Three Decision-making Mechanisms to facilitate Negotiation of Service Level Agreements for Web Service Compositions

Jakub Brzostowski, Mohan Baruwal Chhetri, Ryszard Kowalczyk

Swinburne University of Technology
Faculty of Information and Communication Technologies
John St, Hawthorn, 3122, Australia
{jbrzostowski,mchhetri,rkowalczyk}@swin.edu.au

Abstract. The negotiation of Service Level Agreements for composite web services is a very complex process. It involves the coordination of the negotiation process so that the end-to-end QoS requirements of the user request are satisfied while ensuring that the atomic QoS requirements are also simultaneously satisfied. This paper summarizes three decision-making mechanisms which support the process of Service Level Agreement negotiation for composite web services. The mechanisms include: the decomposition of the overall user preferences into the preferences of individual negotiation agents representing each atomic services within the composition; the selection of the prospective negotiation partners for the actual interaction from a list of potential service providers and finally the negotiation of Service Level Agreement with the selected provider agents while ensuring that the end-to-end QoS is satisfied.

Keywords: negotiation, end-to-end QoS, composite web services;

1 Introduction

Automated negotiation is gaining more attention recently. There are a number of real world applications where agent based negotiation is used. These applications include: e-commerce, e-business, planning, resource allocation and scheduling (Lai et al. (2004)). More recently automated negotiation has been applied to Web service compositions, for the negotiation of quality-of-service (QoS) of compound services (Chhetri et al. (2006)). A compound service may consist of different atomic services composed according to different composition patterns. An example of composition pattern is illustrated in Figures (2)(3)(4).

The negotiation of QoS usually involves a number of attributes such as: price, quality or response time. There are three kinds of decisions involved in the negotiation framework. First the utility function that encodes the preferences is specified by the user to the coordinator agent (Figure 2). The coordinator agent then has to assign the utility functions to all the atomic negotiation agents which negotiate with the different provider-agents representing the atomic services. This means that the coordinator agent has to extract the utility functions of the individual negotiation agents from the overall utility function. This task is not trivial and is described in Section 3. The next decision involved is the selection of negotiation partners (Figure 3) by the negotiation agents and is described in Section 4. Finally the negotiation agents have to negotiate with their counterparts i.e. the provider agents as shown in Figure 4, and forward the results back to the coordinator agent. The process of exchanging offers between the involved parties is described in the Section 5.

The work described in this paper is based on research conducted in the context of the Adaptive Service Agreement and Process Management (ASAPM) in Services Grid project (AU-DESTCG060081) and the EU FP6 Integrated Project on Adaptive Services Grid (ASG) (EU-IST-004617) (Wu et. al. 2006). The project aims at developing intelligent agent-based techniques and tools to facilitate the adaptive service management and process management in order to ensure collective functionality, end-to-end QoS and the stateful coordination of complex services.

2 The problem description and approach

Figure 1 illustrates the multi-agent approach used for negotiation in the ASAPM project. The whole system is a middleware between the service client and providers of the various atomic services. The task of the system is to find the best providers for each atomic service within the composition which can collectively satisfy the user request while ensuring that the end-to-end QoS requirements are met.

Our negotiation framework (Chhetri et al. 2006) uses a two-layered architecture, with the Coordinator Agent coordinating the negotiation of the whole composition while ensuring that the end-to-end QoS requirements are met. Similarly at the atomic level, the atomic negotiation agents conduct one-to-many negotiations with the candidate service provider agents. The atomic negotiation agents try to achieve the best negotiation outcome for the provided local QoS constraints.

In our negotiation scenario, the coordinator agent is assigned a utility function by the user. This utility function is specified for the compound service, and therefore it is decomposed by the coordinator agent into individual service utilities that are forwarded to the individual negotiation agents. After the negotiation agents have been assigned the utility functions they may perform the negotiation partners' selection process, what results in the determination of smaller groups of candidates from a large set of potential providers. The utility functions are needed in this process because of the specific approach to the selection which is described in Section 3. After all negotiation agents have selected the groups of negotiation partners they may start the negotiation process. In this stage each negotiation agent is negotiating concurrently with a set of potential partners that may provide the needed atomic service. Only one provider agent can be chosen from the group of candidates, and the choice is based on the negotiation outcome. What this means is that the agent that yields the highest utility value is chosen as the final provider of the required atomic service. In the case where the negotiation agent did not reach agreement with any of the candidates the partial negotiation results are returned back to the coordinator agent. Based on these results the coordinator agent computes new less restrictive utility function for the negotiation agent that previously failed. The negotiation agent can now continue the negotiation process with all the candidates using the newly assigned utility function. The process of reassigning the utility function may be repeated until the negotiation agent finds agreement with at least one of the candidates. If all the negotiation agents manage to find agreements the whole negotiation process ends and the Service Level Agreements may be prepared.

