Journal of Theoretical and Applied Information Technology
10th June 2013. Vol. 52 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

SERVICE RESPONSE WITH OPTIMAL QOS IN SERVICE CLUSTER SCHEMA

[1,2]QIANG HU, [1]YUYUE DU
[1, 2]College of Information Science and Engineering, Shandong University of Science and Technology, Qingdao 266590, China,
[2] School of Information Science and Technology, Qingdao University of Science and Technology, Qingdao 266061, China
E-mail: [1] huqiang200280@163.com , [2] yydu001@163.com

ABSTRACT

The large amount of Web services in internet brings more opportunities for the users, however, it also increases the difficulty to search and find an appropriate Web service for a service request since there are too many similar Web services. To reduce the search space and increase the flexibility of service response, a group of Web services with similar functions are mapped as a service cluster in this paper. A service request and response schema based on service cluster is proposed. The service request from a user is responded by a Web service or a service flow. The service architecture oriented on service clusters is presented and tow algorithms are designed to bind an appropriate Web service or a service flow with the optimal Qos under the service cluster schema. Simulation results show that efficiency is greatly increased in discovering services under service clusters schema, and the rediscovery time is also greatly decreased once the current working Web service is unavailable.

Keywords: *Web service, Quality of Service (QoS), Service Cluster, Flexibility, Service flow*

1. INTRODUCTION

With the development of Web service, the number of Web services on internet is surging rapidly. Different service providers have published a lot of Web service with similar functions. Though it provides more choices for the users, it also makes more difficult to select an appropriateWeb service. The current service schema is a single- service request and response, i.e. to bind one Web service for the service request. Once the binding Web service is unavailable or service request is changed slightly, a substitutable Web service is needed. It means to search an appropriate Web service for another time from the large numbers of similar Web services, and the rediscovery process is very complex and time consuming.

There are two problems that need to be solved in the current service request/response schema. One is how to quickly find an optimal Web service from numerous similar Web services. The other is how to improve the flexibility and self-adaptability of service response.

To reduce the search space and improve the flexibility of service response, a group of Web services with similar functions is mapped into a service cluster in this paper. The service cluster is the basic object to respond the service request, and a service response schema based on the service clusters is proposed. By enlarging the service grain, it can reduce the search space and improve the search efficiency and the flexibility of service response.

In previous studies, service group [1], service pool [2], service community [3], and service container [4] are provided by different researcher. The Web services in the above concepts are strictly required with the same interfaces. Although it can improve the search efficiency, it reduces flexibility and performance to some extent. Different with these concepts, we permit Web service with similar interfaces cluster as a group, thus it can greatly improve the flexibility of service response.

The rest of this paper is organized as follows. Section 2 introduces the concepts of Web service and service architecture oriented service clusters. Section 3 introduces service response with optimal Qos based on service clusters. Simulation experiment is presented in Section 4. Section 5 concludes this paper.

2. SERVICE ARCHITECTURE ORIENTED ON SERVICE CLUSTERS

Definition 1 (Web service)

A Web service is a 6-tuple Ws=(W_{Id}, W_{des}, I, O, Q, L), where

Journal of Theoretical and Applied Information Technology
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(1)W_{Id} is an identification of a Web service;

(2)W_{des} is a function description of the Web service;

(3)*I* and O are the sets of input and output parameters;

(4)*Q* is a set of quality parameters; and

(5)*L* is the URI of a Web Service.

W_{des} is defined as 2-tuple (*Ob, Ac*), *Ob* is the operation object of a Web service, *Ac* is the operation, and *De* is the function description. For example, a Web service with the function of querying flight tickets is defined as the 2-tuple (Flight, Query). The quality parameters in *Q* is defined as Q= {q_i}, q_i ={*N,C,V,U*}, *N* is the name of quality parameter, *C* is a comparison operator, *V* is the value of the parameter, *U* is the unit of quality parameter. The response rate of a Web service is more than *99%* once it has a quality parameter *q*= (*ResponseRat*, >, *99*, *%*).

