Bilateral Bargaining Game and Fuzzy Logic in the System Handling SLA-Based Workflow

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Abstract

In the business Grid, the owner of a workflow is assumed to ask an SLA Workflow broker to execute the workflow for him. The price for executing a workflow on the Grid is negotiated between the user and the broker. Determining a price that satisfies both, the user and the SLA workflow broker, is a difficult task. This paper proposes a method using bilateral bargaining game model based on fuzzy logic to determine the price that the user and the broker could accept after the first negotiation round. We also analyze many parameters affecting the price determination process. The validation results show that the approach is suitable with business rules.

1. Introduction

In Grid Computing environment, there are some users that do not have any time constraints on the execution of their application. That means they are willing to wait for the result of their computing task. However, many users need the result of the computation within a specific period of time. They are willing to pay to have their work finished on time. This agreement is legalized by signing a Service Level Agreement (SLA)[2]. SLAs are defined as an explicit statement of expectations and obligations in a business relationship between service providers and customers.

An SLA workflow broker help users to perform many tedious tasks such as selecting the suitable resource provider for each sub-job, monitoring the running sub-jobs, and handling errors. We proposed a business model for the system depicted in Figure 1 [1, 4]. Within this business model, there are three types of entities: end-user, SLA broker, and service provider.

The end-user asks the broker to execute the workflow within a specific period of time for him and pays the broker

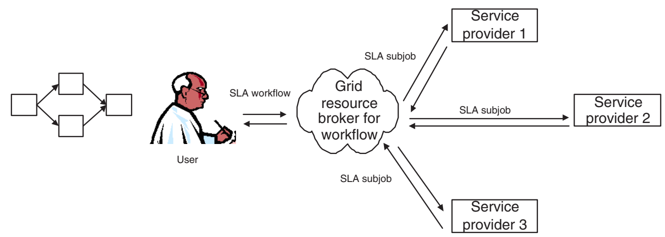


Figure 1. Stakeholders and their business relationship

for the workflow execution service. If there are problems with the workflow execution, for example the deadline is violated, the user will ask for compensation from the broker.

The SLA workflow broker has to perform mapping of sub-jobs to resources, signing SLAs with the services providers, monitoring, and error recovery. When the workflow execution has finished, it pays the service providers and charges the end-user. The profit of the broker is the difference between both. The value-add 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.

One workflow has many parameters such as number of input, output data, required CPU speed, required number of memory, required number of storage, QoS, execution duration and so on. With each user, one or some of those parameters are modified to fit with the specific requirement. As far as we know, there is rarely more than one user having the identical workflow.

In the early phase of business Grid, the scale of the Grid is small and the number of SLA workflow brokers is also small. Even when the Grid has large scale, some local Grid organizations such as DEISA [6] still exist. When the local

Grid organization establishes an SLA workflow broker service, this broker could have many supports about technique and pricing policy from the local Grid community. It is obvious that those users of this Grid should choose this broker as default.

The scenario described above illustrated a market with one user and one broker. This is the ideal condition for bilateral bargaining. The user wants to have a price as low as possible while the broker wants to maximize its profit. Thus, the central problem is how to set the appropriate price that both user and broker can accept. This paper, which belongs to a continued effort to build the basic theory for a system handling SLA-based workflows [3, 4], proposes a solution to this problem. In this paper, we focus on the bilateral relation between a user and a broker. The market structure is not considered. It is outside the scope of this paper. The contributions of the paper comprise:

- Analysis of the bargaining game with asymmetric impatience between user and broker.
- Analysis of parameters such as the critical of the workflow, the Grid state and so on contributing to the price making decision.
- Method of fuzzy logic to determine the price.

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 the paper with a short summary.

2. Related works

The literature comprises many ideas for supporting QoS for workflows such as ICENI [5], QoS-aware Grid Workflows [7], and Spooner‘s Performance Aware Workflow Management [12]. However, none of them define a business model for their system. There are also many Grid projects working on SLA issues [9]. Most of them focus on single jobs and, thus, only on the direct relation between users and service providers. The business role of the broker in such systems has not been fully examined. Moreover, bargaining has not been considered in all of the above works.

