An Approach to QoS based Selection and Composition of Semantic Web Services based upon Multi-Agent Negotiation

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Abstract: - This paper presents a QoS (Quality of Service) based selection and composition model for semantic web services in which the negotiation is performed with all the discovered service providers and the negotiation results are used in the selection process. In semantic web service composition, the selection can also be performed after negotiating with all the discovered service providers and the negotiation-agreements generated from the negotiation can also be used in the selection process. This paper presents a semantic web service selection and composition model based upon this concept. In this paper, a multi-agent negotiation based semantic web service composition approach has been presented. A negotiation agreement based selection model has also been presented that uses the assessment of the various quality parameters included in the negotiation agreement for rating the service provider agents. The implementation issues in the work has been discussed and the comparative analysis has been performed.

Keywords:- Semantic web, negotiation, multi-agent system, selection, composition

1 Introduction

Semantic web service (SWS) composition is the process of generating aggregated service by the integration of independent available component services for satisfying a client request that can not be satisfied by any available single service. The work presented in the paper is based upon the multi-agent based SWS composition. Multi-agent based semantic web service composition involves the composition of SWSs considering each of the agent capability to serve a particular service request. The paper presents models for the selection and composition of SWSs based upon the multi-agent negotiation. This paper is the expansion of the work in our other paper in [1].

The basic understanding underlying the presented work is that the negotiation in the agent based SWS composition process can also be performed before the selection of final service provider for a task. The selection and composition models presented here is based upon the SWS composition model presented in our earlier work in [1] that uses dedicated coordinator agent and performs the negotiation between service requester agent (SRA) and all the discovered service provider agents (SPAs) before selection of final SPA. However, the earlier work in [2] also presents the selection and composition of SWSs based upon the same composition model, but that work does not consider the QoS (Quality of Service) assessment of the SWSs.

Apart from introduction in section-1, the paper has been organized as follows. Section-2 presents a multi-agent negotiation based SWS composition model. The negotiation agreement based QoS selection model has been presented in the Section-3. In section-4, the implementation issues regarding the implementation of a composition system based upon the proposed selection and composition models has been presented. The comparative analysis of the presented work has been given in the section-5. The work has been concluded in the section-6.

2 SWS Composition based upon Multi-Agent Negotiation

This section presents a multi-agent negotiation based SWS composition approach. The approach is based upon the SWS composition model presented in our earlier work in [1] that uses dedicated coordinator agent and performs the negotiation between SRA and all the discovered SPAs before selection of final SPA. Figure-1 shows the layout the presented composition model. In this model, three types of agents are involved [1]: Service Requester Agent (SRA), Service Provider Agent (SPA), and Coordinator Agent (CA). SRA has the responsibility to perform the request to CA. The request by SRA is then specified in the term of ontology, which is then used by the CA. An intelligent CA has various properties and capabilities. CA is a modular, self-contained software component wrapping coordination services, with ontological service description. It has the capability of validating the constraints, preferences, and other higher level parameters of the input request by the SRA. It has the capability of validating if the input activity is atomic or complex. In case it is complex, interpreting it as task comprising of various atomic activities of varying granularity and decomposing it into atomic tasks according to their ontology description. CA can negotiate with the SPAs using some negotiation approach, resulting into some common agreement over the various service-attributes. Further, it can evaluate and assess the SPAs based upon the nature of their negotiation-agreements and quality attributes. It makes arrangement for outsourcing the activity to SPAs based on FIPA Contract Net Protocol [3] and agent's communication interface built upon FIPA-ACL [4]. SPA is a self-contained, modular agent wrapping services in the form of software components, with the corresponding ontological service description. The purpose of SPA is decided by the services it wraps. It is able to understand the meaning of activity, it has to perform. SPA joins the composition process, only for the time its service is required.