Definition 2 (service cluster)

A service cluster is a 6-tuple *S*cluster=(C_{Id}, C_{des}, *P*, *S*w, *Q*c, *F*), where

(1)C_{Id} is an identification of a service cluster;

(2)C_{des} is a function description of a service cluster;

(3)*P* is a parameter list which is composed of input and output parameters of all the Web services in the service cluster;

(4)*S*w is the set of Web services included in the service cluster, *S*w={ws_1,ws_2,…ws_n}, where ws_i is a Web service, 1≤i≤n;

(5)*Q*c is the quality constrain of service cluster, let *Q*c ={q_i}, q_i ={*N*,*C*,[V_{min}, V_{max}],*U*}, where V_{min} and V_{max} represent the upper and lower bound value of q_i respectively.

(6)*F* is a set mapping *P to* integers, which is used to represent the input and output parameters of the service cluster.

If the quality constrain of a service cluster is defined as: Qc={(ResponseTime, <, [1,3], ms), (Cost, =, [0,0.01], $), (*ResponseRat*, >, [95,99], %)}. It means all of it component Web services are with the following quality properties: the maximal response time is less than 3 ms, the minimal response time is less than 1 ms, the cost of service is from 0$ to 0.02$, and the maximal response rate is more than 99%, the minimal response rate is more than 95%.

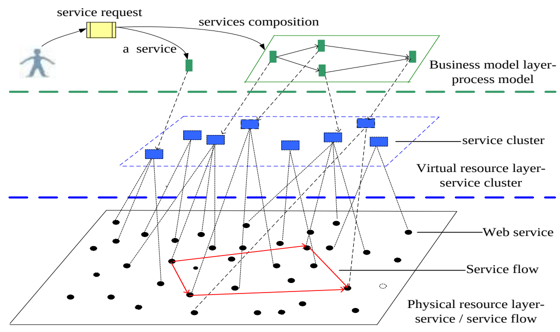

Figure 1: Service Architecture Oriented On Service Clusters

Fig.1 shows the service request/response schema based on service clusters. Compared with the traditional SOA, a virtual resource layer is located as medium between the layer of physical service resources and users. Web services in physical service resource layer with same or similar functions are mapped into a service cluster in virtual resource layer.

Different from the current service request/ response schema, it is a service cluster which responses the service request under the service request/response schema based on service clusters. An optimal Web service will be bund in the reposing service cluster. The service request may be responded by a service cluster, or by a service flow composed of a group of service clusters. We will discuss how to find a service response with the optimal service qualities for the service request in next section.

3. SERVICE RESPONSE WITH OPTIMAL QOS

To find a response Web service with optimal Qos for a service request is divided into two phases, the first is to select a group of candidate Web services with the matching interfaces, the second is to bind the Web service with the optimal Qos.

Since Web services and their parameters with same or similar function may be described by different syntax, we eliminate syntax difference by ontology when computing similarity of them. All the information about the Web services, service clusters and their parameters assumed to be constructed and annotated based on domain ontology in this paper.

Definition 3 (semantic similarity)

Let *CCP* be the closest common parent of ontology concepts O_1 and O_2 in domain ontology tree. *Level(CCP)*, *level*(O_1) and *level*(O_2) denote the number of level depth of *CCP*, O_1 and O_2 in the domain ontology tree. Let *level*(O_{top})*=1*, O_{top} is the

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top concept node in the tree. The semantic distance between O_1 and O_2 is defined as follows.

$$dist(O_1,O_2)=\begin{cases}(2^{-level(CCP)}-2^{-level(O_1)})+(2^{-level(CCP)}-2^{-level(O_2)}), & O_1\neq O_2\\ 0, & O_1=O_2\end{cases} \quad (1)$$

The semantic similarity of two concepts O_1 and O_2 in domain ontology tree is defined as $SeSim(O_1,O_2)$=1-$dist(O_1, O_2)$.

