A Review of QoS Driven Optimal Selection of Web Services for Compositions

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Abstract. Web services technology promises to enable rich, flexible and dynamic interoperation of highly distributed and heterogeneous applications using Web standards. The providers of composite Web services involving composition plan with different flow patterns need to discover and select suitable candidate Web services for each task of the composition plan at runtime. The dynamic nature of Web services prompts a need for the mechanism to enable the frequent editing of QoS offers of composite Web services by the Composite Service Providers (CSP). In this paper, the authors present a detailed survey of literature in QoS based selection for Web service compositions. The paper also presents different architectures for QoS aware Web service compositions and evaluates various QoS aware selection techniques. The authors classify QoS aware selection techniques for composition based on the nature of composition plan, complexity of QoS requirements and nature of techniques/methodology used in the selection and QoS aggregation.

Keywords: Web Services, Compositions, Aggregation, Quality of Service, Service Selection, Broker Architecture.

1 Introduction

A Web service is defined as an interface which implements the business logic through a set of operations that are accessible through standard Internet protocols. The eXtensible Markup Language (XML) based protocols namely Universal Description, Discovery and Integration (UDDI), Web Service Description Language (WSDL) and Simple Object Access Protocol (SOAP) are the *three* major building blocks of Web services. The conceptual Web services architecture facilitates both atomic (elementary) and composite Web services to be published into the service registry for discovery without any implementation distinctions. The composite Web services involving composition plan normally select Web services for the individual tasks at runtime which satisfy local (task level) or global (end-to-end) QoS constraints. The QoS offers of such composite Web services are dependent on individual Web services selected for each task of the

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composition plan. The dynamic nature of Web services enforces the providers of composite Web services to estimate and update (publish) the QoS offers regularly. The frequent editing of QoS offers of composite Web services is necessary since the provider of composite Web service has to compete with other Web services offering same set of functions/operations.

In order to update the QoS and service offers of composite Web services regularly, the provider requires a tool to estimate QoS of composite Web service and to advertise a competitive service offer based on his requirements. In literature, the QoS of composition is evaluated based on the requirements involving single QoS property [2] or combinations of multiple QoS properties [3]. While evaluating QoS of composition, the Web services are selected for the tasks based on either local [2] or global [3] QoS constraints. As the service offers play a role in selection of business Web services, the composite business Web service has to be created by selecting good quality and profitable services for all the tasks which satisfy both QoS and service offer requirements of the composite service provider. Publishing of composite Web services involve publishing of its functional, QoS and service offer specific information into the repository (registry) [4]. Therefore, QoS and service offer for the composite Web service need to be estimated prior to the publishing activity. To obtain estimation on QoS and service offers, QoS and service offer aggregation schemes are required for the composite Web services involving different composition patterns. A selection mechanism has to be defined to select the most suitable Web service for the tasks of composition plan based on the provider's requirements and preferences.

2 QoS Driven Selection for Compositions

The selection of most suitable (best in terms of quality, compatibility and service offers) Web service for the various tasks is a crucial issue in Web service composition. In order to update the QoS and service offers of composite Web services regularly, the provider requires a mechanism to estimate the QoS of composite Web service and to advertise a competitive service offer based on his requirements and preferences. As a motivating example, consider the conference (or symposium) arrangement scenario. Assume that, there exists a single service, which caters to the requirements of conference arrangement involving various tasks. The different tasks are: booking of hall or hotel for presentations (or discussions), catering service for food on conference days, vehicle for local travel, a service provider to decorate the venue, city tour (night or day) arrangement service, conference bag and conference kit providers. Fig.1 represents the composition plan involving composition patterns of the conference arrangement service. The rectangles represent individual task nodes and ovals represent composition pattern nodes.

Over the Internet, many service providers are available for the atomic activities like hotel booking, vehicle hiring etc. The provider of the conference arrangement service tries to arrange the conference with low costs, expects good response from the reputed service providers for atomic activities and would like

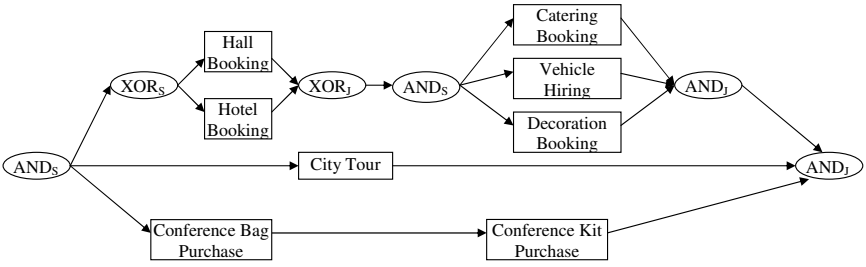

Fig. 1. Motivating Example: A Conference Arrangement Service

to offer discounts on the service charge. As an example, consider the composite service provider's requirements as follows. "The service should be delivered at a faster rate with the lowest cost or popular (reputed) service provider who offers service discounts". The conference arrangement service should satisfy the provider's requirements defined on the multiple QoS properties and service offers by assigning suitable (or best) Web services to the tasks of the composition plan. Thus, a need arises to estimate QoS and net profit from service offers, to update (frequently) QoS and service offers of the composite Web services based on the provider's requirements and preferences.

