Asymmetric information issues and solutions for the broker executing SLA-based workflows

Dang Minh QUAN[1], Jörn ALTMANN[2]
[1] *School of Information Technology, International University in Germany*
76646 Bruchsal, Germany
Tel: +49(0)7251700231, Fax: +49(0)7251700250, Email: quandm@upb.de
[2] *School of Information Technology, International University in Germany*
76646 Bruchsal, Germany
Tel: +49(0)7251700130, Fax: +49(0)7251700250, Email: jorn.altmann@acm.org

Abstract: In the business Grid environment, the user should ask the broker to execute the workflow for him and then pays the broker for the workflow execution service. As the sub-jobs of the workflow must be distributed over many Grid resource providers to ensure the QoS, the broker knows about all aspects of all service providers while it is difficult for user to have this information. Thus, there is an asymmetric information situation. The asymmetric information may bring a negative effect to the broker. This paper will analyze the asymmetric information issues and propose possible solutions to solve the problem.

Keywords: Grid-based workflow, Service Level Agreement, asymmetric information.

1. Introduction

In the Grid Computing environment, many users need the results of their calculations within a specified period of time. Examples of those users are meteorologists running weather forecasting workflows, and automobile producer running dynamic fluid simulation workflows [13]. Those users are willing to pay for having their work completed on time. However, this requirement must be agreed on by both the users and the Grid provider before the application is executed. This agreement is called the Service Level Agreement (SLA) [14]. In general, SLAs are defined as an explicit statement of expectations and obligations in a business relationship between service providers and customers. SLAs specify the a-priori negotiated resource requirements, the quality of service (QoS), and costs. The application of such an SLA represents a legally binding contract. This is a mandatory prerequisite for the Next Generation Grids.

In order to finish the workflow on time, sub-jobs of the workflow must be distributed to Grid resources. Assigning sub-jobs of the workflow to resources requires the consideration of many constraints such as workflow integrity, on-time conditions, and optimal conditions. To free users from those tedious tasks, it is necessary to have an SLA workflow broker performing the co-operating task of many entities in the Grid. Thus, the business relationship of the SLA workflow broker with the users and the Grid service providers will determine the working mechanism of the broker.

We proposed a business model for the system as depicted in Figure 1 [1,11]. There are three main types of entities: end-user, SLA workflow broker and service provider.

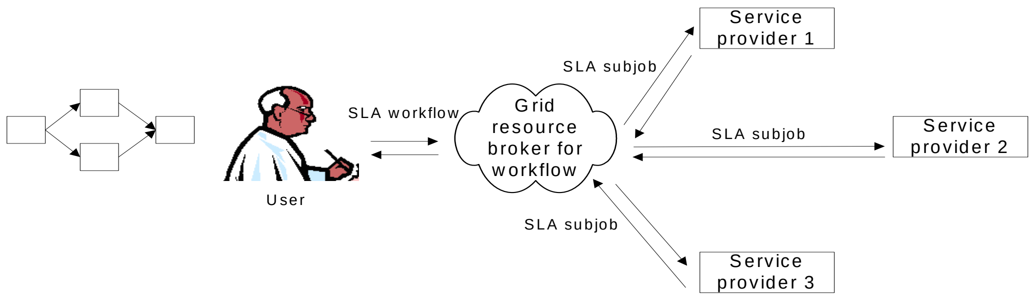

Figure 1: Stakeholders and their business relationship

- The end-user wants to run a workflow within a specific period of time. The user asks the broker to execute the workflow for him and pays the broker for the workflow execution service. It is not necessary for the user to know in detail how much he has to pay to each service provider. He only needs to know the total amount which depends on the urgency of the workflow and the budget of the user. If there is an SLA violation for example if the runtime deadline has not been met the user will ask the broker for compensation. This compensation is clearly defined in the Service Level Objectives (SLOs) of the SLA.
- The SLA workflow broker represents the user as specified in the SLA with the user and controls the workflow execution. This includes the mapping of sub-jobs to resources, signing SLAs with the services providers, monitoring, and error recovery. When the workflow execution has finished, it settles the accounts. It pays the service providers and charges the end-user. The profit of the broker is the difference. The value-added that the broker provides is the handling of all the tasks for the end-user.
- The service providers execute the sub-jobs of the workflow. In our business model, we assume that each service provider fixes the price for its resources at the time of the SLA negotiation. As the resources of an HPCC usually have the same configuration and quality, each service provider has a fixed policy for compensation in the event its resources fail. For example, such a policy could be that *n%* of the cost will be compensated if the sub-job is delayed by one time slot.