Definition 5 (semantic equivalence)

For a given threshold value δ, O_1 and O_2 is called semantic equivalence if $SeSim(O_1,O_2)\geq\delta$. If O_1 is semantic equivalence with O_2, it is marked as $O_1\leftrightarrow O_2$.

Definition 6 (adapted parameter)

Let *Pa* and *Pb* be two different groups of parameters, *Pa* is called value-covered parameter of *Pb* if the follows hold.

(1)$Num(Pa)\leq Num(Pb)$, where $Num(p)$ represents the number of parameter *p*.

(2)$\forall m_i\in Pa$, $\exists n_j\in Pb$, such that $m_i\leftrightarrow n_j$ and $Type(m_i)\cong Type(n_j)$;

(3)$\forall m_i\in Pb$, $\exists n_j\in Pa$, such that $Value(m_i)\subseteq Value(n_j)$;

Type(*m*) represents the parameter type of *m*, and the symbol of ≅ represents the type of parameters is compatible.*Value* (*m*) represents the value scope of *m*. If *Pa* is the value-covered parameter of *Pb*, it is marked as *Pa* » *Pb*.

Let *r* be a service request , *r*.*Q*={(*Rt*,<,2,ms), (*Co*,=,0,$), (*Rr*,>,95,%)}, *s* is a service cluster, and *s*.*Qc*={(*Rt*,<,[1,5],ms), (*Co*,=,[0,0.01],$), (*Rr*,>,[93, 98],%)}, we can get the conclusion that *s*.*Qc* » *r*.*Q*.

There are two major types of quality parameters of Web services: positive parameters and negative parameters. Positive parameters, such as reliability, capacity and cost, with a large value denote the high quality of a Web service. Conversely, negative parameters, such as delay time and response time, with a small value denote the high quality. We should standardize the value of quality parameters before comparing them. The method presented in the paper [5] is introduced to estimate the quality score of a Web service in our work.

Definition 8 (quality score)

Let S={ws_1,ws_2,…ws_m} be a group of Web services. Assume each Web service in *S* has *n* quality parameters, and [q_{i1}, q_{i2}, …, q_{in}] is the quality vector of Web service s_i. The quality score of s_i is defined as formula (2). Formula (3) and (4) are used to standardize negative parameters and positive parameters respectively.[8]

$$Score(s_i)=\sum_{j=1}^{n} q_{ij}*w_j, \quad \sum_{j=1}^{n} w_j=1 \quad (2)$$

$$q_{ij}=\begin{cases}\dfrac{q_j^{\max}-q_{ij}}{q_j^{\max}-q_j^{\min}}, & if\ q_j^{\max}-q_j^{\min}\neq 0;\\ 1, & if\ q_j^{\max}-q_j^{\min}=0;\end{cases} \quad (3)$$

$$q_{ij}=\begin{cases}\dfrac{q_{ij}-q_j^{\min}}{q_j^{\max}-q_j^{\min}}, & if\ q_j^{\max}-q_j^{\min}\neq 0;\\ 1, & if\ q_j^{\max}-q_j^{\min}=0;\end{cases} \quad (4)$$

3.1 Response Of A Single Web Service

Let a_1, a_2, …, a_n be the number of 1 or 0, then number string"$a_na_{n-1}…a_2a_1$" is a binary number. We define a function *f* to transform the binary number to an integer, $f=\sum_{i=1}^{n} a_i*2^{i-1}$.

Let *S* be a service cluster, the component Web services Sw={ws_1, ws_2,…ws_m}. The input and output parameters of *S* are I={I_1, I_2, ,…I_p} and O={O_1, O_2,…O_q} respectively, i.e., all the input parameters of its component Web services constitute the set *I*, all the output parameters of its component Web services constitute the set *O*. We sort the parameters with a fixed order and construct a parameter list *P*. Let P= {I_1, I_2, ,…I_p, O_1, O_2,…O_q}.