Sim et. al. developed a market-driven bargaining strategy for G-negotiation agents [10] and describe the price setting and adjusting along multiple negotiation steps among customer agents and provider agents. The key difference between our work and the work in [10] is that our work attempts to determine a suitable price at the first negotiation round while Sim et. al. try to reach the suitable price after many negotiation rounds.

In [11], the authors present the fuzzy judgment theory. It is used for describing and analyzing buyer-seller bargaining conditions and the price determination processes. Given the players' initial utility structure, thirteen distinct situations in the negotiation space have been identified and described formally. Each situation defines a particular negotiation space and a settlement price range. However, the work of Roszkowska et. al. does not analyze in deep any particular situation with respect to the impact of certain factors on the decision making process. Our work focuses on the situation of asymmetric situation.

3. Bargaining game of the price negotiation

The cost of running the same workflow is different through time. Assume that after many times running the same workflow, the user knows the highest cost C_h of running the workflow. Thus, C_h is the highest price that the user can pay for the workflow execution. The broker maps the workflow to the available resources to determine the base price C_l of running the workflow. C_l includes the cost of buying the resources from the service providers and the cost for the broker service itself. The broker will not accept to run the workflow if the user's offer is less than C_l. If $C_l > C_h$ the trading will not happen at all. For the case that $C_l < C_h$, the cost calculation is presented in Figure 2. As the broker is a business entity, he also wants to gain profit. Thus, the actual price of the service C will satisfy $C_l \leq C \leq C_h$. It is also possible in the business environment that the seller tells the customer about the based cost and the market state to persuade the customer about his proposed price. Similar to that, we can assume that the broker tells the user about the based cost C_l and the Grid state. The case that broker does not want to tell the user about this information is not considered in this paper.

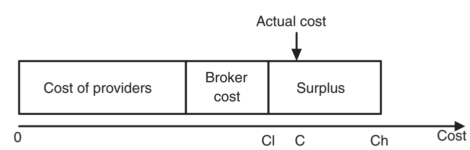


Figure 2. Pricing schema of the game

During the negotiation phase, broker and user will do bargaining over the division of the surplus $Ch - Cl$ using alternate offers. The duration of the negotiation process is limited, since there is a fixed start time of the workflow. It is also assumed that each negotiation round needs one time slot for user to analyze the change of the SLA content or for broker to find an appropriate mapping solution. Considering these conditions, we can say that both, broker and user, are impatient. However, the level of user's impatience is different from the broker's impatience. This is discussed in more detail in Section 4. Consequently, we can say that this situation is a bargaining game with asymmetric impatience [8]. The participants will accept the offer when they are exactly indifferent about accepting or rejecting it.

We also assume that the cost of delaying an agreement by one round reduces the trade gain of the user by p_u percent and the gain of the broker by p_b percent . This cost relates to the opportunity cost. p_u and p_b are common knowledge of the user and the broker because all related information is revealed. The $1-p$ percent is defined as the discount factor. We call d_u % ($d_u = 1 - p_u$), d_b % ($d_b = 1 - p_b$) as the discount factor of the user and the broker respectively.

Assume that the game can take place in N rounds. Consider the last sub-game, the game in the final round N, where the broker offers a price C_h and the user accepts it. The reason is that if the user does not accept, his utility will be reduced seriously because of the lateness. Thus, at this sub-game, the share surplus of the broker Sb_N=100 % and the share surplus of the user Su_N=0%. Now, we move back the subgame at round $(N-1)$th beginning with user's offer. As the user knows that delaying the negotiation one more round can waste the broker p_b % of his share surplus, the user offers the broker a share surplus as in Formula 1 and the broker should accept it.

$$Sb_{N-1} = Sb_N * (1 - p_b) = Sb_N * d_b \quad (1)$$

At the subgame at round $(N-2)$th beginning with broker's offer, the broker also knows that delaying the negotiation one more round can waste the user p_u % of his share surplus, the broker offers the user a share surplus as in formula 2 and the user should accept it.

$$Su_{N-2} = Su_{N-1} * (1 - p_u) = Su_{N-1} * d_u \quad (2)$$

Using the backward deduction like above we can compute the price at the first round. It is the ideal proposed price for both user and broker. From the analysis, we can see that the discount factor is the key issue in the price determination process. The discount factor depends on many variables: the remaining time period, the urgency of the workflow and the Grid state. We will apply fuzzy logic to determine the discount factor as described in Section 4.

