An Active Negotiation Model for Service Selection in Web Service Composition

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Abstract—Web service composition (WSC) offers a range of solutions for rapid creation of complex applications in advanced service-oriented systems by facilitating the composition of already existing concrete web services. One of the critical challenges is the dynamic selection of concrete services to be bound to the abstract composite service. In our research, we identify and elaborate on the challenges involved in developing an automated negotiation solution for service selection. We propose an active negotiation model in order to more effectively benefit from the dynamic environment created by negotiation, through an active coordinator. The active coordinator prioritizes the atomic services based on a calibration of the risk of not achieving an agreement in negotiation, and starts the negotiation in ascending order of risk. This strategy enables the coordinator to effectively utilize the negotiation result of lower risk services to improve the negotiation of those associated with higher risk and thus achieves higher rate of negotiation success for the composite service.

Keywords—Web service composition; negotiation; service selection; service level agreement (SLA); quality of service (QoS)

I. INTRODUCTION

Web service composition (WSC) has been an active research area for the past ten years. Its main goal is to compose existing concrete web services together to achieve a new value-added service [1]. Manual composition of web services is time-consuming, error-prone and not scalable [2]. As a result, researchers have been attempting to automate different stages of this process to deal with the high level of complexity involved. In a typical automatic WSC solution lifecycle (Fig.1), the first stage is goal specification. At this stage, the service requester’s goal and preferences are defined. Then, the goal is decomposed into an abstract business process (BP) comprising a set of tasks, i.e. abstract atomic services or briefly atomic services, each with clear functionality, along with the control and data flow among them. The QoS requirements for the BP (end-to-end QoS requirements) as well as for each atomic service are also specified. During the next stage, service discovery, concrete web services that match the atomic services’ functional and non-functional requirements are located by searching a service registry that holds information about the concrete web services. The discovery is performed for all the atomic services in the BP to find a match for each of them. At this stage, it is very likely that more than one candidate web service will be found for each atomic service that, while satisfying the basic required functionality, are offered with different QoS attributes; i.e. different levels of availability, price, etc. Therefore, at the subsequent service selection stage, the service requester has to use complex optimization techniques to rank the candidates and select best concrete web service that matches the specified requirements of the atomic service. After finding the best matches for all the atomic services in the BP and binding the abstract atomic services to the concrete services, the concrete composite service (CS) is created. During service execution stage, a process instance is created by executing the CS. The process instance is continuously monitored for necessary responses toward any failure or change in its status at the final stage of WSC, i.e. service monitoring.

The implicit assumption in the current solutions for service discovery and selection is that the provider would publish the services with a predetermined set of attributes. Therefore, the requester has to search within this set of fixed attributes to find the services that match her requirements. In most cases, as there will be more than one candidate, the service requester has to use complex multi-objective optimization techniques for the trade-off analysis of the QoS attributes. On the one hand, this assumption forces the provider to fix all the service’s attributes based on pre-determined set of values that can be offered generally to all the different requesters. On the other hand, this assumption deprives the service requester of the option of receiving customized services based on her preferences.
To address these problems, this research aims to apply the concept of negotiation for Web service selection during WSC. Negotiation is the process of searching a space of potential agreements to find a solution that satisfies all the negotiating parties’ requirements [3]. In our case, negotiation enables service requester to receive more customized services and frees the service providers from the obligation of offering general services with predetermined attributes that match every one. The remainder of this report is as follows: Section 2 discusses the research problem in more detail. Different approaches in applying negotiation for service selection are explained in Section 3. The current passive coordination approach and the proposed active negotiation model are discussed in Section 4 and 5, respectively. Research challenges are presented in Section 6. Finally, Section 7 reports the conclusion and our research plan.

