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A Multiple Qos Parameter Based Web Service Composition Using Petri Net Verification

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Abstract**—**Automatic Web service composition aims at combining several existent web services to generate composite web service automatically that satisfies more complex user requests. The process of automatic web service composition comprised of pre-processing phase, service discovery and ranking phase and planning, verification and execution phase. A domain-ontology-based Particle Swarm Optimization (PSO) inspired Balanced Iterative Reducing and Clustering using Hierarchies (BIRCH) method was used in the pre-processing phase. It filtered the noisy data and clustered the web services. The matching and ranking problem is considered in the discovery and ranking phase where the web services were discovered by Improved Bipartite Graph (IBG) and the discovered web services were ranked by Quality of Service (QoS) based fuzzy ranking algorithm. A Petrinet based model was used for planning, verification and execution of web services. In this model, the web services can be directly mapped into the Petrinet. In this paper, the planning, verification and execution of web services is improved by including multiple QoS such as availability, reliability, time, cost, accuracy, accessibility, modifiability and security in Petrinet model. Based on the multiple QoS parameters, the Petrinet model verified the composition plan. It describes the static vision of a system and dynamic behavior of processes. The Petrinet with multi QoS models the internal operations of web services, interactions among them and the processes in all phases of automatic web service composition process.

Keywords**—**Automatic web service composition, Petrinet based model, Petrinet with multiple QoS, Verification of composite web service, optimal selection of composition plan

I. Introduction

A web service [1, 2] is a software system devised to support interoperable machine-to-machine interaction over a network. Web services allow organizations to communicate and process data without deep knowledge of each other system technologies. Most of all organizations have engaged their core business or scientific competencies with collections of web services over the internet. It allowed users to dynamically resolve complex problems by combining available web services. This integration of various web services is called web service composition.

A web service composition should concerns how and which web services will be integrated to obtain a composite web service satisfying the user needs. User requests can express functional and non-functional requirements [3]. Functional requirements specify the functions that a system must be capable of performing. It defines the fundamental process to produce outputs from inputs whereas the non-functional requirements are constraints that allow description of an application in terms of quality attributes. These types of requirements often related to Quality of Services (QoS) [4] criteria allow optimal solution which ensures consistent state of the whole system. A composite web service is a service with more complex structure and more powerful functionality.

A domain-ontology-based PSO-inspired Balanced Iterative Reducing and Clustering using Hierarchies (BIRCH) clustering [4] was introduced to improve the web service clustering. Then, the relationships between the pairs of dissimilar web services were identified through Improved Bipartite Graph (IBG). In order to generate the optimal composition plans, the discovered web services from IBG were ranked by QoS based fuzzy ranking algorithm.

A Petrinet based model [5] was used for generation and verification of composition plans. In this model, the ranked web services were directly mapped into Petrinet. The most important verification problems are reachability, liveness and existence of deadlocks which were easily verified using Petrinet. However in the Petrinet based model, including multiple QoS parameters can provide more efficient automatic web service composition. So in this paper, multiple QoS parameters such as availability, reliability, time, cost, accuracy, accessibility, modifiability and security are included in the Petrinet model for efficient web service composition. These QoS parameters are calculated for each web services involved on the web service composition plan. With the help of these QoS parameters, the Petrinet model verified the web service composition plan.

The rest of the article is structured as follows: Section II presents related work of web service composition method. Section III explains the proposed methodology. Section IV illustrates the experimental results of the proposed method. Finally, Section V concludes the research work.

II. RELATED WORK

A heuristic web service composition method [6] was proposed for web service composition. This method of web service composition was based on graph and it described the service relations for fishery domain. The search space of this method was reduced by semantic similarity and the service success times were introduced as a heuristic function of service path searches. The heuristic function was dynamically adjusted based on the success or failure frequencies. However, this method requires improvement in terms of execution time.

A Colored Petri Net (CPN) based method [7] was proposed for web service composition. CPN was an extension of Petri Net and it had some precise automated verification tools and mathematics semantics. This method detected the bugs at design stage and through the behavioral and structural analysis the correctness of web service composition was ensured. Even though it enhanced the confidence in the correctness of the model of web service composition, the efficiency of CPN is low.

A genetic-based approach [8] was proposed for web service composition in geo-distributed cloud environment. A realistic QoS-based composition model was specified that considered both the distributed network environment and QoS for web service composition. In addition to this, an approach was presented to calculate the QoS of composited service in cloud computing. The computational complexity to solve the network-aware composition problem was reduced by using Genetic Algorithm which minimized SLA violation and maximize user experience. A runtime recovery approach could be developed to improve the efficiency of genetic-based approach.

