Real-time Environment Aware Web Service Selection and Evaluation

Feifei Wu, Jun Xu, Jiawei Lu, Gang Xiao, Yuanming Zhang
[1]College of Computer Science and Technology
Zhejiang University of Technology, China
feishyla@163.com, xujun, viivan, xg, zym @zjut.edu.cn

ABSTRACT: *Currently, the quality of service (QoS) of web services can not to be guaranteed, because the cloud environment lacks the ability to be real-time aware of their load capacity changes. For non-trusted and trusted web service providers may make the different service description of the meta-service, where exists deceit. As consumers may simultaneously invoke the same high quality service and thus it is very likely to occur that the users' access exceeds the load capacity of service. In this paper, we propose a service selection and evaluation method based on real-time environmental-aware. The service dispatch center proposed in this paper aims to select meta-service clusters by way of bidding and tendering to guarantee the QoS of the selected service. Meanwhile, the QoS aware module of each meta-service will make real-time perception of QoS to ensure web service with high real-time and high reliability. Furthermore, a QoS prediction algorithm is proposed to evaluate the promised reputation of the service providers. Extensive simulation results show that the method can achieve evaluation and forecast of QoS efficiently and provide an optimal web service for users.*

Keywords: Service Turbulence, Environmental-Aware, Bid and Tender, QoS Prediction Algorithm

Received: 23 June 2015, Revised 29 July 2015, Accepted 2 August 2015

1. Introduction

Web Service [1], a way of implementation for Service-Oriented Architecture (SOA) [2] technology is based on standards such as XML (Extension Markup Language), WSDL (Web Services Description Language) and SOAP (Simple Object Access Protocol). The core of Web Service employs standard interfaces and when the interfaces meet the standard, they communicate with each other.

The emergence of cloud computing [3] brought major research challenges in the process of selection and evaluation of web services. The key to success in obtaining a web service is helping consumers select optimal candidate service instances that achieves the maximum benefits between the service providers and consumers. QoS (Quality of Service) [4], an index set for description of service capability, has two properties, namely functional and descriptive properties [16]. The functional properties have a decisive influence on the service, including CPU utilization ratio, processing speed, memory, network bandwidth, packet loss rate etc. The descriptive properties have no decisive influence on the service, including deadline, response time, service execution time, reliability, price, etc.

However, there appear "service turbulence" [5, 6], i.e. the uncertainty of QoS causes a large deviation between the results of the service selection and the fact. This is mainly due to the uncertain of QoS in dynamic, open and multiple cloud environment. Applications which have extremely different characteristics and demands will compete for limited network resources, resulting in load imbalance, failing to respond to consumer requests timely and the decline of service capability. At the same time, the evaluation of the reputation of QoS is derived from historical experience generally and non-trusted web service providers may make the uncertain service description for the meta-service [15]. Meanwhile, the service dispatch center can't aware the changes of the nodes synchronously and form a stable reputation degree hardly. Inspired by this phenomenon, a service selection and evaluation method is proposed to select the best fitting service. Web services can evaluate their own capabilities to aware failure services real-timely and reliably. The reputation mentioned in this paper refers to the promised QoS that the meta-service can achieve. Meta-services obtain higher reputation as long as meta-services keep their promise, finally forcing dishonest meta-services to be honest and building a fair competition environment.

2. Related Work

The service selection and evaluation problem has been discussed in many studies:

In [5], it proposed that the QoS of service entity is characterized with different load QoS feature vectors and apply the load characteristic diagram to characterize of meta-service QoS characteristics comprehensively in order to select optimal candidate service. In [7], it proposed a service execution environment oriented service selection approach by establishing the mapping relationship between QoS of web services and environment states (server states and network states) to provide a service selection approach for consumers. In [8], it proposed a fast QoS-aware web service selection approach which adopts a particle swarm optimization algorithm select the most service with users' QoS requirements. In [9], it proposed a web service discovery model supporting QoS difference degree control to control the difference between the consumers' required values and offering data by providers and make a more accurate and objective reputation from service and service providers in the transaction process. In [10], it proposed a multi-user oriented load-aware dynamic service selection model which can adapt to the varied workload in a multi-user environment and provide an optimal service selection scheme while meeting the end-to-end QoS constraints. In [20], it proposed an approach for selecting services based on context-aware factors of QoS attributes.

