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Using Semantic Technologies to Improve Negotiation of Service Level Agreements

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Abstract. The need for automation of the negotiation process between Service Providers and costumers requires flexible protocols that address the issue of Semantic Interoperability. In this work, we present an enhancement of the traditional Service Level Agreement Negotiation Protocols using a lightweight annotation framework borrowed from the SAWSDL specification. We present a complete ontological framework that consists of a set of components that assist the negotiating parties to establish an agreement without having to agree on the same metrics. In order to avoid non-deterministic run times we propose the incorporation of the Monte Carlo algorithm in the negotiation protocol. Finally, we illustrate the applicability and the benefits of our work in a business use case.

1. Introduction

One of the motivations behind the adoption of Service Oriented Architecture (SOA) is the creation of a truly global marketplace where new business opportunities can arise. In this global market Service Providers and costumers need to come to a mutual agreement on the functional and non-functional properties of the service(s) under negotiation. The outcome of the negotiation process is a Service Level Agreement (SLA) and requires that both parties (Service Provider and Service Consumer/costumer) share a common understanding of the terms being used. However, the entities taking part in the negotiation of a Web Service can be coming from different countries or different continents, hence using different vocabularies to describe the terms. Even the definitions of the technical terms might be considerably different even across organisational boundaries. We believe that the use of commonly agreed conceptual models captured in the form of ontologies could greatly improve the interoperability between parties that want to automate the process of service negotiation. In this paper, we will describe an *ontological framework for SLA negotiation.* The remainder of the paper is structured as follows: Section 2 describes the objectives; Section 3 discusses the methodology and how it relates to other research initiatives. Section 4 describes the details of the framework as well as some implementation details and Section 5 analyses the benefits for a business scenario where this framework will be demonstrated. Finally, Section 6 presents conclusions and future work.

2. Objectives

The objective of the ontological framework is to extend current standardisation efforts on SLA negotiation in a way that the new specification will be backwards compatible and will offer advanced flexibility and performance to users who have deployed the appropriate semantically enabled infrastructure. Overall, the proposed ontological framework aims to provide the means to the user to easily annotate SLA Templates by providing the appropriate contextual information stored in the knowledge base. The knowledge base plays an important role, as it will manage the assembled knowledge such as ontologies, annotations and mappings between different parameters. It will facilitate the translation process during negotiation and will enable the interpretation of semantic annotations of the SLAs. Finally, by incorporating the Monte Carlo algorithm the negotiation process will avoid non-deterministic run times.

3. Methodology

The methodology for negotiation of Service Level Agreements has been recently the subject of investigations by several research projects. Some early results show that current state of the art in SLA Negotiation lacks flexibility in the protocol and execution. On one side, several European funded projects like NextGRID[1], Akogrimo[2] or TrustCoM[3] have proposed protocols for SLA Negotiation which mainly follow the so-called Discrete Offer Protocol which adopts a “Take it or leave it, terms of SLAs not negotiable” approach. On the other hand, standardisation efforts are still in early stages hindered by competing specifications. In total there is a huge gap in research related to Multiphase Negotiation and Term Adaptation, which implies the necessity for semantic enhancements for SLA Negotiation.

Usually, negotiation protocols are defined on top of existing protocols and standards for the establishment of an agreement between two parties. Two competing standards have been proposed for the establishment of agreements between Service Provider and costumer, namely Web Services Agreement Specification (WS-Agreement)[4] developed with the Grid Resource Allocation Agreement Protocol working group (GRAAP-WG) and the Web Service Level Agreement Language (WSLA)[5] proposed by IBM. WS-Agreement is a Web Service protocol and language for establishing agreements based on Quality of Service parameters. The focus of this specification is to extend current Web Services standards with the appropriate functionality to allow the establishment of an agreement rather than the provisioning of a complete language for the definition of an SLA. WSLA on the other hand provides a framework for monitoring and evaluating Service Level Agreements. The language is defined as an XML schema to be used by both parties in their respective deployments in order to be able to monitor the service. An attempt to merge the two standards initiated by IBM does not seem to have materialised yet. A negotiation protocol based on WS-Agreement has been described in a relatively new specification called WS-AgreementNegotiation [6] which seems to ignore any issues of semantic interoperability caused by the definition of new QoS terms either by the costumer or the Service Provider. Other initiatives include ongoing research from Parkin et al [7] on an abstract definition of SLA Negotiation in combination with an adequate protocol, which is based on contract law principles. To overcome the issues of limitations, Hudert et al [8] proposed a framework augmenting WS-Agreement, and presenting a “meta-protocol” enabling to choose the best fitting protocol (of supported protocols) for negotiation. A more relevant approach to our suggested ontological framework proposed by Oldam et al [9] was based on an extension of WS-Agreement with semantic tags to allow automatic matching between providers and consumers. However, this approach is not generic enough to be considered as an alternative negotiation protocol.