From the business model, we can see that the broker has more information about the Grid than the user because he knows about all aspects of all service providers such as resource configurations, pricing scheme, and past performance. It is difficult for the user to know all this information. This situation leads to the asymmetric information issues as the user does not believe the proposed solutions from the broker.

This paper will analyze the effect of the asymmetric information issues and propose possible solutions. In particular, the contribution of the paper includes:

- The description of the asymmetric information about the Grid state and the quality of the mapping solutions.
- The appropriate information which should be revealed during the SLA negotiation to solve the asymmetric information issues.

The paper is organized as follows. Section 2 describes the related works, while Section 3 and 4 analyze the bargaining game and the fuzzy logic, respectively. Section 5 presents the validation, and Section 6 concludes with a short summary.

2. Related works

The literature records many efforts supporting QoS for workflow. AgFlow is a middleware platform that enables quality-driven composition of Web services [17]. QoS-aware Grid Workflow is a project which aims at extending the basic QoS support to Grid workflow applications [2]. The work in [16] focuses on mapping the sweep task workflow to Grid resources with deadline and budget constraints. However, none of them defines a business model for the system. Recently, there have been many Grid projects working on the SLA issue [12,15]. Most of them focus on single job and thus consider only the direct relation between user and service provider. The business role of the broker in such systems has not been fully evaluated. Thus, the derived problems such as the asymmetric information issue have not been considered in any of the above-mentioned works.

The structure and content of the SLA used in the Grid environment are described in many previous works. According to [3-9], the content of an SLA varies depending on the service offered and incorporates the elements and attributes required for the particular negotiation. In general, it includes:

- An end-point description of the contractors (e.g., information on customer/provider location and facilities)
- Contractual statements (e.g., start date, duration of the agreement, charging clauses, fines)
- Service Level Specification (SLS)s, i.e. the technical QoS description and the associated metrics.

However, all of them do not describe how to set the appropriate value to each parameter in the SLA. In particular, with the case of running SLA-aware workflow, the question of how to give suitable information to solve the asymmetric situations has not been considered.

3. Asymmetric information issues

In the contractual context between the user and broker, asymmetric information could bring negative effects as illustrated in the following scenarios.

3.1 – Asymmetric about the Grid state

We assume that the price of provider is fixed at the point of doing mapping. This assumption is suitable as many present resource providers such as Sun and Amazon use this model. The cost of running a workflow depends mainly on the cost of the mapping solutions and then cost of a workflow mapping solution depends on the Grid state. When the Grid is free, there are many free resources and the broker could have a large opportunity to assign many sub-jobs of the workflow to inexpensive providers. Moreover, if the resources in each provider are free, there is a strong possibility to exist a solution that dependent sub-jobs of the workflow are executed on the same RMS. Thus, the cost of data transfer among those sub-jobs is neglected. This leads to a low cost mapping solution. In contrast, when the Grid is busy, there are few free resources and the broker may have to assign many sub-jobs of the workflow to more expensive providers. The busy state of the Grid also leads to the strong possibility that sub-jobs of the workflow will have to be executed in different RMSs. In this case, the cost of data transfer could become a significant part of the total workflow running cost, thereby leading to a higher cost.

The user does not know beforehand whether the Grid is free or busy. Therefore, the user's best guess for a mapping solution is that the mapping is done in the average state of the Grid and the user is thus willing to pay a cost correlated to the average. Thus, when the state of the Grid is busy, the higher cost of the mapping solution may irritate and antagonize the user.

