SERVICE RESPONSE WITH OPTIMAL QOS IN SERVICE CLUSTER SCHEMA

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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 two 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 appropriate Web 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 $W_s=(W_{id}, W_{des}, I, O, Q, L)$, where

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Definition 2 (service cluster)

A service cluster is a 6-tuple $w^i = (C_{id}, C_{des}, P, S_w, Q_c, F)$, 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, $S_w = \{w_{s1}, w_{s2}, \ldots, w_{sn}\}$, where $w_{si}$ is a Web service, $1 \leq i \leq n$;
5. $Q_c$ is the quality constrain of service cluster, let $Q_c = \{q_i\}, q_i = (N, C, V, U), N$ 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 $q = (\text{ResponseRate}, >, 99\%)$.

Definition 3 (semantic similarity)

Let $CCP$ be the closest common parent of ontology concepts $O_1$ and $O_2$ in domain ontology tree. $\text{Level}(CCP)$, $\text{level}(O_1)$ and $\text{level}(O_2)$ denote the number of level depth of $CCP, O_1$ and $O_2$ in the domain ontology tree. Let $\text{level}(O_{top}) = 1$, $O_{top}$ is the
top concept node in the tree. The semantic distance between $O_1$ and $O_2$ is defined as follows.

$$\text{dist}(O_1,O_2) = (2^{-\text{dist}(\text{Type}(O_1),\text{Type}(O_2))} + 2^{-\text{dist}(\text{Num}(O_1),\text{Num}(O_2))}) \cdot 0 \cdot O_1 \neq O_2.$$ 

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

**Definition 5 (semantic equivalence)**

For a given threshold value $\delta$, $O_1$ and $O_2$ is called semantic equivalence if $\text{SeSim}(O_1,O_2) \geq \delta$. 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. $\text{Num}(Pa) \subseteq \text{Num}(Pb)$, where $\text{Num}(p)$ 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 $\text{Type}(m_i) \subseteq \text{Type}(n_j)$;
3. $\forall m_i \in Pb$, $\exists n_j \in Pa$, such that $\text{Value}(m_i) \subseteq \text{Value}(n_j)$;

$\text{Type}(m)$ represents the parameter type of $m$, and the symbol of $\subseteq$ represents the type of parameters is compatible. $\text{Value}(m)$ represents the value scope of $m$. If $Pa$ is the value-covered parameter of $Pb$, it is marked as $Pa \rightarrow Pb$.

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

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 $S = \{w_1, w_2, \ldots, w_m\}$ be a group of Web services. Assume each Web service in $S$ has $n$ quality parameters, and $[q_{i1}, q_{i2}, \ldots, q_{in}]$ 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.

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

$$q_0 = \begin{cases} 
q_{ij}^{\max} - q_{ij}^{\min}, & \text{if } q_{ij}^{\max} - q_{ij}^{\min} \neq 0; \\
1, & \text{if } q_{ij}^{\max} - q_{ij}^{\min} = 0; 
\end{cases} \quad (3)$$

$$q_0 = \begin{cases} 
q_{ij}^{\min} - q_{ij}^{\max}, & \text{if } q_{ij}^{\max} - q_{ij}^{\min} \neq 0; \\
1, & \text{if } q_{ij}^{\max} - q_{ij}^{\min} = 0; 
\end{cases} \quad (4)$$

### 3.1 Response Of A Single Web Service

Let $a_1, a_2, \ldots, a_n$ be the number of 1 or 0, then number string “$a_n a_{n-1} \ldots a_2 a_1$” is a binary number. We define a function $f$ to transform the binary number to an integer, $f = \sum_{i=0}^{n} a_i \cdot 2^{i} - 1$.

Let $S$ be a service cluster, the component Web services $S_k = \{w_{1}, w_{2}, \ldots, w_{m}\}$. The input and output parameters of $S$ are $I = \{I_1, I_2, \ldots, I_p\}$ and $O = \{O_1, O_2, \ldots, O_q\}$ 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 $P = \{I_1, I_2, \ldots, I_p, O_1, O_2, \ldots, O_q\}$.

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 $Sr = \{R_{\text{des}}, I, O, Q\}$. $R_{\text{des}}$ 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 threshold, the
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.

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 request, we define some service flows and store all function descriptions of component Web service, and there be relations.

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 $s \in Sr$, $s' \in Sc$, such that $s \Rightarrow s'$, 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 $Sr$, 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 express 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 $\rightarrow, \otimes, +, *$. 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 $W_2$, $W_1 \otimes W_2$ represents both $W_1$ and $W_2$ are parallely 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 $A1 \rightarrow B2 + C1 \rightarrow D3$, $A2 \rightarrow B1 + C1 \rightarrow D2$, and $A3 \rightarrow B1 + C2 \rightarrow D1$, etc. Thus, a service flow with an optimal Qos is needed to find and return to the user.

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

$$\text{score}(w_1 \rightarrow w_j) = \text{score}(w_1) + \text{score}(w_j)$$ (5)

$$\text{score}(w_i \rightarrow w_j) = \text{Max}(\text{score}(w_i),\text{score}(w_j))$$ (6)

$$\text{score}(W_i) = \text{Min}(\text{score}(w_i),\text{score}(w_j))$$ (7)

$$\text{score}(w_i)^* = \text{score}(w_i)$$ (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 $A1 \rightarrow A2 \rightarrow \ldots \rightarrow An$, then $\text{Score}(A) = \sum_{i=1}^{n} \text{score}(Ai)$. Here the Web service $Ai$ in $A$, where $1 \leq i \leq n$, 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.
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.

\[
\begin{align*}
1 & \text{ for } \forall SF \in SFR \\
2 & \text{ if } (SF \Rightarrow SR) \\
3 & S_f = S_f \cup SF; \\
4 & \text{ for } \forall S \in S_f = \{ S | \max (\text{Score}(S)) \} \\
5 & \text{Output}(S_f);
\end{align*}
\]

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 \( 1 \leq M_i \leq 10^*(10000/N) \).

(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 cluster 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.

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.
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.

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