However, the existing methods of service evaluation are a post assessment methods which fail to perceive the state of invalid service in time. Thus, we propose a service selection method based on the strategy of bidding and tendering with reputation evaluated in prior, which can provide a real-time perception of the state of meta-service and avoid the occurrence of load imbalance resulted by "service turbulence". At the same time, the QoS prediction algorithm proposed in this paper to predict whether the meta-services can achieve their promised QoS. Service predicted quality is provided by QoS perception module which make real-time response to monitor the changes of meta-services' quality. Promised reputation proposed in this paper which ensure the quality of service predictable according to actual situation. As long as services keep their promises, they can attain a higher reputation certainly.

3. Method and Framework

In diversity cloud environment, different meta-services may exist in different servers. It influences the implementation effect of service greatly and service scheduler can't perceive the QoS synchronously. At present, the reputation proposed in many literatures refers to whether the service could satisfy the requirements and only based on the historical experience. The "service turbulence" caused by environmental change affects the execution efficiency of the meta-services directly. Therefore, in this section, we propose a service selection and evaluation framework based on the bidding and tendering. The framework of our proposed is shown in Figure 1.

Our notations are introduced in Table I.

The framework contains three components including SDC, SRC and SL, two steps including service design step and service execution step, a key algorithm, i.e. QoSPA and a model which is QoSEM.

The responsibility of SDC can be divided into three parts: the decomposition of user's requirement, service scheduling and reputation library for management. SRC is used to manage the sequence of the bid meta-services clusters and make a real-time perception of QoS. SL is used to store meta-services.

Symbols	Meaning
SDC	Service Dispatch Center
SRC	Service Registry Center
SL	Service Library
QoSPA	QoS Prediction Arithmetic
QoSEM	QoS Evaluation Model
MS	A single service which completes a single service request
MSC	Meta Composite Services
MD	The demands that are completed by meta-service or meta-service composition
CD	Consumer Demand
MSS^i	A set of MSs which meet the needs of meta-demand group

Table 1. Notations

The lifetime of service can be divided into two stages: the first stage is the design step which generates queue of services based on the meta-demand of the consumers. The second step is the execution stage which selects the best service from queue and execute it.

In the service design step, QoSPA collects feedback information from meta-service node, analyzes and calculates information and sorts the results of the bidding services. In the execution step, QoSPA generates pre-invoke meta-service queues and makes timely adjustment if the quality change with real-time perception. After invoking, QoSAM collects the actual properties of QoS, QoSPA compares with the bidding indexes and update reputation library. In the service design step, QoSEM evaluates the promised reputation of service providers and calculates the benefit value of the bidding service. In the service execution step, the change attributes of bid services will be monitored by QoSEM and calculate real-time benefit values.

Step 1: When SDC receives the consumer requirements, analyzes the CD. If it is a meta-service demand, there is no need to divide. Else if the demand is composite services, CD is required to be decomposed into MDs. Any requirement that is not provided by MS or MCS is required to change into MDs completed by multiple MCSs.

Step 2: SDC calls for bids according with transformed MDs. The index of QoS of bidding service includes the functional requirements and descriptive requirements, e.g. service performance, service price ceiling, service load. SDC broadcast the MD to MS who has registered in SRC.

Step 3: Received the SDC bid invitation, the satisfactory MS will bid and SRC will add the bidding MS into MSS^i . Otherwise, MS will make a feedback to reject directly.

Step 4: Each MS in contains a QoSAM which makes a real-time perception of service itself, including the expected time, failure time, price and reliability. Among which the expected time is also determined by service node performance, load and network environment.