The layout of the presented composition approach is shown in the Figure-1. Figure 1(a) shows the various steps for the selection of CA [5]. The steps for the selection of SPA are shown in the Figure 1(b). In this model, the negotiation has been performed with all the discovered SPAs for a task and after that the selection is performed from among the all successful SPAs. In this model, the selection is performed based upon the assessment of the quality of service (QoS) parameters in the various negotiation agreements corresponding to each of the successful SPA. This assessment can be used for the indexing of the SPAs for selection of the best SPA. The advantage of this aspect is that in this case, the selection has been performed for the best from among the all the acceptable agreements, so it will result into more reliable and accurate selection. Further, the composition model also facilitates the assessment of the QoS parameters in the selection process.

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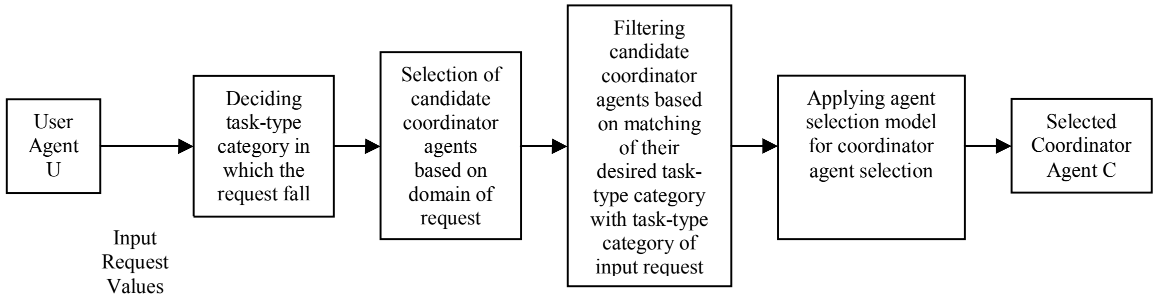

