can be compared to *bids*, after which offers can be accepted or rejected, similar to acceptance/rejection of bids in the Contract Net protocol.

As resources are the topic of negotiation, the issues are usually not the price but rather the conditions under which the resource can be made available. There is limited room to change those conditions during a single negotiation process, except when several negotiations are taking place in parallel and either the resource agent or the consumer agent can choose to drop one requirement for one negotiation in favor of another requirement in a second negotiation. The process of weighing the priorities between the different negotiations going on should be governed by the policies of the respective agents.

Figure 4 shows the negotiation documents involved in each of the phases in the negotiation.

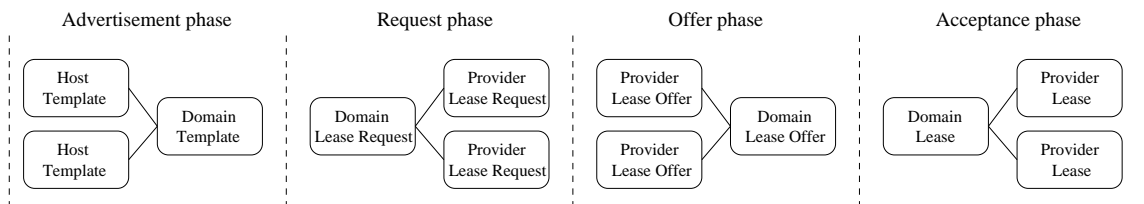


Figure 4: The negotiation model phases.

3.3 Two-tiered Negotiation

The negotiation model is a two-tiered negotiation model. In the upper tier, consumer agents negotiate with mediator agents. Mediator agents hide provider-level details and aggregate resources throughout a domain, offering a single consumer interaction point.

In the lower tier, the mediator agent negotiates with resource provider agents offering individual resources. The mediator agent translates requests from consumers into provider-level negotiation sequences. Resource provider agents do not interact directly with consumer agents.

The negotiation interactions used in both tiers allow for a simple request-response type negotiation interaction. This ensures that a single interaction has an upper limit in the amount of time it requires to complete (i.e. the time it takes for the negotiation process to pass through all four phases).

Management policies regarding the allocation of resources can be consumer oriented or provider oriented, in the sense that policies can attempt to optimize resource usage (i) for individual consumer agents, which can result in a less optimal allocation of resources from a provider point-of-view, or (ii) for resource provider agents, which can result in less optimal resource allocation from the perspective of consumers. A mediator agent can use its position in the negotiation model to apply management policies, while attempting to optimize resource allocation for both parties. For example, a mediator agent can impose a “load-balancing” policy, selectively choosing provider agents to negotiate with within the virtual organisation, in an attempt to distribute consumer agents across the available resources.

The mediator agent does not play an active role in the implementation of the leases. After acceptance of the lease by the consumer agent, resource provider agents are responsible for enforcing leases and enabling access to the negotiated resources.

Figure 5 shows a complete overview of the negotiation process.