Step 5~6: SDC collects the bidding information in MSS^i which provided by QoSAM. The QoSEM will analyze and compute the bidding information to attain the bidding benefit value. The previous evaluation results of MS are stored in reputation library which located in SRC. QoSPA will compute based on the bidding benefit value and historic reputation of MS. If the bidding index is excellent, but has a low historical trust, then its QoS forecast result will be lowered. If MS has high reputation, its QoS predicted result will get a higher trust.

Step 7~8: SDC transforms the service composition into a service invocation workflow whose nodes are composed of meta-service sequences. Meta-service sequences are composed of the same functionality meta-services with the specific bidding capacity. They are collected by SDC and QoSPA sorts the bidding services based on QoS forecast results.

Step 9: SDC performs according to service workflow, the optimal service will be invocated when reaching the certain node. While QoSAM perceives a greater decline of the bidding service' QoS, it informs SDC with real-time QoS and QoSPA re-ranks the meta-service sequence according to the feedback value.

Step 10: After the invocation, QoSAM collects the completed information of the winning services. QoSAM calculates the actual reputation by comparing between service bidding QoS and service actual QoS. Finally, updating reputation library.

Steps (1) ~ (8) belong to service design step and step (9) is the execution step.

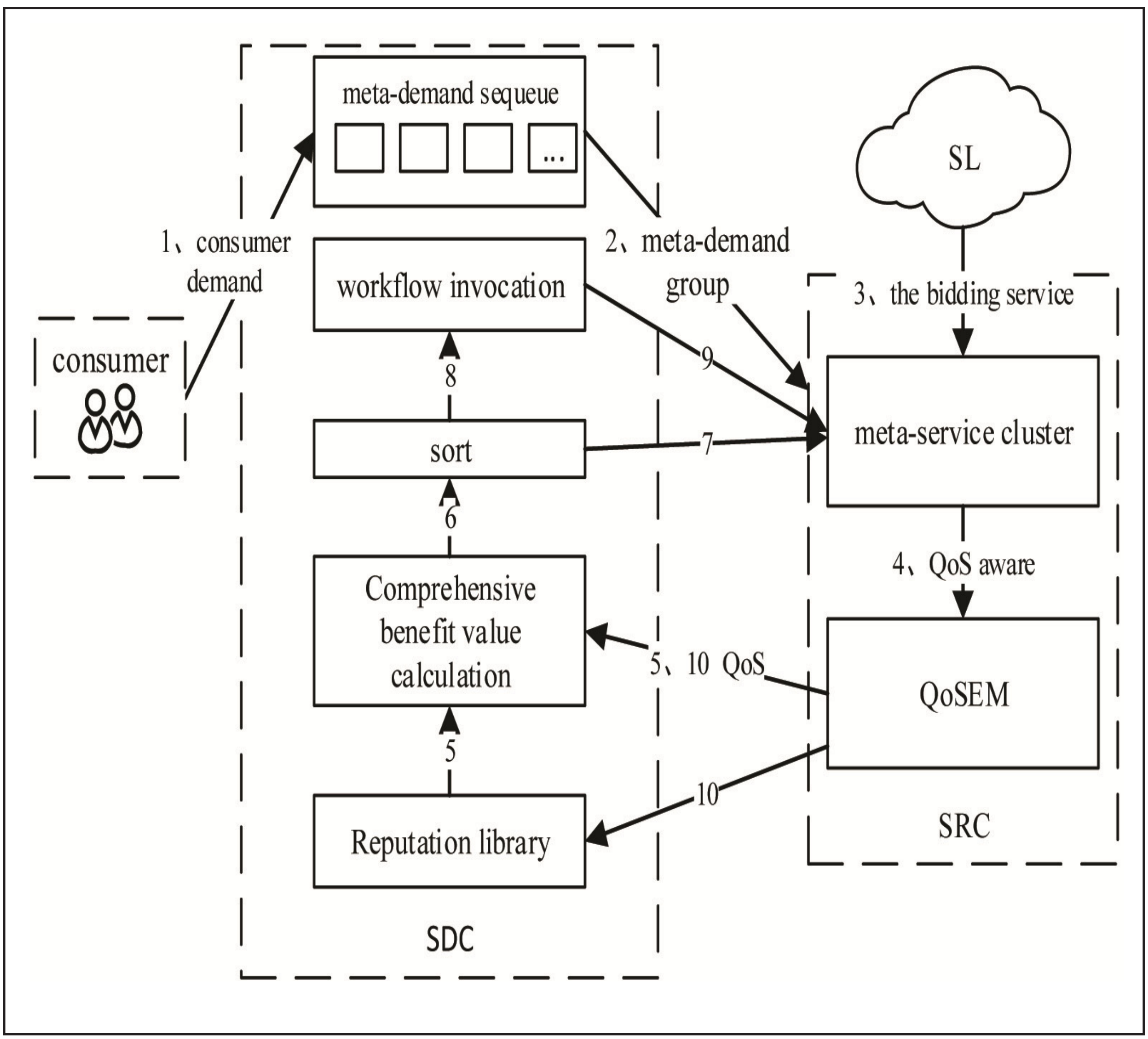

Figure 1. Service selection framework

The feature of the service selection framework represents a high level of real-time of the service select both in service design step and in execution step. In service design step, QoSAM is used to perceive the index of QoS of bidding service. Meanwhile, QoSPA sort the meta-service sequence in each node based on bidding information and historical reputation. In the service execution step, when the QoS of meta-service of the non-executed nodes appears to decline, QoSAM will perceive the changes timely and make a feedback to SDC. Thus, QoSPA recalculates the predicted value according to the feedback value and re-ranks the meta-service sequence in the service nodes.

