Optimizing Service Selection in Combinatorial Auction by Resolving Non-Linear Programming Constraints

K. Uma Devi, B. Lalitha

Abstract: The selection of services with the aim to fulfill the quality constraints became critical and challenging research aspect in the field of service computing to promote automated service selection in service-based systems (SBSs), especially when the quality constraints are stringent. However, none of the existing approaches for quality-aware service composition has sufficiently considered QoS parameters to determine the best service. This paper proposes an optimization model for SBS to automate the process of quality aware service selection. Furthermore, this paper presents a compositional quality model to analyze and optimize the quality constraints that play a vital role in Winner Determination Problem (WDP).

Keywords: critical and challenging research aspect, computing to promote automated service selection, QoS parameters, optimization model for SBS, Winner Determination Problem (WDP).

I. INTRODUCTION

In recent years service oriented computing is emerging as a novel research area to design and model software systems in which automation of the services play a vital role. Service based systems are mainly composed of the services that could be accessed locally or remotely based on the service request. In order to offer inexpensive solutions while handling multiple tenants, there is a need of automating the service based systems. To model and construct a multitenant centric service based system, multiple levels of system development including application level, infrastructure level and data centric level are considered. This paper mainly focuses on designing and modeling a service based system based on combinatorial auction. In the previous auction formats items are auctioned separately either sequentially or in parallel. The bidders are forced to bid on each item separately and speculate on the value of each item individually. But the actual value of the item depends on what other items the bidder receives in the auction. The bidders associate a price with a specific collection of goods; associating a value with the individual items can be problematic. This requires the bidder to look ahead and base the price decisions of its bids on its expectations to win other items in future auctions. Even after forecasting and predicting the expected course of the auctions, there remains an uncertainty factor due to the absence of complete information about the other bidders participating in the auction.

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This leads to inefficient allocations of items where the bidders do not win their required combination of products and as a result the bidders may value it at a price less than what they had paid for it. The inefficiencies in the allocations resulting from the sequential and parallel auction mechanisms can be overcome by various techniques. The bidders can be allowed to retract their bids when they do not get the combinations they needed. These items can then be auctioned again or the item can be allocated to the bidder who ended up second. But if the winning price of the second auction was less than the price of the first then the difference in the amount has to be paid by the retractor as a penalty. Another approach that has been practiced is to sell the option for retracting upfront. Also an aftermarket can be setup where the bidders exchange items among them after the auction has ended. This approach can undo some of the inefficiencies in the allocation. But to reach an optimal allocation among the bidders there might have to be impossibly large number of exchanges between the bidders [2]. Combinatorial auctions can be used to overcome deficiencies of the single item sequential or parallel auctions. In combinatorial auctions, instead of selling items individually, the seller allows bidders to bid on collections or bundles of items. The bidder is allowed to express complements and substitutes between items being auctioned. This allows the bidders to express their requirements completely without room for speculation and avoid the risk of obtaining incomplete bundles. The bidders do not have to interpolate the outcome of other auctions with complementary and substitutable items when valuing prices of items or bundles of items. The efficiency and the benefits resulting from combinatorial auctions attracted Federal Communications Commission to switch its auction mechanism to combinatorial auctions in June 2002 [3]. Other proposals to use combinatorial auctions for resource allocation of airport takeoff and landing time slots [4] and for the telecommunications industry [5] have been suggested. The combinatorial auction mechanism works based on the assumption that the participating bidders are able to express their requirement exactly without any compromise and can submit any number of bids as required. In case of auctions with small number of items, bids containing complementary and supplementary items can be expressed with the bidders submitting bids with the list of items they require and an attached value. The auctioneer has to allocate items to bidders so that the items in the allocated bids do not conflict. But as the number of items being auctioned increases and the requirements of the bidders become more complex, the number of bids that the bidder has to submit in order to completely and exactly express his requirements becomes larger in size. Allowing the bidders to

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submit their requirements in the form of a computer algorithm or program that completely express the requirement can solve this problem of exponential number of bids.