Figure 1(a): Selection of Coordinator Agent

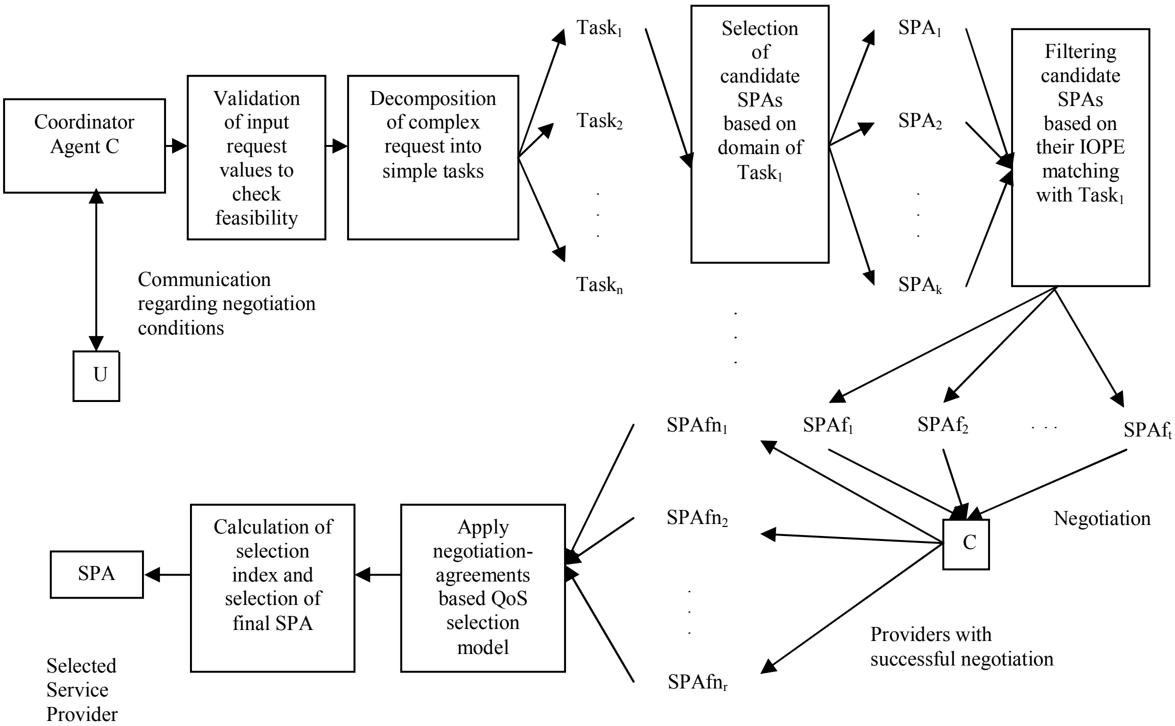

Figure 1(b): Selection of Service Provider Agent for a task

This approach follows the same process for the selection of CA as depicted in the Figure 1(a). The input request from the SRA, user-agent U, is represented in the term of ontologies. The parameters in the request are used to decide the domain and further the task-type category within the domain of the request. The domain of request is used to discover the entire candidate CAs after matching from their published ontological service profiles. Filtering of the candidate CAs are performed based on the matching that if the task-type category of the input request is matching with any of the category mentioned in the set of desired task-type categories of the candidate CA or not. At this step, various techniques for the matchmaking process can be used such as LARKS [6], service discovery techniques based on UDDI protocol [7], semantic matching [8] based on ontology profiles like in DAML-S [9], OWL [10]. Different techniques of discovery [11] that can be applied are keyword matching, controlled vocabulary matching, semantic matchmaking etc. The system can be made to proceed with the exact match, plug-in match, subsumption match, or intersection match as required in the process. From the discovered CAs, the selection is performed for the most appropriate CA using an agent selection model. The user agent assigns the requested task and the condition of negotiations to CA by means of agent's communication interface built upon FIPA-ACL [4]. After the selection of CA, the rest of the activities for the selection of SPAs for satisfying input composite request are coordinated by the CA. The process for the selection of SPA for a task is shown in the Figure 1(b). CA performs validation of the input request over the parameters, preference, and constraints to check their feasibility. It also checks the input request, if it is an atomic activity or complex one. If it found that the input request is complex one, it decomposes the complex task into atomic tasks, $Task_1$, $Task_2$, $Task_3$ ... $Task_n$, of varying granularity. For each of these atomic tasks, the candidate SPAs are discovered and filtering over discovered SPAs are performed based on their IOPE matching with the required task. The matchmaking at this stage can be performed in the similar way as described above for the CA. With each of the filtered SPAs, the negotiation is performed using any of the multi-attribute negotiation approach. Various attributes forming the basis of negotiation can be response-time, quality, price etc. However, in this case, with some of the SPAs, the negotiation may not be successful. So, only the SPAs that have successful negotiation will generate the negotiation-agreements. After that, the service selection model providing selection based upon the negotiation-agreements is applied over these SPAs. One of such selection model based upon the QoS assessment of the parameters included in the negotiation-agreement has been presented in the next section. Selection Index (SI) is then calculated for each of such SPA based upon the values of various attributes in their negotiation agreements and the agent with maximum SI is selected as service provider. Figure 1(b) shows this process for $Task_1$ only. The same process is followed for each of the atomic task.

3 QoS Selection Model based upon Negotiation-Agreements

The presented selection model is based upon the assessment of parameters in negotiation-agreements generated from the multi-attribute negotiation with various candidate SPAs. Multi-attribute negotiation involves the use of multiple attributes of SWSs for negotiation. The proposal between SPA and SRA contains the values for multiple attributes and decision of agreement is taken based upon their combined values. The successful negotiation of SRA and SPA results into a negotiation agreement containing the values of various attributes such as price, response-time, reliability etc. on which both SRA and the SPA agrees. The assessment of these QoS parameters can be used to index of the various SPAs and the SPA with the highest index can be selected as the final SPA for a task. The successful negotiation of SRA with a SPA, the values for various attributes is resulted on which both SRA and SPA agrees. So, all these agreements and hence the corresponding SPAs are acceptable to the SRA. If the selection is performed from all these acceptable SPAs for the sake of best SPA, then more favorable and reliable selection should occur. The presented selection model is based upon the same understanding.