4. Model and Algrithm

The key algorithm in service selection framework is QoSPA. QoSEM normalizes the QoS and calculate the benefit value. The whole framework is realized based on the service selection model of environmental-aware, as shown in Fig. 2.

4.1 QoS Evaluation Model

QoS attributes which have higher exposure rate include performance, price, reliability, availability, etc. [11, 12] In this paper, we mainly consider the QoS attributes related to environmental perception and reputation, including response time, reliability, availability, cost and reputation, etc.

The QoS attributes of Web Service can be divided into positive attributes and negative attributes [13]: the positive attributes show positive correlation with user satisfaction, e.g. availability. The negative attributes show a negative correlation with user satisfaction, e.g. price.

During the period of service bidding, SRC will form a meta-service sequence with those meta-services meet the CDs. The bidding meta-service sequence are in (1).

$$Q_{all}^{response} = \begin{pmatrix} q_{s_1}^{1} & \cdots & q_{s_1}^{u} \\ \vdots & \ddots & \vdots \\ q_{s_i}^{1} & \cdots & q_{s_i}^{u} \end{pmatrix} \qquad (1)$$

In the matrix, $q_{s_i}^{u}$ refers to the evaluation of the QoS attribute u in meta-service S_i.

According to the QoS benefits value calculation [19], comprehensive benefits value of each service in meta-service sequence can be obtained in (2):

$$\varphi^{response} = [\varphi_{S_1}, \varphi_{S_2}, ..., \varphi_{S_i}] \qquad (2)$$

In the service execution step, we can obtain the real-time QoS attributes of each bidding service by way of QoSAM. Thus, a similar matrix is concluded as shown in (3):

$$Q_{all}^{monitor} = \begin{pmatrix} q_{s_1}^{ti,1} & \cdots & q_{s_1}^{ti,u} \\ \vdots & \ddots & \vdots \\ q_{s_i}^{ti,1} & \cdots & q_{s_i}^{ti,u} \end{pmatrix} \qquad (3)$$

In the matrix, $q_{s_i}^{t_i,u}$ refers to the evaluation of the QoS attribute u in meta-service S_i at time t_i.

