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Consumer-Centric QoS-aware Selection of Web Services

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ABSTRACT

There exist many web services which exhibit similar functional characteristics. It is imperative to provide service consumers with facilities for selecting required web services according to their non-functional characteristics or quality of service (QoS). However, the selection process is greatly complicated by the distinct views of service providers and consumers on the services QoS. For instance, they may have distinct views of the service reliability — wherein a consumer considers that a service is reliable if its success rate is higher than 99%, while a provider may consider its service as reliable if its success rate is higher than 90%. The aim of this paper is to resolve such conflicts and to ensure consensus on the QoS characteristics in the selection of web services. It proposes a QoS Consensus Moderation Approach (QCMA) in order to perform QoS consensus and to alleviate the differences on QoS characteristics in the selection of web services. The proposed approach is implemented as a prototype tool and is tested on a case study of a hotel booking web service. Experimental results show that the proposed approach greatly improves the service selection process in a dynamic and uncertain environment of web services.

Keywords: QoS Consensus, Web Service, Fuzzy Logic, service selection

1. Introduction

Web services have become a promising technology for e-trading and for the development of new Internet-based software systems. For example, a hotel booking application can be exposed as a web service and integrated with other services such as flight booking or car-rental in order to provide an integrated environment for service consumers. However, there exist a large number of (hotel booking) services providing similarly functional characteristics. Multiple services with similarly functional characteristics give rise to the problem of service selection. Consumers do not only expect the service to meet functional aspects but they also demand good quality of services (QoS) such as service reliability, security, trust and execution cost etc. It is therefore imperative to devise techniques to publish less subjective QoS values to assist service consumers in selecting services according to the desired level of QoS.

Current research has devised such techniques in order to help consumers in the service selection process. For example, Benatallah et al defined in the Self-Serv framework, *service communities* which are containers of web services that provide similar functionality [14]. Self-Serv employs a scoring policy for the selection of the best fitted service according to a set of criteria. Services are scored according to various QoS factors such as execution price, execution duration, availability and reliability [16]. Further W3C [2] defines various QoS attributes [1] such as performance, reliability, scalability, capacity, and so on. Though W3C provides a list of standardized QoS attributes, their evaluation still involves great complexity, especially, when fuzzy terms (e.g. good quality, very reliable, and good performance) are employed to express service requests and advertisements in the discovery process. Such definitions of the fuzzy terms vary according to the opinions and preferences of service consumers and service providers. For instance, a service with 95% success rate is considered as reliable for some service consumers and providers, but others may demand 99% reliability. Similarly, a service with 8 ms response time can be considered as having sufficient efficiency by some while others may rate this service as inefficient. This reveals that service consumers and providers have different expectations of the QoS characteristics.

Also, the traditional ontological engineering approach [8] assumes that the shared conceptualization is defined by a bounded set of participants. However, in the process of

[1] The terms 'QoS attributes' and 'QoS characteristics' are used interchangeably

service selection participants can leave and join the group at any time. Thus, the definitions of the terms can evolve over time in order to meet the newly joined participants' demands. Therefore, a static ontology cannot meet the QoS requirements derived from a dynamic environment.

This paper proposes a consensus-based QoS moderation method, called QCMA (QoS Consensus Moderation Approach) which is built on MFDM (Moderated Fuzzy Discovery Method) framework [1], SAM (Similarity Aggregation Method) and RMGDP (Resolution Method for Group Decision Problems) [3][4][5][6][7]. It attempts to provide an architecture / mechanism for a group of service consumers and providers to reach consensus on the definitions of QoS characteristics. It assumes that a set of QoS characteristics are predefined. It adopts the QoS characteristics defined by W3C [2]. Given such QoS characteristics, the proposed approach enables a group of service providers and consumers to reach a consistent consensus on the definition of these characteristics. The proposed approach moderates their preferences and expectations in order to have coherent definitions of QoS characteristics using fuzzy terms. That is, service consumers and providers can express their QoS requirements using fuzzy terms such as 'very reliable' and 'less efficient'.

The remainder of the paper is organized as follows. Section 2 describes the traditional QoS-aware selection of a web service, and describes the concept of fuzzy logic based moderation. Section 3 describes MFDM, SAM and RMGDP methods on which the proposed QCMA framework is based. Section 4 presents QCMA framework. Section 5 reports on experimental results with a case study of a hotel booking web service. Finally, Section 6 illustrates the conclusion and the future work.

2. QoS-aware Web Service Selection – Existing Solutions

A number of QoS-aware web services selection mechanisms have been developed in recent years. These mechanisms focus on performance improvement in order to facilitate web service composition in an open and dynamic environment. W3C [3] defines different attributes such as reliability, security, and efficiency as part of web service QoS model, but it leaves the users to judge the level of QoS. This may result in the inconsistency of consumers' views on the values of QoS attributes. That is, one consumer may perceive a particular QoS attribute differently from another consumer.

Menasce (2004) studies the QoS of component web services in terms of cost and execution time [15]. It employs probability techniques to measure the cost and execution time of component web services by considering different execution scenarios such as parallel, sequential, fastest-predecessor-triggered and so on. This study helps in selecting appropriate component Web services for web service composition. However, it does not consider any consensus nor does it take into account QoS attributes with fuzzy definitions.

Michael C. Jaeger (2005) proposed a mechanism for composite web services with pattern-based QoS aggregation [17]. The QoS aggregation is used to verify that a set of services satisfies the QoS requirement for the required composite web services. In this approach the aggregation of QoS for service composition is defined by using a number of pre-defined composition patterns [18] which include QoS ratings. The concept of the composition pattern is inspired by van der Aalst's Workflow Pattern [19]. The identified workflow in web service composition is represented by directed graphs in order to impose the restrictions on the order in which activities are executed specified by the selected aggregation scheme. Based on the model, the aggregation of numerical QoS dimensions is performed and the required web composition is determined and executed.

Yutu Liu et al. proposed an open, fair and dynamic QoS computation model for web service selection. The model is tested using a QoS registry in a hypothetical phone service provisioning market place application [20]. The aim of this model is to investigate the relationship between QoS value and the business criteria, and to study the effectiveness of price and the service sensitivity factors in QoS computation.

The above approaches have advanced the knowledge and methods in QoS-aware service discovery and selection. However, these approaches fall short of addressing the following issues:

1. The representation of QoS characteristics, which plays an important role in the service selection, has been ignored. This can be improved by introducing fuzzy terms in the representation of the QoS in order to avoid the problem associated with crisp terms.

2. The issue of how to combine different QoS characteristics is not addressed. Different weightings may be given to different characteristics to form a compound request in order to reflect service consumers' preferences.

3. The issue associated with aggregating different service consumers' and providers' fuzzy views on the attributes are not considered. For example, different views on definition of the term "good performance"

may exist among service consumers and providers. It is essential to have consistent definitions of these terms for service consumers to discover and select desired services and for a service provider to use such definitions in service advertisement.

The proposed QCMA, based on our previous work MFDM [1], compliments existing research works by considering service consumers' and providers' subjective views and their arbitrary preferences on QoS attributes by employing a set of mechanisms to assist them to reach a consensus on QoS attributes.

3. Moderated Fuzzy Discovery Method

The Moderated Fuzzy Discovery Method MFDM was proposed to achieve effective web service discovery through a moderated fuzzy matchmaking mechanism. It not only measures the similarity between services in terms of capability, syntax and semantics [1][8][9], but also uses the services' underlying data and information as discovery and selection criteria.

MFDM is built upon: fuzzy logic; a semantic web, and, decision support methods, to form a framework. In addition it provides a set of procedures for service consumers and providers to follow so that they can reach consensus on the representation of services' contents [10]. A built-in domain dependent fuzzy classifier is employed to classify into concise semantic representation for service discovery, a large amount of data and information stored in services' repositories. The moderation process initiated by a fuzzy moderator minimizes the differences among service consumers and providers. The feedback from consumers on vague queries can be tracked in order to help categorizing similar terms into fuzzy classes. MFDM consists of two parts: Functional Deployment in the MFDM Framework, and, the Similarity Aggregation Method.

3.1 Functional Deployment in the MFDM Framework

The MFDM framework consists of a number of system components including Fuzzy Discovery, Fuzzy Classifier, Fuzzy Engine, UDDI / OWL and Fuzzy Moderator as shown in Figure 1.

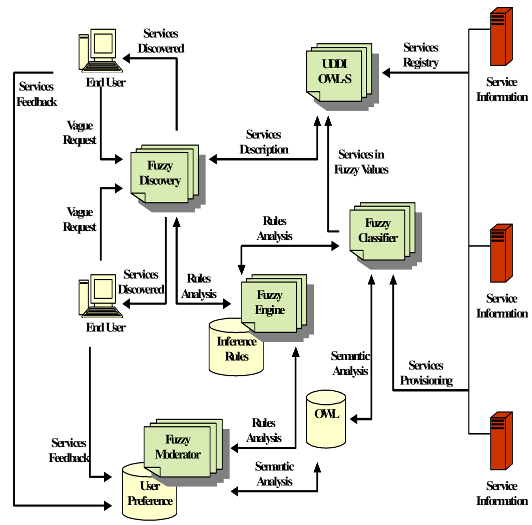

Figure 1: The Framework for the MFDM

The main functionalities of MFDM are described as follows:

1. *Fuzzy Discovery:* is defined for receiving all vague requests from service consumers and returning the related service information generated either from the Fuzzy Engine or from UDDI / OWLS to the Fuzzy Engine for further refinement.