A QoS driven selection problem for compositions can be defined as follows. "Given a flow pattern (composition pattern) based composition plan of composite Web service involving activities (tasks) and candidate Web services (their QoS and service offers) for each task of the composition plan, estimate the QoS and competitive service offers for the composite Web service, by selecting suitable Web services to each task based on the provider's QoS properties and service offers with varied preferences". The QoS and competitive service offers for the composite Web service can be estimated by selecting suitable Web services for each task of the composition. The Web services need to be selected based on the provider's QoS and service offer requirements and preferences. The estimated QoS and profit from various service offers help the provider to frequently update or publish the QoS and competitive service offers for a composite Web service.

3 Architectures for QoS Driven Compositions

Dynamic composition of Web services requires the discovery of different service providers that satisfy given functional and nonfunctional requirements of consumers [5]. The QoS optimal composite Web service is today's need as the requesters are keen on the delivery of QoS by service providers. In literature, a model driven methodology has been proposed for building new Web service compositions that are QoS optimized [6]. Various architectures have been proposed towards the management and monitoring of QoS aware dynamic composition [7] and composite Web services involving composition patterns [8]. Different composition patterns have been defined to represent composite Web services involving multiple execution paths [9]. In literature, different QoS models have been

defined to describe QoS of compositions at the level of part names i.e. operations [10] and compositions involving transactions [11]. In order to estimate QoS properties of composition at runtime, researchers have defined QoS aggregation schemes for different composition patterns [9].

The QoS based composition of Web services is facilitated by defining either *Broker based* or *Agent based* architectures. In broker based architecture, the broker plays a major role in managing and building Web service composition rather than execution of composition [4]. The other functionalities of the broker include composition schema search, composition plan optimization and QoS optimal selection of Web services to the tasks of composition plan [12]. In literature, agent technology is used to compose Web services based on QoS constraints, where the agents are responsible for the discovery, selection and execution of composite process [13]. The authors of [4] propose broker based architecture for the selection of QoS optimal and profitable Web services for compositions. Fig.2 presents the broker based architecture which facilitates the composite Web service provider to select an optimal Web service for each task in order to publish QoS and attractive service offers into QoS registry and Service Offer (SO) registry respectively. The broker architecture consists of *three* registries which include *service registry*, *QoS registry* and *SO registry*. The *register* operation is defined between the Web service providers and broker which facilitates QoS and service offer aware Web service publishing.

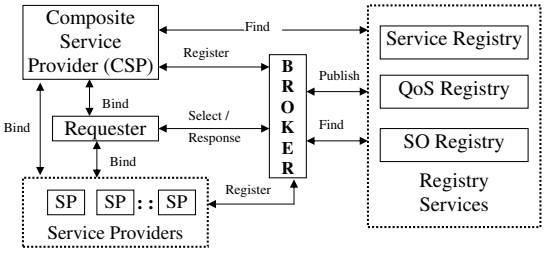

Fig. 2. The Broker Based Architecture for Compositions

4 Review of QoS Based Web Service Compositions

The QoS based Web service composition involves discovery and optimal selection of candidate Web services for each task of the composition plan which is either sequential or parallel (composition pattern based) in nature. In literature, various techniques have been defined towards optimal (local or global) selection and assignment of Web services to the tasks of composition plan. Fig.3 depicts the classification of selection techniques for QoS based Web service composition. The selection techniques for compositions can be broadly classified based on the nature of composition plan as *selection for sequential plan* and *selection for parallel plan*.