II. RESEARCH PROBLEM

In WSC, service discovery and selection is the process of finding concrete web services that match atomic services in the BP. Therefore, WSC solutions need to define clear search criteria to be executed against the web service registry. What to include in this search criteria varies among different solutions. The matchmaking algorithm proposed in [4] ranks the functionally equivalent services on the basis of their ability to fulfill the service requester’s requirements (functional and non-functional) while maintaining the price below a specified budget. The authors in [5] propose a matchmaking framework based on the context of Web services, defining context as all the information needed for enabling interactions between service requester and providers. Semantic and behavioral information are used in [6, 7] for web service matchmaking during WSC; Web service behavior is the order of the execution of the service operations or the order of message exchange with a service and the constrains governing the operations’ execution order [8]. The selection algorithm proposed in [8] takes into account not only the functional requirements but also the transactional properties, and QoS characteristics of web services; where transactional properties guarantee consistent outcome and correct execution of the composite web service. An information retrieval approach is suggested in [9] for discovering and ranking web services automatically, given a textual description of desired services.

This variation with respect to search criteria arises from the fact that a web service can be defined from different aspects and various perspectives, such as the functionality, QoS attributes, interface, semantics, behavior, and context. Although some aspects are compulsory elements in a web service definition, e.g. the web service interface, what other additional aspects to include in the service definition depends on the application domain and the service user’s request. Note that there is no standard distinct boundary between these aspects and how to define them varies among different researchers. For example [5] suggests that all information about a web service needed for enabling interactions between clients and providers can be defined as its contexts. Context in this definition even includes the functional attributes of a web service, besides the non-functional, domain-dependant, and value-added optional attributes, such as security and privacy. Indisputably, all existing solutions seem to concur that the interface is necessary but not sufficient. Whatever criteria are considered in the search query in order to find the concrete matches of each atomic service, the service registry returns a number of candidate matches after executing the query. Then, the service requester has to use complex optimization techniques to select the one service that best matches the requester’s requirements.

The current solutions for service discovery and selection implicitly assume that the service providers would publish the concrete web services with a predetermined set of fixed attributes in a very strict manner of take-it or leave-it. However, there are a number of serious problems with this approach: i) in many cases, the providers are not able to specify all the service’s attributes based on pre-determined values that can be offered generally to all the different requesters, and ii) no mechanism is available by which the requester could receive a customized service based on her preferences. This problem has been referred to as defining the QoS profile in a static non-negotiable, non-configurable manner which is the current trend in process optimization and Web service selection literature [4].

This approach is very different from real world services. Consider a scenario when someone is looking for a specific service, for example a comprehensive car insurance policy for her car. First she searches for the companies who are offering this type of services in a registry, i.e. the city yellow page book. Up to this point, it is very similar to the web service world where the requester tries to find the functional matches for her desired functionality. Afterwards, in the real world, the service requester starts a series of negotiations with different service providers. She may use the information obtained during her first round of negotiation with the provider A, in negotiation with provider B. For example, while negotiating with B, she may claim to have a lower price from A, but as her Third-party insurance is with B, she prefers to buy her comprehensive car insurance policy from B too, only if they can lower their price. Moreover, the provider can customize the offer according to the requesters’ context; i.e. as the service requester is over 30 years with no previous accident history, she can benefit from a special discount.

In computer science, negotiation as a distributed search through a space of potential agreements[10], has been used for many years to solve different problems, e.g. resource allocation in grid computing, or getting agents to cooperate or compete over a common goal in multi-agent systems. In the web service domain, researches have employed negotiation mainly for (semi-)automatic creation of Service Level Agreement(SLA) where service consumer and provider negotiates over QoS attributes to reach an agreement, that satisfies both sides’ requirements.

In the web service composition area, employing negotiation becomes much more interesting by considering the fact that negotiating to find a match for one atomic service is part of a series of negotiations to find matches for other atomic services while they are not independent from each other. For example if the discovery process for one specific atomic service returns only one concrete service, called S1, with a specific response
time, it is useless to match the services parallel with SI in the process, with concrete services which have much smaller response times, as anyway, SI cannot respond faster than a specific time. Therefore, it is useful to consider this information during negotiation for other services in order to not compromise another important QoS attribute for the response time.