2. *Fuzzy Engine:* is used for further analysis of the output produced by Fuzzy Discovery. After receiving the input from Fuzzy Discovery, Fuzzy Engine analyzes the information with fuzzy logic and interprets the fuzzy terms which have been processed by Fuzzy Classifier. Also, if the fuzzy terms are re-defined following the recommendations of the rule analysis, Fuzzy Engine will communicate with Fuzzy Moderator to carry out tuning actions and term modification.

3. *Fuzzy Classifier:* is to classify and interpret the information stored in the services which have been deployed in UDDI / OWLS. The rules built upon service domain knowledge for semantic analysis, classification and interpretation were represented in OWL. When Fuzzy Classifier receives the request for rules analysis from Fuzzy Engine, the interpretation of given fuzzy terms will be completed and the crisp answer will be retrieved from UDDI / OWLS.

4. *Fuzzy Moderator:* is a mechanism for tuning the definition of each fuzzy term. The input for tuning the fuzzy terms is not only delivered from fuzzy analysis

in Fuzzy Engine, but is also uses responses from service consumers. It is a key module to allow a consensus on fuzzy service information to be employed in web service discovery. The Similarity Aggregation Method (Section 3.2) and Resolution Method for Group Decision Problems (Section 3.3) are used in the moderation process.

According to the definition of each system component in MFDM, the fuzzy classifier (including built-in domain knowledge) is able to interpret raw data stored in the service provider's repositories and represent them with fuzzy terms. These fuzzy terms will be employed by the service provider to advertise their services via UDDI. Since UDDI does not have the facility for modeling semantics, the OWL is used for capturing the semantics. The opinions and preferences given by the service providers and consumers are processed via Fuzzy Moderator in order to identify their consensus. This enables service consumers (issuing vague requests) and the service providers (using different terms for service advertisement) to coordinate their expectations.

3.2 Similarity Aggregation Method

SAM was developed for resolving conflicts that emerged from different opinions [4,5] In SAM different fuzzy opinions will be aggregated into an opinion consensus class so that they can be measured by their similarities to each other. Therefore, the similarity measuring method is the key to generating the consensus index in the fuzzy opinions set. This characteristic was used by the Fuzzy Moderator for moderating definitions of fuzzy terms. During the process of fuzzy term moderation, the consensus indexes are collected and a consensus agreement is formed. The procedure to perform SAM is organized into 7 steps as stated below [1]:

1. In this step, each participant represents his/her subjective fuzzy preference on one specific criterion with a positive trapezoidal fuzzy number. In QCMA, the positive trapezoidal fuzzy number is used for describing fuzzy perception in each QoS attribute and is represented in Figure 2.

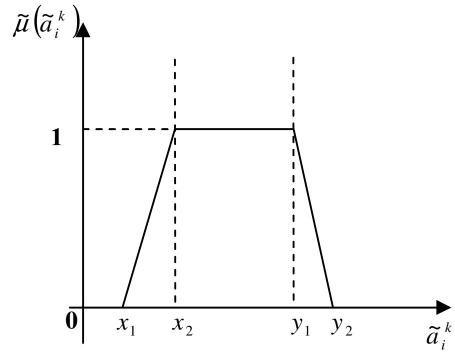

Figure 2: A Trapezoidal Fuzzy Number

2. This step obtains opinion similarity between any two participants ($User_i$ and $User_j$) for the specific criterion. The similarity between $User_i$ and $User_j$, which is denoted as $Sim(User_i, User_j)$, can be obtained via the following equation:

$$Sim_{ij} = \frac{\int \left(\min\{\tilde{\mu}(User_i), \tilde{\mu}(User_i)\}\right)dx}{\int \left(\max\{\tilde{\mu}(User_i), \tilde{\mu}(User_i)\}\right)dx} \tag{1}$$

3. This step builds an agreement matrix *AM*, which can represented as equation (2), for showing each similarity between each pair of participants in the group.

$$AM_{n\times n} = \begin{bmatrix} 1 & Sim_{12} & \cdots & Sim_{1j} & \cdots & Sim_{1n} \\ Sim_{21} & 1 & \vdots & \vdots & \vdots & \vdots \\ \vdots & \cdots & 1 & \vdots & \vdots & \vdots \\ Sim_{i1} & \cdots & \cdots & 1 & \vdots & Sim_{in} \\ \vdots & \cdots & \cdots & \cdots & 1 & \vdots \\ Sim_{n1} & Sim_{n2} & \cdots & Sim_{nj} & \cdots & 1 \end{bmatrix}_{n\times n} \tag{2}$$

4. This step calculates average agreement degree for each single participant *i*, denoted as $A(User_i)$, in the group. The $A(User_i)$ can be obtained via the equation (3):

$$A(User_i) = \frac{1}{n-1}\sum_{\substack{j=1 \\ i\neq j}}^{n} Sim_{ij} \tag{3}$$

5. This step obtains RAD (Relative Agreement Degree) for each individual participant using the following formula.

$$RAD(User_i) = \frac{A(User_i)}{\sum_{j-1}^{all} A(User_j)} \quad and \quad i \neq j \tag{4}$$

6. This step involves the assignment of a weighting variable to each participant.

7. This step obtains the individual CDC (Consensus Degree Coefficient) for each participant:

$$CDC(User_i) = \beta \times w_i + (1-\beta) \times RAD(User_i) \quad (5)$$

where β is a correlative control variable to indicate the relation between CDC and RAD. If β = 0, then CDC is completely equivalent to RAD.

3.3. Resolution Method for Group Decision Problems

Opinion similarity enables the service consumers and providers to reach a consensus on the interpretation of a QoS criterion for web services. But they may have different preferences on the criteria. Therefore, RMGDP is proposed to alleviate their differences on preferences. RMGDP comprises the following three steps:

3.3.1. The transformation phase

In the transformation phase, all participants will be grouped. Each participant has to evaluate alternatives according to given criteria, and to assign his/her preference orders to the related alternatives.

The participants allocate the orders based on their preferences and subjective judgments. A transfer function, p_{ij}^{k}, is defined for converting these orders of alternatives to a preference relation which sets the ordering preference degree between alternative a_i and a_j, denote as o_i and o_j. This is can be expressed by a participant (denoted $User_k$) as follows:

$$p_{ij}^{k} = f(o_i^k, o_j^k) = \frac{1}{2}\left(1 + \frac{o_j^k}{m-1} - \frac{o_i^k}{m-1}\right) \quad (6)$$

where p_{ij}^{k} is a preference relation given by $User_k$ who has subjectively prefers a_i to a_j. m indicates the number of alternatives in the analysis.

3.3.2. The aggregation phase

In the aggregation phase, p_{ij}^{c} is defined by aggregating the participants' preferences $\{p_{ij}^{1},...,p_{ij}^{n}\}$ for a particular pair *i,j* by means of a fuzzy majority [12]. The fuzzy majority is formed with the OWA (Ordered Weighted Averaging) operator F_Q and the fuzzy quantifier *Q*. The function with F_Q and Q aggregates the individual preference values to obtain the group preference order from *n* users via the following formula:

$$p_{ij}^{c} = F_Q(p_{ij}^{1},...,p_{ij}^{n}) = \sum_{i=1}^{n} w_i b_i \quad (7)$$

where b_i is the *i*-th large value in $\left(p_{ij}^{1}, p_{ij}^{2}, \cdots, p_{ij}^{n}\right)$ and $w_i = Q(i/n) - Q(i-1/n)$.

3.3.3. The exploitation phase

This phase calculates the consequence of collecting each alternative priority into group preferences. Two well-known fuzzy ranking methods, Quantifier guided Non-Dominance Degree (*QGNDD*) and Quantifier guided Dominance Degree (*QGDD*) [13] are adopted to provide different aspects for the evaluation of alternative priorities.

(a). Quantifier guided Non-Dominance Degree (QGNDD)

QGNDD is a fuzzy ranking method based on fuzzy preference relations. The method determines the relative preference degree of the alternatives. The Non-Dominance Degree (*NDD*) fuzzy ranking can be calculated from the participants' group preference relations, and is formulated as follows:

$$(u_{NDD})_{ji} = 1 - \max\{p_{ji}^{c} - p_{ij}^{c}, 0\} \quad (8)$$

A membership function $\mu_{NDD}(a_i)$ based on Eq. (8) can be interpreted as the degree to which a_i is not dominated by any other $a_j (j = 1,...,m)$. The function $\mu_{NDD}(a_i)$ is taken to find the highest order of alternatives. The *NDD* for alternative a_i is taken to identify a criterion which has a higher preference degree than others. For a linguistic quantifier Q (e.g. "most"), the *NDD* of the linguistic quantifier is represented as Quantifier Guided Non-Dominance Degree (*QGNDD*) defined as below:

$$QGNDD(a_i) = F_Q(1 - d_{ji}^{c}, j = 1...m, j \neq i) \quad (9)$$

where $d_{ji}^{c} = \max\{p_{ji}^{c} - p_{ij}^{c}, 0\}$. According to (7) the (9) can be represented as:

$$F_Q(1-d_{1i}^{c}, 1-d_{2i}^{c}, ..., 1-d_{mi}^{c}) = w_1.(1-b_1) + ... + w_m(1-b_m) \quad (10)$$

where b_i is the *i*-th small value in $\left(d_{1i}^{c}, d_{2i}^{c}, \cdots, d_{mi}^{c}\right)$

The solution offered by Eqs. (9) (10) indicates that the fuzzy majority in the remaining alternatives $a_j(j=1,\ldots,m)$ cannot dominate the alternative a_i . Also, all the preferences in the alternatives can be prioritized and the corresponding order can be obtained.