For each Web service in a service cluster, a binary number string is set to denote its parameters. Comparing with the parameter order in *P*, the corresponding position is replaced by 1 once the Web service has the parameter, otherwise, replaced by 0. Thus a binary number string can be obtained for each Web service. From the function *f*, the binary number string is inverted into an integer number. Hence, we can get a group of integer numbers for a service clusters, and these integer numbers compose the set *F* in Definition 2.

Only one service cluster responds the service request once the service request can be achieved by a single Web service. A service request is formally described as a 4-tuples Sr={R_{des}, *I*, *O*, *Q*}. R_{des} represents the requested service function, *I* and *O* represent the providing and requesting parameters of the service request, *Q* represents the constrains on the quality of service request. Similar with Web services in the service cluster, we can substitute the parameters in *I* and *O* by 1 or 0, and get the corresponding binary number string and integer number. We use *f*(*Sr*.*I*, *Sr*.*O*) to denote the integer number for the parameters of service request.

To search a matching service cluster, we need compare the function description, interfaces and service quality between the candidate service clusters and service request. If the value of function similarity between a service cluster and service request is more than a given thresholdδ, the

Journal of Theoretical and Applied Information Technology
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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

interfaces and service quality matching will be executed. By performing aforementioned operation, a group of candidate Web services are obtained. We compute quality score for these candidate Web services and select the best one for the service request. Let *SC* be the set of service clusters, algorithm 1 is proposed to bind an optimal Web service in the schema of service clusters.

```
for ∀S∈SC
  if SeSim (S.C_des, Sr.R_des)>δ
    if (f(Sr.I, Sr.O)∈S.F) and (S.Qc»Sr.Q)
      S′=S;
for ∀ws∈S′.S_w s={ws| max(Score(ws))}
Output(s);
```

Algorithm 1 Bind a Web service with the optimal Qos

3.2 Response Of Service Flow

If a service request cannot be responded by a Web service, it should be respond by a group of Web services with a special business process, i.e. a service flow. It is difficult to implement an effective service composition in a real business world, especially for dynamic Web service composition. To quickly respond the service request, we define some service flows and store them in a service flow repository. A pre-defined service flow will be bund for a complicated service request.

A service flow is defined as a directed graph *SF*=(*Sc*, *Fc*), where *Sc* is the set of service clusters in the service flow and *Fc* is the flow relation of the service clusters.

When a user requests a service flow, he should provide all function descriptions of component Web services in the service flow and their flow relations.

Let *SR*=(*Sr*, *Fr*) be the formal description of a service request for the service flow, and there be *n* component Web service descriptions in *Sr* and *m* flow relations between them in *Fr*.

If for $s \in Sr$, $\exists\, s' \in Sc$, such that $s \leftrightarrow s'$, then Ts=1 else Ts=0. If a relation *f* in *Fr* is started form s_p and ended by s_q, Tf=1 once there exists a relation *f'* starting form s_a and ending by s_b with $s_a \leftrightarrow s_p$ and $s_b \leftrightarrow s_q$, else Tf=0. If a service flow *SF* can service for *SR*, denoted by $SF \Rightarrow SR$, the value of $\sum_{i=1}^{n} Ts_i$ /n and $\sum_{i=1}^{m} Tf_i$ /m should be 1.

In order to succinctly and formally expressed a service flow, four types of structures are defined in this study, namely sequence, parallel, alternative, and loop. According to the above structures, four structural operators are defined, which are $\rightarrow$, $\otimes$, +, and *. Two Web services W_1 and W_2 linking by "$\rightarrow$", i.e. the service flow $W_1 \rightarrow W_2$, means to perform the service W_1 followed by service W_2. W_1+W_2 represents both W_1 and W_2 are parallelly executed, and the service process is terminated only when both of them completely performed. The service flow $W_1 \otimes W_2$ represents only one of W_1 and W_2 can be executed, i.e., either service W_1 or service W_2. The service flow $(W_1)^*$ represents to cyclically perform the service W_1 while the required condition is satisfied.

