# An Application of Dynamic Service Level Agreements in a Risk-Aware Grid Environment

Sanaa Sharaf and Karim Djemame
School of Computing
University of Leeds, UK
Email: {sharaf,karim}@comp.leeds.ac.uk
Keywords: Grid Computing, Dynamic Service Level Agreement (SLA)
Quality of Service (QoS), Renegotiation, Fuzzy systems

***Abstract:*** Grid computing systems need to achieve levels of Quality of Service (QoS) necessary for enterprise applications in science and industry. A Service Level Agreement (SLA) specification provides a formal method for describing QoS requirements. WS-Agreement is a language and protocol designed for advertising the capabilities of providers and creating agreements based on initial offers, and for monitoring agreement compliance at runtime (Andrieux, Czajkowski et al. 2006). The motivations for the design of WS-Agreement stem out of QoS concern. The definition of the protocol is totally general and allows for the negotiation of QoS in any Web service enabled distributed system. However, the WS-Agreement specification does not contemplate the possibility of changing an agreement at runtime. Therefore the challenge is to provide extensions of WS-Agreement and of its semantics in order to make agreements robust and more long-lived to individual term violations. The Grid is dynamic by nature, and at run time an SLA may be affected either positively or negatively. Therefore the terms or QoS parameters of the agreement could ideally be acclimatized. This paper will show extensions of the WS-Agreement specification to support the dynamic nature of SLAs.

## 1. INTRODUCTION

Today, most Grid environments are based on ***best-effort***, which means that the use of shared resources will be on equal priorities and also there are no guarantees that the execution of applications will succeed without any errors. Within this environment, a large number of Grid service requests may lead to a degradation of the Grid performance and efficiency (Al-Ali, von Laszewski et al. 2004). One possible solution to overcome this is to introduce QoS mechanisms that enable service providers to partition their services based on quality criteria such as priority, fairness, and reliability (Al-Ali, von Laszewski et al. 2004). In addition, it is necessary for both service provider and service consumer to guarantee that usage of services are within the QoS constraints and conditions (Menasce and Casalicchio 2004). This can be achieved using Service Level Agreements (SLA) which are contracts between a service provider and its customers that describe the service, terms, guarantees, responsibilities and level of the service to be provided (Pichot, Wieder et al. 2007)

The main problem here is that the current protocol for creating, monitoring and executing an SLA is by definition *static*, which means that once the SLA is signed before the application execution, it cannot be changed or modified. In addition to this the SLA monitoring system should stick to the terms in the SLA and prevent breaching them. The existing state of the SLA could be an important reason for reducing the reliability and trustworthiness of parties if an unexpected event occurs at run time, which may affect the SLA positively or negatively. Therefore we could not adapt the terms or the QoS parameters of this agreement to be acclimatized with the new state.

The aim of this paper is to increase QoS within the Grid and reduce the possibilities of SLA failures by allowing different parties in this virtual organization to cooperate and communicate better with more flexibility. This research proposes giving SLA a dynamic nature. A dynamic SLA refers to the ability to change and adjust the initial SLA signed by both parties pre run time; these adjustments could be requested by any parties (service provider, service consumer) at run time according to the dynamic nature of the Grid (D'Arienzo, Esposito et al. 2001). In order to add this functionality, several extensions are added to WS-Agreement specification. In this research we mainly consider the SLA management at pre run time, run time and post run time. For this reason, we have modified parts of the existing WS-Agreement protocol to support the negotiation and renegotiation processes.

The remainder of the paper is structured as follows: Section 2 describes WS-Agreement and its limitations; Section 3 describes our proposed extensions in WS-Agreement; Section 4 presents an application of dynamic SLA in the context of the AssessGrid project; Section 5 describes the related work and finally Section 6 provides a conclusion.

## 2. WS-AGREEMENT

Several based XML language specifications and tools have been proposed recently to describe the agreement between the service provider and the service consumer. For example the Grid Resource Allocation Agreement Protocol (GRAAP) group (OGF 2008) have designed and published a clear specification of the contract or agreement between two parties including all the terms required to describe this agreement: the WS-Agreement specification.