II. RELATED WORK

Two critical limitations are observed in existing quality aware service selection approaches for multiple tenant SBSs. Initially, the existing service selection techniques analyze the essential functionalities of all the tenants from an SBS are exactly the same. This assumption is not realistic. A real world multi-tenant SBS should be able to provide different tenants with similar yet customized functionalities realized by enacting differentiated execution plans within the SBS [5]. Let us assume that if one needs to design a Travel Booking SBS for two tenants. One tenant wants to use this SBS to book railway tickets, accommodation and purchase insurance while the other tenant only wants to book railway tickets and purchase insurance. This SBS needs an railway ticket search service and an insurance quote service shared by both tenants, plus an accommodation booking service specifically for the first tenant. The approach developed in [6] customizes the functionality of an SBS for different tenants. On the other hand, to our best knowledge, existing quality-aware multiple occupant service selection techniques do not consider functionality customization, and thus are not suitable for composing such an SBS. A possible solution is to adopt the existing single-tenant approaches to compose multiple instances of the SBS, one for each tenant. However, it is very difficult for such an approach to achieve the SBS provider's optimization goal. While the quality delivered to tenants is individually optimized, the overall quality of the SBS is usually not optimal. The work presented in [7] uses genetic algorithms to address the issue of quality-aware web service composition. Their work focuses on domain-specific QoS attributes and customized QoS aggregation formulas. WS-Binder Tool is implemented to support both cross domain and domain-specific QoS attributes and to determine suboptimal solutions for web service compositions according to given fitness functions and QoS constraint sets. However, the approach aims at providing service consumers with tools for domain-specific QoS definition and (re)binding, and no experimental results are provided for the evaluation of the approach. The analysis in [8] use a different philosophy from works described above to address the quality-aware service selection problem. They use service composition graph to represent the composite service. Then, they employ Dijkstra's shortest-path algorithm to find the optimal solution to the service composition problem. The above mentioned research does not fully consider the fact that complementary services can be provided at better QoS levels by a single provider than multiple providers. SBS designers can improve the system optimality of their SBSs by exploring the complementarily between the services. Exploring the complementarily between the services also enables attempts to increase the possibility of finding a solution for SBS optimization problem, especially in scenarios where the quality constraints for SBSs are severe.

III. PROBLEM ANALYSIS AND MOTIVATING EXAMPLE

Initially, let us consider three different bidders are participating in an open auction for designing an automated service based system for a travel agency. The SBS for travel agency should be designed in such a way that it should serve the request of multiple customers with different needs such that if a customer enters their travel requirements, e.g., city of departure, destination, departure date, return date, preferred type of rental car, etc. In response to the request, the SBS returns a list of candidate travel plans for the customer to book. Key functionality of the proposed SBS is represented as a business process that includes five specific tasks such that (S_1…, All customers from different travel agents share not all but only some of the tasks. In this SBS, the *Hotel search* task is performed for customers from ***Airjet, Railenq*** as well as ***Busenq*** while the *car rental* task is performed for customers of ***Airjet***.

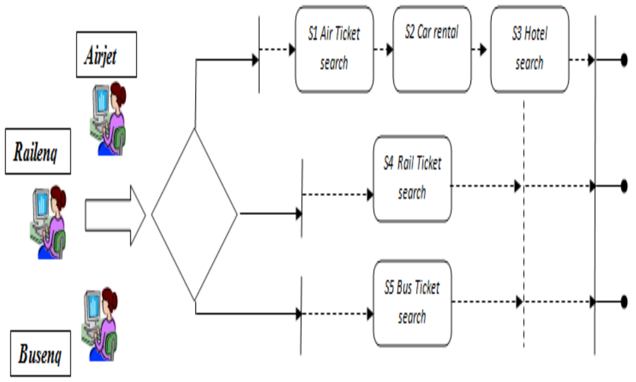

Figure 1. Multiple tenant SBS

S_5). The SBS should be designed in such a way that it generates travel plans for customers of different tenants for their respective tasks. In order to design a service based system for a travel agency multiple tenets place their unique services. Let us assume that the first tenant as ***Airjet*** that provides the candidate services as air ticket search, car rental and hotel searching options, Secondly the next tenant is assumed as ***Railenq*** such that it provides candidate services as Train ticket search and hotel search for its customers and finally ***Busenq*** is considered as one more tenant that provides its candidate services as Bus Ticket search and Hotel search. All customers from different travel agents share not all but only some of the tasks as shown in Figure 1. On one hand; these travel agents usually have diverse requirements for the quality of the SBS. For example, ***Airjet*** requires a very fast response time despite a high price, while ***Railenq*** is more concerned about minimizing the cost of using the SBS. The SBS provider, on the other hand, also has its own optimization goal for the SBS, e.g., to minimize the system cost of the SBS, i.e., the total cost of the services selected to compose the SBS. A set of services must be selected from the candidate services to perform the tasks of the SBS that serves the travel agents with satisfactory quality and achieves the SBS provider's optimization goal. In the process of designing the proposed multiple tenant service based systems the services can be composed in such a way that three independent systems are composed, each in specific is customized for every travel agent. The travel agents do not share an execution engine or any component services.

IV. PROPOSED OPTIMIZATION SCHEME

This section initially presents compositional quality model and the optimization model that is adopted in this research and on the other hand we present an optimized and automated service selection approach for composing the candidate services in designing SBS.