To address these problems, this research aims to develop a novel framework that provides an effective automated negotiation solution for dynamic selection of concrete web services during WSC. More precisely, the intended framework will provide the service requester with an automated negotiation mechanism to negotiate over the desired QoS attributes and preferences, with different service providers for each atomic service. This can eventually lead to effective selection of concrete web services for the BP. Negotiation will enable the service requester to receive customized services based on her specific context and it frees the service providers from the obligation of defining their offered services with a predetermined set of fixed attributes in order to publish them in a registry. More specifically this research seeks to answer the following questions:

1) What are the specific requirements of WSC that distinguish negotiation in this context from negotiation in other close research areas such as grid computing or multi-agent systems, 2) What are the necessary elements for building an automated negotiation solution in the context of service selection during WSC, considering the specific requirements of this context, 3) What are the necessary modifications to the current negotiation protocols and decision making models to effectively address the specific requirements of negotiation in the above mentioned context, 4) How to exploit the specific characteristic of negotiation in the intended context to develop more effective and efficient negotiation techniques (e.g. using different types of dependencies among atomic services in the BP to improve the negotiation process).

A. Progress to date

In our research, we have identified and elaborated on the challenges involved in applying negotiation for service selection during web service composition, including the need for coordination, and the critical design factors associated with it: time limitation, management complexity, and effective use of negotiation information. To address the specific requirements of negotiation in this context, we have extended the negotiation framework proposed in [3] for autonomous agents capable of negotiation, by adding negotiation architecture as an additional element. We have carefully reviewed and analyzed the current approaches toward designing the coordination layer and how they have addressed the critical design factors. Based on this, we argue that the current coordinators take a passive approach toward negotiation; they neither efficiently consider the negotiation space before starting the negotiation, nor do they take advantage of all the available information to improve the negotiation success rate in achieving the agreement for the whole BP. To address these problems, we have proposed an active coordinator which calibrates the risk associated with not achieving the agreement for each abstract atomic service in the BP and prioritizes the atomic service’s negotiation initiation according to the risk. It initiates the negotiation of those with lower risk before the ones with higher risk. This enables the active coordinator to effectively utilize the negotiation result of lower risk services to improve the negotiation of those associated with higher risk and thus totally achieve higher rate of negotiation success for the composite service.

III. NEGOTIATION IN WSC

There are currently two approaches related to how and when to use negotiation for service selection during WSC lifecycle (Fig. 2): a) negotiation as a complementary strategy to optimization techniques for service selection, b) negotiation as the main strategy for service selection. In the first approach, negotiation takes place after the optimization technique, only when it fails to find appropriate concrete services for all the atomic services, due to their not satisfying the end-to-end QoS requirement of the BP[11]. Even though this approach is an improvement on the purely optimization approach, it still faces the problems mentioned in the foregoing, namely, considering only a static set of QoS values for web services and the lack of customization. In the second approach [12-15], negotiation is used as the main technique for service selection. Negotiation makes it possible to dynamically select concrete services for atomic services without the need to statically define a QoS profile for either atomic services or concrete services. Our focus is on the second approach, and whenever we discuss negotiation in the context of WSC, the second approach is intended.

![Figure 2. Different perspectives on how to apply negotiation for service selection during WSC](image)

Basically in this approach, a high-level negotiation process (overall negotiation process) is conceptualized that negotiates for the overall BP. It consists of multiple negotiation subprocesses (briefly negotiation process) each associated with one abstract atomic service in the BP. Each negotiation process in turn, may include multiple negotiation threads to choose the best provider for the specific atomic service that this negotiation process is associated with. Meanwhile, when dealing with negotiation at the BP level, negotiation itself may not be enough for achieving the end-to-end QoS requirement and ensuring a successful overall negotiation outcome for the composite service. Thus, a further management layer referred to in the literature as coordination becomes necessary.