4. Fuzzy logic to determine the discount factor

The overall architecture of the price negotiation process using fuzzy logic is presented in Figure 3.

As can be seen in Figure 3, the fuzzy logic engine receives the remaining time period and the workflow critical level from the user, the Grid state from the mapping module. Based on those input parameters, the fuzzy logic engine

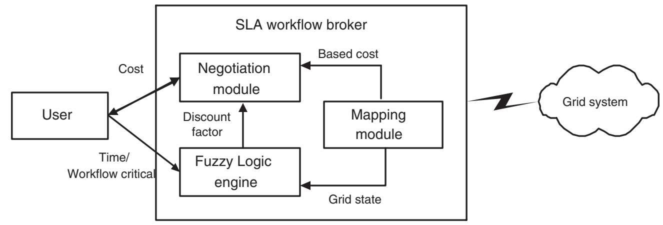


Figure 3. The architecture of using fuzzy logic in the price negotiation process

will compute the discount factors d_u and d_b and provides it to the negotiation module. The negotiation module uses d_u, d_b, C_l, C_h to compute the cost of executing the workflow and then proposes to the user.

4.1. Membership function of the input parameters

4.1.1 Remaining time period

The remaining time period has five levels: Very Low (VL), Low (L) Medium (M), High (H) and Very High (VH). The level is determined based on the ability to re-negotiate with the broker. As each negotiation round needs about 1 time slot, 9 time slots are the safe period for the user to change a lot of things. Thus, if the remaining time period is greater than or equal to 9, it is considered as Very High. In contrast, if the remaining time period is 1 time slots, the user has 1 time slot to recognize what should be change and 0 time slot to negotiate with the broker. Thus, the period of 1 time slot is quite dangerous for the user and is considered as Very Low. The level of the remaining time is mapped to the real value as presented in Figure 4.

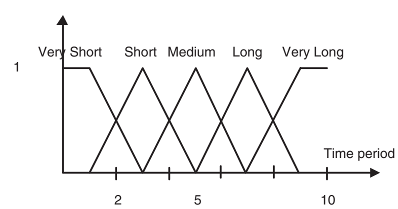


Figure 4. Membership function of the remaining time periods

4.1.2 State of the Grid

The Grid state has five levels: Very Busy (VB), Busy (B), Medium (M), Lightly-Used (LU), and Free (F). The level is determined based on the number of feasible solutions that the Workflow broker can find for the workflow, using the H-Map algorithm. In particular, this number corresponds to the number of feasible solutions in the reference set created by the H-Map algorithm [3]. If the number of feasible solution is low, this means the Grid is busy. Call nf is the number of feasible solutions, nt is the total number of configurations in the reference set. The Grid state level is mapped to the rate (nf/nt) as presented in Figure 5.

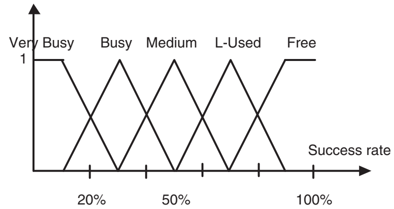


Figure 5. Membership function of the Grid state

4.1.3 Urgency of the workflow

The urgency of the workflow has five levels: Very Low (VL), Low (L) Medium (M), High (H) and Very High (VH). The user selects the discrete value for the urgency of workflow. The membership function of the workflow urgency is illustrated in Figure 6.