According to benefits calculation formula, we can obtain the comprehensive benefits value by monitoring each bidding service as shown in (4):

$$\varphi_{t_i}^{monitor} = [\varphi_{S_1}^{t_i}, \varphi_{S_2}^{t_i}, ..., \varphi_{S_i}^{t_i}] \quad (4)$$

Figure 2. Service selection model based on real-time environmental-aware

4.2 Service Selection Model Based on Environmental Aware

In the cloud environment, in order to avoid “service turbulence”, we proposed a service selection model based on environmental aware to make a real-time perception of QoS:

$$\begin{cases} Object\ maximize < \xi_{S_1}, \xi_{S_2} \cdots \xi_{S_i} >, & 1 \le i \le r \\ s.t.\ \xi_k\ (\mathrm{Q}_{s_1}^u, \cdots, Q_{s_i}^u) \le \xi_k\ (Q_u^{max}), & 1 \le k \le r \\ \xi_{S_i} = \sigma(\xi_{S_i^1}, \cdots, \xi_{S_i^t}), & 1 \le i \le r; 1 \le t \le r \\ Q_{s_i}^u = \sum_{i=1}^{t} \sum_{u=1}^{m} x_i^k q_{s_i}^u, & x_i^k = \{0,1\}; 1 \le k \le r \\ \{Md_1, Md_2 \cdots Md_n\} = divide\ in\ UC, & 1 \le n \le r \\ \{S_n^1, \cdots, S_n^t\} \xrightarrow{Md_n} SL, & 1 \le n \le r \end{cases} \quad (5)$$

Md_n refers to the demand after decomposition of CD that can be completed by a single meta-service or meta-service composition.

S^t_n refers to the meta-service that meets the needs of Md_n.

$\xi_k\ (Q_{s_i}^u)$refers to the comprehensive benefits value of S_i which biding for the Md_n.

x^k_i is a Boolean variable refers that whether S_i is chosen while the task k is executed.

$\xi_k(Q_u^{max})$ refers to the maximum of comprehensive benefits value of bidding service which meet the requirements k. (Assume that all attributes are converted into positive attributes.)

The goal of model is to find an optimal sequence to make sure that whether in service design step or in execution step, the comprehensive benefits value of actual invoked service must be optimal. The constraint condition is the QoS attributes that meet the requirements of meta-services need to satisfy the QoS in a global scope. However, the network environment is always changing, which influences the implementation effect of composite services greatly. When service nodes get aware of QoS decline, the SDC can't percept synchronously. Hence, we proposed QoSPA based on service selection model.

4.3 QoS Prediction Algorithm
The QoSPA described by formal methods, as shown as follows:

Algorithm 1 SDC selects MSs among each meta-service sequence in MSS^i and the algorithm offers an optimal MS group.

Input: the QoS matrix (1) fed back by SQPM from each meta-service sequence in , the index of service Res_i and history reputation extracted from reputation library.

Output: Select the optimal meta-service in the cloud environment from each meta-service sequence.

1) SDC calls for bid according to MD and obtains the QoS attribute matrix (1) from the bidding meta-service sequence. Then, SDC gets the comprehensive benefits value matrix (2) according to benefit value calculation equation.

In order to avoid the interference of the historical reputation, time decay factor is introduced [17], i.e. the closer distance from the current moment, the reputation is more credible. The method of calculating the time decay factor will not be described here. We obtain the current time decay factor by using the method in [18]:

is the D-value between the moment of c and initial time.

$$\lambda_{t_c} = \Delta t_c \,/\, (\Delta t_c + \sum_{c=1}^{n} \Delta t_c)$$

Δt_c is the D-value between the moment of c and initial time.