Semi-automated SLA negotiation requires inevitably the involvement of human users who will need to understand the context of the terms being negotiated. In order to assist this task, we propose a Text-Content Analysis (TCA) tool which stores and analyses existing domain ontologies to automatically provide contextual information regarding the SLA terms. The proposed tool enables a more detailed understanding of the text and the content. In order to understand text and content it is necessary to analyze the semantics as well. Information retrieval and text mining techniques can be used for the evaluation of existing domain ontologies stored in the TCA ontology registry. Part of the approach is the creation of a Mapping Syntax between domain ontologies that will allow the negotiation of SLAs mapped to different domain ontologies.

The annotation methodology is based on the lightweight annotation mechanism adopted in SAWSDL[10] which has become the dominant approach in the area of Semantic Web Services. Our main driver behind the adoption of this approach is the need to be able to operate in a mixed environment where some clients will be able to interpret the added semantics while others will just ignore them and graciously fall back to the XML based interpretation of the SLAs. The experience gained from various Semantic Grid projects has led us to the belief that the move towards knowledge based systems will happen gradually, hence in the foreseeable future, Grid middleware will vary in terms of knowledge capabilities.

The terms of the agreement between a Service Provider and a Client is part of a contract signed by both parties. The agreed terms are included in a document called Service Level Agreement while the document containing only the terms of the negotiation is called Service Level Agreement Template (TSLA). Our annotation framework is based on the TrustCoM SLA. We name the annotated version of the TrustCoM TSLA as SATSLA (Semantic Annotated Template Service Level Agreement). This specification will utilize a combination of WS-Agreement and extended WSLA from IBM to enable semantically enhanced negotiation, monitoring and SLA breach detection

Our proposal for an enhanced SLA negotiation tool will extent current state of the art in two ways. Firstly, *interoperability* can be also improved by incorporating automated reasoning based on the semantic annotations that will allow negotiations between parties that use different SLA templates. Secondly, *performance* of the negotiation algorithms can be improved by adding heuristics to avoid local minimums based on the Monte Carlo algorithm [12].

4. Development

In order to clarify how the proposed ontological framework works in practice, we provide an overview of the architecture.

4.1 Architecture

The architecture consists of a set of components that assist the Service Provider and the costumer before or during the negotiation process. The front-end components are:

- The SATSLA GUI provides a friendly way to interact with the SATSLA repository and allows the CRUD operations (Create, Read, Update, Delete) with the SATSLAs stored in the repository.
- The TCA tool manages the ontologies used for the annotation of the SLA documents. The TCA tool is integrated with the SATSLA GUI to present additional contextual information to the user when dealing with an SLA. The bidirectional nature of this tool means that the user can enrich the knowledge base with new facts such as new QoS metrics or mapping between metrics. The possibility to combine new and old metrics

increases the flexibility of the negotiation process and makes it easier for both parties to negotiate without the added burden of translating each others metrics when defining their SLOs.

The back-end components that realise the negotiation processes are:

- A SATSLA Template repository that allows the Service Provider to store all the SATSLA Templates relevant to a specific service as a service can be offered in different ways depending on different circumstances.
- A hierarchy of Ontologies that will be necessary to inform the different aspects of the SLA such as Quality of Service Ontology, Monitoring Ontology, Time Ontology, etc.

The components were developed using different programming languages and platforms, while interoperation was addressed by exposing them as Web Services. However, Web Services do not fulfill yet the promise of interoperation between different platforms, as several incompatibilities still exist. A stable version of the components will be released before in December 2008 while limited demonstrators will be available earlier. The annotation tools will be gradually integrated to the rest of the BREIN platform in order to demonstrate their use within larger business scenarios.

