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QoS-Aware Service Selection Using QDG for B2B Collaboration

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Abstract

Collaboration among enterprises through web service has become a hot topic. Before the collaboration, how to select the most appropriate enterprise to collaborate with, from a set of enterprise candidates that provide similar functions, is an important issue. Existing work focus on proposing evaluation rules, and aggregating these rules to evaluate a service, where subjectiveness is usually involved. In this paper, we propose to utilize "serve, be served" relationship to evaluate the quality of services. In more detail, we use Quality Dependency Graph (QDG) method model the relationship among enterprises, and then, by traveling the built QDG, an Analytic Hierarchy Process (AHP) model is used to calculate the evaluation result of each candidate organization. Our method provides a more objectvie way for collaboration on enterprise level.

1. Introduction

With the support of networks, enterprises nowadays can publish their services online, particularly, using the web service [6][8], in order to accelerate their business process and reduce cost. The collaboration among enterprises then develops towards a new direction, i.e., collaboration using web services. Widely available and standardized Web Services make it possible to realize Business-to-Business Interoperability (B2Bi) by interconnecting web services provided by multiple business partners according to some business process [11]. Contrast to traditional collaboration by web service, which focuses on collecting and integrating distributed services to accomplish a task, collaboration on enterprise level focuses on accomplish a business task using restricted services, which are provided by the involved enterprises. Typical collaborative transactions in a Business-to-Business (B2B) environment involve multiple organizations. They prescribe business processes, which are published online via some service registers [3].

The first important problem of enterprise level collaboration using web service is how to choose the most appropriate enterprise to collaborate with, from a set of candidate enterprises with similar functions known as service selection [21]. Nowadays there are many works focus on this issue and there are many service selection method such as the ontology based method provided by [5], and the QoS-aware method [4][11][18]. In our work we adopt the QoS-aware method to evaluate the quality of service (QoS) of each candidate enterprise Many work has been done on the QoS evaluation criterion, such as [2][11][13], they have contributed on proposing evaluation rules and combining the rules to evaluate the service, although the combinations are usually in subjective ways.

Moreover, few works above noticed that, in collaboration on enterprise level, an evaluator is required, which performs the evaluation of candidate enterprises. How to select the evaluator is an ignored problem.

In this paper, we propose to use "serve, be served" relationship to form an objective evaluation criteria as well as a method for evaluator selection. Since the collaboration among enterprises are tightly coupled, it is natural to form a "serve, be served" map. The evaluator can be naturally selected as the service provider. Afterwards, to form evaluation criteria with less subjectiveness, we consider the following two points on the characteristics of enterprise level collaboration:

1) *Dependency*. Since enterprises always provide services for other enterprises, the "serve, be served" is an objective relationship. Thus the quality of enterprises can be defined from the relationship.

2) *Diversity*. When accomplishing different business tasks, the same service provider may have different quality of its service.

From these two points, we present a Quality Dependency Graph (QDG) method to evaluate candi-date enterprises. Particularly, our contribution are 1) pro-

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posing "serve, be served" relationship to be used as a objective property in collaborations; 2) using Quality Dependency Graph to model the relationship for evaluator selection and candidate evaluations; 3) use AHP [15] model as the quality criteria weighting method.

The rest of our paper is organized as follows. The architecture of our method is presented in Section 2 and the explanation of our Quality Dependency Graph method is given in Section 3. Then case study is presented in Section 4, and in Section 5 we compare our work to the relative works. The conclusion and future work are in Section 6.

2. Enterprise Modeling for B2B Collaboration

In order to implementing the business specification of collaboration [14] in B2B environment much better, we must have one model to specify the architecture of the collaboration, and then implementing the candidates selection method. Our method not only specifies the architecture of the B2B collaboration but also interprets how to choose an appropriate organization or enterprise from abundant of candidate organizations.

We first describe the architecture of our model. We adopt the enterprise modeling method interprets by F. Vernadat [7] and the policies provided in Aagedal [9] and [17]. Then based on their views of enterprise modeling, we construct our architecture.

The collaborative organizations and enterprises construct a ***virtual organization*** which gives the ***business specification***. The business specification shows the commercial mission of this collaboration and differentiates the obligation of each component. The independent organization or enterprise from candidates set which takes on the obligation specified in the business specification is called a ***business role***. The business role gives the logical requirement of each component in the business specification. The appropriate organization or enterprise must be chosen from the candidates set of this business role while implementing the business specification. It seems a little similar to the service selection in the service composition scenario: the one which best satisfied the requirements will be chosen.