Since the component elements in the service flow are service clusters, an optimal service flow needs to be found for the service request when a service flow is obtained. A service flow, which is starting form the service cluster *A*, next parallelly performing the service cluster *B* and *C*, and ending by the service cluster *D*, is shown in Fig.2. The final service flow provided for the user may be *A1→B2+C1→D3*, *A2→B1+C1→D2*, and *A3→B1+C2→D1*, etc. Thus, a service flow with an optimal Qos is needed to find and return to the user.

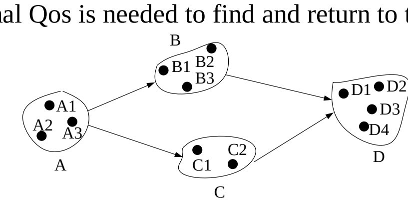

Figure 2: An Example Of Service Flow Based On Service Cluster

Based on Definition 8, the Qos of a service flow is decomposed to compute the summation of all the sequence service flow.

$$score(w_i \rightarrow w_j) = score(w_i) + score(w_j) \quad (5)$$

$$score(w_i + w_j) = Max(score(w_i), score(w_j)) \quad (6)$$

$$score(w_i \otimes w_j) = Min(score(w_i), score(w_j)) \quad (7)$$

$$score((w_i)^*) = score(w_i) \quad (8)$$

Since how many times for each loop is executed is hardly anticipated, the quality score of the service flow in the loop structure is used to represent the final quality score of a loop structure, i.e. the formula (7). For a given service flow *A*, if A is formally described as *A1→A2→… →An*, *Score*(*A*)= $\sum_{i=1}^{n} score(Ai)$. Here the Web service *Ai* in *A*, where 1≤i≤n, may be any form of a sub service flow with the aforementioned four types of structures.

From the above, the algorithm 2 is proposed to search a service flow for an complex service request. Let *SFR* be the set of all the service flows

Journal of Theoretical and Applied Information Technology
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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

in the service flow repository, *SR* be the service request. S_f is the set of service flows which can service for the service request.

for $\forall SF \in SFR$
  if $(SF \Rightarrow SR)$
    $S_f = S_f \cup SF$;
for $\forall S \in S_{fr} = \{S |\ max(Score(S))\}$
Output(S_{fr});

Algorithm 2 Bind a service flow with the optimal Qos

4. SIMULATION EXPERIMENT

Since there are few Web services designed based on ontology in internet, Web services used in the experiment are constructed based on the concepts of an ontology tree built by ourselves. The ontology tree is designed with depth of eight and width of seven. The leaf nodes represent the ontology concepts, and our Web services are built on these concepts, i.e., we adopt these concepts to express the parameters and function descriptions of Web services. Given two Web service, we can quickly compute semantic similarity from the ontology tree.

The Web services and service clusters in the experiment were acquired as follows.

(1) Set the number of service clusters and Web services. Let *N* be the number of service clusters, *N*= {100, 200, 500, 1000, 2000}. The total number of Web services in all service clusters is *10000*. For the *i*-th service cluster, the number of its component Web services is randomly generated, denoted as M_i, where $1 \le M_i \le 10*(10000/N)$.

(2)Generate the service clusters. For each service cluster, the function description, the common input and output parameters are randomly generated from the concepts in ontology tree. The common parameters are restricted not identically for any two service clusters. The interval value of service quality parameters for every service clusters are also produced randomly, which include the three parameters, i.e the ResponseTime, Cost and ResponseRate.

(3)Generate the Web services in service clusters. For the *i*-th service cluster, the number of its component Web services is M_i. We construct these Web services by randomly allotting the private input and output parameters and setting the specific values of their service quality parameters.

(4) By Definition 2, we construct the *P* and *F* in the service clusters.