After the successful negotiation of the SRA with a SPA, a set of various quality attributes is resulted on which both SRA and SPA agrees. This set of attributes can be called as the agreement set of the SPA. Various attributes in the agreement-set can be price, response-time, execution-time, reliability etc. An index of selection (SI) is calculated based upon the assessment of these attributes. The SI of an agent can be defined as the weighted arithmetic mean of the quality ratings of different QoS parameters. This SI represents the relative indexing of the corresponding SPA. But, the complexity in the calculation of SI is that the different quality attributes have different value range, value types, and measurements. The user have different tendency towards different quality metric. For example, for the metrics like 'Price', 'Execution Time', the user has the tendency of 'lower the better', while for metrics like 'Reliability', the tendency is 'higher the better'. And also the metric even may have higher weight in calculation of SI, but its impact may be lowered by its smaller value than other metrics. The presented model presents a normalization method to solve this problem. The model normalizes the values of all the attributes such that the values of all attributes lies between 0 and 1 and they all of tendency 'higher the better'.

Let $(Al_1, Al_2 \ldots Al_k, Ah_{k+1} \ldots Ah_{n-1}, Ah_n)$ be the values of set of attributes in the agreement-set of reference SPA. Out of these n attributes, the first *k* attributes i.e. $(Al_1, Al_2 \ldots Al_k)$, have the user-tendency 'lower the better' and the rest of *(n-k)* attributes i.e. $(Ah_{k+1}, Ah_{k+2} \ldots Ah_n)$, have the user-tendency 'higher the better'.

Consider that $Al\max_r$ and $Al\min_r$ be the maximum and minimum numerical values for the attribute Al_r among all the agreement-sets of various SPAs. Further consider that Al'_r is the normalized value for the quality attribute Al_r (r = 1, 2, 3…k). In this case, the normalization needs to be applied for two conditions: firstly, normalization of value of Al_r to the range between 0 and 1 and secondly, the normalization of Al_r from user-tendency 'lower the better' to 'higher the better'. The value satisfying first condition can be obtained from the division by $Al\max_r$, but for changing the user-tendency the subtraction of this value from 1 is required. Hence, Al'_r can be represented by the equation-(1).

$$Al'_r = \left[1 - {(Al_r - Al\min_r)} \big/ {(Al\max_r + Al\min_r)}\right], \quad Where \quad 0 < Al'_r \leq 1 \qquad \ldots 1$$

Now, the value Al'_r obtained from the equation (1) has the user-tendency of 'higher the better' and the value range between 0 and 1. This equation can be used for normalization of first *k* attributes i.e. $(Al_1, Al_2 \ldots Al_k)$ in the required form.

Further consider that $Ah\max_r$ and $Ah\min_r$ be the maximum and minimum numerical values for the attribute Ah_r among all the agreement-sets of various SPAs. Further consider that Ah'_r is the normalized value for the quality attribute Ah_r (r = k+1, k+2, k+3…n). Now, for normalizing the rest of these *(n-k)* attributes i.e. $\left(Ah_{k+1}, Ah_{k+2} \dots Ah_n\right)$ to the required form, only the first normalization of changing the value-range between 0 and 1 is required, as these values already have user-tendency of 'higher the better'. The value satisfying this normalization can be obtained from the division of $Ah\max_r$. Hence, Ah'_r can be represented by the equation (2).

$$Ah'_r = {Ah_r}\Big/{Ah\max_r}, \quad Where \quad 0 < Ah'_r \le 1 \qquad \dots 2$$