Three important factors affect the design of such a coordination layer: time limitation, management complexity, and effective use of negotiation information. Time limitation is caused by the fact that service selection is one stage in the overall WSC lifecycle, and the time to accomplish it is limited. When applying negotiation as the selection technique, the overall negotiation time depends on the individual negotiation...
processes’ time. In each negotiation process, all negotiation threads take place concurrently. The negotiation process will finish when an agreement is formed between the atomic service and one of the available providers or negotiation deadline expires without reaching an agreement. Therefore, the minimum overall negotiation time is achievable if all of the concurrent negotiation processes successfully terminate.

However, the concurrent execution of negotiation processes makes their management exponentially complex, because, a negotiation process which tends to find a match for one atomic service is not independent from other negotiation processes. In fact, if the opportunities brought by negotiation for dynamically specifying the QoS values are about to be used, the coordinator should be able to effectively use one individual negotiation process’ status and final result, in order to improve its dependant negotiation processes status and final result. This can lead to improvement in the overall negotiation performance in terms of reaching an agreement for the whole BP. Nevertheless, how each negotiation process can improve others’ situation in negotiation is determined by the dependencies that exist among the atomic services in the BP. There exist different types of service dependencies in a BP, e.g. regarding the timing, QoS attributes, budget, data flow, or control flow[16]. If a coordinator decides to consider more than one type of dependencies among atomic services, this will further exacerbate the complexity of managing the overall negotiation process with concurrent sub-processes.

IV. PASSIVE COORDINATION

We argue that the current proposals for coordination[13, 14, 17] take a relatively passive approach toward negotiation. The passive approach forces the coordinator to wait till the conclusion of all the negotiation processes to decide upon the necessary action. Then, even if one negotiation process is not successful, the service selection will not be successful. Then, the coordinator should restart negotiation of one or more atomic services, with some new values for negotiation issues. This means that the coordinator does not benefit from any individual negotiation process outcome to improve the situation of other negotiation processes. In[15] however, the coordinator does not wait for all the processes to finish. It receives the result of each negotiation process at its end and acts upon receiving the result.

The following assumptions structure the passive coordinator approach in the current literature on negotiation: a)initial decomposition of the end-to-end QoS attributes takes place regardless of the negotiation space, b)simultaneous initiation of all negotiation processes, independent of the negotiation space, and with no feedback for each other. As a result, the coordinator does not benefit from the information that emerges during the negotiation.

Although there is not much coverage in the literature on the overall agreement rate of such a passive coordinator, we argue that these assumptions make the coordinator’s success rate in achieving an overall agreement for the whole composite service reasonably low, especially if the QoS requirements are very severe. The passive coordinator might have to change the QoS requirements distribution over the atomic services several times to ultimately achieve overall agreement.

V. AN ACTIVE NEGOTIATION MODEL

In order to address the above mentioned problems of current passive coordinators, we propose an active negotiation model. This model follows an active coordination strategy which allows the coordinator to effectively intervene in the negotiation processes in order to increase the agreement rate of the overall negotiation. The ideal case of such an active coordinator is aware of the status of all the concurrent negotiation processes and threads. Thus, it does not just wait to receive the negotiation results to coordinate them, rather it may intervene in the negotiation processes, and can do this in any of them if it assesses the negotiation process to be unsatisfactory (e.g. close to negotiation deadline, or to withdraw without agreement). By getting the status of the concurrent negotiation processes, it may use the information of one process to improve the negotiation in another process. For example if a negotiation process for an atomic service finishes successfully with a final price below the expected budget, the active coordinator is able to assign the remaining budget to another atomic service which negotiation is about to fail due to dissension over price.