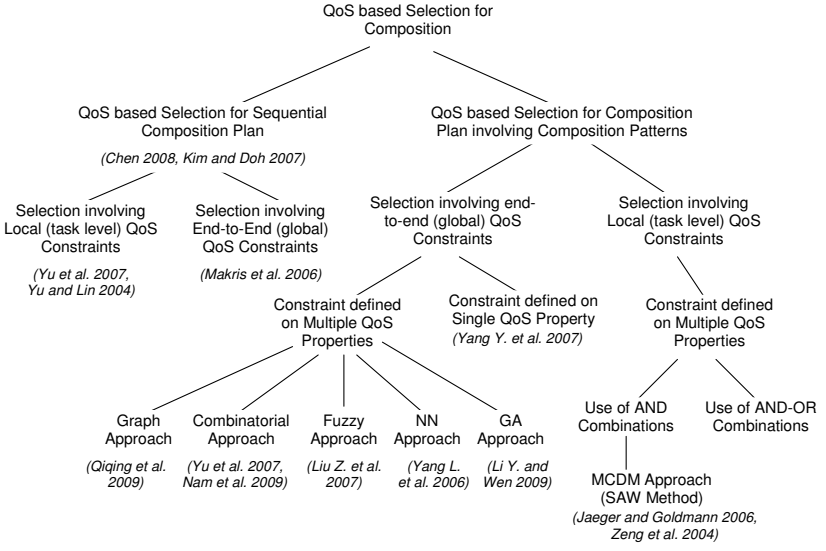

Fig. 3. Taxonomy of Web Service Selection Techniques for QoS Composition

4.1 Selection Techniques for Sequential Plan

The selection mechanisms for the sequential composition plan assign QoS optimal Web services to the tasks which satisfy the requirements defined on the multiple QoS properties [14]. In literature, a number of mechanisms have been proposed towards the selection of QoS optimal Web services for sequential composition plan based on either local (task level) or global QoS requirements. The authors [3][15] map the service selection problem for sequential composition to 0-1 Multi-dimension Multi-choice Knapsack Problem (MMKP or MCKP) which is NP complete. In literature, an exhaustive search [3], heuristic approach [17] and dynamic programming algorithms [15] are proposed to solve MMKP problem. The authors of [3] propose Multi Constraint Shortest Path (MCSP) problem for the graph model (service candidate graph) of a composition plan. A single QoS property is also used to find the global (end-to-end) optimal solution for the sequence of tasks [3]. The authors of [2] perform the selection based on single QoS property for the graph model with a solution to Single Source Shortest Path Problem (SSSP). The main problem associated with QoS based sequential composition is that, all discovered services for the tasks need to be executed sequentially. This kind of execution increases the cost of composition in terms of QoS, especially execution duration of composite service.

4.2 Selection Techniques for Parallel Plan

Suitable candidate Web services for each task of the parallel (workflow pattern) composition plan are assigned based on the task level QoS requirements

defined on the multiple QoS properties with varied preferences. In literature, the suboptimal solution to the QoS based composition is obtained through Simple Additive Weighting (SAW) method of Multiple Criteria Decision Making (MCDM or MADM) technique [9][16] and k-armed bandit theory [14]. The selection techniques for QoS based composition involving end-to-end requirements are defined on the multiple QoS properties with varied preferences. A number of mechanisms (approaches) have been proposed by researchers to find an optimal or suboptimal Web service assignment for the composition plan involving composition patterns.

A. Selection Based on Global QoS Requirements

In literature, an optimal Web service assignment is performed through optimization of an objective function using global planning. Some of the solutions for global planning problem are: *Graph approach*, *Combinatorial approach*, *Genetic algorithm approach*, *Neural network approach* and *Fuzzy logic approach*. In literature, various solutions have been proposed towards the Directed Acyclic Graph (DAG) modeling of the the multi-objective optimization problem [18]. A *Service Candidate Graph* to model the general flow structure of composition plan is proposed in [3], which explains the use of MCSP algorithm (e.g. Bellman-Ford) to solve the problem. The main idea of service selection is to maximize an application specific utility function under the end-to-end QoS constraints. A dynamic programming based solution is proposed [19] to solve multi-stage decision making problem which is modeled as a *service graph*. The service graph contains various candidate Web services with calculated QoS as a weight on the edges. The major problem of graph approach is that, the high computational complexity for the composition plans involving large number of patterns. The inclusion of separate nodes and edges for each discovered Web service increases the computational efficiency of the approach as the efficiency is dependent on the size of the graph model.

The combinatorial approach for the optimal assignment of Web services to the tasks of composition involves optimization of objective function subjected to a set of QoS requirements. The popular approaches are: *Linear programming Approach*, *Greedy (Heuristic) Approach* and *Bottom-up Approach*. In linear programming approach, the QoS aware composition problem is modeled as *Integer Programming problem (0-1 IP problem)* [3] [16] or *Mixed Integer Linear Programming (MILP) problem* [20]. The paper [16] proposes a middleware platform for QoS composition which maximizes the user satisfaction expressed as utility functions over QoS attributes, while satisfying the constraint set by the user and the structure of the composite service. The selection of an execution plan relies on the application of a Multiple Criteria Decision Making (MCDM) technique on the quality matrix of the execution path. The Integer Programming method selects an optimal execution plan without generating all possible execution paths. The computation cost of global planning by exhaustive searching is very high even in very small scale in aspect of the number of the tasks with few candidate Web services.