Hence, after applying the equations (1) and (2) on various attributes of the agreement-set of a reference SPA, all the attributes with normalized values $(Al'_1, Al'_2 \dots Al'_k, Ah'_{k+1} \dots Ah'_{n-1}, Ah'_n)$ has the user-tendency of 'higher the better' and value range between 0 and 1. Now, all these attributes may not be having equal weight in the calculation of SI. The assessments of some of the attributes may be having more weight in the selection of corresponding SPA as compared to others. So, consider that $W_1, W_2 \dots W_n$ be the weights given to the various attributes $(Al'_1, Al'_2 \dots Al'_k, Ah'_{k+1} \dots Ah'_{n-1}, Ah'_n)$ respectively. So, the SI can be represented as the weighted mean of the assessments of the various parameters, as shown by the equation (3). From equations (1) and (2), it can be noted that the values has been normalized in such a way that the rating obtained for different attributes for different SPAs are relative to each other. Hence, the SI obtained from equation (3) for a SPA is relative to other competitive SPAs.

$$SI = \left[\left(\sum_{j=1}^{k} Al'_j * W_j + \sum_{j=(k+1)}^{n} Ah'_j * W_j \right) \Bigg/ \left(\sum_{j=1}^{n} W_j \right) \right], \quad Where \quad 0 < SI \le 1 \qquad \dots 3$$

4 Implementation

This section presents the implementation of a SWS composition system based upon the proposed composition and selection model. The comparative analysis of the presented work has also been done. A SWS composition system that uses the presented composition methodology has been implemented. In this system, firstly the selection of CA is performed using CPBSM [12] and after that the selection of SPAs for different tasks are performed using the presented negotiation agreement based QoS selection model. The presented system implements an education planner. Education planner is the system which can be used for planning the complete process of securing admission in some higher education program. It involves various activities such as counseling and preparation for entrance examination, choosing the appropriate institute, getting funds, completing admission formalities, and arranging transportation to join [13]. The profiles of both coordinator and other task specific agents are implemented in OWL [14] language using Jena [15], which are published on the Web and cab be accessed or manipulated by the SWS composition system.