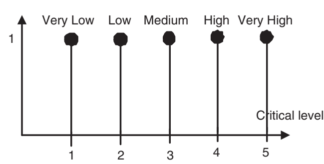


Figure 6. Membership function of the workflow critical

4.2. Effect of input parameters on the discount factors

In this section, we will analyze the effect of input parameters on the user discount factor and the broker discount factor. These effects are expressed as fuzzy inference rules. For the broker, the discount factor depends on the ability of attracting users to use the broker service. If the ability of attracting user is high, the discount factor is low, and vice versa. For the user, the discount factor is mainly based on the utility of making the workflow deadline. If the probability of delaying the deadline is high, the discount factor is low, and vice versa.

Table 1. Effect of Grid state on the broker discount factor

Grid state	F	LU	M	B	VB
Discount	VL	L	M	H	VH

Table 2. Effect of Grid state on the user discount factor

Grid state	HF	F	M	B	VB
Discount	VH	H	M	L	VL

4.2.1 State of the Grid

Effect on the broker: The Grid state effects the policy of attracting user to use the Grid. When the Grid is free, this means that only a small number of customers use the Grid at that time. Thus, the broker wants to attract more users using the Grid. If the negotiation takes a long time, the negotiation could annoy the user and, therefore, could negatively effect the success of attracting users. Thus, the discount factor of the broker is low. The discount factor is high when the Grid is busy and low when the Grid is free. The assumption about effect of the Grid state on the broker discount factor is shown in Tab 1.

Effect on the user: The Grid state affects the ability of finding a feasible mapping solution for the workflow. When the Grid state is busy, at time slot t, the broker finds out a feasible mapping solution. If the negotiation process extends longer to time slot $t+1$, the probability for the broker to find out a feasible mapping solution is small. Because the number of free resources is small, just another resource demand within $[t, t+1]$ can eliminate greatly the available resource space of the workflow. Thus, the effect of the Grid state to the discount factor of the user is summarized in Table 2.

4.2.2 The urgency of the workflow

Effect on the broker: The urgency of the workflow does not affect the discount factor of the broker.

Effect on the user: The urgency of the workflow effects the ability of finding a feasible mapping solution for the workflow. When the critical of the workflow is high, it will require high quality resources. If the negotiation process extends longer, the probability of loosing the feasible found solution is very big. Because the space of suitable Grid resources is small, just another resource demand can greatly eliminate the feasible solution space of the workflow. Therefore, the discount factor is low when the critical

Table 3. Effect of the urgency to the user discount factor

Critical	VL	L	M	H	VH
Discount	VH	H	M	L	VL

Table 4. Effect of remaining time period to the user discount factor

Time	VS	S	M	L	VL
Discount	VL	L	M	H	VH

of the workflow is high and vice versa. It is summarized in Table 3.

4.2.3 Remaining time period

Effect on the broker: The big or small remaining time period does not effect the broker's ability of attracting user.

Effect on the user: The remaining time period effects the utility of the user through the probability of ensuring the deadline for the workflow. When the time remaining period is small and the negotiation time extends longer, the user will face the big probability of not starting the workflow on time. The effect of the remaining time period to the discount factor of the user is summarized in Table 4.

4.3. Membership function of the output

The output of the fuzzy logic system are the discount factors for the user and for the broker. For both of them, we use the membership functions as presented in Figure 7.

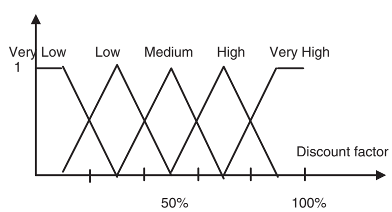


Figure 7. Membership function of the output

To determine the crisp value of the discount factor, we use the popular RSS (Root Mean Square) and centroid methods.

5. Algorithm to calculate the price

The algorithm to calculate the proposed price includes following steps:

Step 1: Get the urgency level of the workflow from user, compute the remaining time period, determine the highest cost of executing the workflow C_h.

Step 2: Use the H-Map algorithm to get the Grid state and the cost for providers.

