A Review of Quality of Service (QoS) Driven Dynamic Web Service Selection Techniques

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***Abstract*—The increasing number of Web service providers throughout the globe, have produced numerous Web services providing the same or similar functionality. This necessitates the use of tools and techniques to search the suitable services available over the Web. The effective dynamic Web service selection mechanism is a challenging problem as the requester is involved in the selection having wide variety of requirements. Quality of Service (QoS) is one of the decisive factor in selecting the desired Web service for the requester. This paper reviews various QoS based Web service selection mechanisms and architectures which facilitate qualitatively optimal selection. The authors classify various selection mechanisms based on the nature of QoS requirements used for the selection. The paper also compares the performance of QoS based selection mechanisms with respect to a set of evaluation criterion.**

I. Introduction

Service Oriented Computing (SOC) has emerged as a powerful paradigm for building complex distributed Web applications from simpler application components known as services. The SOC can be realized through the Web services which facilitate independently developed services to interact with each other through well-defined interfaces. The primary intension behind the Web services is to enable the inter operation of heterogeneous software systems and the reuse of system functions in an application development. Web services also facilitate an efficient execution of business to business (B2B) and business to customer (B2C) e-commerce by integrating business applications over Internet.

Web service [1] is defined as an interface which implements the business logic through a set of operations that are accessible through standard Internet protocols. The Web service can be used alone in an application or with other Web services to carry out a complex aggregation or a business transaction. A Web service is described using a standard, formal XML notion, called its service description using WSDL. The service description covers all the information necessary to interact with the service including operation descriptions, access mechanisms, message formats, transport protocols and location. The WSDL has a role and purpose similar to that of IDLs (Interface Definition Language) in conventional middleware platforms. The WSDL specifications are XML documents that describe Web services and in particular describe service interfaces. The SOAP defines how to organize and communicate information using XML in a structured and typed manner so that it can be exchanged between peers. In particular, SOAP specifies a message format, a set of conventions for using SOAP messages and a description of how a SOAP message should be transported on top of HTTP and SMTP.

The conceptual Web services architecture [2] is defined based upon the interactions between *three* roles: *service provider*, *service registry* and *service requester*. The interactions among them involve the *publish*, *find* and *bind* operations. The increasing number of Web service providers over the Web has prompted the need for research in service description, discovery and selection. Web Services provide service specifications (descriptions) for the static or dynamic matchmaking of service advertisements and service requests over the Web. Web service discovery is crucial for the requesters; especially for modern software developers and business organizations in B2B scenario. The discovery allows requesters gain access to descriptions of advertised Web services through suitable static operations defined in the Web service architecture. The Web service requesters need more sophisticated tools in order to search suitable services that satisfy the requester's functional needs. UDDI (Universal Description, Discovery and Integration) is the first initiative to find suitable Web services based on the requester's functional demands. However, the requester's requirements may also include nonfunctional aspects like Quality of Service (QoS) and service offers. The Web service selection is the process of choosing one Web service from functionally similar Web services for the binding (execution). The Web service selection ranks the functionally similar Web services based on the nonfunctional requirements of the requester and the Web service with the highest rank is selected for the requester.

Many a times the Web service discovery mechanism explores multiple Web services for the requester having same or similar functionality with no distinction. The requester selects suitable Web service from functionally similar services based on his nonfunctional demands defined on either quality (QoS) or service offer. In B2B or B2C e-commerce scenario, the questions on QoS level of a Web service such as "can I get the result in 25 seconds?" or "Is the service popular?" usually are critical to the requester before a service is invoked. Similarly, question on service offers like "can I get best discount on service" is quite practical in B2C e-commerce scenarios.

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UDDI based Web service architecture does not provide support for QoS or service offer based Web service discovery and selection. This makes the requester to select the desired Web service for binding by analyzing nonfunctional descriptions of the discovered Web services.

Quality of Service (QoS) is a decisive factor in distinguishing functionally similar Web services. Recently many researchers have proposed QoS models to define various QoS properties, measurement metrics and verification mechanisms [3]. In literature, there have been investigations to define QoS aware selection models (mechanisms) to rank the Web services as per the requester's needs [4]. The QoS models and QoS aware selection mechanisms have been defined for semantic Web services by few researchers [5]. The proposed QoS aware selection mechanisms distinguish and rank the functionally similar Web services based on the requester's QoS requirements involving QoS properties [6].