(5) For the service request, we randomly selected a Web service in a service cluster as the request for a single Web service. To test the response of a service flow, we first randomly generate some service flow with 8 to 12 service clusters, and their flow relations are also be randomly generated. We select one service as service request.

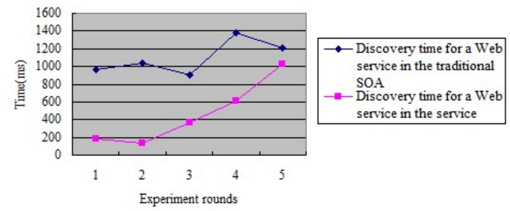

Figure 3: Discovery Time For A Web Service In The Traditional SOA And The Service Clusters Schema

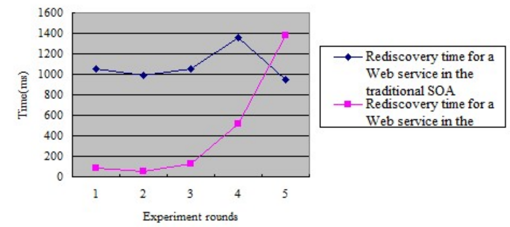

Figure 4: Rediscovery Time For A Web Service In The Traditional SOA And The Service Clusters Schema

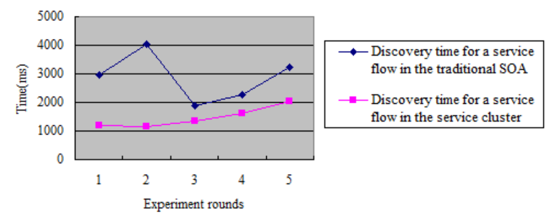

Figure 5: Discovery Time For A Service Flow In The Traditional SOA And The Service Clusters Schema

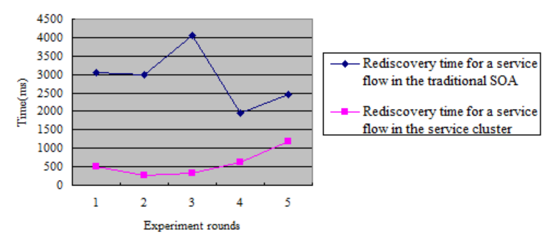

Figure 6: Rediscovery Time For A Service Flow In The Traditional SOA And The Service Clusters Schema

Experiments of this paper are in the same hardware environment as follow: CPU is the Intel core i3-2120 with 3.3GHz; memory is 2G, the operating system is Windows 7. The simulation program is developed based on Java. Five rounds of experiments were presented in this paper. We performed the experiments in each round for 10 tests, taking the average of the results as the final simulation results.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

From the above simulation result, we find that the service response is with a higher efficiency in the service cluster schema compared with the traditional service response schema. However, the efficiency is decreased or increased when the grain of Web service is changed. We can get the conclusion that the discovery time depends not only on the number of Web services but also on the grain of service clusters. Similar results and conclusions are true for the rediscovery time in the service clusters schema.

5. CONCLUSIONS

A new service request and response schema, namely the service cluster schema, is proposed in this paper. Since a group of Web service is encapsulated as a service cluster, the grain of service response is increased. It can not only greatly reduce the search space but also improve the flexibility of service response.

The service architecture oriented on service clusters is presented. A service request is mapped into a Web service or a service flow. We provide two algorithms to bind an appropriate Web service or a service flow with the optimal Qos under the service cluster schema. Simulation experiments are performed to show the efficiency of the service cluster schema. The relation between the grain of service clusters and service response will be studied in future work.

ACKNOWLEDGEMENT

This work is supported by the National Basic Research Program of China under grant 2010CB328101; the National Natural Science Foundation of China under grant 61170078; the doctoral program of higher education of the specialized research fund of China under grant 20113718110004; The Project of Shandong Province Higher Educational Science and Technology Program under Grant number J12LN11.

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