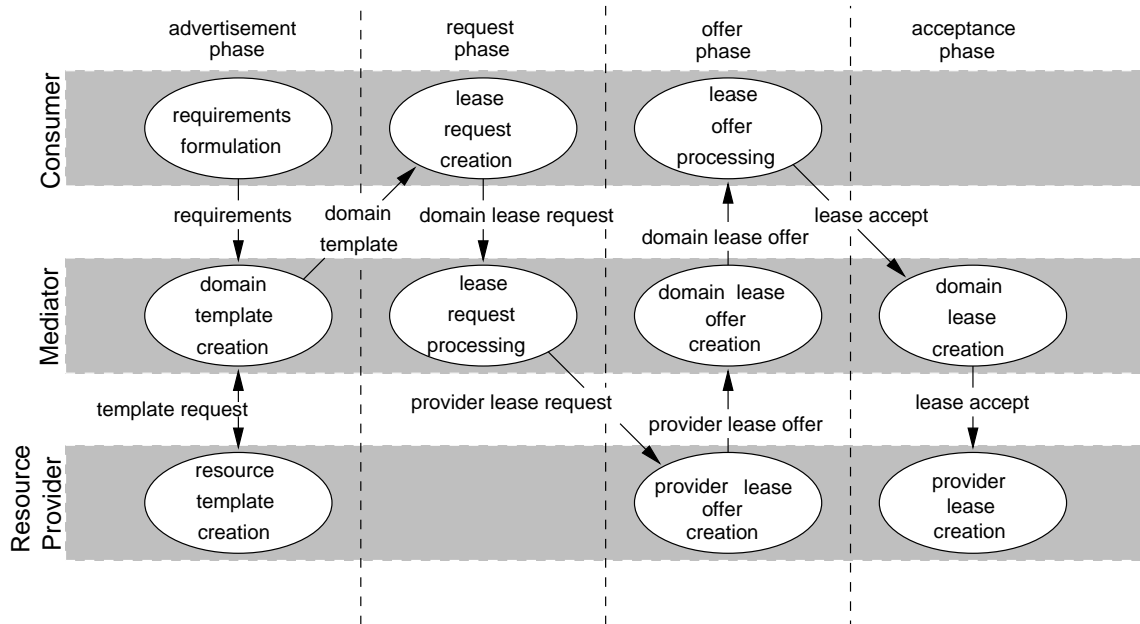


Figure 5: The negotiation process.

How the process works can be illustrated in the context of distributed energy management example domain used above. Energy consumer agents negotiate with mediator agents of virtual organisations representing energy resource providers. The mediator agents represent their own RP agents. An example of a negotiation process is the following. A consumer agent that represents a refrigeration facility, requires a large amount of energy at intervals to keep temperatures below a certain threshold. The consumer agent contacts the mediator agents of the available energy providers requesting their current advertisements. Each mediator agent returns a set of advertisements describing the initial boundaries as retrieved from the RP advertisements, indicating under which conditions the energy can be provided by the RPs in their domains (e.g. time constraints,

maximum load constraints, etc.). The consumer agent selects one or more advertisements which are suitable for its requirements, and uses this as a basis for its lease requests, indicating the precise conditions under which it requires energy (e.g. between 1 and 2 PM, minimum required kWh, etc.). Each mediator agent analyzes the incoming request, and determines which resource provider agents within its domain are capable of supplying the requested amounts, which results in a list of RPA negotiation candidates. Additionally, domain policies are applied, possibly reducing the RPA list further (e.g. one of the RPAs in the list has recently received a large number of requests, and any new incoming requests should be distributed across other RPAs). The mediator agent contacts the selected RPAs, and receives offers from each of the RPAs indicating the conditions under which they are willing to provide the requested resources (or less, if the requested amount cannot be delivered currently). The mediator agent analyzes the offers, and selects those it considers suitable for the consumer agent. The consumer agent receives offers from multiple mediator agents, and can select the offer which it considers best. After acceptance, a lease is created, which the consumer agent can use to claim the requested energy from the resource provider agents.

4 Negotiation Language

The negotiation document types introduced in Section 3.1, are described in this section in more detail.

4.1 Agreements

The basic document type used for lease request, lease offer, and lease documents in the model, is the WSA Agreement document type.

In the WSA specification the *agreement name* field is optional. In our negotiation model it is not: a *lease* document requires a unique identifier, to allow consumers and the management architecture to refer to specific lease documents in communications.

Context

The agreement context section of a lease document contains fields for specifying the (i) initiator of the agreement, (ii) the provider of the agreement, (iii) a boolean field indicating if the initiator of the agreement is also the consumer, (iv) the expiration time of the agreement (after which the agreement is no longer valid), (v) the name of the template on which the agreement is based, and (vi) references to related agreements if present. Relationships between agreements are not further defined in the WSA specification. The structure of the context section of a lease document is shown in the example below:

```
<Context>
  <AgreementInitiator>Example Application</AgreementInitiator>
  <AgreementProvider></AgreementProvider>
  <AgreementInitiatorIsServiceConsumer>yes</AgreementInitiatorIsServiceConsumer>
  <ExpirationTime>2005-01-10T12:30:00</ExpirationTime>
  <TemplateName>Template A</TemplateName>
</Context>
```

Terms

Two term types are recognized in the terms section of a document: service description terms, and guarantee terms. A service description term consists of a *service name*, and a domain-specific description of the service functionality. Agreements can contain multiple SDTs, which can refer to multiple services.

A guarantee term contains four main elements:

- A service scope: Defines the services to which the guarantee applies.
- Qualifying conditions: Pre-conditions that must be met for the guarantee to be enforced (e.g. time of day)
- Service level objectives: Conditions that must be met for the guarantee to be satisfied.
- A business value list: Used to assign value aspects to service level objectives (e.g. importance, penalties, rewards).