We propose an active coordinator which overcomes the complexity problem by initiating negotiation processes based on their priority. The priority class is decided based on the risk associated with the atomic service for not achieving an agreement. We calibrate such a risk using two factors: the number of potential providers (the lower the number of potential providers for negotiation, the higher the risk of negotiation failure) and the weight associated with it for its importance in the BP in the general term (the more important the atomic service, the more critical its negotiation success). The details of the calibration algorithm are not discussed here due to space limitation. Note that the negotiation space (i.e. the number of potential providers available for negotiation for each individual atomic service, how close is the acceptable interval of a negotiation issue of the atomic service to that of any of the providers, the negotiation deadline of atomic service with regard to those of the providers) and the QoS requirements space (i.e. the severity of limitations over the QoS requirements) affect the result of the overall negotiation process and how successful it can be. However, the only piece of information accessible for coordinator is the number of potential providers (output of the service discovery stage) which is used in our active negotiation model.

A. Risk Calibration and Class Determination

We assume that the end-to-end QoS requirements is decomposed over the individual atomic services in the BP either manually or automatically through one of the already existing techniques (Reverse Stochastic Workflow Reduction [20], utility decomposition [8]) and that the potential service providers are identified through a service discovery technique searching in a service registry for semantic and syntactic matches for each atomic service.
Atomic services are once categorized based on the number of potential providers (the two right-hand columns of the Risk Calibration table, in Fig. 3) and another time based on their weight in the BP (the two left-hand columns of the same table). Each categorization will place an atomic service in one of the categories of “low, medium or high number of providers available” and one of the “low, medium, or high importance”. Afterwards, based on the decision table depicted in table 1, atomic services will be classified into three categories: high, medium and low risk atomic services. Each risk class outlines one prioritized class of atomic services.

<table>
<thead>
<tr>
<th>Available providers category</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
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</thead>
<tbody>
<tr>
<td>Low</td>
<td>MR</td>
<td>LR</td>
<td>LR</td>
</tr>
<tr>
<td>Medium</td>
<td>HR</td>
<td>MR</td>
<td>LR</td>
</tr>
<tr>
<td>High</td>
<td>HR</td>
<td>HR</td>
<td>MR</td>
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H: High, M: Medium, L: Low, R: Risk

Table I. Decision Table for Atomic Service Classification

For example, consider a business process comprising of five atomic services ($S_1$ to $S_5$), each with an identified number of available providers ($P_{i,j}$, $j$th provider available for atomic service $i$) and a normalized weight ($w_1$ to $w_5$). Calibration of the risk of each atomic service and assigning it to a class of priority is depicted in Fig 3.

Figure 3. Active Coordinator calibrates the risk level of atomic services and classifies them into Low, Medium, or High risk class

The classes of priority can be more or less than our suggested three classes. Increasing the number of classes allows the coordinator to more effectively intervene in the negotiation result, while increasing the total time of negotiation for BP. Therefore, based on the number of the atomic services in a composite service and the total acceptable negotiation time, it is possible to raise the number of the classes in order to increase the success rate of the overall negotiation process. As we do not want to augment the total negotiation time dramatically from the current passive approaches, and based on an assumption that only two classes of high and low risk will not give enough opportunity to the active coordinator to exploit the negotiation result for necessary adjustments, we chose three classes for our model.

When the risk level of the atomic service is identified, its negotiation will start concurrently with the other members of the same class of priority. The active coordinator starts the negotiation processes of those in low risk class first, and after they all ended, it starts the medium risk class, followed by the high risk class. At the end of negotiation of each class, the coordinator analyses the result to determine the possible actions for improving the negotiation result of the next priority class.