The main limitation of WS-Agreement is that being short in supporting negotiation and this for two reasons. The first one is the limitation in message types since only two are considered: ***offer*** and ***agree***. The agreement initiator sends the offer and the responder either accepts or rejects it without any possible way to negotiate. The second reason is the lack of an interaction protocol between two parties, as a result of having a simple "take it or leave it protocol" (Wooldridge 2005). For more details on WS-Agreement see (Andrieux, Czajkowski et al. 2006).

## 3. EXTENSIONS OF WS-AGREEMENT

### 3.1. Proposed extended XML schema

Very little research has been done to extend the XML schema of WS-Agreement. The aim of our research is to manage dynamic SLAs for QoS provision at all the three stages of an application run: pre, during and post run time. In this context, the service consumer and the service provider negotiate and agree an SLA pre run time. At run time either party may want to hold the application execution and renegotiate a new SLA, based on the previous agreed one. This may occur of course occur more then once. Post run time, a set of SLAs have been negotiated and possibly agreed.

Therefore, new elements in the Agreement context presenting the Endpoint Reference (EPR) of the next SLA need to be included after re-negotiation. Post run time there should be a list containing at least one initial SLA negotiated pre run time, and possibly additional ones negotiated at run time. This list will be kept in the repository of both parties for future usage.

By analyzing the behaviour of service provider and service consumer at run time through this SLA list, an analysis tool can determine the reliability of both parties, which could increase or reduce their performance and reputation. Several assumptions have been proposed for our research such as the following:

1- No broker used, the communication is between the service provider and the consumer directly.
2- For simplicity, there is only one service provider providing all the needed resources.
3- In the first and initial SLA which service provider and consumer agreed pre run time, we have to define which Service Level Objectives (SLO) will be static (not modifiable) and which can be changed at run time.
4- The allowed number of renegotiations will be agreed between both parties pre run time.
5- To protect the service execution, no renegotiation will be permitted after a specific period of run time (for example after 90% of run time).

### 3.2. Motivation Scenarios

An important aspect of this research is taking the consideration of the most likely scenarios that may take place at run time. As said earlier unexpected events may occur at run time, which may affect the SLA, either positively or negatively. We refer to these scenarios as *optimistic* and *pessimistic,* and both are considered from the perspective of the service provider and consumer:

In an optimistic scenario, consider the situation where a service provider finds out that high reliable resources are now available and ready to use, for example following the cancellation of a resource reservation. In this case, the service provider enages into a renegotiation process with the service consumer in order to reduce the probability of failure (PoF) of the SLA by providing additional resources. This, of course, will lead to increasing the price previously agreed with the consumer. From the resource consumer point of view, in a similar optimistic scenario more budget becomes available which may lead to renegotiation with the provider for better resources provision (which may also lead to a higher penalty fee in case of SLA failure).

On the other hand, in a pessimistic scenario the service provider anticipates a possible violation of a term or a failure in the agreed SLA (for example an application will not finish on time, a possible resource failure), The renegotiation process with the consumer may therefore lead reducing the agreement price.

## 4. CASE STUDY: AssessGrid

### 4.1 Risk Assessment in Grids

AssessGrid (Advanced Risk Assessment and Management for Trustable Grids) focuses on the integration of risk management functionality within Grid middleware (Birkenheuer, Djemame et al. 2006; AssessGrid 2008) It does this by addressing the concerns of end-users and providers through encouraging greater commercial interest in Grid usage through incorporation of risk assessment mechanisms into Grid infrastructures as well as automated SLA agreement processes utilizing risk information. Incorporation of risk-aware components within the SLA negotiation process as an additional decision support parameter for the end-user is of primary importance. Risk is an ideal decision support parameter within the AssessGrid scenario since it combines both the quantifiable probability of SLA failure with the non-deterministic expected loss, a parameter known only to the beneficiary of the services stated in the SLA. The usage scenarios addressed by the AssessGrid architecture consider 3 principle actors: end-user, broker and provider.

An end-user is a participant from a broad public approaching the Grid in order to perform a specific task which comprises of one or more services. In order to make a request for such services, the end-user must indicate the task and associated requirements formally within an SLA template. The information contained within the template is used to negotiate access for the end-user with providers offering these services, such that the task may be completed. The inclusion of risk information within the SLA negotiation process allows the end-user to make informed, risk-aware decisions on the SLA offers received so that any decision is acceptable and balances cost, time and risk.