Reputation evaluation matrix is calculated by followed formulas.

$$\overline{R_{S_i}^{t_c}} = \sum_{c=1}^{n} \sum_{i=1}^{m} \lambda_{t_c} \cdot R_{S_i}^{t_c}$$

$$R^{history} = [\overline{R_{S_1}^{t_c}}, \overline{R_{S_2}^{t_c}}, \cdots, \overline{R_{S_i}^{t_c}}]$$

The benefit value of each meta-service in the bidding matrix multiplied by the reputation evaluation matrix so as to obtain the comprehensive benefit value of each meta-service.

$$\xi_{S_i}^{weight} = \varphi_{S_i}^{response} \cdot R_{S_i}^{history}$$

Generate benefit value evaluation matrix of bidding meta-service sequence.

$$\xi_{S_i}^{weight} = [\xi_{S_1}^{weight}, \xi_{S_2}^{weight}, \ldots, \xi_{S_i}^{weight}]$$

In service design step, we select the optimal meta-service in each meta-service sequence to form meta-service scheduling workflow.

$$<S^1_{best1}, S^2_{best2}, \dots, S^i_{besti}>$$

2) In the service execution step, QoSAM makes a real-time perception of the quality change of each meta-service which non-executed in the meta-service sequence. We can obtain real-time QoS attribute matrix in (3), and then calculate the benefit value of each meta-service according to benefit value calculation formula and finally obtain benefit value matrix (4).

Calculate the change of the meta-service's benefit value in the sequence according to benefit value matrix.

$$\Delta\varphi^{t_i}_{S_i} = (\varphi^{t_i}_{S_i} - \varphi^{t_{i-1}}_{S_i}) \ / \ \varphi^{t_{i-1}}_{S_i}$$

Obtain the meta-service benefit value change matrix at the moment of t_i.

$$\Delta\varphi^{t_i}_{S} = [\Delta\varphi^{t_i}_{S_1}, \Delta\varphi^{t_i}_{S_2}, \cdots, \Delta\varphi^{t_i}_{S_i}]$$

If there are negative changes in $\Delta\varphi^{t_i}_{S_i}$, the comprehensive benefit value of each meta-service is recalculated. Update comprehensive benefit value matrix in time and get new meta-service scheduling workflow.

$$\xi^{newWeight}_{S_i} = \varphi^{current}_{S_i} \cdot R^{history}_{S_i}$$

Update benefit evaluation matrix. The service whose benefit value is optimal will be deemed as the winning service. After the service scheduling, the actual service benefit value of the winning service ($\varphi^{actual}_{S_i}$) is divided by the bidding benefit value ($\varphi^{response}_{S_i}$) to obtain the actual reputation of the winning service, which is added into reputation library.

5. Performance Evaluation

In this section, we design and conduct extensive simulations to evaluate the performance of proposed the service selection model. The simulation aims to solve the "service turbulence" and enable the selected service optimally under current environment.

This experiment adopts five common attributes of QoS: response time (RT), responsibility (Res), availability (Ava), cost (Fee) and reputation(R). The reputation of each MS is 1 at initial moment by Service Dispatch Center. With the increase of the scheduling times of the service, if the index of actual QoS is lower than service bidding value, the reputation will be lower so as that the chance to win the bid is decreased. Otherwise, the chance to win will increase for those who have high reputation. Through this experiment, the feasibility of the scheme is proved.

Parameter setting in this paper is similar to [2]. MS can be divided into high reputation MS and its interval is (1, 2), average reputation MS is as same as the initial reputation 1 and the low reputation MS and its interval is (0, 1). In a single experiment, the number of MS is 100, among which the number of high, average and low service are 30, 40 and 30 respectively, the demand is 50. The experiment needs to be performed for 100 times. In a single experiment, if one service wins the bid once again, the actual benefit value will decrease by 20% and the same service can only be invoked for 3 times at most to simulate the decreasing performance for the service load. Meanwhile, the "service turbulence" simulated by using QoS random values within the interval.

The simulation will evaluate the model proposed in this paper from the following aspects.

1) Changes of QoS with Same Meta-Service

SDC publishes the meta-demand $Md_1 \sim Md_{50}$ and calling for bids to MSs in MRC. The meta-services $S_1 \sim S_{100}$ which meets the requirement feed back to SDC with their bidding QoS. QoSEM calculates the bidding benefit values of each service. The actual value and the bidding value of the service are listed as shown in Table II.