In the virtual organization, interactions happened among business roles and each interaction between two business roles has a ***contract*** to describe the interaction details. The content of the contract constructed by these two collaborative business roles must contain the ***quality criteria*** which describe the quality requirements and the "serve, be served" relationship of these two business roles. In the interaction, there must be the relationship that one business role provides service to another business role which acts as a service user. Then due to the dependency property, the quality of the service provider is determined by the service user, then we must find out the holistic ***quality determined guideline*** (we then use ***quality guideline*** for short) to specify the dependency property while confirming the quality of each business role. That is to say, quality guideline specifies who will specify the quality of the given business role, and the quality criteria specifies how the quality of this given business role will be confirmed. For the diversity property, we know that different business role has different quality requirements, and then the quality criteria may be different in the different contracts.

We can get the architecture as figure 1 shows.

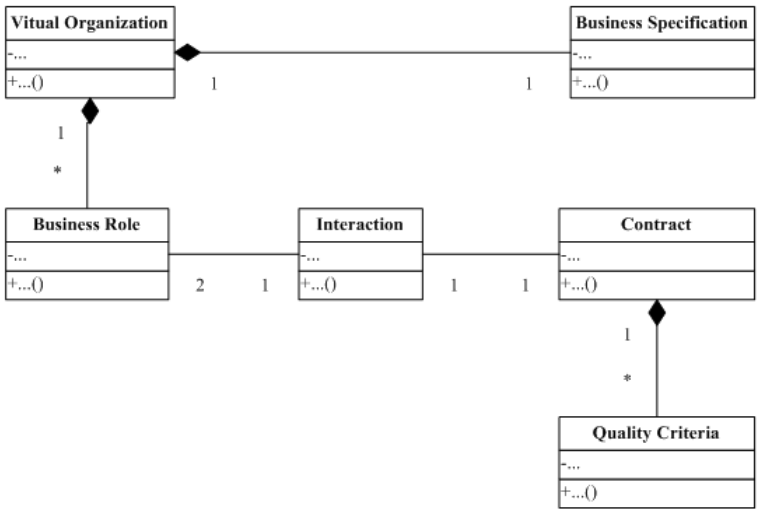

Figure 1. Model of the virtual organization

3. Service Selection Using QDG Method

Before implementing our model, we first formalize the conception used in our model.

3.1 Build & Travel the QDG

Definition 1: Business Role. The tuple <functionality, partner set> is defined as a Business Role, in which functionality interprets the required service of this business role; partner set is the set of its collaborators. We always use the functionality to interpret business role later in this paper.

The candidates set of a business role is defined as BRS. We use *BRS (name)* to denote the candidate set of a business role *name*. What shall we do is to choose the best satisfied business role from the BRS. In order to interpret the quality of a business role, we use *Quality (name)* to delegate the quality of *name*, which value domain is between 0 and 1(we will illustrate how to calculate *Quality (name)* later). We use *Quality (P) = Satisfy (U,P)* to interpret how the business role *P* satisfies *U*. *Satisfy (U,P)* is a function which takes business role *U,P* as input, *U* is the service user and *P* is the service provider.

Interactions happened among business role, and then we use Contract to describe the interaction.

Definition 2: Contract. The *Contract (U, P)* stands for the quality criteria between business role *U* and *P* and the "serve, be served" relationship between these two business roles. In the Contract, there must be a service provider and a service user, how the service user determines the provider's quality depends on the Quality Criteria listed in the contract.

Definition 3 Service Dependency. There are two kinds of Service Dependency: Directed and Undirected.

A tuple $<U, P, \rightarrow>$ is defined as a Directed Service Dependency if and only if:

(1)*U* is a real organization or a business role $\in$ *BRS(u)* , $P \in BRS(p)$ and *U* is not in *BRS(p)*;

(2) $\rightarrow$ is the "serve, be served" relationship and $U \rightarrow P$ means business role *U* uses the service provided by business role *P*.