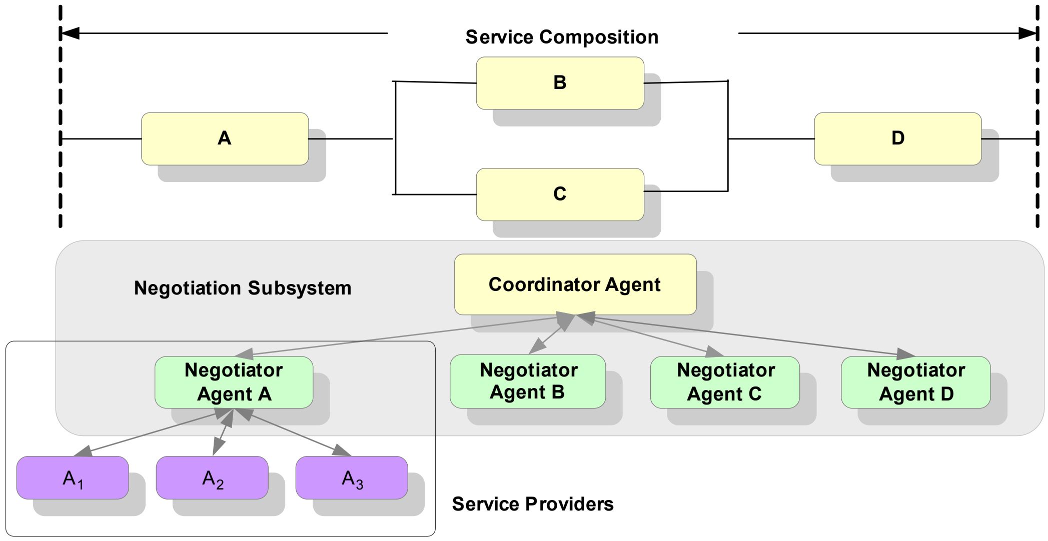

Figure 1: Two-layered architecture of the Negotiation framework

3 The decomposition of preferences for coordinated negotiations

The negotiation agent has to know its preferences in order to choose the negotiation partners and to negotiation the SLA with them. The preferences are typically encoded by the utility function that assigns to each potential solution a level of satisfaction gained from consuming a service. The specification of utility function is crucial because the aim of a negotiation is to get as high utility as possible (Keeny and Raiffa 1976; Luce and Raiffa 1957; Raiffa 1985) assuming all other constraints such as our deadline and the knowledge about our opponent. The concept of utility function has been used in the multi-agent interactions for the software agents negotiating on behalf of their users (Braun et al. 2006; Jennings et al. 2001; Kowalczyk 2002; Kraus 2001; Rosenschein 1994). In our context of coordinated negotiations the coordinator-agent is assigned the overall utility function specifying the preferences over the compound service. The user specifies the overall utility function because he/she is interested in the end to end QoS of the compound service, and does not care about the utility functions of the negotiation agents negotiating the SLA of atomic services. However, all the negotiation agents, responsible for the negotiation with provider-agents representing the atomic services, have to know the utility functions describing the preferences over the atomic services. This means that the overall utility function specified by the user has to be decomposed into a number of single service utility functions and assigned to the individual negotiation agents, so the negotiations of atomic services SLA may be performed simultaneously (Figure 2). The initial individual utilities are extracted from the overall utility function using the idea of fuzzy projection (Brzostowski and Kowalczyk 2007). After the negotiation agent fails to reach agreement with any of the potential candidates it notifies the coordinator-agent about the failure. After each failure of the negotiation agent the new utility function is assigned by the coordinator-agent based on the bisection algorithm and the round of negotiations is repeated by the negotiation agent (Brzostowski and Kowalczyk 2007). The reassignment of utility may be repeated multiple times until finally the negotiation agent finds an agreement.