Attributes	Response time (s) Reliability (%) Availability (%) Fee($)	
Number of scheduling	S_1 win the bidding for Md_1	S_1 win the bidding for Md_2
Actual QoS	(4, 60, 90, 5)	-
Actual benefit value	2.1	1.7
Bidding QoS	(5, 70, 85, 9)	(5, 70, 85, 9)
Bidding benefit value	2.8	2.8
Comprehensive benefit value	2.8	2.5
Historical reputation	1	0.9
Current reputation	0.8	0.6

Table 2. The Bidding QoS Attributes of Meta-service S_1

The maximum and minimum of $S_1 \sim S_{100}$ bidding attributes in Table II are (10, 95, 95, 10) and (2, 25, 15, 2) respectively. SDC publishes the meta-demand Md_1 and is the optimal bidding service in which the bidding benefit value is 2.8 and the historical reputation is 1. The comprehensive benefit value is 2.8, actual benefit value is 2.1 and the current reputation is 0.8 which will be recorded into reputation library; SDC publishes the meta-demand, wins the bid again. As wins for another time, its actual quality will decrease by 20 % on the original basis. Historical reputation is the weighted value of initial reputation and actual reputation which the scheduled each time. The comprehensive benefit value of is 2.5. The selection of meta-service is jointly determined by bidding benefit value and historical reputation.

In the process of service selection, if the bidding benefit value of the winning service is higher than actual benefit value, it will obtain a lower reputation and the chance for this service to win the bid next time will decline. Otherwise, Meta-service will obtain higher reputation that increase the chance to win the bid.

2) The result of reputation evaluation with different kind meta-services

Figure 3 shows the number of winning the bids in high reputation MS and low reputation MS. Fig. 3 illustrates that with the increasing interaction beatween SDC and each MS, the number of winning the bids of high reputation MS is increasing. Besides the chance to win the bids for the low reputation MS is decreasing. The changes are always in line with the actual situation.

Figure 4 shows the change trend of reputation for different MS. The initial reputation of each service is 1. Fig. 4 illustrates that with the increase times of execution, the trend of high reputation MS increase obviously and finally stand around 1.3. As in each experiment, if the service wins the bid once more, its actual benefit value will decrease by 20 %, so that the average reputation is lower than initial reputation. Low reputation service decline obviously in the initial period of the simulation. In the end, its reputation tends to 0.7.

3) Comparison between the service selection method in this paper and others

This simulation is compared with the optimal QoS of service selection algorithm (QoS_Best) [14]. The QoS_Best service selection algorithm selected a historical optimal service as the best service from the journal.

Figure 5 shows the comparison between QoS_Best and the method proposed in this paper. The traditional methods is