A tuple $<U, P, T, \sim>$ is defined as a Undirected Service Dependency if and only if:

(1) *U* is a real organization or a business role $\in$ *BRS(u)*, $P \in BRS(p)$, $T \in BRS(t)$, and *U* is not in *BRS(t)*, $P \neq T$.

(2) $\sim$ is the transparent "serve, be served" relationship in the service outsourcing scenario;

(3) $U \sim T(P)$ means that while *P* service for *U*, it outsourced some actions to *T*.

Definition 4 Quality Guideline. The formula like $Quality\ (P) = \cup Satisfy\ (U_i, P)$ is called a Quality Guideline for the service provider *P* if and only if:

(1) *U* is a real organization or a business role $\in BRS\ (u)$, $P \in BRS\ (p)$ and *U* is not in *BRS(p)*;

(2) Each business role U_i in the formula has the direct / undirected service dependency with the service provider *P*.

Assume there is a tuple $<U,P, \rightarrow>$, we can say that the quality of business role *P* is defined by *U*, that is to say, the quality of *P* is determined by its user *U*. Then we say that *Quality (P) = Satisfy (U, P)*. However, there may be another service dependency, $< U_2,P, \rightarrow>$ in the business specification, in which $U_2 \neq U$, then we can get that $Quality(P) = Satisfy(U_2,P)$.Then we can see that *Quality (P)* is determined by both *U* and U_2. If there is not any other directed service dependency that business role *P* acts as a service provider, we use $Quality\ (P) = Satisfy\ (U, P) \cup Satisfy\ (U_2, P)$ to describe this statement. Meanwhile, suppose that business role U_3 order something from *P*, then *P* outsources the shipment action to *T*, then we can get the transparent " serve, be served " relationship $U_3 \sim T(P)$ and $Satisfy(U_3 ,P)$ is also one essential element while confirming the *Quality(P)*. Then we use $Quality\ (P) = Satisfy\ (U, P) \cup Satisfy\ (U_2, P) \cup Satisfy\ (U_3, P)$ to describe the entire business role *P*' s service dependencies, and the formula like this type is called a Quality Guideline.

Then what shall we do is to find out all the service dependencies of one business role *P* and then get the quality guideline of it. Then we can choose the best organization from *BRS (p)* which satisfied the needed requirements of this business role *P*.

Definition 5 Quality Dependency Graph (QDG). A directed graph is defined as a QDG if and only if

(1) the QDG is an AOV net[16];

(2) for each vertices v_i in QDG, v_i is a business role, and for each couple v_i, v_j ($v_i \neq v_j$), $<v_i,v_j>$ is an edge from v_i to v_j.

(3) for each vertices v_i in QDG, count[i] stands for the in-degree of v_i;

Algorithm I. Create *QDG*
Input: Business Specification
Output: Quality Dependency Graph
01 for each *Contract (U, P)* in *BS*
02 if not exited *U* then
03 new node name = *U*
04 endif
05 if not exited *P* then
06 new node name = *P*
07 endif
08 Add edge <*U,P*> in *QDG*
09 end for

Algorithm I.

(4) the edge e $<v_i,v_j>$, e.sour = v_i stands for the source vertices, e.dest = v_j stands for the destination vertices;

(5) for each edge $<v_i,v_j>$ in QDG, $< v_i,v_j \rightarrow >$ is a Service Dependency;

We can create a QDG from business specification by algorithm I.

We check all the contracts in the business specification to find out all the "serve- be served" dependency relationships. Based on these single contracts, we get the service provider *P* and service user *U* of each contract, what we shall do is only to create the business role that has not been created, and then draw a directed line from the service user to the service provider.

After creating the QDG, we travel this graph by algorithm II and get the service guideline for each business role.

In algorithm II, line 4-20 is the top sort procedure [16]; it searches the vertices which have zero in-degree, for each directed line in the QDG delegates the Service Dependency, then we can get the service guideline of each business role after top sorting.

3.2 AHP Service Selection Method

After getting the service guideline of each business role in the business specification, what shall we do is to choose the best satisfied one from BRS depending on the service guideline. There exist many methods to choose a best one, such as the QoS-aware middleware supported by [10] [11], semantic QoS Selection Algorithm provided by Xia Wang [19], and the statistical model such as AHP method [12] [20]. We use AHP method provided by Saaty in 1970s to choose the best satisfied business role for its hierarchy nature satisfied our model much well and its mathematical property makes the weight of Quality Criteria more objective than the subjective ones[1].