Consider an example of on-line buying scenario in a shopping domain (typically e-commerce scenario) to illustrate the need of Web service selection mechanism when the requester has both functional and nonfunctional requirements involving multiple QoS properties with varied preferences. In shopping domain, the buyers will be having several requirements on the service quality. The buyers normally prefer speedy and free delivery of the purchased goods (items). The buyers sometimes will have relative preferences for the requested QoS properties. For example, the buyer might give higher preference to delivery time when compared to the delivery price if the item to be purchased is of an urgent requirement to him. Thus, requesters will have different requirements on the service quality depending on the circumstance or his behavior.

As an illustration, consider the book buying scenario with the buyer's requirements on QoS as follows: (a) A reputed book seller (ranked above 6 out of 10) who delivers book within 8 days with a delivery price less than $10 (b) book seller who freely delivers a book within 15 days. The buyer expects one of the requirements to be satisfied by the book seller and he gives higher preference to QoS requirement (a). Assume that, a Web service discovery mechanism for the book purchase request finds multiple book seller services for the buyer. In such a situation, how to select the best book seller service for the buyer? Similarly the requester may enforce requirements on service offers such as 50% discount on the delivery charge, a free gift hamper of worth $50 on purchase etc. If the requester has several requirements involving quality or service offers with varying preferences, then a need arises to identify the suitable (best) Web service which satisfies his nonfunctional requirements.

Remainder of this paper is organized as follows. The next section explores the various architectures proposed in literature for the QoS based Web service selection. Section 3 classifies various proposed matchmaking techniques used for dynamic Web service selection and provides the comparison between various QoS based Web selection techniques. Section 5 draws conclusions and explores future research in Web service selection.

II. Architectures for QoS Based Web Service Selection

In literature, different architectures have been proposed by researchers to facilitate QoS aware dynamic Web service selection. The architectures for QoS based Web service selection are classified based on the involvement of different architectural components in the selection mechanism. The architectures are: *Conceptual Web Service architecture with extended UDDI for QoS support (Augmented architecture)*, *The broker (middleware) based Web service architecture (Broker architecture)* and *Multi-Component based Web service architecture (Hybrid architecture)*.

A. Augmented Architecture for Selection

In augmented Web service selection architecture, the existing UDDI information model is extended for QoS support i.e. QoS aware Web service publishing and discovery [7], [8]. The UDDI is extended with *blue pages* which store QoS information pertaining to Web services. This information is retrieved to distinguish Web services based on QoS.

B. Broker Architecture for Selection

The broker based selection architecture uses the concept of middleware (broker) for QoS aware Web service publishing and selection mechanisms. In broker based architecture the broker is a critical architectural component of interaction for the requester and provider towards dynamic Web service selection and publishing [10], [9]. The functionality of the broker is to select the most suitable Web service for the requester that satisfies his QoS constraints and preferences. The other functionalities of the broker may include QoS publishing, QoS verification & certification and QoS management & monitoring.

C. Hybrid Architecture for Selection

The hybrid Web service selection architecture involves multiple cooperating architectural components along with UDDI registry to enable QoS aware Web service publishing and selection [6], [11]. In such architectures, the architectural components are either spread over geographical locations or at the same location involving heterogeneous computing resources.

III. QoS Based Web Service Selection Techniques

In literature, various selection techniques for QoS aware Web services have been proposed by many researchers. Fig. 1 depicts the taxonomy of techniques for QoS aware Web service selection. The QoS aware Web service selection techniques are classified based on the nature of requester's QoS requirements. The tree nodes with dark color indicate the unavailability of Web service selection techniques in literature for such QoS requirements. The QoS based Web service selection methods can be broadly classified into *two* categories. In the first category, the Web service selection is made for a single task whereas the second category involves an optimal selection of Web services for different tasks of the composite