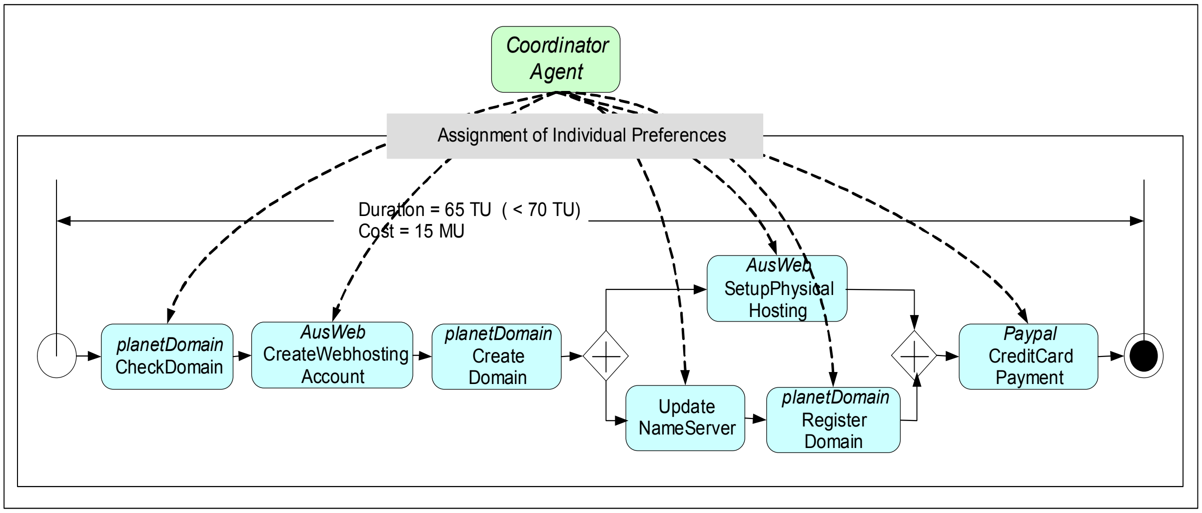

Figure 2. The illustration of composition pattern with the illustration of the coordinator assigning the individual preferences to the agents negotiating with the agents representing the atomic services.

4 Selection of the negotiation partners

In the coordinated negotiations the atomic negotiation agents responsible for the negotiation of Service Level Agreement with the provider agents representing the atomic service have to first choose a subset of agents from a large set of potential candidates (Figure 3). First of all, the negotiation agent has to find a set of provider agents representing the needed atomic service and in the next stage, estimate the expected negotiation outcome for all the potential candidates and choose a subset of potential partners maximizing the expected outcome. Most of the research supporting the selection of interaction agents employs the concepts of trust/reputation. However, in such approaches the agents are mostly assessed and selected based on their behaviour during the past transactions (the commitments to the contracts). In the approach that we proposed for the selection of negotiation partners (Josang et al. 2006) we base the decision on the behaviour of agents in the past negotiations and not the past transactions what differs significantly from most of the related research. In our approach (Brzostowski and Kowalczyk 2005; Brzostowski and Kowalczyk 2006), we construct a possibility distribution for each of the considered potential partners. The distribution assigns to each potential negotiation outcome (the values of negotiated attributes) a level of plausibility of being an outcome in the potential negotiation. The distribution is obtained in the process of case-based reasoning where the case base consists of past negotiations descriptions. The negotiation description involves the negotiation strategy description of the client-agent, the utility function description of the client-agent and the negotiation outcome description. As mentioned, the reasoning from such a case base yields the prediction about every potential partner in a form of possibility distribution. The selecting agent has its own preferences encoded by the utility function. The utility may be aggregated with the distribution encoding the prediction about the partners, what finally gives expected utility of the potential negotiation. After deriving the expected utility for all the partners we can chose the subset of required agents that maximize the value of expected utility.