Based on each service guideline, we can differentiate the service provider and the service users and

Algorithm II: Find out the Guideline.
Input: QDG.
Output: Quality Guideline.
01 var top: integer, j: integer;
02 top = -1;
03 for each node v_i in QDG
04 if count[i] := 0 then
05 count[i] := top;
06 top := i;
07 end if
08 end for
09 for each node v_i in QDG
10 j := top; top := count[top];
11 for each vertices $v_{dest} = v_j$.dest
12 add Satisfy(v_j,v_{dest}) to Quality(v_{dest})
13 end for
14 for each edge l <v_j, v_l>
15 k := l.dest;
16 if (count[k] -1) := 0 then
17 count[k] := top; top:=k;
18 end if
19 end for
20 end for

Algorithm II.

then choose the best service provider depending on the quality criteria supported by the service users.

In the traditional AHP model, there are 3 levels: Objection, Criteria, and Plan. In our methodology, the Objection level is "to best satisfy service users' requirements", just the same as the normal one, but the Criteria level is a little different from the traditional model. We adopt the multiple levels AHP model which the second level in our model is the service users of the candidate business role. Then the third level is the quality criteria required by each service user and the Plan level is the BRS – the candidate business roles set. We give a typical AHP model used in our procedure in Figure2.

After we get this AHP model, we apply the iterative maximal eigenvalue to calculate how each candidate organization satisfies all its service users' requirements.

First we construct the pairwise comparison matrix for each level to its higher level in terms of the relative importance between each two factors. While constructing the pairwise comparison matrix for one level, we use the 1-9 theory provided by Saaty presented in Table1.

The pair wise comparison matrix $A_n = (a_{ij})_n$ must satisfy the following properties:

(1) $a_{ij} = 1 \quad i = j = 1,2,3,\ldots,n;$

(2) $a_{ij} = 1/a_{ji} \quad i,j = 1,2,3,\cdots,n$ and $i \neq j;$

(3) $a_{ij} = a_{ik}/a_{kj} \quad i,j,k = 1,2,3,\cdots,n$ and $i \neq j;$

Table1.The Saaty Pair-wise Combination Scale, where 2,4,6,8 is the intermediate value of its left and right.

Measurement	Equal		Moderate		Strong		Demonstrated		Extreme
a_{ij}	1	2	3	4	5	6	7	8	9

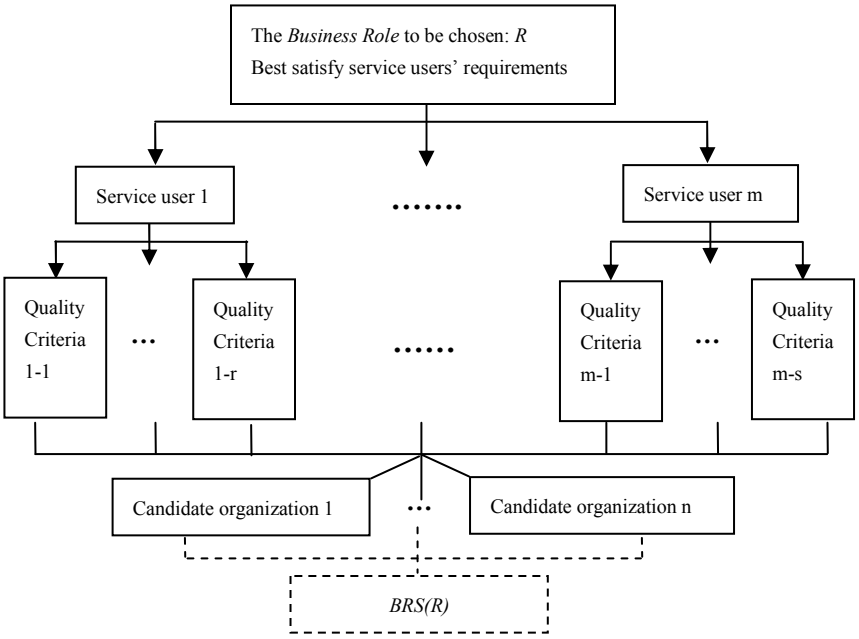

Figure 2. The multiple AHP model for candidate organization selection.