3.2– Asymmetric about the quality of mapping solution

The deadline of the workflow has different meanings for different people. The importance of a deadline depends on the urgency of the workflow. For example, the result of the weather forecasting workflow is very important, especially in storm prediction contexts. Lateness of the weather forecasting workflow in this case may lead to the death of many people. Thus, the urgency is very high. In contrast, the minimal lateness of a dynamic fluid workflow in a scientific research project does not have great effect on the progress of the project. In this case, the urgency is very low.

Under different urgency levels, the user requires different levels of ensuring the deadline. This requirement equates to running the workflow with different risk levels with the risk being defined here as the inability of finishing the workflow on time. Among many factors affecting the risk level of a workflow mapping solution, the failure probability is the most important. The failure probability includes both small-scale failures and large-scale failures. The small-scale system failure is mainly caused by the breakdown of computing nodes. Large-scale system failures could affect the entire computing system of the provider. Those failures can be large hardware failures, network connection failures and security holes.

Under the workflow with high urgency level, sub-jobs of the workflow should be assigned to RMSs having low failure probability. Under the low urgency workflow level, the demand of mapping sub-jobs to high reliability is not so high. In general, the price of the RMS having the higher reliability level is higher than the price of the RMS having lower reliability level. Thus, the cost of running a high urgency workflow could be higher than the cost of running the lower one.

However, the user does not know beforehand about the failure probability of the RMSs and how to evaluate the risk of the mapping solution. If the user requires a high level of ensuring the deadline and is asked to pay a high price, the user may suspect that the broker has found an unreliable mapping solution to achieve a higher revenue.

In both described scenarios, if the broker does not have suitable ways to resolve the asymmetric information problem, the broker may lose customers. Unlike the scientific Grid where the support is mainly from governments or foundations, the existence of the business Grid depends on the users. The business users always have two choices. They can build the computer system themselves or use the Grid services. If the broker and providers cannot persuade the users to use the Grid service, the end users will build their own computer system and Grid providers will disappear. By using symmetric information policy, the broker and providers make reliable and trustworthy sense for end users while using the Grid. Thus, it contributes to encouraging end users to use the offered service.

4. Possible solutions

To solve the asymmetric information issue, the broker should have some ways of revealing the relevant information. Here, we present some such approaches.

4.1– Pricing and guarantee as the signal

From the obligation description between user and broker, we refer to the monetary penalty. If the broker cannot finish the workflow execution at the due time, he will be fined. There is a question that what the suitable fining rate is. In this part, we present a way to answer the question.

The user and the broker form a contract to execute the Grid-based workflow. The workflow can be finished on time or be late. If the workflow finishes on time, its monetary value to the user is *b1*. If the workflow is late, its monetary value to the user is *b2*. Assume that the late probability of the workflow mapping solution is *q*. We can also assume that the broker is risk-neutral and the user is risk-averse. The broker proposes a contract that the cost to execute the workflow is *p* and a guarantee *g*. If the workflow is late, the broker has to pay the user *g*. The utility of the buyer is *u(b1-p)* if the workflow is not late and *u(b2-p+g)* if it is. As the user is risk-averse, $u''<0$. The user will accept the contract when his expected utility is greater or equal to *u(0)*=0. The utility of the broker is presented in Formula 1.

$$B(p,g) = (1 - q)*p + q*(p - g) \tag{1}$$

The utility of the user is presented in Formula 2.

$$U= q*u(b2 - p + g) + (1 - q)*u(b1 - p) \tag{2}$$

The optimal contract must satisfy following conditions:

Max $\{B(p,g)\}$

S.t $U >= u(0)$

Using Lagrange multipliers, we have following results:

$$g = b1 - b2 \tag{3}$$

$$p = b1 - u^{-1}(u(0)) = b1 \tag{4}$$

$$\frac{g}{p} = 1 - \frac{b2}{b1} \tag{5}$$

It is possible to say that with low urgency level, the difference in monetary terms between late and on time result is not so large. For example, if a dynamic fluid workflow in a scientific research project is late one or two hours, it has little effect on the progress of the whole project. This means that the $\frac{b2}{b1}$ value is high. Thus, from Formula 5, the $\frac{g}{p}$ value would be low. In contrast, under a high urgency level, for example with the weather forecasting workflow, if the result is late by 1 hour, many ships may not be able to return the harbour to avoid the storm. Thus, the difference in monetary terms is great. This means that the $\frac{b2}{b1}$ value is low and the $\frac{g}{p}$ value is high. From Formula 5 and the analyzed aspect of price and guarantee, we apply to our case as follows.