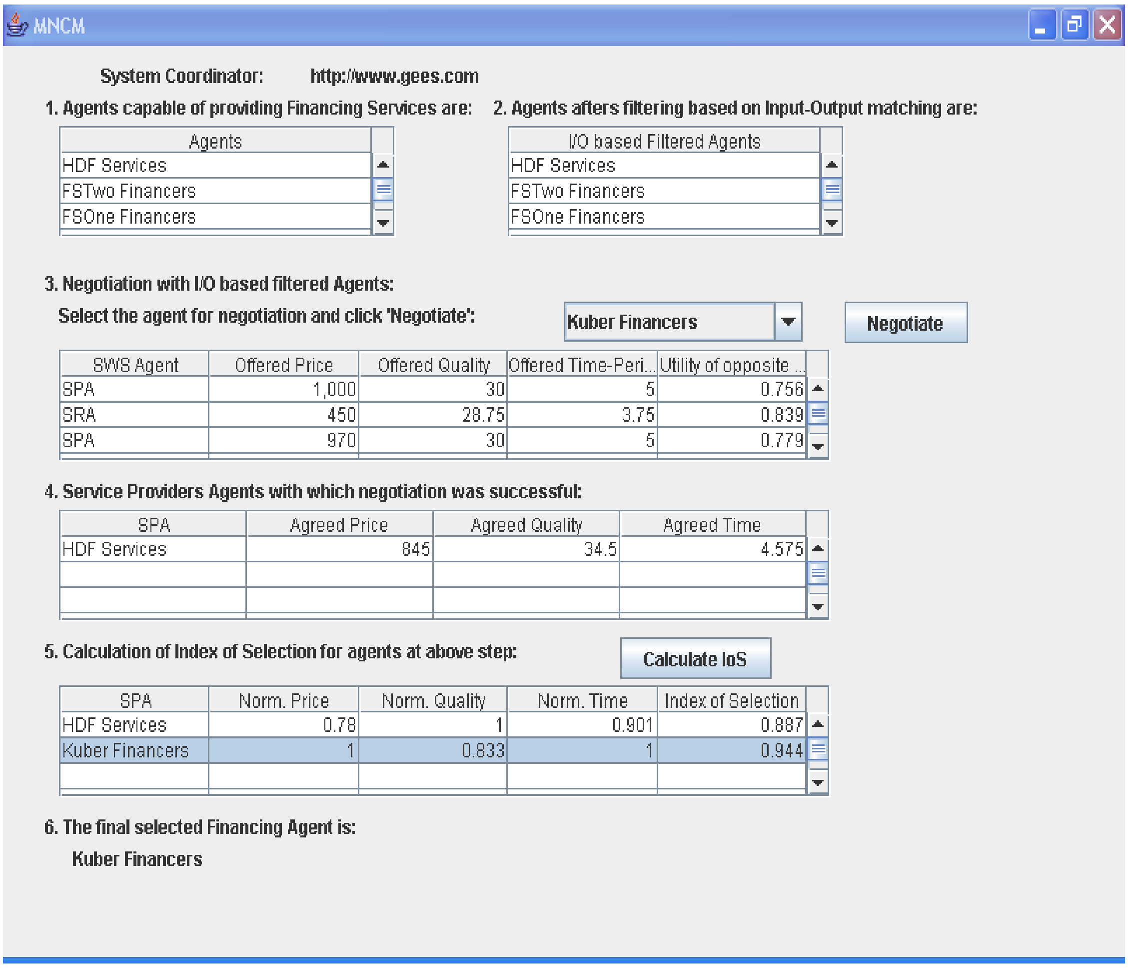

Figure 2: Selection of Financing Services Agent

The different steps of selecting a Financing Services agent 'Kuber Financers' are shown in Fig. 2. As shown in the figure, firstly the negotiation is performed with all the discovered SPAs. The QoS based selection model is then applied on the successful SPAs. The result of applying the selection model and corresponding selection index is shown in the last step in Figure 2. This step also shows the intermediate results of applying the various normalizations on the different attributes such as price, quality, and time. As the SPA 'Kuber Financers' is having the highest relative index, so it get selected.

5 Evaluation

Similar to the composition model presented here, the works by Preist et al. [16], Cao et al. [17], Kungas et al. [18], and Kungas and Matskin [19] have also presented the negotiation based SWS composition.

A web service composition approach for the composition of e-services has been presented by Preist et al. [16]. In their work, the negotiation has been performed in the multiple auctions simultaneously with the customer as well as with the service providers for generating the composite services dynamically. But, the main emphasis of their work is only on the negotiation aspects. A very limited discussion is only given on the selection and composition of SWSs.

Cao et al. [17] have presented as workflow based SWS composition model based upon the multi-agent negotiation approach. Their work mainly emphasizes the aspects of the multi-agent negotiation involved in the service composition system. In their work, the service composition process has been modeled as a constraint satisfaction problem and multi-agent negotiation algorithms are used for solving it. However, the use of multi-agent negotiation in the service selection process is not explored by them. They have provided a very limited discussion over the various processes such as selection, discovery etc.

Further, Kungas et al. [18] have presented the use of symbolic negotiation for the discovery process in service composition process. Their work has been further extended in Kungas and Matskin [19] that also presents the use of non-symbolic negotiation for negotiating over the cost or other such attributes of composite service. But, these works also presents very limited discussion over the selection process.

In addition, none of the above discussed works presents the mathematical formulation of the service selection process and the architectural details of the composition process. Further, these works have not explored the use of negotiation process in service selection process. Due to these factors, the presented composition model can be considered as the more efficient model for SWS composition.

6 Conclusions

This paper mainly presents a multi-attribute negotiation based semantic web service selection and composition model. A negotiation based composition approach has been presented in which the QoS based selection for a SPA for a task is performed from among the all successful SPAs from the negotiation between SRA and various discovered SPAs for that task. The paper presents a QoS based selection model that generates the rating of SPAs based upon the assessment of the various QoS parameters in the negotiation agreement of the SPA generated from the successful negotiation of the SPA with SRA. The model generates the relative rating of the SPAs independent of the expectations of the SRA. So, the rating of the SPAs for a task can be used for any of the SRA. A composition model has also been implemented based upon the presented selection and composition model. The work has also been evaluated by using a reported evaluation approach and by performing the comparative analysis.

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