After checking the consistence of the matrix we then calculate the maximal eigenvalue and its corresponding eigenvector. For the second level – the service users level, we get its eigenvector ω_2 to the first object level. Then the comparison matrix for the third level to the second level we construct a matrix for each Quality Criteria to the higher level and then calculate its eigenvalue and eigenvector, we construct matrix $W^{(3)}$ by all the eigenvectors calculated from the matrix constructed for weighting the Quality Criteria to the service user. Then we can also construct the matrix $W^{(4)}$ by all the eigenvectors calculated from the matrix that constructed for weighting the candidate organizations in the BRS of the business role.

Then we can get the Quality Satisfy Degree Vector of BRS which satisfied all the service users' Quality Criteria by the formula:

$$\omega = W^{(4)}W^{(3)}\omega_2.$$

where ω is a n-dimension vector, each value w_i in is the Quality Satisfy Degree of the candidate organization i. Then we sort these n values in the vector and get the highest one, the corresponding organization is the one that satisfies the Quality Criteria best.

4. Case Study

This section shows how to use Quality Dependency Graph Method to select candidate organization through a sample from real life.

A manufacture wants to order some materials from some supplier, and we know that nowadays, supplier almost outsource their shipment procedure to the professional shipment company. The requirements of the manufacture to the supplier are like following: it wants to get the materials in 2 weeks, the whole price is below $500,000 and the supplier can accept the money via the online bank. Then this manufacture can first search the supplier which can satisfy its requirements well through the web, then the manufacture may get a collection of those suppliers.

We can easily find out that the manufacture and the supplier is two different business roles in our business specification and they have the relationship of "serve, be served": manufacture use the "order materials" service provided by the supplier, i.e., we can get the directed service dependency <*Manufacture*, *BRS(Supplier)*, →>. And then we can get the content of *Contract(Manufacture, Supplier)* depending on the manufacture's requirements.

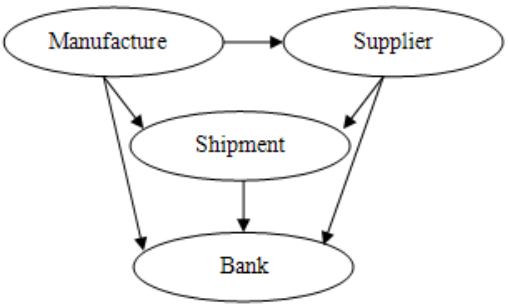

Figure 3. The Quality Dependency Graph

Then suppose the business role supplier outsource its shipment to another business role -- Shipment Company, which is transparent to the manufacture. Then there are two service dependency:<Supplier, *BRS(Shipment)*, →> and <Manufacture, Supplier, *BRS(Shipment)*, ⇝>.

At last, the money exchanging through the online bank relates to another business role that must to be selected: bank.

All the service dependencies are shown following:

<Manufacture, BRS(Supplier), →>,
< BRS(Supplier), BRS(Shipment), →>
<Manufacture, BRS(Supplier), BRS(Shipment), ⇝>
<Manufacture, BRS(Bank), →>
<BRS(Supplier), BRS(Bank), →>
<BRS(Shipment), BRS(Bank), →>

Then use the algorithm I, we can create the Quality Dependency Graph like Figure 3.

Then use algorithm II to get the top sort of this Quality Dependency Graph we get the quality guideline as following:

Quality(Supplier) = Satisfy(Manufacture, Supplier)

Quality(Shipment) = Satisfy(Supplier, Shipment) ∪ Satisfy(Manufacture, Shipment)

Quality(Bank) = Satisfy(Manufacture,Bank) ∪ Satisfy(Supplier, Bank) ∪ Satisfy(Shipment, Bank)

The top sort of the Quality Dependency Graph gives the quality guideline and the selection sequence.

Then based on the quality guideline, we first confirming the business role of Supplier from the candidate supplier organizations, then confirming the business role shipment from the *BRS(shipment)*, at last we confirm the business role Bank.

In order to explain the multiple AHP model we used explicitly, we give the procedure of confirming the business Shipment and we suppose that there are 10 different candidate shipment organizations in *BRS(Shipment)*.

Notice the model in Figure 2. In this case, the first level is to choose the best one from the *BRS(Shipment)*, the second level is Manufacture and Supplier(Notice that while confirming the business role shipment, we have already confirmed the Supplier due to the top sort).