- The broker provides a menu of contract. Each contract contains the urgency level and the appropriate guarantee. The guarantee is computed in percent of the total cost and the guarantee is higher when the urgency level is higher.
- The user chooses a contract from the menu. Based on this requirement, the broker will do the mapping solution and negotiate the SLA.

The higher guarantee rate with higher price will persuade the user to believe in the quality of the service provided by the broker.

4.2– Signalling during the SLA negotiation

From the business mode, there are three different types of sub-SLA negotiation using three different kinds of SLA text. User - Broker negotiation focuses on the definition of the submitted SLA. Broker – Provider negotiation considers the workflow sub-jobs and uses the analyses of the sub-job SLAs. Provider - Provider negotiation deals with the data transfer between sub-jobs (and also between providers) so the SLA part for data transfer is used.

Although there are three types of SLA negotiations, the negotiation procedure remains the same; only the service attributes differ. Figure 2 describes this basic procedure in a client - server model. In the first step, the client creates a template SLA with some preliminary service attributes and sends those to the server. The server parses the text and checks the client requirements. In case of conflicts, a new SLA version is compiled and sent back.

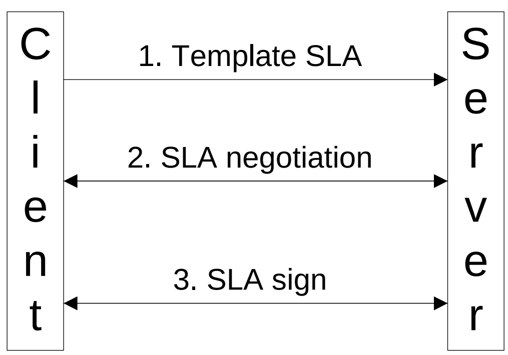

Figure 2: Basic SLA negotiation procedure

Here, we focus on the negotiation process between user and broker. When receiving an SLA from a customer, the broker parses it to get all information about the general SLA, sub-jobs, SLO, data transmission, the dependency among sub-jobs and the structure of the workflow. From the information of the sub-jobs and the structure of workflow, the broker does mapping to determine the appropriate provider and the time period to run each sub-job. During the negotiation process, the broker could provide the user the following information to avoid the asymmetric information issue.

- The number of feasible solutions in the reference set created by H-Map algorithm [10].
- Mapping information. The mapping information include the start, stop time of the workflow and the RMS for each sub-job. Depending on the state of the Grid, a mapping

module can find a feasible solution in the expected time period or not. If not, it will find the earliest solution and ask for the consumer's approval.

This information contains many signals for the user.

- Firstly, the number of feasible solutions in the reference set created by H-Map algorithm can tell about the Grid state. The H-Map algorithm created a reference set that it distributed over the search space. If the number of feasible solutions is low, this means the Grid is busy and vice versa.
- The second is the start, stop time of the workflow. If this is not within the user's preferred period, it means that the Grid is very busy and the user should prepare for a higher execution cost.
- The third is the RMS for the sub-jobs of the workflow. By providing this information, the broker signals the user about the cost of the mapping solution. With this information, the user can make queries himself in order to know the price from each provider. From this, he can evaluate the cost of the mapping solution.

It is noted that the broker should not provide detail information about start, stop time of the sub-jobs or the data transfer. This is because this information does not signal the user about the mapping solution. It may help user bypass the broker to work directly with providers.

5. Conclusion

This paper has presented the asymmetric information issues between the user and the broker. In particular, the user has less information about the cost of executing the workflow and the quality of mapping solutions than the broker. Thus, the user may suspect that the broker derives a benefit from this information. To avoid these negative effects, the broker should have suitable guarantee policy and reveal suitable signal information in the SLA negotiation phase.