The structure of the terms section is shown in the example below:

```
<Terms>
  <All>
    <ServiceDescriptionTerm Name="..." ServiceName="...">
      ...
    </ServiceDescriptionTerm>
    <GuaranteeTerm Name="...">
      <ServiceScope>
        <ServiceName>...</ServiceName>
      </ServiceScope>
      <ServiceLevelObjective>
        ...
      </ServiceLevelObjective>
    </GuaranteeTerm>
  </All>
</Terms>
```

4.2 Templates

The WSA Template document type is used as the basis for the advertisements used in our negotiation model. The structure of a template is similar to an agreement based document, with the addition of a Creation Constraints section. A creation constraint section consists of *Offer Items*, and *Constraints*. An Offer Item is a restriction describing a field that must be present in the agreement, and possible values for that field. To allow for more elaborate restrictions to be defined, possibly spanning multiple terms in an agreement, the top-level Constraint element of the Creation Constraints section can be used to define constraints using a specialized constraint language explicitly left unspecified in the WSA specification. The structure of a lease template is shown in the example below:

```
<Template>
  <Name/>
  <Context/>
  <Terms/>
  <CreationConstraints>
    <Item>
      <Location>...</Location>
      ...
    </Item>
  </CreationConstraints>
</Template>
```

5 Negotiation Protocol

This section describes the tasks performed by each of the agents in more detail in the context of the protocol-phases.

5.1 Advertisement phase

Consumer Agent

For a consumer agent the advertisement phase entails obtaining one or more advertisements from selected mediator agents. It is assumed that mediator agents have already been discovered and are available for communication. Two subtasks can be distinguished: (i) Formulating resource requirements, and (ii) communicating these requirements to the selected mediators,

The formulation of resource requirements by the consumer agent entails determining which resources are required and translating this into a form which can be interpreted by the mediator agent. The requirements do not specify specific resources or conditions, as these will be determined during the negotiation process.

The consumer agent sends these requirements to the selected mediator agents. As a result, each mediator agent returns zero or more advertisements, describing which resources are available within its virtual organisation at this point in time.

Mediator Agent

For mediator agents, the template phase entails responding to incoming requests for advertisements

from consumer agents. Upon receiving a request, a mediator agent analyses the resources specified in the request (i.e. the list of resource types), and determines if advertisements are available in the virtual organisation it represents which match the requested resources. To this end, the mediator agent requests individual advertisements of from resource provider agents within the virtual domain. These individual advertisements consist of creation constraints as specified in the template document model described earlier. These constraints are aggregated into domain-wide advertisements, depending on their compatibility, and policies regarding the matching and combining of resources offered by resource provider agents. The resulting advertisements are returned to the consumer agent.

Resource Provider Agent

For resource provider agents, the template phase entails responding to requests for advertisements by the mediator agent of the virtual organisation. A provider agent must ensure that the advertisements returned to the mediator agent reflect the current state of the resources. To this end, a provider agent must maintain an accurate view of available resources, and local resource access policies, and translate these into creation constraints as specified in the template document model.

5.2 Request phase

Consumer Agent

The request phase of the negotiation protocol from a consumer agent's point-of-view consists of formulating a lease request based on the advertisements received in the template phase, and communicating this to the mediator agent. This process entails selecting an advertisement, and using the information concerning resource access conditions specified herein, together with the consumer agent's specific resource requirements to create a lease request. For each required resource, the consumer agent determines if the advertisement specifies boundaries or other limitations. If the required amount lies within these limitations, the consumer agent adds the required negotiation terms within the lease request document. If all required resources are specified, the request is sent to the mediator agent. If not all required resources can be provided (i.e. conditions specified in the advertisements are not sufficient for the consumer), the negotiation process is halted.

Mediator Agent

For a mediator agent, the request phase entails processing incoming lease requests from consumer agents. For each request, the advertisement used as a basis for that request is retrieved, and the mediator agent determines which provider advertisements have served as a basis for the used advertisement. The incoming request is then split into one or more resource provider agent-level lease requests, each containing the terms related to the resources advertised by that provider. During this phase, the mediator agent can apply domain-wide resource access policies by imposing its own restrictions on the terms specified in the consumer agent's request.

Provider Agent

The request phase from a resource provider agent's point-of-view consists of processing incoming lease requests from the mediator agent of the virtual organisation. For each request, the underlying advertisement used for the request is retrieved, and the request is validated against the conditions specified in the advertisement: Each of the terms specified in the request is retrieved, and the associated resource is examined to see if the resource can deliver the requested amount. If the request is valid, an offer will be created for the request in the offer phase.

5.3 Offer phase

Consumer Agent

In the offer phase, a consumer agent receives one or more offers from the mediator agents with which it is in negotiation. Each offer is evaluated and compared to the other offers and the original request. If a suitable offer is found, the offer is accepted in the acceptance phase.