4.2 Semantic Annotation of Templates for Service Level Agreements (SATSLA)

As we mentioned before, our approach is based on the extension of the TrustCoM SLA specification [3] with semantic information using the extensibility points provided by the specification. These extensions are similar to the annotations proposed by Oldham *et al* on their paper "Semantic WS-Agreement Partner Selection" [9] but instead of adding another XML node we adopted the SAWSDL approach. According to this approach, we propose the replacement of the “tag” <OntConcept> that links the SLA term with the ontology with an extension element that carries the semantic information (annotation) following the SAWSDL approach. In the case of TrustCoM SLA, the SLAParameter represents the QoS guarantees (Performance, Response Time, Cost, Availability, etc.) and the Metric represents the metrics used by the Service Provider in relation to a specific QoS.

Currently, the proposed extension with semantic annotations affects the schema of the TrustCoM SLA in the two previous elements, SLAParameter and Metric. Inside the service description element of the WS-Agreement (where the TructCoM is based) we have a service definition based in the WS-Agreement standard and inside this element the SLAParameters which indicate the Service Level Objectives that the Service Provider offer guarantees. Each of these “SLAParameter” is associated directly with one Metric. In Table 1 we present an example that reflects the way the annotations are inserted in the document and the way in which the semantic and non-semantic elements are related.

Adding these sorts of annotations, the schema offered by the service provider is able to contain semantic information, as well as more conventional SLA properties. These annotations will be used during negotiation and monitoring to ensure the service guarantees. These annotations can be in case one party cannot interpret the annotations.

```
<wsla:Operation name="Operation Name" type="OperationDescriptionType">
 <!-- The Total Cost -->
 <SLAParameter name="Total Cost" type="double" unit="Euro"
satsla:modelReference="http://eu-brein.com/ontology/Upper/QoS">
        <Metric>Total Cost Metric</Metric>
</SLAParameter>
 <!-- Total Cost for Service Usage -->
<Metric name="total_cost_metric" type="double" unit=""
satsla:modelReference="http://eu-brein.com/ontology/Upper/QoS#PriceMetric">>
        <Source>Provider</Source>
        <Function resultType="double" type="Plus">
                <Operand>
                        <Metric>Usage Time</Metric>
                </Operand>
                <Operand>
                        <Metric>Number of requests</Metric>
                </Operand>
        </Function>
</Metric>
</Operation>
```

Table 1: Annotated TrustCoM SLA Template

4.3 Ontologies

In order to annotate the SLA, providers and clients can use several ontologies in order to define new QoS parameters. The TCA tool manages the knowledge base that stores and retrieves concepts from the available ontologies in order to allow the user to retrieve the appropriate concept or to find similar concepts in other ontologies. We have defined a hierarchy of ontologies that can be used from both parties of the negotiation. An Upper Business Ontology contains the basic terms related to QoS and its purpose is to the set the basis for the development of other specialised ontologies used in each domain of discourse. For example, the term *performance* in the Upper Business Ontology is abstractly defined as a QoS parameter. However, in the Domain Ontology created for the Virtual Engineering domain investigated in the BREIN project, the term Performance is expanded to other terms such as CPU Speed, Memory, Hard Drive speed, etc. Similarly, the client can import a different ontology or ontologies relevant to the type of service he is offering and use it to annotate her SLA template. Creating and storing mappings between ontologies can lead to the negotiation of services defined using completely different QoS parameters.

4.4 Enhanced Negotiation using Monte Carlo

SLA Negotiation algorithms are hard to develop mainly because they can get stuck on a local minimum. Optimisation is possible but the search for exactly the right answer can lead to indeterminate run time as in the case of the Las Vegas algorithm [11]. The Monte Carlo algorithm can improve the precision of the results the longer it runs and can be stopped whenever a “good enough” solution is found avoiding local minimums.

Let us assume that a SLA has a set of Service Level Objectives (SLO) and there is a Customer that is willing to negotiate within two providers that are offering a set of possible