References

[1] J. Altmann, M. Ion, A. A. B. Mohammed, Taxonomy of Grid business models, in Proceedings of the 4th International Workshop on Grid Economics and Business Models, Rennes, France, August 28, 2007, pp. 29-43.

[2] I. Brandic, S. Benkner, G. Engelbrecht, and R. Schmidt, QoS Support for Time-Critical Grid Workflow Applications, in Proceedings of the 1st e-Science 2005, Melbourne, Australia, Dec. 5 - 8, 2005, pp. 108-115.

[3] H. Chen, H. Jin, F. Mao, H. Wu, Q-GSM: A QoS Oriented Grid Service Management Framework, in Proceedings of the 7th Asia-Pacific Web Conference

[4] IBM Corporation, WSLA Language Specification, Version 1.0, 2003.

[5] Open Grid Forum, Web Services Agreement Negotiation Specification (WS-AgreementNegotiation), https://forge.gridforum.org/projects/graap-wg.

[6] Open Grid Forum, Web Services Agreement Specification, http://www.ogf.org/documents/GFD.107.pdf, 2007.

[7] J. Padgett, K. Djemame and P. Dew, Grid Service Level Agreements Combining Resource Reservation and Predictive Run-time Adaptation, in Proceedings of the UK e-Science All Hands Meeting 2005, Nottingham UK, September 19th - 22nd, 2005, pp. 298-305.

[8] D.M. Quan, O. Kao, SLA negotiation protocol for Grid-based workflows, Proceedings of the International Conference on HighPerformance Computing and Communications (HPPC-05), Sorento Italia, 23-25th September, pp.505-510, 2005.

[9] D.M. Quan, O. Kao, On Architecture for an SLA-aware Job Flows inGrid Environments, Journal of Interconnection Networks, World scientific computing, pp. 245 - 264, 2005.

[10] D.M. Quan, Mapping heavy communication workflows onto grid resources within SLA context, in Proceedings of the 2nd International Conference of High Performance Computing and Communication (HPCC06), Munich, Germany, Sep. 12-14, 2006, pp. 727-736.

[11] D.M. Quan, J. Altmann, Business Model and the Policy of Mapping Light Communication Grid-Based Workflow Within the SLA Context, in Proceedings of the 3rd International Conference of High Performance Computing and Communication (HPCC07), Houston, USA, Sept. 26-28, 2007, pp. 285-295.
[12] M. Hovestadt, Scheduling in HPC Resource Management Systems: Queuing vs. Planning, in Proceedings of the 9th Workshop on JSSPP at GGF8, Washington, USA, Jun. 24, 2003, pp. 1-20.
[13] R. Lovas, G. Dózsa, P. Kacsuk, N. Podhorszki, D. Drótos, Workflow Support for Complex Grid Applications: Integrated and Portal Solutions, in Proceedings of the 2nd European Across Grids Conference, Nicosia, Cyprus, Jan. 28-30, 2004, pp. 129-138.
[14] A. Sahai, V. Machiraju, M. Sayal, L. J. Jin, F. Casati: Automated sla monitoring for web services, in Proceedings of the 13th IFIP/IEEE International Workshop on Distributed Systems, Operations and Management (DSOM) 2002, Montreal, Canada, 2002, pp. 292-300.
[15] M. Surridge, S. Taylor, D. De Roure, and E. Zaluska, Experiences with GRIA, in Proceedings of the 1st e-Science 2005, Melbourne, Australia, Dec. 5 - 8, 2005, pp. 98-105.
[16] J. Yu, and R. Buyya, Scheduling Scientific Workflow Applications with Deadline and Budget Constraints using Genetic Algorithms, Scientific Programming Journal, Volume 14 (3-4), pp. 217-230, 2006.
[17] L. Zeng, B. Benatallah, A. Ngu, M. Dumas, J. Kalagnanam, and H. Chang, QoS-Aware Middleware for Web Services Composition, IEEE Transactions on Software Engineering, Volume 30 (5), pp. 311-327, 2004.