(b). Quantifier guided Dominance Degree

QGNDD cannot be used for ordering of the preferences if $\mu_{NDD}(a_i)$ obtained from numerous alternatives is in Unfuzzy Nondominated (UND) situation [13], i.e., $\mu_{NDD}(a_i)=1$. Also, in order to avoid more than two UND situations occurring simultaneously, the obtained fuzzy preference orders need to be validated by other fuzzy ranking methods such as QGDD.

Using Eq. (6) QGDD can quantify the dominance for each a_i which has preference order over all other alternatives. QGDD can be taken for prioritizing the final ordering preference using the following equation:

$$QGDD(a_i) = F_Q(p_{ij}^c, j=1...m, i \neq j) = \sum_{i=1}^{m} w_i b_i \qquad (11)$$

where $w_i = Q(i/m) - Q(i-1/m)$ and b_i is the *i*-th largest value in $\left(p_{i1}^c, p_{i2}^c, \cdots, p_{im}^c\right)$. By (11) the UND situation can be solved and final preference ranking for $a_1, a_2, \ldots, a_m$ can be determined.

4. The Proposed Approach – QCMA

The proposed QCMA (QoS Consensus Moderation Approach) extends MFDM in order to obtain and moderate group consensus on QoS in selecting web services.

QCMA enhances the moderation for opinion similarity and preference on QoS attributes. The following sections illustrate the function enhancements in QCMA and a mechanism for providing group consensus moderation on QoS.

4.1 Functions Enhancement

The QCMA extension uses QoS evaluation and consensus analysis and moderation. It includes additional components in order to improve the functional enhancement for QoS moderation. Figure 3 represents QCMA components which are explained as follows.

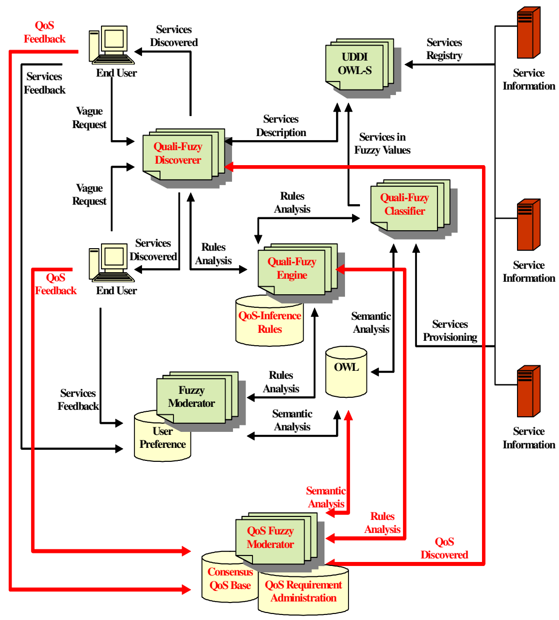

Figure 3: The Framework of QCMA

1. *UDDI / OWLS:* The service information and corresponding QoS fuzzy attributes and their associated definitions are deployed to UDDI and represented in OWLS before the discovery process takes place. Since there is no record input from service consumers when the system is initialized, the QoS attributes (through QoS Fuzzy Moderator) will be created in UDDI and the initial values for the QoS terms will be assigned by the service providers. The update to QoS attributes will be executed when the consumers start to have their feedback.

2. *Quali-Fuzy Classifier:* classifies and interprets all participating web service information that includes all corresponding QoS fuzzy attributes. The web service information provided by web service providers will be classified by the Quali-Fuzy Classifier according to the representation of the fuzzy QoS attributes. In addition, the vague requests issued by service consumers will be analyzed semantically by Quali-Fuzy Discoverer and to be forwarded to and interpreted by Quali-Fuzy Classfier according to its fuzzy classification. The process includes the discovery of web service information and possible QoS requirements with the help of the Quali-Fuzy Engine.

   However, the classification rules are modeled in OWL. The rules are triggered and reasoned over the domain information in order to produce the required knowledge for OWLS and UDDI. When Quali-Fuzy Classifier receives the request from Quali-Fuzy Engine, the meanings of the given fuzzy terms and expected

QoS can be interpreted. As a result, the related information can be retrieved from UDDI / OWLS using a pattern match.

3. *Quali-Fuzy Engine:* is designed to analyze the vague inquiry and the QoS requirements received from Quali-Fuzy Discoverer. After receiving the input from Quali-Fuzy Discoverer, Quali-Fuzy Engine reasons over the input with Fuzzy logic and interprets the fuzzy terms in the request which have been processed by Quali-Fuzy Classifier for rule analysis. If both fuzzy terms and the corresponding QoS expectation need to be tuned after rule analysis, Quali-Fuzy Engine will either communicate with QoS Fuzzy Moderator for fuzzy terms modification, or communicate with QoS Fuzzy Moderator for QoS modification.

4. *Quali-Fuzy Discoverer:* receives all vague requests from service consumers for the selection of the appropriate services. Quali-Fuzy Discoverer receives vague request (including possible given QoS requirement) and requests the feedback from the users' perceptions and opinions on QoS in order to modify service definition after locating and selecting the required web services. The steps involved not only analyzing the semantic definition of each vague request, but also examining the meaning of the required quality attribute which is represented in the vague request. Quali-Fuzy Discoverer intensifies the intelligence of Fuzzy Discovery and supports meaningful and concise discovered web information analysis through either Quali-Fuzy Engine or UDDI / OWLS.

5. *QoS Fuzzy Moderator:* is dedicated to tune both the definition of QoS terms and QoS perception derived from both service consumers and service providers which are associated with corresponding web service information deployed in UDDI / OWLS. In the system initialization, QoS Requirement Administration provides an initial set of QoS term definitions for group consensus.

   In order to reach the group consensus on the definitions of QoS terms, both the service consumers' and providers' subjective opinions and preferences over QoS have to be registered and stored in QoS Requirement Administration in advance of further processing. When additional service consumers or providers with different opinions or preferences join, the process of moderating group consensus may have to take place. So, any new opinions or requests have to be analyzed by comparing with the information in the QoS Consensus Base in order to determine whether the moderation process has to be carried our or not.

In order to gather the required information for the QoS Consensus Base, a questionnaire approach is adopted to collect service consumers' and providers' subjective opinions and preferences in relation to QoS aspects. QoS Fuzzy Moderator provides an interface for collecting the feedback from the service consumers. With the provision of the information, the Similarity Aggregation Method and the Resolution Method for Group Decision Problems can be employed to process and reason with the information in the moderation process.

According to the above description, the service consumers will first register their QoS expectations (definitions) with QoS Requirement Administration. For example, a service consumer may demand a query regarding service performance by specifying the condition: "The response time should not be slow". Using fuzzy analysis this condition can be interpreted as "the response time delay should be no more than 7~10 seconds"). All the fuzzy terms with corresponding QoS representations used by the service providers have been employed in UDDI and declared in QoS Requirement Administration (via Quali-Fuzy Classifier). Since UDDI does not have facility for modeling semantics, the OWL is used for capturing the semantics.

With the availability of the required information provided by service consumers and providers, the Quali-Fuzy Classifier (including built-in domain knowledge) is able to interpret QoS information within services and represent them in a fuzzy way. The fuzzy information will be employed by the service provider to advertise their service via UDDI. The opinions, with expected QoS requirements and preferences, given by the service providers and consumers, will be processed via both the Fuzzy Moderator and the QoS Fuzzy Moderator in order to identify their consensus. This enables service consumers (issuing vague requests with QoS representation) and the service providers (using QoS fuzzy terms for service advertisement) to moderate their expectations.

4.2 QoS Consensus Moderation in QCMA

Various QoS characteristics for web services have been defined such as reliability, performance, integrity (as in [2]). Even if a set of standardized QoS characteristics for web services are accepted by service consumers and providers, their opinions on these characteristics may not be always consistent. In addition, QoS should be treated as a set of dynamic variables rather than fixed/static variables due to the frequent changes that may occur in services in the dynamic web environment. So, in terms of the operations in QCMA, the proposed framework will focus on the design of a framework that can facilitate reaching consensus on the opinions of Web service QoS characteristics.

QCMA mainly takes into account consumers' opinions on QoS by adopting the W3C-define [2] set of QoS characteristics.

The QoS opinion set is defined as S_{QoS} which comprises the QoS terms shown as below:

$$S_{QoS} = \{a_1, a_2, a_3, \cdots, a_{13}\} \quad (12)$$

where a_1 = "Performance", a_2 = "Reliability", a_3 = "Scalability", a_4 = "Capacity", a_5 = "Robustness", a_6 = "Exception Handling", a_7 "Accuracy", a_8 = "Integrity", a_9 = "Accessibility", a_{10} = "Availability", a_{11} = "Interoperability", a_{12} = "Security" and a_{13} = "Network-Related QoS Requirement". Note that QCMA is capable of accommodating new QoS characteristics, which can be introduced as additional variables to the system.