Ant Colony Optimization based algorithm [9] was proposed for web service composition in cloud computing. ACO algorithm selected the cloud combination that contains a minimum number of clouds based on pheromone and problem-specific local heuristic information. Pheromone information was assigned to the edges of the graph and it was evaporated at a certain rate at each iteration. The pheromone information was also updated based on the quality of the solutions containing this edge.

A time based learning method called reinforcement method [10] was proposed for web service composition. In this method, the planning for web service composition was considered as uncertain planning problem. A partially observable Markov Decision Process was used to deal with the uncertain planning problem for composition of web services. The reinforcement method was an uncertainty planning method and it doesn't needs to know complete information of services. It composed web services by using the historical data and then computed the successful possibilities that services were composed together with respect to service outcomes and Quality of Service (QoS). However, it is applicable for limited amount of data.

Two-stage approach [11] was proposed for dynamic web service composition. In the first stage of two-stage approach, top k web service composition schemes were selected based on QoS values of each web services with the proposed Culture Genetic Algorithm (CGA). In order to minimize the number of web services and select the best one, component services in the top K schemes were filtered. The global QoS constraints were decomposed into local QoS constraints with CGA and it increased the flexibility of dynamic web service composition. In the second stage of two-stage approach, QoS values of each candidate service were predicted based on improved case-based reasoning and the best service was selected according to the predicted QoS values. However, CGA has convergence problem which affect the performance of web service composition.

A dynamic Multi-Attribute Decision Making approach (MADM) [12] was proposed for large-scale web service composition. The problem of QoS Web Service Composition (QWSC) was addressed in MADM based on genetic algorithm and information theory. According to the distinguished capability of QoS attributes QoS attribute was weighted in both subjective perspective and information-based perspective. Hence, it solved the MADM problem. In addition to this, a GACRM algorithm was developed to navigate into the web services. However, the GA has convergence problem.

III. METHODOLOGY

In this section the proposed Petrinet with QoS is described in detail to generate effective web service composition. Initially, a domain-ontology-based PSO-inspired BIRCH clustering is applied on the web service to group the web service based on the similarity metrics. The clustered web services are then matched with other web services using improved bipartite graph and then a QoS based fuzzy ranking is applied to rank the discovered web services. From the output of the discovered web services, composition plans are generated which are verified using Petrinet model. For more efficient automatic web service composition, QoS parameters such as cost, accuracy, accessibility, robustness, scalability, modifiability and security are included in Petrinet.

A. Web Service Clustering

The Domain-Ontology-based PSO-inspired BIRCH clustering clusters the web services in a hierarchical manner using the BIRCH and PSO techniques [3]. The BIRCH clustering comprised of four phases. In the first phase, clustering feature (CF) tree is generated to load the services into the memory. In the second phase, the services are condensed into desirable range and it is an optional phase in BIRCH clustering. In the third phase, global or semi-global algorithm is used to cluster all leaf nodes of CF tree. In the fourth phase, the obtained sets of clusters are purified and reorganize the data points to its neighboring seed to acquire a set of new clusters. Then the clusters are optimized by using PSO evolutionary algorithm.

B. Web Service Discovery and Ranking

The web services are required to be discovered and ranked to satisfy the customer requests. The service discovery is achieved by matching the web services based on the relationships between the pairs of disparate services. An Improved Bipartite Graph [3] is used to discover the web services by using Maximal Bicliques Enumeration algorithm (MBE). Then, the discovered services are ranked using QoS based fuzzy ranking algorithm where a fuzzy ranking approach is used to class the services in the QoS ranked based on the QoS criteria such as cost, reputation, average response time, frequency, and success rate.

C. Petrinet with QoS based Web Service Composition

A Petrinet [8] is used to model the web service composition where a Petrinet-based algebra is used to represent a web service. This called as Service Net which is formally defined as a tuple

$$SN=(P,T,W,i,o,l) \qquad (1)$$

where, P- Finite set of places representing the state of the ranked services

T- Finite set of transactions representing the operation of the services

W- Flow relation between the web services $W \subseteq (P\times T)\cup(T\times P)$

i- Input place with $i=\{x\in P\cup T|(x,i)\in W\}=\emptyset$

o- Output place with $o=\{x\in P\cup T|(o,x)\in W\}=\emptyset$

l- labeling function

A web service composition starts when a information is in place i and terminates when a token reaches the place o. In order to facilitate the composition operators, SN contains only one input and one output place. For each web service composition operator, SN provide a direct mapping from each operator to a Petrinet construction. While such a Petrinet based model allows the detection of inconsistencies both within and among web services by verifying the well known properties of Petrinet such as reachability, deadlock and liveness. However, this approach doesn't consider some important QoS of web services such as availability, reliability, time, cost, accuracy, accessibility, modifiability and security to verify the correctness of composition plans. So, the above mentioned QoS of web services are included in basic Petrinet approach for efficient composition of plans.