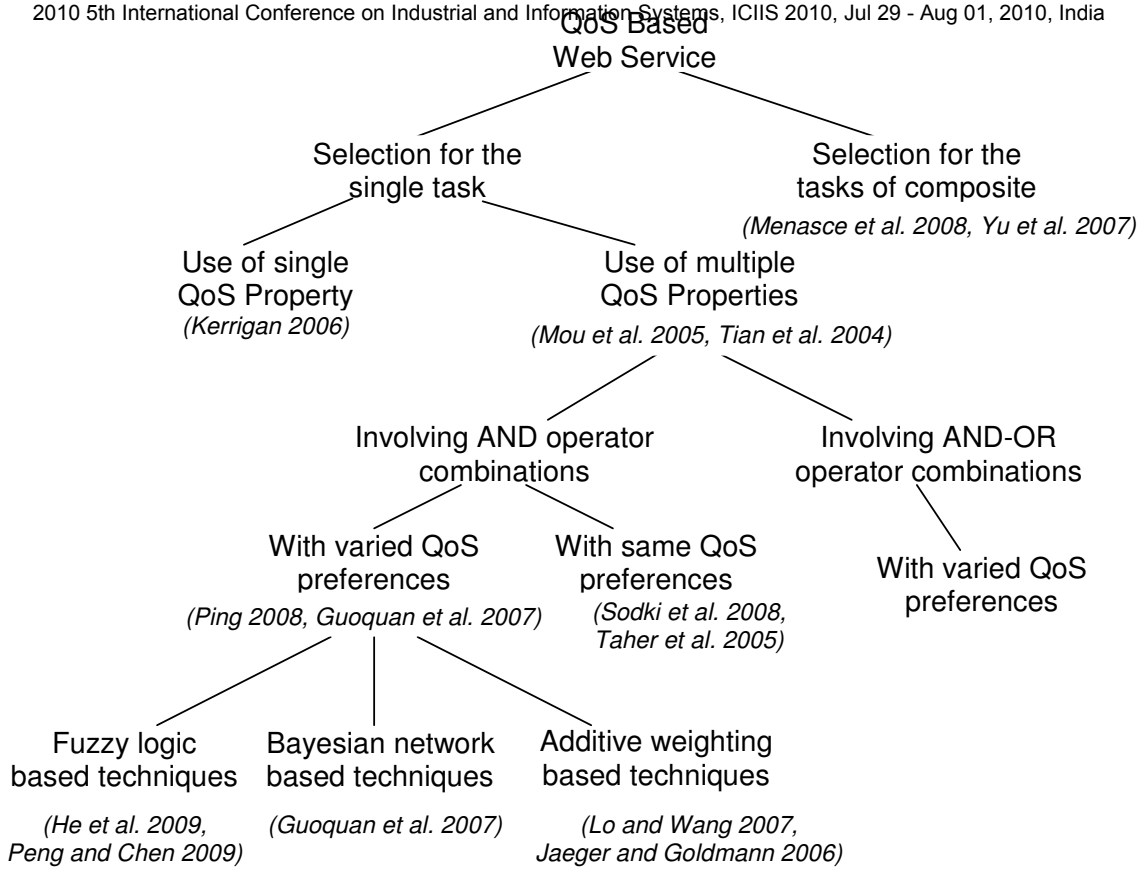

Fig. 1. Taxonomy of QoS aware Web Service Selection Techniques

process. Many researchers have proposed various techniques for the optimal (or sub-optimal) selection and assignment of Web services to the constituent tasks of composite process or composition plan [12], [13], [14].

A. Requester's QoS Requirement Based Selection

In literature, researchers have proposed various techniques to find the most suitable Web service for the specific task based on the requester's QoS requirements. Kerrigan [15] proposes a selection method which finds the best Web service for the requester based on single QoS property (e.g. service price). Some efforts have been made towards the QoS aware Web service selection based on QoS requirements involving multiple QoS properties [16], [17]. In such QoS aware Web service selection techniques, the requester's varied preferences for QoS properties are considered to rank the functionally similar Web services [18], [19]. A few researchers have proposed selection mechanisms which take same preference for all requested QoS properties [20], [21], [22]. The Web service selection mechanism for QoS requirements involving multiple QoS properties is implemented using computational concepts (principles) like Fuzzy logic [23], [24], [18], [25], [26], [27], Bayesian Network [19] and Simple Additive Weighting (SAW) methods [28], [29], [30]. Subsequent sub-sections provide a review of various techniques proposed for QoS based Web service selection.