A broker acts as matchmaker between an end-user and provider, furnishing a risk optimized assignment of SLA requests to SLA offers. It is responsible for matching SLA requests to resources and services, which may be operated by an arbitrary number of providers. The broker's goal is to drive this matchmaking process to a conclusion, when the provider will propose an SLA offer. Beside resources and services for single tasks, the end-user may also ask the broker to find resources for a workflow. Here, the broker has to decompose the workflow, finding suitable resources and services for each sub-task, whilst respecting the end-user's requirements. For the end-user, a major service of the broker is the pre-selection of Grid providers, comparable with an independent insurance agent which is supporting its customers by pre-selecting insurance policies from a number of insurance companies.

A provider offers access to resources and services through formal SLA offers specifying risk, price, and penalty. Providers need well-balanced infrastructures, so they can maximize the Quality of Service (QoS) and minimize the number of SLA violations. Such an approach increases the economic benefit and motivation of end-users to outsource their business processes and IT tasks. A prerequisite to this is a providers' trustworthiness and their ability to deliver an agreed SLA offer. Assessments of risk allow the provider to selectively choose which SLA requests result in offers. The core of the communications between end-user, broker, and provider layers is accomplished using WSRF and the WS-Agreement protocol (Dominic, Odej et al. 2007; Padgett, Djemame et al. 2009)

### 4.2 Experimental Setup

- **Scenarios**

Anticipate violations**:** state for the agreement in which a warning has been issued due to the fact that one or more guarantees are likely to be violated in the near future.

Pessimistic scenario: the provider is anticipating a possible violation of a term following the monitoring of dynamic risk. Therefore the provider would like to re-negotiate the SLA instead of paying a (high) penalty fee. Following re-negotiation the end-user is expected to get a lower price.

Optimistic scenario: the provider is anticipating its ability to provide a better service, for example following the availability of spare resources which their consequent use would not only fulfil the SLA but lower the Probability of Failure as well. Following re-negotiation the end-user is expected to pay a higher price.

- **Details on the actual experiments**

To protect the stability of the application execution, special evaluation technique will used in this research to guide both parties towards taking the right decision of accepting or rejecting the new modified SLA. In our experiments we just study the output results and charts in general and prefer to postpone the real experiments after finishing the whole application and protocol.

To build the decision system a fuzzy logic technique used. This fuzzy system built by using MATLAB program. In this system we define all parameters as well as the rules and conditions which construct and build the logical scenarios and the expected outputs.

- **Parameters setting**

The three main parameters in describing a SLA in AssessGrid are the Probability of Failure (PoF), price and penalty fee. The fuzzy system is based on the differences in the current SLA and the proposed SLA in these parameters. Since we are defining a value of the difference between two numbers then we have a range from negative number to positive number. For example [-1.0, 1.0].

For each parameter PoF, price and penalty we divide the range of values to three member functions: low, medium and high. All the different combinations of these parameters will describe the different scenarios might happen. In this research these combinations are limited to 10 considerable cases. We consider three output values indicating the benefit of accepting the new SLA according to the application execution, resource provider and resource consumer. These values are: Benefit of Accepting (BoA), Benefit for Provider (BfP) and Benefit for Consumer (BfC). Similarly to Inputs, the Outputs are also ranged in three different intervals: Low, Medium and High. The Transfer from Inputs to Outputs is controlled through the logical IF Statement rules which represent the 10 scenarios previously mentioned. The list of rules is:

| |
|---|
| If (PoF increased) and (Price increased) and (Penalty increased) Then (BoA is Low) and (BfP is Medium) and (BfC is Low) |
| If (PoF decreased) and (Price increased) Then (BoA is High) and (BfP is High) and (BfC is Medium) |
| If (PoF decreased) and (Price increased) and (Penalty decreased)Then (BoA is High) and (BfP is High) and (BfC is Medium) |
| If (PoF increased) and (Price decreased) Then (BoA is High) and (BfP is Medium) and (BfC is Medium) |
| If (PoF increased)and (Price decreased) and (Penalty decreased) Then (BoA is Medium) and (BfP is High) and (BfC is Low) |
| If (PoF decreased) and (Price increased) and (Penalty increased) Then (BoA is Medium) and (BfP is Medium) and (BfC is Medium) |
| If (PoF decreased) and (Penalty decreased) Then (BoA is Medium) and (BfP is Medium) and (BfC is High) |
| If (PoF increased) and (Price decreased) and (Penalty increased) Then (BoA is Low) and (BfP is Low) and (BfC is High) |
| If (PoF increased) and (Penalty decreased) Then (BoA is Low) and (BfP is Medium) and (BfC is Low) |
| If (PoF increased) and (Penalty increased) Then (BoA is Low) and (BfP is Low) and (BfC is High) |