values for a certain SLO. Now, suppose the customer doesn't agree within the values provided by the providers. The customer has two options; on one hand he can decrease his goals, which means that the service that originally is expecting is going to be reduced as well, so indeed he won't achieve his goal. Then the second option is to propose to the Service Providers to alter the original values of the SLOs, keeping in mind their original SLOs but slightly adjusting them to satisfy his needs. By randomising the SLOs over a finite set there is the possibility that the requirements of both parties are met arriving finally to an agreement on the negotiation of the SLA. The Monte Carlo algorithm can be used to iterate over this set of values until it produces a set that satisfies both parties. Let us assume the following parameters of the SLOs defined in TrustCoM specification (see Table 2).

```
<wsag:GuaranteeTerm wsag:Name="SLO_CLOCKSPEED" wsag:Obligated="ServiceProvider">
<wsag:ServiceLevelObjective>
<wsla:Expression>
<wsla:Predicate xsi:type="wsla:Greater">
 <wsla:SLAParameter>ClockSpeed</wsla:SLAParameter>
 <wsla:Value>4</wsla:Value>
    </wsla:Predicate>
    </wsla:Expression>
    </wsag:ServiceLevelObjective>
    </wsag:GuaranteeTerm>
<wsag:GuaranteeTerm wsag:Name="SLO_TOTALCOST" wsag:Obligated="ServiceProvider">
<wsag:ServiceLevelObjective>
<wsla:Expression>
<wsla:Predicate xsi:type="wsla:LessThan">
<wsla:SLAParameter>TotalCost</wsla:SLAParameter>
<wsla:Value>800</wsla:Value>
    </wsla:Predicate>
    </wsla:Expression>
    </wsag:ServiceLevelObjective>
</wsag:GuaranteeTerm>
```

Table 2: SLO definition using the TructCoM SLA specification

Then we provide the following parameters to the Monte Carlo algorithm:

1. For each Service Provider:
   a) W_{spi} Weight or importance that the provider gives to the parameter to provide.
   b) Range: [$Va_{sp(i)}$, $Vb_{sp(i)}$]
   - <wsla:Predicate xsi:type="wsla:Greater"> → Va
   - <wsla:Predicate xsi:type="wsla:LessThan"> → Vb
2. For each customer:
   a) W_{ci} → Weight or importance that the customer gives to be satisfied in the parameter i.
   b) V_{ci} → Desired value for the parameter i.

5. Business Case

The scenario chosen to demonstrate the applicability of this framework is derived from the need of an engineering company to diversify its offerings by launching a Virtual Engineering platform where small engineering firms can carry out complex engineering simulations without having to buy and configure a complex and expensive infrastructure. In order to facilitate the potential users of this platform coming from all over the globe, we propose the enhancement of the negotiation process using this ontological framework. The parameters (Service Levels Objectives) of the services offered by the engineering company acting as a Service Provider, hosted by the Virtual Engineering platform and consumed by the costumer need to be

negotiated. There is clear business mandate addressed by our work that is to make it easier for new clients to participate and consume services within this Virtual Organisation (VO) by improving several aspects such as interoperability, performance and ease of use of the negotiation tools. Improving semantic interoperability during the negotiation phase implies that more costumers will be able to negotiate and possible join the Virtual Organisation. By allowing the users to define their own terms for negotiation and automating large part of the negotiation process we decrease the entrance barrier that deters new clients from joining the VO. The principle behind this framework is to provide additional contextual information to the users during or before the negotiation process, hence giving them the confidence that the result of the negotiation will not contain unwanted terms.

Generalising from this use case, we can infer that companies who want to become key players with a view to establish real and long-term business relationships in the wide market place of the Service Oriented Infrastructure paradigm need to be evaluated and monitored constantly based on well defined QoS metrics. The key factor in the establishment of the parameters to be negotiated and eventually monitored is to know exactly how to define and evaluate them. This process requires the contextual information that will be provided by the proposed ontological framework. A demonstrator with real life data provided by ANSYS UK will be developed in the second half of the BREIN project.

6. Conclusions

Current state of the art in SLA negotiation should be advanced in order to improve the semantic interoperability between negotiating parties. Our work takes a fist step to address some of the challenges but it is by no means complete. We aim to release the complete specification for the annotation of SLAs following the TrustCoM specification along with annotation tools (December 2008). The development of a complete knowledge base containing mappings between several domain ontologies is yet to be addressed. We aim to provide the tools for the community to engage to this process and contribute to the development of this knowledge base. Our business case needs to enriched with real data demonstrating that companies participating in VOs offering business services have vested interests to improve the way service negotiation takes place given that conflict resolution (e.g. the civil court system) can be expensive and time-consuming. Our work aims to meet this need through the use of semantic technologies, which have matured enough to allow us to extend current SLA negotiation frameworks to become more flexible, intelligent and user friendly.

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