In QCMA, the QoS Consensus Base comprises group consensus opinions of the terms and preferences (e.g. good, fair, bad, etc.) for QoS characteristics in S_{QoS} . The opinions for QoS terms are updated regularly by the QoS Fuzzy Moderator in line with the interactions taking place between the participants. The QoS and their moderated opinions are represented in OWL as part of an ontology. However, the participants have their private spaces to store their own opinions. A mechanism is devised for mapping their subjective opinions onto the moderated opinions, when a request is initiated. Each action for QoS consensus moderation is driven by the interactions between service consumers and providers, and is called a Web Service Activity (*wsa*), which must be processed by SAM and RMGDP. The structure of *wsa* is defined as below:

Structure *wsa // QoS information in QCMA*
{
*wsa*_id: Index of *wsa*.
role_cat: The category of the role: {SERC (Service Consumer), SERP (Service Provider} who deliver the *wsa*.
role_id: Index of role (service consumer / service provider) who deliver the *wsa*.
ws_id: Index of associated web service information in UDDI.
rmgdp_ptf[i, j]: The relative preference from QoS attribute i to j for transfer function in transformation phase of RMGDP.
qos_att01: fuzzy QoS attribute (Performance)
opd_qos_att01: the ordering preference degree of qos_att01.
qos_att02: fuzzy QoS attribute (Reliability)
opd_qos_att02: the ordering preference degree of qos_att02.
qos_att03: fuzzy QoS attribute (Scalability)
opd_qos_att03: the ordering preference degree of qos_att03.
qos_att04: fuzzy QoS attribute (Capacity)
opd_qos_att04: the ordering preference degree of qos_att04.
qos_att05: fuzzy QoS attribute (Robustness)
opd_qos_att05: the ordering preference degree of qos_att05.
qos_att06: fuzzy QoS attribute (Exception Handling)
opd_qos_att06: the ordering preference degree of qos_att06.
qos_att07: fuzzy QoS attribute (Accuracy)
opd_qos_att07: the ordering preference degree of qos_att07.
qos_att08: fuzzy QoS attribute (Integrity)
opd_qos_att08: the ordering preference degree of qos_att08.
qos_att09: fuzzy QoS attribute (Accessibility)
opd_qos_att09: the ordering preference degree of qos_att09.
qos_att10: fuzzy QoS attribute (Availability)
opd_Qos_att10: the ordering preference degree of qos_att10.
qos_att11: fuzzy QoS attribute (Interoperability)
opd_qos_att11: the ordering preference degree of qos_att11.
qos_att12: fuzzy QoS attribute (Security)
opd_oos_att12: the ordering preference degree of qos_att12.
qos_att13: fuzzy QoS attribute (Network-Related QoS Requirement)
opd_qos_att13: the ordering preference degree of qos_att13.

}

Each fuzzy QoS attribute defined in wsa can be represented as trapezoidal fuzzy number shown as below:

$$\text{qoS\_att01} = (x_1, x_2, y_1, y_2) \quad 0 \le x_1, x_2, y_1, y_2 \le 10 \quad (13)$$

Each (x_1, x_2, y_1, y_2) represents service consumer's and service provider's fuzzy score on each QoS attribute. For instance, the service consumer *k* provides feedback (wsa_i^k) on QoS after he/she issued a vague request to Quali-Fuzzy Discoverer, so wsa_i^k can be created and updated by the service consumer *k*:

```
wsa_i^k =
{
wsa_id ← i;
role_cat ← SERC;        // (Service Consumer)
role_id ← k;
ws_id ← 003847BC   //Index of associated web service
                     information in UDDI.
qos_att01 ← (0, 0, 7, 9); // fuzzy QoS attribute ("Good
                     Performance")
opd_qos_att01 ← 6;
qos_att02 ← (0, 0, 5, 8); // fuzzy QoS attribute
                     ("Acceptable
                     Reliability")
opd_qos_att02 ← 9;
qos_att03 ← (0, 0, 6, 8); // fuzzy QoS attribute ("Good
                     Scalability")
opd_qos_att03 ← 8;
qos_att04 ← (0, 0, 5, 7); // fuzzy QoS attribute
                     ("Sufficient
                     Capacity")
opd_qos_att04 ← 7;
qos_att05 ← (0, 0, 4, 9); // fuzzy QoS attribute
                     ("Acceptable
                     Robustness")
opd_qos_att05 ← 10;
qos_att06 ← (0, 0, 5, 8); // fuzzy QoS attribute ("Good
                     Exception Handling")
opd_qos_att06 ← 2;
qos_att07 ← (0, 0, 3, 8); // fuzzy QoS attribute
                     ("Acceptable
                     Accuracy")
opd_qos_att07 ← 4;
qos_att08 ← (0, 0, 6, 9); // fuzzy QoS attribute ("Good
                     Integrity")
opd_qos_att08 ← 3;
qos_att09 ← (0, 0, 5, 7); // fuzzy QoS attribute ("Good
                     Accessibility")
opd_qos_att09 ← 11;
qos_att10 ← (0, 0, 7, 9); // fuzzy QoS attribute ("Good
                     Availability")
opd_qos_att10 ← 13;
qos_att11 ← (0, 0, 7, 8); // fuzzy QoS attribute ("Good
                     Interoperability")
opd_qos_att11 ← 1;
qos_att12 ← (0, 0, 6, 10); // fuzzy QoS attribute ("High
                     Security")
opd_qos_att12 ← 5;
qos_att13 ← (0, 0, 7, 8); // fuzzy QoS attribute
                     ("Qualified
                     Network-Related QoS
                     Requirement")
opd_qos_att13 ← 12;

}
```

This opinion wsa_i^k of the service consumer k can be also treated as an input to QoS Fuzzy Moderator at the moderation stage that involves SAM and RMGDP. In order to cluster the opinions of the service consumers who have similar opinions on QoS, the threshold values for CDC in SAM, t_{cdc_l} and t_{cdc_u}, are set to correspond all wsa_i^k which can be classified into the same $S_{cdc\_l}^{cdc\_u}(Q_{wsa^k}(x))$. $Q_{wsa^k}(x)$ indicates the set of QoS attributes with index x for wsa_i^k. $S_{cdc\_l}^{cdc\_u}(Q_{wsa^k}(x))$ can be defined as below:

$$S_{cdc\_l}^{cdc\_u}(Q_{wsa^k}(x)) = \left\{ x \text{ is index for } wsa_i^k \mid t_{cdc\_l} \le CDC(Q_{wsa^k}(x)) \le t_{cdc\_u} \right\}$$

Where both the t_{cdc_l} and t_{cdc_u} can be represented as:

$$t_{cdc\_l} = \left(t_{l1}, t_{l2}, t_{l3}, t_{l4}, t_{l5}, t_{l6}, t_{l7}, t_{l8}, t_{l9}, t_{l10}, t_{l11}, t_{l12}, t_{l13}\right) \quad (15)$$

$$t_{cdc\_u} = \left(t_{u1}, t_{u2}, t_{u3}, t_{u4}, t_{u5}, t_{u6}, t_{u7}, t_{u8}, t_{u9}, t_{u10}, t_{u11}, t_{u12}, t_{u13}\right) \quad (16)$$

All the RAD($Q_{wsa^k}(x)$) can be obtained through similarity analysis. To simplify the operation of CDC($Q_{wsa^k}(x)$), we set β in CDC($Q_{wsa^k}(x)$) as zero so that CDC($Q_{wsa^k}(x)$) is equal to RAD($Q_{wsa^k}(x)$). In other words, all wsa_i^k with "similar" relative agreement degree (acceptable relative difference degree between t_{cdc_l} and t_{cdc_u}) was made for grouping them into $S_{cdc\_l}^{cdc\_u}(Q_{wsa^k}(x))$.

After the SAM process is completed, each $Q_{wsa^k}(x)$ in $S_{cdc\_l}^{cdc\_u}(Q_{wsa^k}(x))$ having consistent definitions over the QoS terms will be used for preference analysis via RMGDP.

The preference order of QoS terms for each wsa_i^k and the group preference of QoS terms for $S_{cdc\_l}^{cdc\_u}(Q_{wsa^k}(x))$ will be ranked. Since wsa_i^k comprises the fuzzy web service terms given by service consumers or providers, the result generated by SAM and RMGDP will be treated as the consequence of the QoS group consensus.

5. Validation and Evaluation of QCMA

This section presents the validation and evaluation of the proposed approach in order to test its effectiveness in the selection of QoS-aware web services.

A prototype system was developed in order to validate the functionality of the proposed approach. The system is based on a case study using hotel booking web services.

Various experiments have been conducted by taking into account a number of hotel booking services (hbs). hbs is denoted as a web service activity wsa^k_{hbs}, which defines QoS-aware web services using the W3C-defined QoS characteristics [2] . For a consumer k, The QoS attributes defined in wsa^k_{hbs} can be represented as $Q^{hbs}_{wsa^k}(x)$ and defined as follow:

$$Q^{hbs}_{wsa^k}(x) = (\tilde{a}_1^k, \tilde{a}_2^k, \cdots, \tilde{a}_{13}^k) \quad (17)$$

where $(\tilde{a}_1^k, \tilde{a}_2^k, \cdots, \tilde{a}_{13}^k)$ follows the definition in S_{QoS}. $a_1 .. a_{13}$, represent different QoS attributes which are described as follows.

a_1: The perception of "Performance" in the web service response time,

a_2: The perception of "Reliability" in the web service access,

a_3: "Scalability" for different degree of perception or the scale of domain of hotel information

a_4: The perception of "Capacity" for the amount of hotel information in each web service access,

a_5: The perception of "Robustness" of the web service access

a_6: The perception of "Exception Handling" when the service gives rise to exceptions

a_7: The perception of "Accuracy" of required hotel information from web service,

a_8: The perception of "Integrity" when required hotel information from web service,

a_9: The perception of "Accessibility" of web service

a_{10}: The perception of "Availability" of web service

a_{11}: The perception of "Interoperability" of the whole web service system,

a_{12}: The perception of "Security" of the web service access.

a_{13} : The perception of "Network-Related QoS Requirement".