4.1 SBS Compositional Quality Model

During the process of service composition we espouse the same compositional structures for representing the business processes of SBSs. The compositional structures include sequence, branch, loop and parallel [9], that are included in BPMN [10] and addressed by BPEL [11] the de facto standards for specifying service-oriented business processes. A multi-tenant SBS be obliged to fulfill multiple tenants' multidimensional quality constraints. Thus, we need to evaluate the quality of the SBS delivered to individual tenants, considering all the execution plans customized for the tenants. Let us consider the SBS presented in Figure 1 as an exemplar, suppose there are three execution plans, *explAi* for ***Airjet***, *explRL* for ***Railenq*** and *explBS for* ***Busenq***. The system quality delivered to a tenant can be calculated by aggregating the quality of the services selected for the corresponding execution plans based on the compositional quality model presented in [12]. In this paper, the instances are based on cost and response time, which also have been the basis for quality evaluation in other approach. Other QoS parameters can be generalized as additional dimensions in the evaluation. More details about the compositional structures and the quality evaluation methods can be found in [13, 12].

4.2 Optimizing model for Service Selection

Let us assume that SBS consists of *x* (*x*≥1) components. Consequently, there are *x* service classes *Sc*, *c*=1, …, *n*, each containing *y* (*y*≥1) available candidate services *Sc,i*, *i*=1, …, *y*, that provide the same functionality but potentially differ in *q* quality dimensions *op*, *p*=1, …, *q*. The service selection problem for SBS that serves *e* (*e*≥1) tenants is a constraint optimization problem (COP) that intends to find a set of services that could be executed according to tenants' customized execution plans, can fulfill corresponding tenants' *q*-dimensional quality constraints *ck,p*, *k*=1, …, *m*, *p*=1, …, *q*, while achieving the SBS provider's optimization goal *objective*(SBS). Initially the problem is modeled in the context of *constraint* satisfaction problem (CSP), which consists of a finite set of variables *X*={*x*1, …, *xn*}, with respective domains *D*={*D*1, …, *Dn*} listing the possible values for each variable, and a set of constraints *C*={*c*1, …, *ct*} over *X*. A solution to a CSP is an assignment of a value to each variable from its domain such that every constraint is satisfied. Solving the above CSP could generate several solutions that fulfill all tenants' quality constraints for the SBS. These solutions typically yield completely different overall system quality at different system prices. Currently, we have a tendency to obtain to realize the SBS provider's improvement goal for the SBS, that within the model is depicted by associate degree objective operate objective (SBS). The CSP currently turns into a COP. In a COP, every resolution generated by the CSP is related to a ranking worth for the target operate the answer with the optimum ranking worth is that the solution to the COP, i.e., the optimum resolution to the service choice drawback for the SBS. In general, system providers' Optimization goals is varied, which may be depicted discrimination is completely different objective functions. This paper, has a tendency to use a typical improvement objective as an example to reduce the system price of the SBS, i.e., the full value of all the chosen services are reduced.

4.3 Service selection in Composite services

During the process of service composition, the execution engine of the SBS enacts a separate customized execution plan for each tenant. Figure 2 presents the travel agency SBS that achieves the multi-tenancy based on the business process presented in Figure 2. In this system, S_3 is shared by ***Airjet***, ***Railenq*** and ***Busenq***, as presented in Figure 1. Thus, three services are selected for S_3, one for execution plan #1 to serve ***Airjet*** , the other for execution plan #2 to serve ***Railenq*** and finally for execution plan #3 to serve ***Busenq***. It is the same for S_3, which is shared by ***Airjet***, ***Railenq*** and ***Busenq***. Assume that $S_{3,3}$ is selected for ***Airjet*** and $S_{3,6}$ is selected for ***Railenq*** to execute S_3, The execution plans for the three tenants will be *explAi*($S_{1,3}$, $S_{2,5}$, $S_{3,3}$, $S_{6,2}$), *explRL*($S_{5,1}$, $S_{6,5}$) and *explBS*($S_{4,2}$,$S_{3,6}$), as presented in Figure 2. Upon the receipt of a request, the execution engine of the SBS enacts the corresponding execution plan based on the sender of the request. Each execution plan is specifically customised for a tenant based on its quality requirement. For *m* tenants, there are *m* × *n* × *r* 0-1 variables *Xk,i,j* (*k*=1, …, *m*, *i*=1, …, *n*, *j*=1, …, *r* and *Dk,i,j*={0, 1}), *Xk,i,j* being 1 if the *i*th candidate service in the *j*th service class is selected to create the execution plan for the *k*th tenant, and 0 otherwise. To compose a multi-tenant SBS at the second multi-tenancy level, the CSP model for service selection is formally expressed such that the optimization objective is to minimize the system cost. The corresponding objective function is as follows:

$$Minimize \sum_{k=1}^{m} \sum_{i=1}^{n} \sum_{j=1}^{r} q\ price(Sij) * Xk,i,j$$

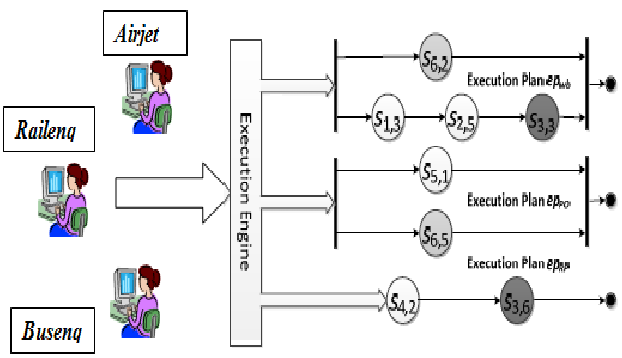

Figure 2. Optimized service selection in multiple tenant SBS.

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V. EXPERIMENTAL ANALYSIS

This paper proposed a combinatorial auction mechanism which is capable of handling non-linear services efficiently compared to the Combinatorial Auction for Service Selection (CASS) proposed in [1]. The analysis defines the performance of both the CASS and the Modified CASS. The metrics used are:

- Success Full Winner Selection
- Time taken to select the winner

The first metric is used to measure the correctness of the WDP in NP-hard cases and the results are promising compared to the existing CASS and they are depicted in figure 3.

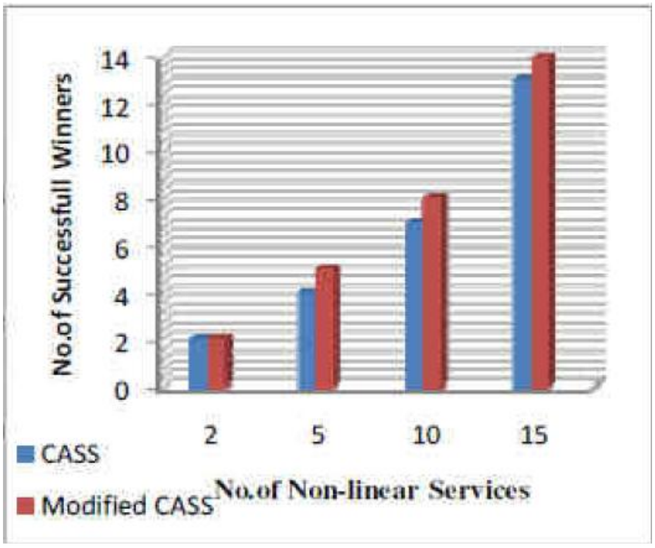

Figure 3: No. of Success Full Winner selections

As the figure clearly depicts that the traditional CASS has less number of successful winner determinations compared to the Proposed CASS. The next metric is the time taken to calculate the winner from number of possible bids. The results are depicted in figure 4.

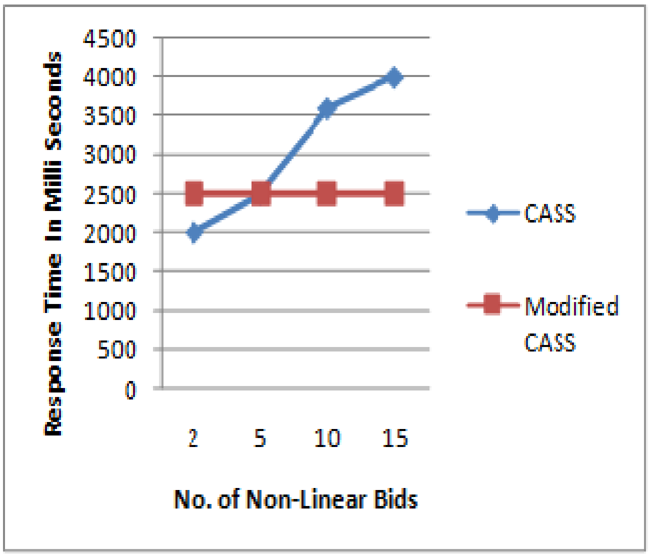

Figure 4: Time taken to select the Winner

As the graph clearly shows that the CASS takes more time as the number of bids goes on increasing. But the modified CASS takes the same amount of time irrespective of the size of the bids.

VI. CONCLUSION

This paper introduced a QoS selection procedure based on the combinatorial auctions, where auctioneer has several items that he wants to put to auction simultaneously. It may be that bidders have synergies on combinations of items, that is, they value specific combinations of items higher than the items separately. The process of providing discounts or offers on multiple auctions are considered as non-linear services the CASS proposed in [1] fails to handle these non-linear services. In order to handle these services this paper uses optimization model for SBS to automate the process of quality aware service selection to solve the WDP. The experimental results shows the performance improvement compared to the existing CASS mechanism.

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