### 4.3 Results

Figures 4.1, 4.2 and 4.3 show the relationship between the difference in price and the difference in PoF and consequently the resulted value of Benefit of Accepting (BoA), Benefit for Provider (BfP) and Benefit for Consumer (BfC) respectively. In Figure 4.1 there first axis (X) represents the difference value for PoF between the current SLA and the new proposed one (PoF(cur) – PoF(new)). This difference would be negative if PoF **increased** in the new SLA, **and positive** if PoF **decreased.** the second axis (Y) represents the difference value for the price (Price(cur) – Price(new)). The third axis (Z) shows the resulted BoA according for each value of PoF and Price.

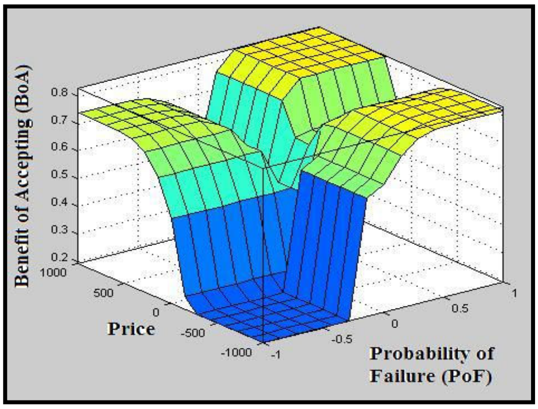


Figure 4.1 PoF, Price and Benefit of Accepting

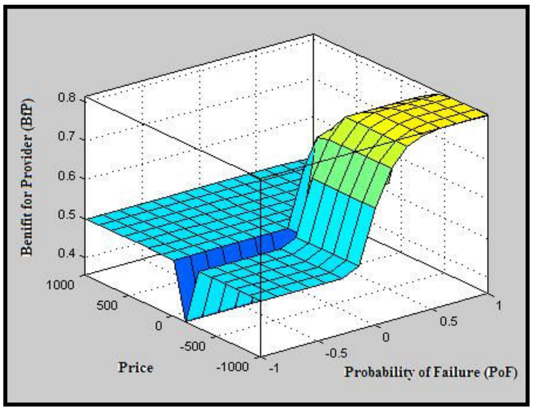


Figure 4.2 PoF, Price and Benefit for Provider

In an optimistic scenario, the new proposed SLA may have a lower PoF since new high reliable resources can be used which means the positive side of the X-axis. The figure illustrates the situation where a new PoF is lower than the current one and the recommendation of taking this new SLA will be high; when a new PoF is high then it is not recommended to go for the new SLA. The same situation can be applied on price since reducing the price is a very good factor from the service consumer point of view (optimistic) and increasing the price with reducing the PoF is very encouraging from the service provider point of view.

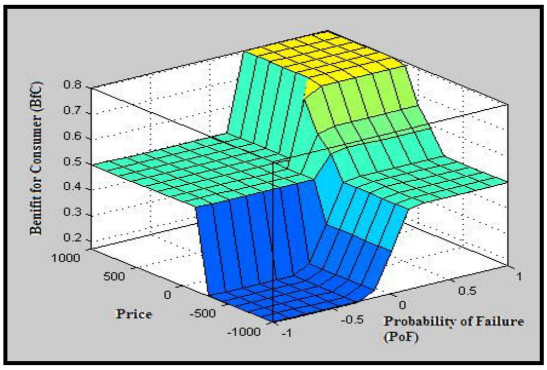


Figure4.3 PoF, Price and Benefit for Consumer

Figure 4.2 illustrates the same aspect but from the resource provider perspective. In this figure, it is clear that reducing the PoF in the new SLA is very good factor since all the positive side in X-axis leads to high values of BfP whereas the negative side of X-axis decreases this value. Similarly, taking the price as a second factor, we can distinguish between the resource provider perspective as well as the resource consumer in Figure 4.3. For example, assuming that the resource provider can use high reliable resources then the new PoF will be lower. In this case for the resource provider an increased price (negative values in Y-axis) is very beneficial (see Figure 4.2) whereas it is not for the resource consumer (see Figure 4.3).