The experiments conducting a group consensus analysis on the QoS involved fifty service consumers with required web services. The opinions about web service activities relating to QoS attributes, $Q^{hbs}_{wsa^k}(x)$, from the fifty consumers were transformed to ($\tilde{a}_1^k$, $\tilde{a}_2^k$, …, $\tilde{a}_{13}^k$) which are positive trapezoidal fuzzy numbers.

5.1 Similarity Analysis via SAM

These form a $Q^{hbs}_{wsa^k}(x)$ matrix shown in Tables 1 and 2. Each $\tilde{a}_i^k$ for the consumer k (Tables 1, 2) will be represented as:

$$\tilde{a}_i^k : (x_1, x_2, y_1, y_2) \quad 0 \le x_1, x_2, y_1, y_2 \le 10 \quad (18)$$

In Table 1, 2, all $\tilde{a}_i^k$ that are the feedbacks from fifty consumers were describes as:

$$\tilde{a}_i^k : (0,0, y_1, y_2) \quad (19)$$

That is $x_1 = x_2 = 0$. It is because the positive trapezoidal fuzzy number shown in Figure 4 was adopted to describe QoS attributes:

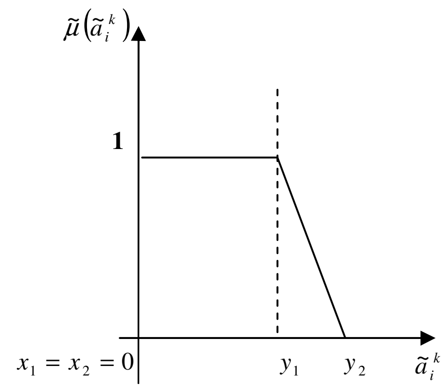

Figure 4: The Trapezoidal Fuzzy Number in Questionnaire

For instance, the service consumer k considers "Acceptable Reliability" as (4 ~ 7) shown in Table 1.This can be mapped to QoS attribute (a_2) in $Q^{hbs}_{wsa^k}(x)$ which is defined as below:

0 : 30% reliability	1 : 40% reliability
2 : 50% reliability	3 : 60% reliability
4 : 70% reliability	5 : 80% reliability
6 : 85% reliability	7 : 90% reliability
8 : 95% reliability	9 : 98% reliability
10 : 100% reliability	

Therefore, for the degree pattern of (4 ~ 7), $\tilde{a}_2^k$ in $Q_{wsa^k}^{hbs}(x)$ can be represented as:

$$\tilde{a}_2^k \leftarrow (0,0,4,7)$$

Since each individual consumer's fuzzy definition over the QoS term has been obtained, the similarity between each pair of feedback from all $Q_{wsa^k}^{hbs}(x)$ can be analyzed via SAM and thirteen agreement matrixes (for all service consumers) for thirteen QoS attributes in S_{QoS} can be generated as below:

$$AM_{a_1} = \begin{bmatrix} 1 & 0.93 & \cdots & 0.87 & \cdots & 0.88 \\ 0.93 & 1 & \vdots & \vdots & \vdots & 0.82 \\ \vdots & \cdots & 1 & \vdots & \vdots & \vdots \\ 0.87 & \cdots & \cdots & 1 & \vdots & 0.76 \\ \vdots & \cdots & \cdots & \cdots & 1 & \vdots \\ 0.88 & 0.82 & \cdots & 0.76 & \cdots & 1 \end{bmatrix}_{n\times n}$$

$$AM_{a_2} = \begin{bmatrix} 1 & 0.93 & \cdots & 0.82 & \cdots & 0.93 \\ 0.93 & 1 & \vdots & \vdots & \vdots & 1.0 \\ \vdots & \cdots & 1 & \vdots & \vdots & \vdots \\ 0.82 & \cdots & \cdots & 1 & \vdots & 0.88 \\ \vdots & \cdots & \cdots & \cdots & 1 & \vdots \\ 0.93 & 1.0 & \cdots & 0.88 & \cdots & 1 \end{bmatrix}_{n\times n}$$

....

$$AM_{a_{13}} = \begin{bmatrix} 1 & 0.73 & \cdots & 0.93 & \cdots & 0.93 \\ 0.73 & 1 & \vdots & \vdots & \vdots & 0.79 \\ \vdots & \cdots & 1 & \vdots & \vdots & \vdots \\ 0.93 & \cdots & \cdots & 1 & \vdots & 1.0 \\ \vdots & \cdots & \cdots & \cdots & 1 & \vdots \\ 0.93 & 0.79 & \cdots & 1.0 & \cdots & 1 \end{bmatrix}_{n\times n}$$

By analyzing similarity between each pair of feedback from all $Q_{wsa^k}^{hbs}(x)$, we can obtain Relative Agreement Degree and individual Consensus Degree Coefficient for each service consumer which is shown as below.

$$A(Consumer_{01}) = \{.89,.90,.80,.91,.85,.92,.91,.82,.85,.71,.91,.91,.81\}$$
$$RAD(Consumer_{01}) = \{.021,.020,.019,.019,.022,.020,.020,.019,.019,.017,.021,.022,.019\}$$
$$CDC(Consumer_{01}) = \{.021,.020,.019,.019,.022,.020,.020,.019,.019,.017,.021,.022,.019\}$$

$$A(Consumer_{02}) = \{.89,.90,.91,.89,.58,.81,.93,.90,.91,.88,.77,.75,.88\}$$
$$RAD(Consumer_{02}) = \{.021,.020,.021,.020,.015,.018,.020,.021,.021,.021,.018,.018,.021\}$$
$$CDC(Consumer_{02}) = \{.021,.020,.021,.020,.015,.018,.020,.021,.021,.021,.018,.018,.021\}$$

....

$$A(Consumer_{50}) = \{.82,.90,.86,.87,.88,.92,.93,.88,.92,.88,.90,.84,.86\}$$
$$RAD(Consumer_{50}) = \{.019,.020,.020,.020,.022,.021,.020,.020,.021,.021,.021,.020,.020\}$$
$$CDC(Consumer_{50}) = \{.019,.020,.020,.020,.022,.021,.020,.020,.021,.021,.021,.020,.020\}$$

The result of RAD is the same as the one produced by CDC in this experiment since β was set as zero. t_{cdc_u} and t_{cdc_l} can be obtained as follows in order to verify if all QoS feedback can be treated as "similar".

$$t_{cdc\_u} = (.025,.025,025,025,025,025,025,025,025,025,025,025,025)$$
$$t_{cdc\_l} = (.015,.015,015,015,015,015,015,015,015,015,015,015,015)$$

As a result, we can conclude that the consumers have shared similar opinions on the definitions of QoS terms. Therefore, the fifty wsa_{hbs}^k (k = 1 ~ 50) were treated and classified into a group consensus.

5.2 Preference Analysis via RMGDP

RMGDP is employed to identify the possible compromised preference order from their diverse preferences. Assume the order preference for the fifty wsa_{hbs}^k (k = 1 ~ 50) are denoted as ($o_{hbs}^1, o_{hbs}^2, o_{hbs}^3$ ….., o_{hbs}^{50}) with corresponding preference orders shown as follow:

$$o_{hbs}^1 = \{a_8, a_3, a_7, a_4, a_1, a_9, a_{11}, a_6, a_5, a_2, a_{12}, a_{13}, a_{10}\}$$

$$o_{hbs}^2 = \{a_3, a_8, a_4, a_7, a_{11}, a_5, a_1, a_6, a_9, a_{12}, a_2, a_{13}, a_{10}\}$$

$$o_{hbs}^3 = \{a_7, a_4, a_8, a_3, a_5, a_{11}, a_2, a_6, a_9, a_{13}, a_{10}, a_{12}, a_1\}$$

....

$$o_{hbs}^{50} = \{a_8, a_{13}, a_{11}, a_9, a_6, a_7, a_5, a_3, a_1, a_4, a_2, a_{12}, a_{10}\}$$