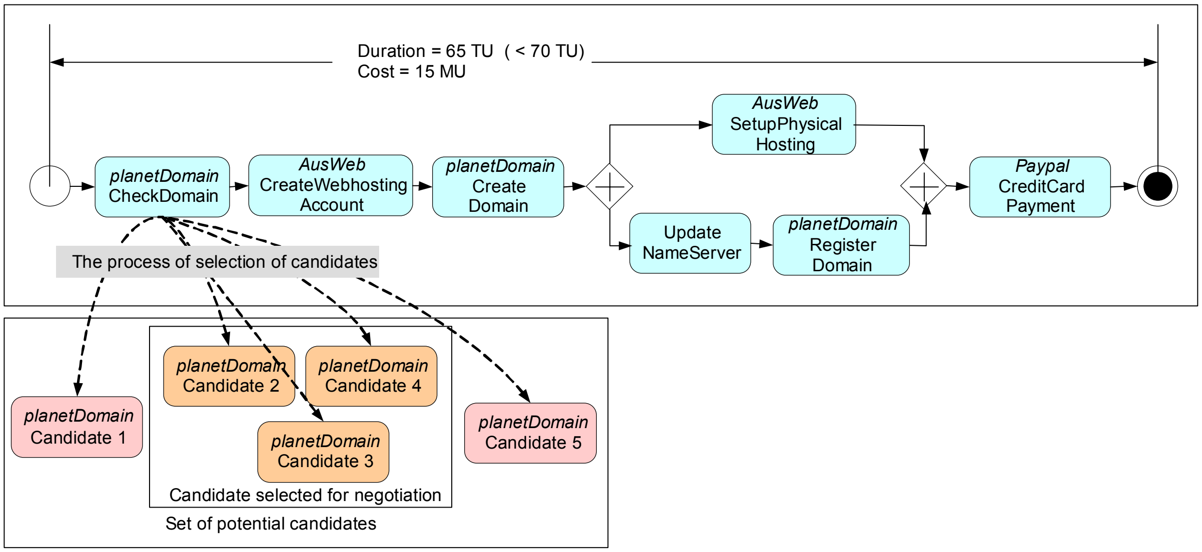

Figure 3. The illustration of composition pattern with the illustration of the selection of the most prospective negotiation partners.

5 Generation of negotiation offers for the negotiation

After the preferences of the negotiation agent are specified and the potential partners selected, the agent has to negotiate with the counterparts (Figure 4). For this task the decision-making model is needed. Some insight into the process of negotiation is provided by the game theory (Binmore 1992). However, the game theory assumes the full rationality of the players and complete knowledge of circumstances. Such assumptions are quite unrealistic and therefore the application of game theory for practical negotiations is limited. The agents bounded information and bounded computational power may be compensated by the ability of learning (Braun et al. 2006), reasoning (Braun 2006) and argumentation (Sierra et al. 1998).