## 5. RELATED WORK

There has been previous work on WS-Agreement and its extensions towards dynamic SLAs. In (Ludwig, Braun et al. 2006) the authors propose a framework for dynamic creation of SLAs based on negotiation between service providers and consumers. They extend the agreement layer in WS-Agreement and add additional components to support the negotiation between service providers and consumers. Similar work to this framework was proposed by the GRAAP working group (OGF 2008) when they published a new draft version of WS-Agreement called Web Services Agreement Negotiation Specification (WS-AgreementNegotiation) (Andrieux, Czajkowski et al. 2007). This new edition contains the required components and new port types with new operations to support the negotiation process plus adding additional state machines describing the agreement state during the negotiation.

In the project VIOLA, Vertically Integrated Optical Network for Large Application (VIOLA 2005), a MetaScheduling Service (MMS) is developed to co-allocate both network resources and computing resources. Before creating the SLA, there is a negotiation process between MMS and different Resource Management Systems (RMS) to choose the best resources. Since VIOLA project uses WS-Agreement protocol in communicating between MMS and RMS the authors in (Pichot, Wieder et al. 2007) proposed a simple offer/counter offer model. To use this model in WS-Agreement they proposed a new function ***negotiateTemplate.*** These research works focus on the process of negotiation between the service provider and the consumer on templates and before the creation of the SLA but the research in (Di Modica, Regalbuto et al. 2007) is concerned with enhancing the flexibility of the WS-Agreement and proposes an extension in WS-Agreement which allow both parties of the agreement to modify it and renegotiate after it is being accepted and **before** the actual execution starts.

In this research, there are two main modifications in WS-Agreement the first one in the protocol similar to the previous mentioned research works, whereas the second modification is in the XML schema of the agreement (Di Modica, Regalbuto et al. 2007). In (Frankova, Malfatti et al. 2006) the authors gave clear definitions for some basic concepts in the agreement such as **term**, **agreement**, **external state** and **internal state.** For any agreement to be changeable during runtime these sets must be altered and some new entries must be added to them. The same authors have published an earlier work on the same research (Aiello, Frankova et al. 2005). In this paper they introduced another important modification they have done in the WS-Agreement structure where they added a new section in the Terms beside Service Description Terms and Guarantee Terms called the ***Negotiation Terms*** (Aiello, Frankova et al. 2005).

Predicting the pessimistic scenario and the worst case that could happen in the network is the key factor in the research published by (Parkin, Hasselmeyer et al. 2008). They do not use UML sequence diagrams to describe the protocol and unlike WS-Agreement where there is one shared finite state machines to describe the state of the agreement, in this research each party has his own copy of the state machines and they are updates with sending and receiving messages. Finally, authors in (Ziegler, Wieder et al. 2008) summarised the suggestions and proposals presented in the three OGF meetings with adding their own suggestion by implementing WS-AgreementNegotiation (Andrieux, Czajkowski et al. 2007)using the appropriate messages to support the negotiation protocol.

## 6. CONCLUSION

To conclude, the dynamic nature of Grids in addition to the negotiation/ renegotiation limitations in WS-Agreement protocol motivate this research in order to give both agreement parties the ability to customize the agreement according to their needs pre run time through negotiation. In addition, this research will increase the flexibility of SLA during run time to make it changeable for better services in optimistic scenarios, and at least to prevent violations and SLA failures in pessimistic scenarios.

The outcome results from the fuzzy system indicate that benefits of accepting the new SLA after both parties have renegotiated will differ according to the changes they made. This benefit will be very high (almost 1) in optimistic scenarios where the PoF decreased in the new SLA which means better services, resources will provided. On the other hand, increasing the PoF or penalty in new SLA will reduce the benefit of accepting it. Although a higher price and a lower penalty are very encouraging agreements from the resource provider perspective, the resource consumer wants lower PoF and lower price.

Enhancing QoS post run time is very challenging research issue as it will affect future agreements. By enabling renegotiation during time, the application execution will be a list of agreements describing changes that occurred during run time. Evaluating these agreements is a good opportunity to evaluate both parties's behaviour at run time. Future work can be done on post run time QoS through this valuation which may affect both parties reputation positively or negatively.

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