Mediator Agent

During the offer phase, the mediator agent receives offers from resource provider agents in the virtual organisation. If for an original consumer agent's request, sufficient resource provider agents offers are available, an offer can be constructed from the terms specified in the individual resource provider agent's offers, and returned to the consumer agent. During this phase, the mediator agent applies domain-wide resource access policies, selecting which resource provider agent's offers are accepted or not.

Provider Agent

For each accepted lease request, the actual requested resource amounts are retrieved from the request, and current resource conditions and access policies are evaluated to see if the requested amount is available. If not all requested resources or amounts are available/allowed by the local policies, alternatives are determined which can be allowed by the resource provider agent. This results in a new lease offer document containing a description of the resources and conditions that can be offered by the resource provider agent. This document is returned to the mediator agent.

5.4 Acceptance phase

Consumer Agent

In the acceptance phase, the consumer agent communicates to the mediator agent which offer it chooses to accept. The result of an acceptance is a lease document, which specifies terms describing the resources and conditions accepted.

Mediator Agent

During the acceptance phase, an incoming acceptance request from a consumer agent results in the mediator agent sending out acceptance requests to the individual resource provider agents involved in the offer that is being accepted. The terms specified in the lease documents returned by the resource provider agents are then combined into a consumer agent's lease document, and returned to the consumer agent.

Provider Agent

During the acceptance phase, a resource provider agent processes incoming acceptance requests. This entails implementing the resource usage conditions as offered, and making the resources available to the consumer agent, for the duration of the lease. As a confirmation, a lease document is returned describing the resources and conditions agreed upon.

6 Implementation

The negotiation model described in this paper is the basis for the negotiation architecture for autonomous mobile software agents in the AgentScape framework [9]. Agents wanting to move from one AgentScape location to another decide to which location to migrate based on the result of resource access negotiation with a number of domain coordinators. The domain coordinators fulfill the role of mediator in the negotiation interactions. Domain coordinators with the best proposals are chosen: agents migrate to these domains. Within AgentScape, a number of negotiable resources are recognized including: *CPU time*; *Communication bandwidth*; *Memory*; *Web service access*; *Disk space*. Additional resources will be defined in the future, as new AgentScape middleware functionality becomes available. The AgentScape negotiation architecture relies on a WS-Agreement implementation designed as part of the AgentScape middleware infrastructure. This implementation currently offers all WS-Agreement management and interaction facilities required for use within AgentScape, and has been tested and evaluated. For more details concerning the implementation and experiments, see Mobach *et al.* [8].

7 Discussion and Related Work

This paper presents a model for document-based mediated resource negotiation. This model has been implemented and tested in the AgentScape system [9]. Web Service Agreements provide the

template for interaction between parties. For the purpose of agent negotiation our model extends the standard Web Service Agreement interaction types: Agreements created by providers are no longer considered as final, but are in stead regarded as *offers*; An additional accept/reject message type has been added to the protocol.

In a very recent paper, Paurobally and Jennings [10] analyse the options for the use of WS-Agreements and Cremona. They also identify the need for more negotiation interactions, proposing to include richer WS-Agreement message types (*inform* and *bid*) allowing for the specification of more complex interaction protocols on top of the WS-Agreement messaging layer. For more complex negotiation types this may indeed be warranted, providing more extensive semantics, another need Paurobally and Jennings identify. In our two-tiered negotiation model, a simple extension of the WS-Agreement specification suffices, but more elaborate negotiation interactions could provide the model with more flexible negotiation options for specific resource domains.

In a paper by Mathieu and Verrons [7], a model is presented enabling the specification of contract-based negotiation models (using XML) based on a set of negotiation interaction primitives similar to the interactions discussed in this paper. For a specific negotiation application domain, the protocol can be configured using a number of protocol parameters.

IBM's Cremona [6] (Creation and Monitoring of Agreements) is an effort to create an architecture and libraries implementing the WS-Agreement interfaces, agreement (template) management and providing agreement functionality suitable for the application of WS-Agreement functionality in domain-specific environments. The Cremona architecture specifies domain-independent and domain-specific components required for agreement-based management: For both consumers and providers of agreement-based services, the architecture specifies two component types: *Agreement Protocol Role Management* (APRM), and *Agreement Service Role Management* (ASRM). The APRM component is responsible for implementing agreement-based interactions, maintaining template and agreement states, and offering agreement monitoring functionality. The ASRM component is responsible for enabling agreements to be translated into the actual provisioning and consumption of services. Cremona is currently being offered as a part of IBM's Emerging Technologies Toolkit. Cremona currently does not provide the flexibility needed for two-tiered negotiation as presented in this paper. The functionality needed for this type of negotiation in virtual organisations with their own policies, interacting with both consumer agents and client agents, has not been included.

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