Step 3: Compute the broker service cost. For example, this cost could be computed in a simple way for example $k\%$ of the cost for providers.

Step 4: Compute the surplus share between broker and user using the procedure presented in Figure 8. At each remaining time period value, we compute the discount factor and then determine the share. In the procedure, we use the Grid state determined at the negotiation time for all remaining time period value. As the Grid state could only be remained or become busier along the time and the affection of Grid state to user is greater than broker, the share for user will be slightly bigger than the equilibrium. It is an incentive for user to accept the proposed price.

```
Share_broker=1
Share_user=0
For I=1 To (time Remaining /2)
{
   Compute The Disc_brk,  Disc_user Using Fuzzy
    With Remaining Time = 2*i -1 And Grid State In Step 2
   Share_broker= Share_broker* Disc_brk
   Share_user=1- Share_broker
   Compute The Disc_brk,  Disc_user Using Fuzzy
    With Remaining Time = 2*i And Grid State In Step 2
   Share_user= Share_broker* Disc_user
   Share_broker=1- Share_user
}
```

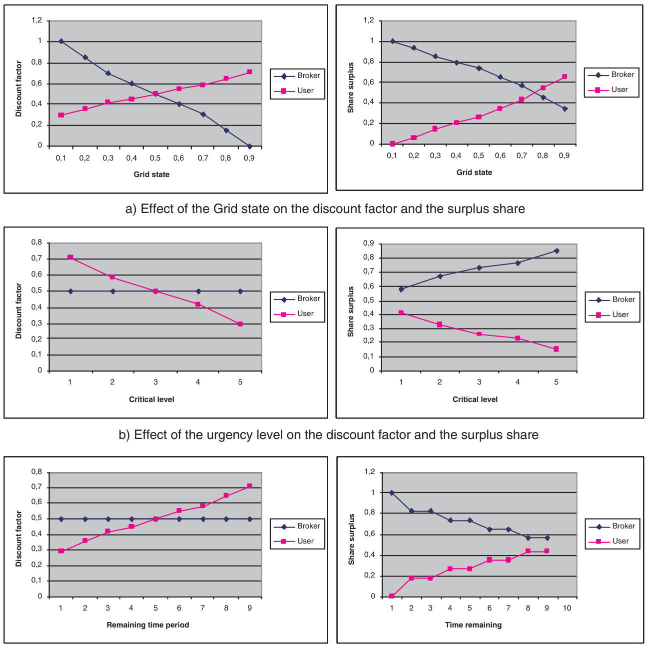
Figure 8. Algorithm for computing the surplus share

Step 5: Compute and propose the final price to the other party.

6. Validation

The goal of this task is to validate the impact of the input parameters to the discount factor and the surplus share. In the first place, we set all the parameters to medium value. After that, we change each input parameter from very low value to very high value. The discount factor and the surplus share of both user and broker are recorded.

In Figure 9a, we can see if the Grid is free, the broker reduces its share surplus to attract more users. Figure 9b shows that if the urgency of the workflow is high, the broker will get a larger part of the share surplus. It is suitable with the practical business. In Figure 9c, we can see the discount factor of the broker does not depend on the remaining time period while the discount factor of the user increases along the increases of the remaining time period. The surplus share of the user increases while the broker's decreases



a) Effect of the Grid state on the discount factor and the surplus share

b) Effect of the urgency level on the discount factor and the surplus share

c) Effect of the remaining time period to the discount factor and the surplus share

Figure 9. Validation result

along the increase of the remaining time period. This result is suitable with the game analyzed in section 3.

7. Conclusion

This paper presents a mechanism to determine the price for executing an SLA-based workflow in an Grid environment. The mechanism calculates a price that can be accepted at the first negotiation round by the user and the broker. In particular, we modelled the problem as a bilateral bargaining game with asymmetric impatience. We analyzed three parameters that effect the price setting process. They are the remaining time period, the urgency of the workflow, and the Grid state. We used fuzzy logic to combine the effects of those parameters. The simulation results confirm that the mechanism is compatible with theory and practical business.

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