Using the ($o_{hbs}^1, o_{hbs}^2, o_{hbs}^3$ ….., o_{hbs}^{50}), the (p^1, p^2, p^3 ……, p^{50}) can be obtained via transformation phase of RMGDP as below:

$$p^1 = \begin{bmatrix} .50 & .71 & .38 & .46 & .67 & .63 & .42 & .33 & .54 & .83 & .58 & .75 & .79 \\ .29 & .50 & .17 & .25 & .46 & .42 & .21 & .13 & .33 & .63 & .38 & .54 & .58 \\ .63 & .83 & .50 & .58 & .79 & .75 & .54 & .46 & .67 & .96 & .71 & .88 & .92 \\ .54 & .75 & .42 & .50 & .71 & .67 & .46 & .38 & .58 & .88 & .63 & .79 & .83 \\ .33 & .54 & .21 & .29 & .50 & .46 & .25 & .17 & .38 & .67 & .42 & .58 & .63 \\ .38 & .58 & .25 & .33 & .54 & .50 & .29 & .21 & .42 & .71 & .46 & .63 & .67 \\ .58 & .79 & .46 & .54 & .75 & .71 & .50 & .42 & .63 & .92 & .67 & .83 & .88 \\ .67 & .88 & .54 & .63 & .83 & .79 & .58 & .50 & .71 & 1.0 & .75 & .92 & .96 \\ .46 & .67 & .33 & .42 & .63 & .58 & .38 & .29 & .50 & .79 & .54 & .71 & .75 \\ .17 & .38 & .04 & .13 & .33 & .29 & .08 & .00 & .21 & .50 & .25 & .42 & .46 \\ .42 & .63 & .29 & .38 & .58 & .54 & .33 & .25 & .46 & .75 & .50 & .67 & .71 \\ .25 & .46 & .13 & .21 & .42 & .38 & .17 & .08 & .29 & .58 & .33 & .50 & .54 \\ .21 & .42 & .08 & .17 & .38 & .33 & .13 & .04 & .25 & .54 & .29 & .46 & .50 \end{bmatrix}$$

$$p^2 = \begin{bmatrix} .50 & .67 & .25 & .33 & .42 & .54 & .38 & .29 & .58 & .75 & .46 & .71 & .63 \\ .33 & .50 & .08 & .17 & .25 & .38 & .21 & .13 & .42 & .58 & .29 & .54 & .46 \\ .75 & .92 & .50 & .58 & .67 & .79 & .63 & .54 & .83 & 1.0 & .71 & .96 & .88 \\ .67 & .83 & .42 & .50 & .58 & .71 & .54 & .46 & .75 & .92 & .63 & .88 & .79 \\ .58 & .75 & .33 & .42 & .50 & .63 & .46 & .38 & .67 & .83 & .54 & .79 & .71 \\ .46 & .63 & .21 & .29 & .38 & .50 & .33 & .25 & .54 & .71 & .42 & .67 & .58 \\ .63 & .79 & .38 & .46 & .54 & .67 & .50 & .42 & .71 & .88 & .58 & .83 & .75 \\ .71 & .88 & .46 & .54 & .63 & .75 & .58 & .50 & .79 & .96 & .67 & .92 & .83 \\ .42 & .58 & .17 & .25 & .33 & .46 & .29 & .21 & .50 & .67 & .38 & .63 & .54 \\ .25 & .42 & .00 & .08 & .17 & .29 & .13 & .04 & .33 & .50 & .21 & .46 & .38 \\ .54 & .71 & .29 & .38 & .46 & .58 & .42 & .33 & .63 & .79 & .50 & .75 & .67 \\ .29 & .46 & .04 & .13 & .21 & .33 & .17 & .08 & .38 & .54 & .25 & .50 & .42 \\ .38 & .54 & .13 & .21 & .29 & .42 & .25 & .17 & .46 & .63 & .33 & .58 & .50 \end{bmatrix}$$

$$p^3 = \begin{bmatrix} .50 & .25 & .13 & .04 & .17 & .29 & .00 & .08 & .33 & .42 & .21 & .46 & .38 \\ .75 & .50 & .38 & .29 & .42 & .54 & .25 & .33 & .58 & .67 & .46 & .71 & .63 \\ .88 & .63 & .50 & .42 & .54 & .67 & .38 & .46 & .71 & .79 & .58 & .83 & .75 \\ .96 & .71 & .58 & .50 & .63 & .75 & .46 & .54 & .79 & .88 & .67 & .92 & .83 \\ .83 & .58 & .46 & .38 & .50 & .63 & .33 & .42 & .67 & .75 & .54 & .79 & .71 \\ .71 & .46 & .33 & .25 & .38 & .50 & .21 & .29 & .54 & .63 & .42 & .67 & .58 \\ 1.0 & .75 & .63 & .54 & .67 & .79 & .50 & .58 & .83 & .92 & .71 & .96 & .88 \\ .92 & .67 & .54 & .46 & .58 & .71 & .42 & .50 & .75 & .83 & .63 & .88 & .79 \\ .67 & .42 & .29 & .21 & .33 & .46 & .17 & .25 & .50 & .58 & .38 & .63 & .54 \\ .58 & .33 & .21 & .13 & .25 & .38 & .08 & .17 & .42 & .50 & .29 & .54 & .46 \\ .79 & .54 & .42 & .33 & .46 & .58 & .29 & .38 & .63 & .71 & .50 & .75 & .67 \\ .54 & .29 & .17 & .08 & .21 & .33 & .04 & .13 & .38 & .46 & .25 & .50 & .42 \\ .63 & .38 & .25 & .17 & .29 & .42 & .13 & .21 & .46 & .54 & .33 & .58 & .50 \end{bmatrix}$$

…………………………………………………

$$p^{50} = \begin{bmatrix} .50 & .58 & .46 & .54 & .42 & .33 & .38 & .17 & .29 & .67 & .25 & .63 & .21 \\ .42 & .50 & .38 & .46 & .33 & .25 & .29 & .08 & .21 & .58 & .17 & .54 & .13 \\ .54 & .63 & .50 & .58 & .46 & .38 & .42 & .21 & .33 & .71 & .29 & .67 & .25 \\ .46 & .54 & .42 & .50 & .38 & .29 & .33 & .13 & .25 & .63 & .21 & .58 & .17 \\ .58 & .67 & .54 & .63 & .50 & .42 & .46 & .25 & .38 & .75 & .33 & .71 & .29 \\ .67 & .75 & .63 & .71 & .58 & .50 & .54 & .33 & .46 & .83 & .42 & .79 & .38 \\ .63 & .71 & .58 & .67 & .54 & .46 & .50 & .29 & .42 & .79 & .38 & .75 & .33 \\ .83 & .92 & .79 & .88 & .75 & .67 & .71 & .50 & .63 & 1.0 & .58 & .96 & .54 \\ .71 & .79 & .67 & .75 & .63 & .54 & .58 & .38 & .50 & .88 & .46 & .83 & .42 \\ .33 & .42 & .29 & .38 & .25 & .17 & .21 & .00 & .13 & .50 & .08 & .46 & .04 \\ .75 & .83 & .71 & .79 & .67 & .58 & .63 & .42 & .54 & .92 & .50 & .88 & .46 \\ .38 & .46 & .33 & .42 & .29 & .21 & .25 & .04 & .17 & .54 & .13 & .50 & .08 \\ .79 & .88 & .75 & .83 & .71 & .63 & .67 & .46 & .58 & .96 & .54 & .92 & .50 \end{bmatrix}$$

As the default value set in QoS Fuzzy Moderator, the initial weight value w_i in equation (7) will be set as:

For each $w_i = 0.02$, (i = 1 ... 50)

Therefore, the collective preference p^c can be obtained as:

$$p^c = \begin{bmatrix} .50 & .55 & .41 & .44 & .49 & .43 & .38 & .39 & .45 & .49 & .47 & .56 & .59 \\ .45 & .50 & .36 & .39 & .44 & .38 & .34 & .34 & .40 & .44 & .43 & .51 & .54 \\ .59 & .64 & .50 & .53 & .57 & .52 & .47 & .47 & .53 & .58 & .56 & .65 & .67 \\ .56 & .61 & .47 & .50 & .55 & .49 & .44 & .45 & .51 & .55 & .53 & .62 & .65 \\ .52 & .56 & .43 & .46 & .50 & .44 & .40 & .40 & .46 & .51 & .49 & .58 & .60 \\ .57 & .62 & .49 & .51 & .56 & .50 & .46 & .46 & .52 & .56 & .55 & .64 & .66 \\ .62 & .67 & .53 & .56 & .60 & .54 & .50 & .50 & .56 & .61 & .59 & .68 & .70 \\ .61 & .66 & .53 & .55 & .60 & .54 & .50 & .50 & .56 & .60 & .59 & .68 & .70 \\ .56 & .60 & .47 & .50 & .54 & .48 & .44 & .44 & .50 & .55 & .53 & .62 & .64 \\ .51 & .56 & .42 & .45 & .50 & .44 & .39 & .40 & .46 & .50 & .48 & .57 & .60 \\ .53 & .58 & .44 & .47 & .51 & .45 & .41 & .41 & .47 & .52 & .50 & .59 & .61 \\ .44 & .49 & .35 & .38 & .42 & .37 & .32 & .32 & .38 & .43 & .41 & .50 & .52 \\ .41 & .46 & .33 & .35 & .40 & .34 & .30 & .30 & .36 & .40 & .39 & .48 & .50 \end{bmatrix}$$

According to equation (9)(10), the QGNDD for each QoS attribute can be represented as below:

$$QGNDD\,(a_1) = F_Q\left(1 - d^c_{02\_01}, 1 - d^c_{03\_01}, \cdots, 1 - d^c_{13\_01}\right)$$
$$QGNDD\,(a_2) = F_Q\left(1 - d^c_{01\_02}, 1 - d^c_{03\_02}, \cdots, 1 - d^c_{13\_02}\right)$$

…………………………………………………

$$QGNDD\,(a_{13}) = F_Q\left(1 - d^c_{01\_13}, 1 - d^c_{02\_13}, \cdots, 1 - d^c_{13\_12}\right)$$

According to equation (11), the QGNDD for each QoS attribute can be represented as below:

$$QGDD\,(a_1) = F_Q\left(p^c_{01\_02}, p^c_{01\_03}, \cdots, p^c_{01\_13}\right)$$
$$QGDD\,(a_2) = F_Q\left(p^c_{02\_01}, p^c_{02\_03}, \cdots, p^c_{02\_13}\right)$$

…………………………………………………

$$QGDD\,(a_{13}) = F_Q\left(p^c_{13\_01}, p^c_{13\_02}, \cdots, p^c_{13\_12}\right)$$

According to equation (9)(10)(11), the initial weight value w_i for each b_i in QoS Fuzzy Moderator will be set as 0.083. This demonstrates that QGNDD and QGDD for all QoS attributes can be fairly assessed without any bias.