Then the third level is the quality criteria for the Shipment business role. The Manufacture's requirements are "speed of the shipment" and "security", the supplier's requirements for quality of Shipment are "price", "speed", "reputation" and "exceptionsafe".

Then construct the pair wise comparison matrix for each level to its upper one.

The pair wise comparison matrix:

Level 2 to level 1:

$$\begin{pmatrix} 1 & 7 \\ 1/7 & 1 \end{pmatrix}$$

There are two quality criteria in the third level for Manufacture, and three for Supplier in the upper level, and then there will be two matrixes for the third level to the second level like the following:

$$\begin{pmatrix} 1 & 3 \\ 1/3 & 1 \end{pmatrix} \text{ and } \begin{pmatrix} 1 & 1/2 & 9 \\ 2 & 1 & 1/5 \\ 1/9 & 5 & 1 \end{pmatrix}$$

At last we construct the pairwise comparison matrix for all the candidate organizations in *BRS(Shipment)* to the upper level – quality criteria. We then get the *Quality Satisfy Degree Vector* of *BRS(Shipment) by calculate* $W^{(4)}W^{(3)}w_2$:

ω*={0.375,0.523,0.580,0.368,0.449,0.477,0.392,0.588,0.370,0.430}*

Then we can get that the maximal value in ω is the 0.588, corresponding to the 8th candidate shipment organization in *BRS(Shipment)*. We choose it to implement our business specification for it can satisfy all its service users' requirements best among all the candidate organizations.

5. Related work and Comparison

Service selection is a very important issue for B2B collaboration. Nowadays the service selection methods focus more and more interesting are ontology-driven [5], semantic composition [19] and QoS-aware [4] [11] [18].

The ontology-driven method such as [5] and semantic method such as [19] are hard to implement in practice for its complexity, and the end-users' constrain is not comprehensive.

The QoS-aware service composition has much notable development such as [4][11][18]. They propose global planning algorithms for dynamic QoS-aware

service composition by computing an initial plan at the start of a composite service execution and then revise the plan necessary during execution. Both the method proposed in [10] [11] and [18] do not notice who will be the executer. The approach of these works focus on optimizing service selection as the composite service level and handles various types of QoS criteria.

This paper adopts the works present in [4] [10] [11] [18], but our interesting is in B2B collaboration and the service dependency. In this scenario, while implementing the business specification, candidate business role uses the services published by the enterprise, the dependency relationship is much more evidence than the distributed service composition scenario. At the same time, while implementing the QoS-aware service selection, how to weight each quality criteria is very different in each work. There are many no functional properties in the QoS evaluation, so more works focus on the subjective way or neglect this issue.

Compared with these works presented above, the contributions of this paper are three fold.

First, we notice the quality dependency while quality evaluation, provide the "serve, be served"relationship to describe it;

Second, we build up the Quality Dependency Graph depending on this relationship and induce the quality guideline from the Quality Dependency Graph to get the quality evaluators;

Third, for each quality guideline we induced, we use the multiple AHP model to implement the service selection for its objective nature.

But we must notice that the AHP model we adopt to implement our quality guideline. However AHP model itself has some faults while constructing the pair-wise comparison matrix while comparing the factors, the subjective affects are also introduced. Different people may have different opinions on the significance of the quality criteria. This drawback affects our object to achieve objective quality criteria evaluation.

6. Conclusion

In this paper, our Quality Dependency Graph Method for organization selection provides a smart method to choose an appropriate organization collaborator. By the virtual organization we constructed, we then specify the business role and the "serve, be served" relationship among them. Then we can construct the Quality Dependency Graph depending on this relationship to solve the question that who will be the executants of quality confirming. Then the quality criteria of one business role concerns about all its collaborators' requirements, it is more comprehensive. At the same time, we use the multiple AHP model to weight each collaborator, this is more objective. In section 4 we present a case study by our Quality Dependency Graph method to show how to construct a Quality Dependency Graph and calculate each candidate organization's evaluation factor for a business role.

Our future work will focus on analysis the business specification to specify the business role automatically and perfect the procedure for constructing the pairwise matrix. And we will use Quality Dependency Graph to more real application to test its performance as well.

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Reference

[1] A. Chu, R. Kalaba, and K. Spingarn, "A comparison of two methods for determining the weights of belonging to fuzzy sets", *Journal of Optimization Theory and Applications*, pp.531-538.