1) Extended QoS Model for Selection: The extended QoS model and quality driven Web service selection has been proposed [30] to distinguish QoS aware Web services. The proposed QoS model categorizes QoS properties as *Generic quality criteria* involving QoS properties like *Execution price*, *Execution duration* and *Business related criteria* consisting QoS properties like *Transaction*, *Compensation rate*. The authors present the design of QoS registry which is responsible for the computation of QoS value for each advertised Web service. The proposed selection mechanism ranks the Web services based on the constraints involving multiple QoS properties and QoS group preferences. The rank for a Web service is computed and assigned as follows. First the QoS property values are normalized individually and then in groups, based on the usability. The normalized score is then multiplied by the QoS group preference to find the final score (rank) of a Web service. Finally, the Web service with highest score is selected as the best Web service for the requester. The problems with this mechanism are:

- The mechanism does not read individual QoS property preferences for the ranking of Web services.
- The ranking mechanism is defined on all QoS properties present in the QoS model and does not allow requester to specify his requirements.
- The mechanism does not provide Web service filtering based on the requester's desired QoS property values or range of values.

2) QoS Based Selection Framework: A framework for QoS based dynamic Web service selection has been proposed [22] which involves UDDI and other supporting components like QoS Manager and Validation Manager. The framework allows the requester to supply the QoS requirements through the header of SOAP message which are retrieved at the SOAP filter component. The proposed service selection mechanism first normalizes the QoS values of Web services and requested QoS values using Min-Max normalization technique. The selection mechanism estimates the correlation (Euclidean distance) value between QoS values of functionally similar Web services and the requester's expected QoS. The Web service with minimum Euclidean distance is selected as a best Web service for the requester's QoS requirements. The major problem with this mechanism is that, Euclidean distance may not find the actual best Web service in all circumstances as the Web services are not filtered based on the QoS requirements before the correlation computation. This problem is illustrated here with a simple example. Consider *three* Web services with *time* values 3, 2, 6 and service requester's desired value as 5. The Euclidean distance measure (correlation computation) selects the *third* Web service since its price value is closer to requested price as compared to other Web services.

3) Web Service Execution Environment: [15] proposes the selection mechanism for Web service execution environment (WSMX) which selects the best Web service based on the requester's filtering requirements and ordering preferences defined on single QoS property (e.g. service price). The proposed mechanism does not support the requester's QoS requirements involving multiple QoS properties and preferences.

4) Quality Driven Web Service Selection: Quality driven Web services selection mechanism involving requirements on multiple QoS properties has also been proposed [31]. The authors propose a decision model of QoS criteria called DQos involving decision matrix, decision modes and set of requirements. The paper proposes weights method involving requester's preferences (weights) to solve Multiple Attribute Decision Making (MADM) problem. The weights are determined based on the *four* different modes. The proposed selection mechanism does not consider the requester's optional (OR combinations) QoS requirements defined on multiple QoS properties.

5) Matrix for Web Service Selection: The QoS based Web service selection which has been explored [20] uses a 2-dimensional boolean array called *selection matrix* for ranking, which is generated as follows. The rows of the matrix represent the Web services and the columns represent the QoS properties. The matrix cell value is set to 1 if the QoS property requirement matches with the advertised value, zero otherwise. The matrix row having maximum number of 1's present in it is identified and the corresponding Web service becomes the best Web service for the given QoS requirements. The major problems of this mechanism are:

- The mechanism does not read the requester's preferences for the requested QoS properties.
- Most of the time the mechanism may find multiple Web services as best services for the requester which requires him to identify the best among the selected Web services. For example consider the requester's requirements as: time < 4 and price < 100. Assume the values of *time* and *price* of *three* functionally similar Web services are $\{3, 50\}$,$\{5, 10\}$ and $\{2, 70\}$. The selection mechanism selects the *first* and *third* Web service as most suitable for the requester from which the requester has to select the best Web service.

6) CosmosQoS Framework: A framework called *CosmosQoS* has been proposed [28] which fulfills the requester's QoS requirements. The CosmosQoS defines Web service reputation appraisal model which is composed of *three* measurement perspectives called price discrepancy, QoS deviation and historical credibility. The estimated values of these three parameters are multiplied by weights and their summation is used to determine the quality score of Web service. A higher value of score indicates the level (higher) of quality of Web services. The proposed reputation appraisal model takes all QoS properties of QoS model for Web service distinction and does not filter the Web services based on the requested QoS property values.