Therefore, the evaluation for thirteen QoS attributes via both QGNDD and QGDD can be represented in Table 3:

QGNDD		QGDD Evaluation
Evaluation	**UND Occurs**	
0.75	a_2, a_4, a_{10}, a_{12}	0.47
0.62	a_{10}, a_{12}	0.42
0.80	a_1, a_2, a_4, a_{10}, a_{12}	0.56
0.70	a_1, a_3, a_{10}, a_{12}	0.53

0.87	a_1, a_2, a_3, a_4, a_{10}, a_{12}	0.49
0.93	a_1, a_2, a_3, a_4, a_5, a_7, a_{10}, a_{12}	0.55
0.89	a_1, a_2, a_3, a_4, a_5, a_{10}, a_{12}	0.59
1.00	All the other attributes	0.59
0.96	a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_{10}, a_{12}	0.53
0.46	No UND Occurs	0.48
0.98	a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_9, a_{10}, a_{12}	0.50
0.54	No UND Occurs	0.40
0.99	a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_9, a_{10}, a_{11}, a_{12}	0.37

Table 3: The QoS Preference Order Evaluation for Hotel Booking Web Service via QGNDD / QGDD

In this case, a number of UND situations occur in the QGNDD analysis shown in the following result.

$$o^c_{hbs} = \{a_7 = a_8, a_3, a_6, a_4 = a_9, a_{11}, a_5, a_{10}, a_1, a_2, a_{12}, a_{13}\}$$

The result shows that the consensus preference for a_7 is the same as a_8 and the consensus preference for a_4 is the same as a_9. The QGNDD analysis may not be able to produce complete order of the preferences. The auxiliary method, QGDD, is deployed to identify the complete order of consensus preferences. For the cases of a_7 vs. a_8 and a_4 vs. a_9, the preference order for QoS consensus via QGDD analysis in o^c_{hbs} is:

$$o^c_{hbs} = \{a_8, a_7, a_3, a_6, a_9, a_4, a_{11}, a_5, a_{10}, a_1, a_2, a_{12}, a_{13}\}$$

According to the opinions and preferences from fifty participated service consumers, the consensus of group preference order of QoS in hotel booking web service will be:

Integrity > Accuracy > Scalability > Exception Handling > Accessibility > Capacity > Interoperability > Robustness > Availability > Performance > Reliability > Security > Network-Related QoS Requirement: The degree of User Friendly

The representation of the web service information can be organized according to the order of QoS attributes, The obtained order of preference helps QCMA perform more effective web service selection.

The resulting consensus, however, is domain dependent and is subject to the members and number of the participants. However, the proposed approach provides an effective and efficient approach by allowing them to reach consensus over the QoS characteristics. This is particular useful in service selection wherein a large number of web services (with similar functional characteristics) are available. Without having consensus on the characteristics of QoS, the selection process may not be effective.

6. Conclusion

The work in this paper focused on the QoS-based web services selection. It proposes a QoS Consensus Moderation Approach (QCMA) in order to perform QoS consensus and to alleviate the differences on QoS characteristics in the web services selection. The proposed QCMA possesses the following features.

1. QCMA is a web service selection mechanism based on fuzzy QoS consensus for a group of participants. The architecture allows them to reach QoS consensus by including a number of activities such as participants' opinion similarity, QoS term preference ordering and QoS fuzzy scale for each QoS term. The contribution of QCMA not only includes the fuzzy inquiry for service selection, but also offers the features to model the QoS preference consensus after aggregating sufficient *wsa*.

2. QCMA is designed for open and dynamic web environment, such that new opinions and preferences as well as new QoS aspects can be modeled flexibly.

Future work will focus on the investigation of other intelligent approaches such as neural networks, and genetic algorithms in order to improve weighting determination for alternatives preference orders in QCMA.

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	a11	a12	a13	a14	a21	a22	a23	a24	a31	a32	a33	a34	a41	a42	a43	a44	a51	a52	a53	a54	a61	a62	a63	a64	a71	a72	a73	a74
Consumer001	0	0	7	8	0	0	5	9	0	0	4	7	0	0	7	8	0	0	4	8	0	0	5	8	0	0	7	8
Consumer002	0	0	6	8	0	0	6	9	0	0	5	9	0	0	7	9	0	0	3	5	0	0	4	7	0	0	5	9
Consumer003	0	0	8	9	0	0	6	10	0	0	3	8	0	0	5	7	0	0	6	9	0	0	4	8	0	0	7	9
Consumer004	0	0	3	8	0	0	4	7	0	0	6	8	0	0	7	8	0	0	5	7	0	0	6	9	0	0	7	9
Consumer005	0	0	7	9	0	0	6	8	0	0	5	8	0	0	6	8	0	0	5	8	0	0	5	8	0	0	4	8
Consumer006	0	0	5	9	0	0	6	9	0	0	6	9	0	0	7	10	0	0	6	8	0	0	6	9	0	0	6	7
Consumer007	0	0	4	7	0	0	7	9	0	0	7	10	0	0	5	9	0	0	8	10	0	0	4	7	0	0	5	9
Consumer008	0	0	5	7	0	0	5	8	0	0	5	8	0	0	6	9	0	0	8	9	0	0	5	8	0	0	7	8
Consumer009	0	0	5	8	0	0	4	8	0	0	6	8	0	0	7	9	0	0	7	9	0	0	6	9	0	0	6	7
Consumer010	0	0	7	9	0	0	6	9	0	0	4	8	0	0	4	8	0	0	5	7	0	0	5	8	0	0	5	8
Consumer011	0	0	5	7	0	0	5	8	0	0	7	9	0	0	6	9	0	0	7	9	0	0	7	9	0	0	6	9
Consumer012	0	0	6	9	0	0	6	9	0	0	6	9	0	0	5	9	0	0	6	8	0	0	6	8	0	0	5	6
Consumer013	0	0	3	7	0	0	7	10	0	0	5	8	0	0	7	8	0	0	6	9	0	0	5	8	0	0	5	8
Consumer014	0	0	5	8	0	0	3	8	0	0	7	9	0	0	6	9	0	0	5	8	0	0	4	9	0	0	6	8
Consumer015	0	0	6	8	0	0	5	8	0	0	6	7	0	0	7	9	0	0	7	9	0	0	6	7	0	0	7	8
Consumer016	0	0	7	10	0	0	6	9	0	0	6	8	0	0	7	9	0	0	4	7	0	0	5	8	0	0	6	9
Consumer017	0	0	4	7	0	0	4	8	0	0	7	9	0	0	6	9	0	0	6	8	0	0	7	9	0	0	5	8
Consumer018	0	0	8	9	0	0	7	9	0	0	5	7	0	0	5	7	0	0	7	9	0	0	6	8	0	0	6	9
Consumer019	0	0	7	9	0	0	6	9	0	0	6	8	0	0	7	9	0	0	8	10	0	0	6	9	0	0	7	8
Consumer020	0	0	5	8	0	0	5	8	0	0	6	8	0	0	8	10	0	0	5	8	0	0	5	8	0	0	6	9
Consumer021	0	0	6	9	0	0	6	8	0	0	7	8	0	0	4	7	0	0	6	8	0	0	6	7	0	0	6	7
Consumer022	0	0	4	8	0	0	7	9	0	0	5	8	0	0	7	9	0	0	4	9	0	0	6	8	0	0	5	8
Consumer023	0	0	7	8	0	0	6	8	0	0	6	7	0	0	6	7	0	0	7	8	0	0	5	8	0	0	5	8
Consumer024	0	0	5	8	0	0	5	9	0	0	4	6	0	0	5	8	0	0	4	9	0	0	5	9	0	0	5	9
Consumer025	0	0	6	8	0	0	7	8	0	0	4	7	0	0	7	9	0	0	6	7	0	0	6	8	0	0	7	8
Consumer026	0	0	6	9	0	0	6	9	0	0	7	10	0	0	7	8	0	0	5	8	0	0	6	7	0	0	6	8
Consumer027	0	0	6	7	0	0	4	7	0	0	7	8	0	0	6	8	0	0	3	8	0	0	4	9	0	0	7	9
Consumer028	0	0	5	9	0	0	7	9	0	0	5	8	0	0	5	8	0	0	7	9	0	0	7	8	0	0	6	9
Consumer029	0	0	4	8	0	0	8	10	0	0	6	7	0	0	8	9	0	0	7	9	0	0	6	10	0	0	7	8
Consumer030	0	0	6	9	0	0	5	8	0	0	3	7	0	0	7	9	0	0	5	7	0	0	5	7	0	0	5	9
Consumer031	0	0	7	9	0	0	6	9	0	0	7	9	0	0	8	10	0	0	6	8	0	0	6	9	0	0	6	8
Consumer032	0	0	5	8	0	0	4	7	0	0	6	9	0	0	7	8	0	0	4	8	0	0	5	6	0	0	7	9
Consumer033	0	0	8	10	0	0	5	8	0	0	5	8	0	0	5	9	0	0	7	9	0	0	4	7	0	0	6	9
Consumer034	0	0	5	9	0	0	6	9	0	0	7	9	0	0	7	10	0	0	6	8	0	0	7	9	0	0	7	8
Consumer035	0	0	7	8	0	0	7	8	0	0	6	8	0	0	7	9	0	0	5	8	0	0	6	8	0	0	8	9
Consumer036	0	0	6	9	0	0	5	7	0	0	5	7	0	0	5	7	0	0	4	7	0	0	5	7	0	0	6	7
Consumer037	0	0	7	9	0	0	7	9	0	0	6	8	0	0	6	9	0	0	6	8	0	0	7	8	0	0	4	9
Consumer038	0	0	5	8	0	0	8	9	0	0	4	8	0	0	4	7	0	0	5	9	0	0	6	8	0	0	5	8
Consumer039	0	0	7	9	0	0	4	8	0	0	6	9	0	0	7	8	0	0	7	8	0	0	5	9	0	0	6	8
Consumer040	0	0	4	7	0	0	5	7	0	0	7	8	0	0	5	7	0	0	5	7	0	0	6	8	0	0	5	7
Consumer041	0	0	6	8	0	0	6	9	0	0	5	8	0	0	6	9	0	0	6	8	0	0	7	9	0	0	5	6
Consumer042	0	0	5	8	0	0	5	7	0	0	6	7	0	0	7	8	0	0	6	9	0	0	6	7	0	0	4	8
Consumer043	0	0	7	9	0	0	6	8	0	0	7	8	0	0	5	7	0	0	5	8	0	0	6	8	0	0	6	9
Consumer044	0	0	6	9	0	0	7	8	0	0	6	9	0	0	6	8	0	0	7	8	0	0	7	9	0	0	6	8
Consumer045	0	0	6	10	0	0	5	8	0	0	7	8	0	0	7	8	0	0	4	6	0	0	5	7	0	0	5	7
Consumer046	0	0	7	7	0	0	6	6	0	0	5	7	0	0	5	6	0	0	7	9	0	0	6	7	0	0	7	8
Consumer047	0	0	5	6	0	0	8	8	0	0	6	8	0	0	6	8	0	0	6	9	0	0	5	6	0	0	5	8
Consumer048	0	0	4	8	0	0	7	9	0	0	7	8	0	0	7	8	0	0	5	8	0	0	7	8	0	0	6	7
Consumer049	0	0	7	9	0	0	5	8	0	0	6	8	0	0	6	9	0	0	7	8	0	0	4	9	0	0	5	9
Consumer050	0	0	8	9	0	0	6	9	0	0	7	9	0	0	5	8	0	0	6	9	0	0	6	8	0	0	6	8