[2] C. Aurrecoechea, A. T. Campbell, and L. Hauw, "A Survey of QoS Architectures", *Multimedia Systems*, Vol.6, No.3,1998. pp.138-151.

[3] C. Ye, S. C. Cheung, and W. K. Chan, "Publishing and Compostion of Atomicity-equivalent Services for B2B collaboration", In: *Proceedings of International Conference on Software Engineering 2006*, Shanghai,China.

[4] D. Xu and K. Nahrstedt, "Finding Service Paths in a Media Service Proxy Network", In: *Proceedings of SPIE/ACM Multimedia Computing and Networking Conference,* 2002.

[5] E. M. Maximilien, and M. P. Singh, "A framework and ontology for dynamic Web services selection", *IEEE Internet Computing, 2004*, pp.84-93.

[6] F. Curbera, M. Duftle, R. Khalaf, W. Nagy, N. Mukhi, and S. Weerawarana, "Unraveling the Web Services Web: An Introduction to SOAP, WSDL, and UDDI", *IEEE Internet Computing*, Vol.6, 2002 pp.86-93.

[7] F. Vernadat, "Enterprise Modeling and Integration: Principles and Applications", Springer, 1996.

[8] G. Alonso, F. Casati, and Harumi, "Web Services: Concepts, Architectures and Applications", Springer, 2003.

[9] J. O. Aagedal, Z. Milosevic, "Enterprise modeling and QoS for Command and Control Systems", In*: Proceedings of the 2nd International Workshop on Enterprise Distributed Object Computing,* 1998, pp.88-101.

[10] L. Zeng, B. Benatallah, M. Dumas, J. Kalagnanam, and Q. Z. Sheng, "Quality Driven Web Services Compositon", In: *Proceedings of the International World Wide Web Conference*, Budapest, Hungary, 2003 pp. 411-421.

[11] L. Zeng, B. Benatallah, A. H. H. Ngu, M. Dumas, J. Kalagnanam, and H. Chang, "QoS-Aware Middleware for Web Service Compostion", *IEEE Transactions on Software Engineering*, VOL.30 No.5, 2004, pp.311-327.

[12] M. Fugini, P. Plebani, and F. Ramoni, "A User Driven Policy Selection Model", In: *Proceedings of International Conference on Service-Oriented Computing 2006*, Chicago, IL, USA, 2006, pp.427-433.

[13] M. Gillman, G. Weikum, and W. Wonner, "Workflow management with Service Quality Guarantees", In: *Proceedings of ACM Conference on Management of Data*, 2002, pp.228-239.

[14] Q. Dai, R. J. Kauffman, "Business Models for Internet-Based B2B Electronic Markets", *International Journal of Electronic Commerce*, Vol 4, 2002, pp.41-72.

[15] T. L. Saaty, "The Analytic Hierarchy Process", McGraw Hill, New York, 1990.

[16] T. H. Cormen C. E. Leiserson, and R. L. Rivest, "Introduction to the Algorithm", MIT press.

[17] G. Wang, A. Chen, C. Wang, C. Fung, and S.Uczekai, "Integrated quality of service (QoS) management in service-oriented enterprise architectures", In: *Proceedings of Enterprise Distributed Object Computing Conference 2004*, 2004. pp. 21-32.

[18] X. Gu and K.Nahrstedt, "A Scalable QoS-aware Service Aggregation Model for Peer-to-Peer Computing Grids", In: *Proceedings of the 11th IEEE International Symposiums on High Performance Distributed Computing*, 2002, pp.73-82.

[19] X. Wang, T. Vitvar, M. Kerrigan, and I.oma, "A QoS-Aware Selection Model for Semantic Web Services", In: *Proceedings of International Conference on Service-Oriented Computing 2006*, Chicago, IL, USA, 2006. pp.390-401.

[20] X. Xie, and K. Chen, "An AHP-Based Evaluation Model for service composition", In: *Proceedings of International Conference on Computational Science and its Applications 2006*, Huhhot, China, pp.756-766.

[21]Y. Liu, AH. Ngu, and L.Z. Zeng "QoS computation and policing in dynamic web service selection", In: Proceedings of *International World Wide Web Conference, 2004*, pp.66-73.