This prioritized gradual initiation from lower to the higher risk enables the coordinator to effectively utilize the negotiation processes’ results of those which are more likely to have a successful negotiation, to decrease the probability of failure for high risk services. Furthermore, coordinator would be able to assign more resources (e.g. the extra budget resulting from low class negotiation) to the more important (and thus critical) atomic services. This will ultimately improve the overall negotiation process agreement rate, compared to the current passive negotiation models. Active coordinator maintains the complexity of its management as low as the passive coordinators since the strategy toward each class of risk is still passive; i.e. the coordinator does not intervene in the negotiation processes associated with atomic services which are members of the same class of priority. A comparison of the proposed active coordinator with the ideal coordinator and the current passive coordinators is depicted in Fig. 4, along the three dimensions of critical design factors of a coordinator.

Figure 4. Comparing the proposed active, ideal and passive coordinators along the design factors

VI. RESEARCH CHALLENGES

To develop an automated solution that applies negotiation as the service selection technique during WSC, we face a number of interesting challenges while designing the solution and also its evaluation. The first challenge is related to the
negotiation and its complexity. Negotiation is a very complex process in the general sense, borrowing from different domains such as economics, social science, psychology, artificial intelligence, game-theory, and multi-agent systems. A careful selection of the abstraction level and the boundary of the research problem is a critical success factor affecting the accomplishment of this PhD study. The other design challenge lies in the complexity of effective negotiation for a composite service which involves multiple one-to-many negotiation processes over multi-attribute negotiation objects where the negotiation processes are not independent. We need an automated negotiation technique that helps us manage the complexity without losing its effectiveness in exploiting the information emerging from the individual negotiation processes. This valuable information can be used to improve the overall negotiation process for the BP.

Another challenge involved in this research is associated with the evaluation criteria for the proposed solution. In the research community, it is very common to evaluate the success of the proposed solution by measuring its efficiency or performance (i.e. response time, and latency). However, we think these metrics are not good enough for the context of our research. In fact, it is very probable that applying negotiation for service selection makes the solution slower than the current approaches without negotiation. But we believe it would be much more effective in terms of the ultimate goal of WSC which is addressing the user functional and non-functional requirements including price, performance, response time, etc. Yet, we have to define the necessary metrics for such effectiveness.

VII. CONCLUSION AND RESEARCH PLAN

In this research, we elaborate on the challenges involved in developing an automated negotiation solution for service selection, including: the need for coordinating the negotiation results, the complexity of concurrent negotiation processes, and the efficient use of emergent information from the negotiation.

We have identified the two strategies for the coordination, namely active and passive and discussed the advantages and drawbacks of each of them. To exploit the advantages of the active coordinator without its complexity problem, we have proposed an active coordinator which takes a divide-and-conquer approach to solve the management complexity. It prioritizes the atomic services based on the risk associated with them for not achieving an agreement and starts the negotiation process in an ascending order of risk. This will enable coordinator to consider the necessary actions (i.e. distributing the extra budget, extra time, etc. over other dependant negotiation processes) to increase the possibility of achieving agreement for those atomic services associated with higher risks which in turn will lead to higher rate of achieving agreement for the whole composite service.

Our future work includes a more detailed study on the influential factors over the risk associated with unsuccessful negotiation to apply them in our model. We also intend to improve coordinator performance in terms of the agreement rate by considering more complex analysis of the current negotiation status and other possible reactions. We are in the process of developing a prototype system to evaluate our proposed architecture and demonstrate its overall functionality in providing an effective solution for the dynamic web service selection. The prototype system first will be developed as a limited-version of the proposed active negotiation model. This prototype will allow us to conduct experiments for measuring the defined evaluation metrics and compare the model with the current existing approaches. Some of the evaluation metrics are adopted from the literature [3],[18], [19]. But as discussed earlier in section 6, there is a need for other evaluation metrics that better reflect the effectiveness of the solution in better addressing user requirements. Early results are expected to be published concurrently. At the next stage, we propose to extend the prototype based on the early results of the experiment.

This prototype system will enable us to conduct experiment to evaluate our hypotheses. The central hypothesis is that our proposed active negotiation model will perform at least as well as the passive proposals in worst case, while in the other cases it will outperform in terms of the overall negotiation agreement rate.

REFERENCES