Figure 3. The service number of winning the bid

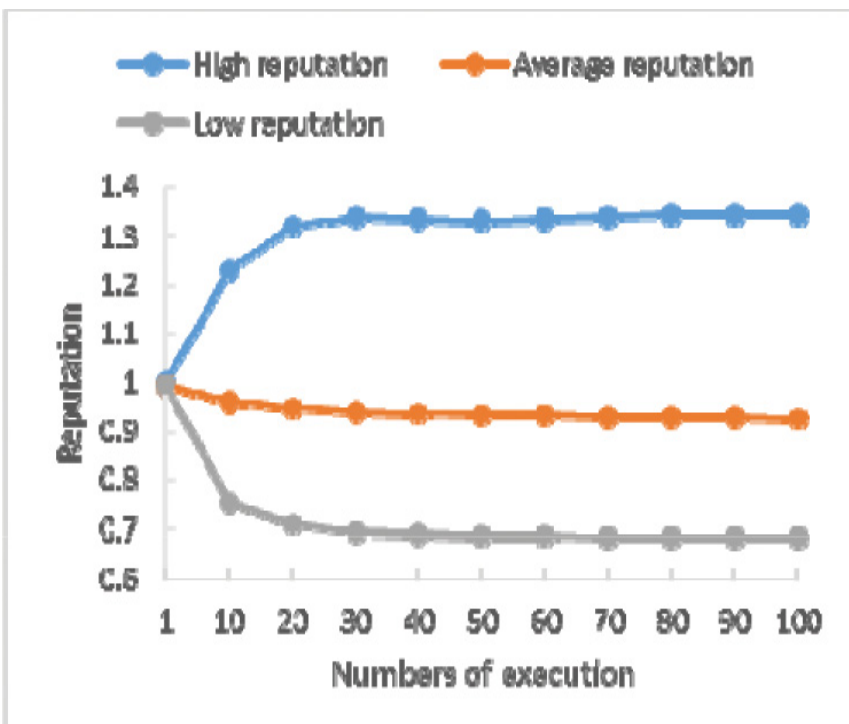

Figure 4. The change trend of reputation for different MS

hysteretic that fail to predict the "service turbulence" in advance. In this paper, we pre-predict the QoS and post-feedback of execution as the criterion to select service. Therefore, in the initial stage, two kinds of methods are indifference, but after a period of running, the QoS of selected service in this method has improved significantly and maintains a stable level. The proposed method is better than the traditional method which overcomes the "service turbulence".

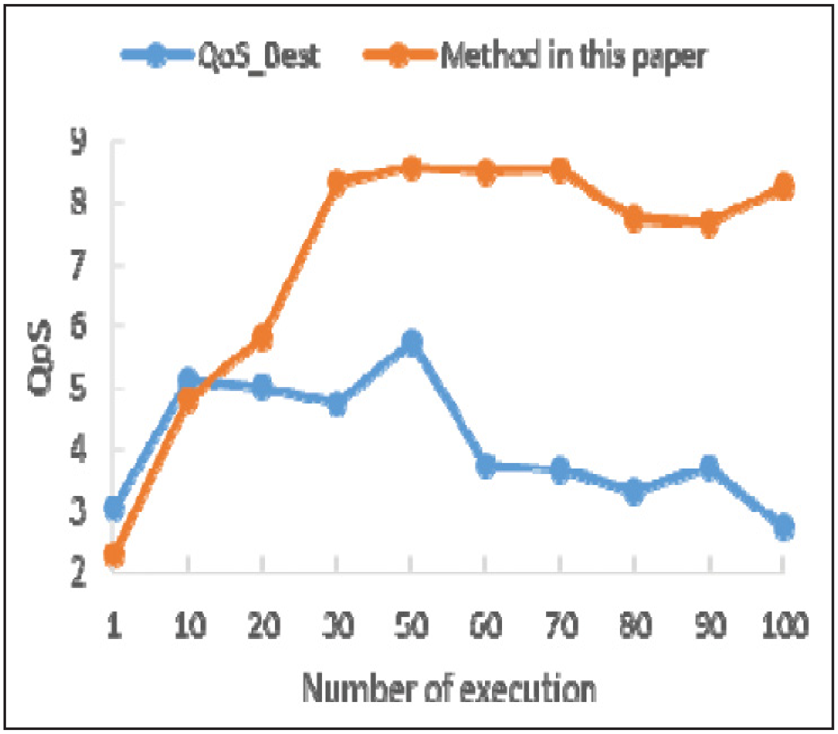

Figure 5. Comparison between the service selection method in this paper and QoS_Best

5. Conclusion

In this paper, we propose a service selection and evaluation method based on real-time environmental-aware. Different from traditional method, this method provides the prediction of QoS in real-time which is more accurate than those methods based on historical experience. The simulation results demonstrate that the proposed method is feasible and high real-time. It overcomes the deviation between the service selection results and the actual results.

Acknowledgment

This work was jointly supported by: (1) the Zhejiang Natural Science Foundation, China (No. LQ12F02016); (2) the Science and Technology Department Project of Zhejiang Province, China (No. 2014C31078ÿ2014C01048).

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