Table 1: The Opinion of QoS in QCMA (1): From attribute 1 ~ 7

	a81	*a82*	*a83*	*a84*	*a91*	*a92*	*a93*	*a94*	*aa1*	*aa2*	*aa3*	*aa4*	*ab1*	*ab2*	*ab3*	*ab4*	*ac1*	*ac2*	*ac3*	*ac4*	*ad1*	*ad2*	*ad3*	*ad4*
Consumer001	0	0	3	8	0	0	6	9	0	0	9	10	0	0	6	7	0	0	4	8	0	0	6	9
Consumer002	0	0	6	8	0	0	5	7	0	0	6	9	0	0	7	10	0	0	7	9	0	0	4	7
Consumer003	0	0	5	8	0	0	5	7	0	0	6	9	0	0	3	7	0	0	5	7	0	0	6	9
Consumer004	0	0	4	7	0	0	7	10	0	0	5	7	0	0	3	8	0	0	6	9	0	0	4	7
Consumer005	0	0	7	9	0	0	6	8	0	0	6	8	0	0	6	8	0	0	5	6	0	0	6	8
Consumer006	0	0	6	8	0	0	5	7	0	0	6	9	0	0	6	7	0	0	6	8	0	0	4	9
Consumer007	0	0	7	9	0	0	4	8	0	0	5	7	0	0	5	8	0	0	4	7	0	0	5	7
Consumer008	0	0	5	7	0	0	6	8	0	0	6	9	0	0	4	8	0	0	5	6	0	0	6	8
Consumer009	0	0	6	8	0	0	5	7	0	0	5	7	0	0	5	6	0	0	5	7	0	0	4	7
Consumer010	0	0	8	10	0	0	6	9	0	0	5	7	0	0	4	8	0	0	4	8	0	0	5	8
Consumer011	0	0	6	8	0	0	5	8	0	0	3	8	0	0	7	9	0	0	5	7	0	0	3	8
Consumer012	0	0	7	7	0	0	5	7	0	0	6	7	0	0	6	8	0	0	3	6	0	0	5	8
Consumer013	0	0	5	8	0	0	6	8	0	0	5	8	0	0	5	7	0	0	6	7	0	0	6	7
Consumer014	0	0	6	9	0	0	4	8	0	0	6	8	0	0	4	7	0	0	5	8	0	0	4	7
Consumer015	0	0	4	7	0	0	5	8	0	0	7	9	0	0	5	8	0	0	4	7	0	0	5	7
Consumer016	0	0	4	7	0	0	6	7	0	0	5	8	0	0	7	9	0	0	3	6	0	0	5	8
Consumer017	0	0	5	7	0	0	5	8	0	0	6	8	0	0	5	6	0	0	4	7	0	0	5	6
Consumer018	0	0	3	8	0	0	7	9	0	0	6	7	0	0	6	7	0	0	4	8	0	0	6	7
Consumer019	0	0	7	8	0	0	6	8	0	0	7	8	0	0	5	9	0	0	5	7	0	0	5	8
Consumer020	0	0	6	7	0	0	5	8	0	0	7	8	0	0	5	8	0	0	4	6	0	0	4	5
Consumer021	0	0	7	9	0	0	4	7	0	0	8	10	0	0	6	7	0	0	6	7	0	0	5	6
Consumer022	0	0	6	8	0	0	5	8	0	0	6	8	0	0	4	6	0	0	4	8	0	0	4	8
Consumer023	0	0	5	7	0	0	6	6	0	0	5	9	0	0	7	9	0	0	5	7	0	0	6	6
Consumer024	0	0	4	8	0	0	3	8	0	0	7	8	0	0	5	8	0	0	3	6	0	0	5	8
Consumer025	0	0	6	9	0	0	6	8	0	0	4	7	0	0	4	9	0	0	4	7	0	0	4	5
Consumer026	0	0	5	7	0	0	5	8	0	0	6	8	0	0	8	10	0	0	5	8	0	0	5	7
Consumer027	0	0	7	8	0	0	4	7	0	0	5	7	0	0	5	9	0	0	4	6	0	0	4	7
Consumer028	0	0	6	9	0	0	5	7	0	0	6	9	0	0	6	7	0	0	6	7	0	0	3	6
Consumer029	0	0	5	8	0	0	6	8	0	0	7	8	0	0	6	7	0	0	5	7	0	0	5	8
Consumer030	0	0	6	7	0	0	4	8	0	0	5	6	0	0	5	8	0	0	5	6	0	0	6	7
Consumer031	0	0	4	8	0	0	5	7	0	0	6	7	0	0	4	7	0	0	4	7	0	0	5	8
Consumer032	0	0	6	9	0	0	6	8	0	0	7	8	0	0	5	8	0	0	3	8	0	0	4	6
Consumer033	0	0	5	7	0	0	4	7	0	0	5	8	0	0	6	7	0	0	4	6	0	0	5	7
Consumer034	0	0	4	6	0	0	5	7	0	0	7	9	0	0	6	9	0	0	5	7	0	0	6	8
Consumer035	0	0	7	8	0	0	4	8	0	0	5	8	0	0	4	6	0	0	5	8	0	0	5	7
Consumer036	0	0	6	8	0	0	5	8	0	0	6	8	0	0	5	7	0	0	6	7	0	0	4	8
Consumer037	0	0	6	9	0	0	6	7	0	0	7	8	0	0	5	9	0	0	6	9	0	0	5	7
Consumer038	0	0	6	8	0	0	4	7	0	0	6	7	0	0	7	8	0	0	4	6	0	0	6	8
Consumer039	0	0	5	9	0	0	7	8	0	0	6	7	0	0	6	7	0	0	5	7	0	0	5	6
Consumer040	0	0	6	8	0	0	5	7	0	0	4	8	0	0	5	8	0	0	6	8	0	0	4	9
Consumer041	0	0	5	9	0	0	6	8	0	0	7	8	0	0	6	9	0	0	5	6	0	0	6	8
Consumer042	0	0	4	7	0	0	5	8	0	0	6	7	0	0	5	7	0	0	4	7	0	0	5	8
Consumer043	0	0	6	8	0	0	5	8	0	0	5	6	0	0	6	8	0	0	5	8	0	0	5	7
Consumer044	0	0	5	9	0	0	6	8	0	0	4	7	0	0	5	9	0	0	6	9	0	0	4	8
Consumer045	0	0	6	7	0	0	6	8	0	0	5	8	0	0	6	8	0	0	5	7	0	0	5	7
Consumer046	0	0	7	8	0	0	7	7	0	0	6	7	0	0	5	8	0	0	4	8	0	0	6	8
Consumer047	0	0	5	7	0	0	6	8	0	0	6	7	0	0	6	9	0	0	5	8	0	0	5	5
Consumer048	0	0	6	6	0	0	5	6	0	0	4	7	0	0	6	9	0	0	6	9	0	0	4	6
Consumer049	0	0	5	7	0	0	6	7	0	0	3	7	0	0	6	8	0	0	4	7	0	0	5	7
Consumer050	0	0	7	8	0	0	5	8	0	0	7	8	0	0	5	9	0	0	5	9	0	0	6	8

Table 2: The Opinion of QoS in QCMA (2): From attribute 8 ~ 13