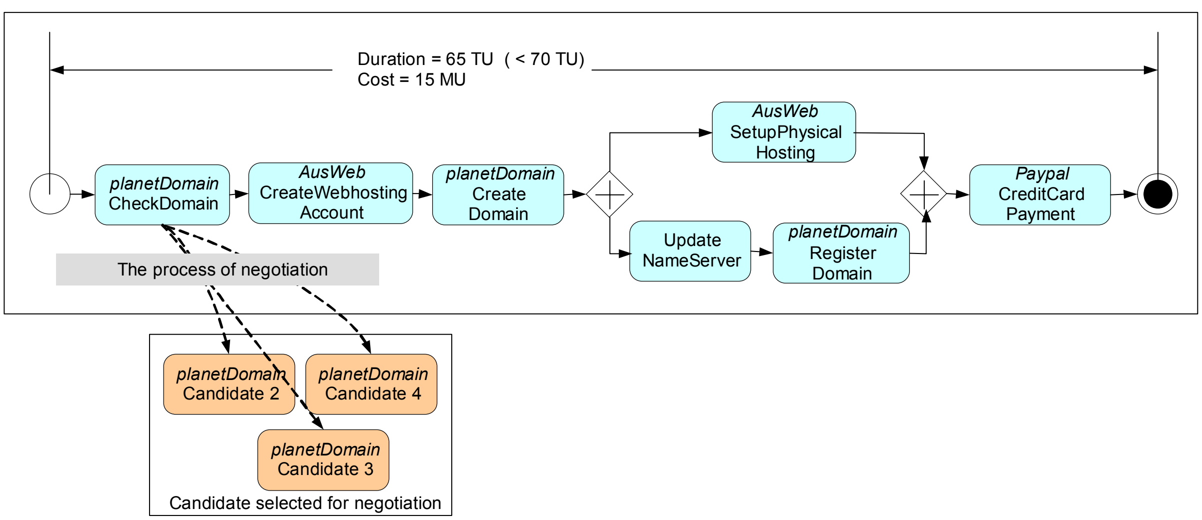

Figure 4. The illustration of the negotiation processes of each atomic negotiation agent with multiple providers

The computational complexity of agents reasoning creates the need for some heuristic approaches for negotiation decision-making. An example of such a heuristic approach is the concept of decision function introduced by Faratin (Faratin et al. 1998). In this approach the agents are equipped with a notion of tactics and strategies allowing for determination of an offer and counter-offer in each stage of the encounter. The negotiation agents are constrained by deadlines determining the time given to reach agreements. The time-dependent tactics compute an offer based on the time remaining for negotiation which means that it is a function mapping a time point into the offer, either in attribute space or utility space. This approach also allows for limited level of adaptation to the behaviour of the negotiation partner. This is done by different types of imitation of the behaviour of negotiation partner (for instance tit for tat). The different tactics may be linearly combined to form a negotiation strategy which is a more sophisticated way of generating negotiation offers.

The approach of Faratin may be complimented by various learning and reasoning approaches. The learning approaches include: Bayesian learning (Zeng and Sycara 1996), Q-learning (Cardoso and Oliveira 2000) and evolutionary computation (Matos 1998; Oliver 1997). However, these approaches require prior knowledge obtained before entering the negotiation and such knowledge may be sometimes difficult to obtain. Alternatively, the agent may learn from the current encounter or it may compliment its prior knowledge with the knowledge acquired from observing the partner in the current negotiation. Such an approach of on-line learning was proposed by Hou (Hou 2000). The agent predicts the shape of the concession curve of the opponent using the regression analysis and then adapts to this forecast by making concessions that maximize its utility. Hou considered the opponent using pure tactics according to Faratins approach. In our work (Brzostowski and Kowalczyk 2006) we extended the regression based mechanism to cope with more sophisticated type of behaviour, namely the mixed tactics (two-tactic strategy). However, the usage of regression based forecasting is limited because of the inability to predict the deadline and reservation value of the opponent. The shape of the concession curve may be predicted and therefore the approach is appropriate for the scenarios where the agents have the same deadline.

6 Conclusions

In this paper we summarized different kinds of decision-making mechanisms facilitating the negotiation process between the service client and service providers. These mechanisms include the decomposition of the overall preferences of the service client, the selection of potential negotiation partners and the generation of offers and counter-offers in the actual encounter.

The mechanism for the decomposition of the overall preferences extracts the individual utility functions from the overall utility function specified for the overall service. The initially computed utility functions usually will be too tolerant what may lead to the solution not satisfying overall preferences. However, the application of bisection algorithm allows for modification of preferences after each repeated negotiation what leads to good solution. The advantage of this approach is solution satisfying preferences of all negotiation parties, assuming that before the process of repeated negotiations nothing was known about the opponents preferences and negotiation behaviour. However, this approach requires to repeat the negotiation multiple times.

The mechanism for selection of negotiation partners is able to predict quite precisely the expected negotiation outcome what allows for the selection of most prospective negotiation partners, and the utility gain of the mechanism is significantly higher than the gain of random selection what has been shown in related work. However, the mechanism works well only when the preferences of the modelled agents do not change in time.

The mechanism for the generation of negotiation offers allows for the forecasting of the shape of the concession curve of the counterpart under the assumption that the types of the decision functions used by the counterpart are known. This is required by the regression based mechanism to predict precisely the shape of the curve. In order to have precise forecast sufficient number of previous offers is needed what is one of the assumptions. Moreover, the basic limitation of this approach is the inability to predict the deadline and reservation value of the negotiation partner. Therefore, the approach may be used when either the deadline or the reservation value of the partner is known. If one of the two parameters is known then the second one can be predicted.

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