Greedy approach represents the simple heuristic rules which are applied to find locally optimal solutions and later used to obtain globally optimal solution to the

composition plan [9]. The backtracking based discarding subsets algorithm [9] uses a search tree which consists of nodes, each representing a possible pair of a candidate Web service and the task. The algorithm establishes a sub-tree cutting rule based on the QoS threshold estimation. The advantage of this algorithm compared to a straight global selection lies in the idea to cut sub-trees representing unfavorable combinations to save computational efforts. This approach normally identifies an optimal solution still meeting the QoS constraints, but the authors establish a cutting rule based on threshold estimation efficient execution.

In literature, heuristic approach has been proposed [21] for composition based on either single or multiple global QoS requirements. The heuristic algorithm finds an optimal solution to problems of moderate size without exploring the entire solution space [5]. The bottom-up approach has been used towards an optimal assignment of services for the tasks of composition plan. The bottom-up approximation mechanism which has been proposed [9] works on heuristic rules to obtain an optimal or suboptimal solution. The proposed combinatorial approaches are computation intensive in nature as the finding of an optimal solution for global QoS requirements is NP hard.

Genetic Algorithms (GA) are designed with the idea of applying the biological principle of evolution to artificial systems. GA iterates the search for the best solution and a finite string of symbols named genome is created to present the solution [22]. The evolution is made by means of *two* operators: the crossover operator and the mutation operator [23]. In literature, genetic algorithms have been proposed for an optimal selection based on global QoS requirements [23][24]. The structure of genetic algorithm is characterized by the special relation matrix coding scheme of chromosomes and the population diversity is handled with simulated annealing. The concept of fuzzy logic and matching defined on fuzzy rules is adopted to find an optimal assignment for QoS aware composition based on global QoS requirements [25]. The preferences of Web service requesters are modeled as fuzzy rules [26] which are used for comparison and ranking of Web service combinations. Neural Network (NN) is another powerful tool used for describing and deposing nonlinear relations [19]. The NN and its variant structures are proposed in literature to model and solve QoS aware composition: a multistage decision making problem. The major problem associated with GA, fuzzy logic and NN based techniques is the nature of iterative processing and redundant operations which increases the time complexity of optimal Web service selection and assignment mechanism.

B. Selection Based on Local (Task level) QoS Requirements

The mechanisms proposed in literature towards Web service composition for end-to-end QoS constraints provide an optimal solution. Such mechanisms require more computational time to find an optimal service assignment due to the complex nature of the problem involving global QoS requirements with multiple QoS properties and preferences. In order to obtain suboptimal (sometimes optimal) solution towards the assignment of Web services to tasks, the service selection should be defined based on the task level QoS requirements.

The authors of [9] proposes a pattern based selection algorithm which explores a combinatorial problem of selection of candidates for Web service compositions. The algorithm determines the best assignment, considering each composition in isolation and takes advantage of an existing representation of the composition by using the composition pattern. The algorithm performs *four* steps: (a) The algorithm walks recursively into the structure and identifies pattern elements that do not contain any sub-patterns (b) For all tasks within such an element, all sets of candidate assignments are evaluated. The combination that delivers the best score is chosen (c) An optimal solution for a particular pattern is determined, by moving one level upwards to evaluate assignment within the new pattern (d) The above steps are repeated until the whole composition is covered and one aggregated QoS is returned. The algorithm shows the best resulting QoS as compared to other heuristic approaches. The problems with this algorithm are: (i) The algorithm seems to depend strongly on composition structure, because it shows the largest deviation of execution time (ii) The algorithm cannot meet global QoS constraints.

In order to advertise the QoS of composite Web service, QoS of composition plan need to be estimated at runtime. Towards this need, SAW method may be applied to find locally optimal and globally suboptimal solution to QoS aware composition. In literature, the authors of [16] have used SAW method towards an optimal assignment of Web services to the tasks of composition plan involving different composition patterns. The advantage of such a mechanism, is that the assignment of Web services to tasks is always suboptimal solution and sometimes they may yield optimal solution. The suboptimal solution for QoS of composition is suitable for advertisement of QoS as, the QoS properties represent maximum tolerable value.

5 Conclusion

The QoS based optimal selection of Web services for composition is an important research issue in the field of Web services. This paper makes a complete survey of the literature and evaluates QoS based Web service composition architectures and selection mechanisms. In literature, the Web services are composed based on multiple QoS properties involving only AND combinations. From the selection for QoS composition review tree (Figure 3), it is observed that, the Web services are not composed based on the QoS requirements (local or global) involving both AND and OR combinations of multiple QoS properties and their preferences (weights).

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