7) SAW Method: The selection mechanism which has been proposed [29] defines a Simple Additive Weighting (SAW) method to rank the functionally similar Web services based on the requester's QoS requirements. The SAW method finds the score for Web services through summation of normalized QoS values which are multiplied by QoS preferences (weight). This mechanism does not filter the functionally similar Web services based on the QoS requirements as the requester does not provide desired (expected) QoS values for selection.

8) QoS Description and Selection: The authors [10] propose QoS description and selection model which reads the requester's QoS requirements in terms of QoS properties and preferences to rank the Web services. The mechanism does not filter the Web services based on QoS constraints prior to ranking to optimize the computation.

9) WSSR-Q Framework: A Web service selection and ranking mechanism has been proposed [32] which defines Web service description model that considers service QoS information. A service selection and ranking framework with QoS (WSSR-Q) is modeled based on service description model. Towards Web service ranking, service selection and ranking algorithm and quality updating mechanisms are proposed concerning QoS attribute values. The selection mechanism considers the requester's desired QoS values and QoS preferences for selection and ranking of functionally similar Web services. The proposed method does not consider requester's choice based

QoS requirements (OR combinations) to rank the functionally similar Web services.

B. Analysis of Selection Techniques

The strength of various QoS aware Web service mechanisms can be evaluated based on the following seven parameters. They are:

C1. Is the requester allowed to specify the desired QoS properties for selection?
C2. Are the requester's preferences (weight) for QoS properties considered for selection?
C3. Is the selection mechanism that optimizes (filters) the candidate Web services (functionally similar Web services) based on requirements?
C4. Does the selection mechanism explore multiple Web services in many cases (situations)?
C5. Does the selection mechanism find the best Web services correctly in all circumstances?
C6. Is the selection mechanism defined for multiple QoS properties?
C7. Does the selection mechanism allow the requester to specify desired QoS property values in the requirements?

The evaluation parameters are defined to analyze the strength and weakness of specific QoS aware Web service selection mechanisms. The parameters consider the nature and accuracy of selection result, facility provided to supply QoS requirements involving multiple QoS properties, requester's QoS preferences and optimization of selection mechanism in terms of reduction in candidate Web services. Table I presents the table showing summary of evaluation (strength and weakness) of various QoS aware Web service selection techniques.

IV. Conclusion

The Web service discovery explores multiple Web services for a given requested functionality. In order to select the most suitable Web service among functionally similar Web services, nonfunctional properties of Web services like QoS are used. In literature, various ranking techniques have been proposed towards selection of QoS aware Web services based on the requester's QoS requirements, defined on the multiple QoS properties and preferences. The observation of taxonomy tree (Fig. 1) of QoS aware selection mechanisms and review table (TABLE I) reveals the fact that, no attempt has been made in literature towards the selection (ranking) of functionally similar Web services based on the requester's QoS requirements, involving AND and OR combinations (Choice based demands) with varied QoS property preferences. Moreover, the requester may also define requirements on different service offers of business Web services in B2C scenario. In literature, a mechanism is not defined to rank the functionally similar business Web services based on the requester's demands, involving different service offers. The mechanisms are required to select the most suitable Web service from discovered Web services for the requester, based on the demands defined either on QoS or service offers, involving AND-OR combinations with varied preferences. To enable QoS or service offer based selection of Web services, the existing conceptual Web service architecture need to be augmented to monitor the publishing of QoS and service offer aware Web services.

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TABLE I
EVALUATION OF WEB SERVICE SELECTION TECHNIQUES

QoS aware Web Service Selection Mechanism	Evaluation Criteria						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
Liu et al. 2004	NO	NO	NO	NO	YES	YES	NO
Taher et al. 2005	YES	NO	NO	NO	NO	YES	YES
Kerrigan 2006	YES	YES	NO	NO	YES	NO	NO
Hu J. et al. 2005	No	YES	NO	NO	YES	YES	YES
Sodki et al. 2008	YES	NO	YES	YES	YES	YES	NO
Lo and Wang 2007	YES	YES	NO	NO	YES	YES	YES
Jaeger and Goldmann 2006	YES	YES	NO	NO	YES	YES	No
Liu G. et al. 2009	YES	YES	NO	NO	YES	YES	YES
Zou et al. 2009	YES	YES	YES	NO	YES	YES	YES

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