1) Availability

Availability is the presence of web service to be connected to for a client. It is the absence of service downtime and signifies the probability that service is available. Availability is related with time-to-repair. Time-to-repair is time taken to repair a service which has failed. Higher value of availability is achieved by smaller value of time-to-repair. The availability factor $\mathrm{Ava}_{\mathrm{pq}}$ can be calculated by the services which are responded to the total number of services as,

$$\mathrm{Ava}_{\mathrm{pq}} = \frac{\mathrm{respond}_{\mathrm{pq}}}{\mathrm{total\ request}_{\mathrm{pq}}} \qquad (2)$$

where, $total\,request_{pq} \neq 0$, p and q are candidate web services.

2) Reliability

Reliability is the capability of upholding the service and service quality. This measure is used to define the ability of a service which it function correctly and consistently. It can be calculated as,

$$\mathrm{R}_{\mathrm{pq}} = \mathrm{e}^{-\int_0^{\mathrm{timepq}} \gamma^{(\mathrm{t})\mathrm{dt}}} * \mathrm{e}^{-\gamma * \mathrm{time}_{\mathrm{pq}}} \qquad (3)$$

where, $\gamma^{(t)}$is the failure rate for the web service.

3) Time

It measures the execution time between the requests sent and results received. It is the amount of time taken for a service to provide a response to various types of requests from composite users.

4) Cost

It is the amount that a service requester needs to pay to execute a service using task.

5) Accuracy

Accuracy denotes how accurately composite the web services for user requests.

6) Accessibility

It is the capability to satisfy a web service request. It represents the It denotes the scale in which a service request is served. It is a measure representing the achievable speed of a service in time. The service is available for a large number of clients at a greater extent of accessibility.

$$\text{Accessibility} = \frac{\text{Number of Acknowledged messages}}{\text{Number of Requested messages}} \quad (4)$$

7) Robustness

Robustness is defined as how robust the web service composition plan.

8) Scalability

Scalability is a system's ability to sustain an acceptable service level for an increasing number of concurrent requests. The service level should be measured from the client side because there is no linear correlation between throughput and response time.

9) Modifiability

The modifiability is how easy an application can be changed in order to modify a specific component's implementation (evolvability), or adding functionalities to it (extensibility), or reuse some components to achieve new functionalities.

10)Security

Security involves confidentiality, authentication, message integrity, authorization and access control. It is considerably characteristic because web service incantation happens over the internet. These measures for web service composition plans are calculated and the web service composition plans are verified using Petri Net.

Based on multiple QoS of web services, the Petrinet is remodeled as,

$$SN = (P, T, W, i, QoS, o, l) \quad (5)$$

Algorithm
Input: web services

Output: web service composition plan

1. Cluster the web services based on Domain-ontology-based PSO-inspired BIRCH clustering.

2. Discover the web services using Improved Bipartite Graph

3. Rank the discovered web services using QoS based fuzzy ranking

4. Generate and verify the composition plans using Petrinet with multiple QoS model

$$SN = (P, T, W, i, o, l, QoS)$$

5. A transition represents the operation of web services $t \in T$ is said to be optimal if and only if $\forall p \in P, l(p) \geq i(p,t)$ and denoted as l[t >

6. Firing a transition t at l leads to l^* denoted as $l[t > l^*$ where:

$$\forall p \in P, l^*(p) = l(p) + o(p,t) - i(p,t)$$

IV. Results and Discussion

In this section, the performance of automatic web service composition is evaluated using 10835 indexed OWL-S services in OWL-S Service Retrieval Test Collection version 4.0. It has nine different domains are education, medical care, food, travel, communication, economy, weapon, geography and simulation. The education medical care, food, travel, communication, economy, weapon, geography and simulation domains consists of 286, 73, 34, 197, 59, 395, 40, 60 and 16 services respectively. The efficiency of existing Petrinet based model and proposed Petrinet with multiple QoS model are tested in terms of Time, availability, reliability and cost.

A. Time

Time measures the execution time between the requests sent and results received. It is the amount of time taken for a service to provide a response to various types of requests from composite users. Table 1, shows the comparison of time in terms of seconds between Petrinet model and Petrinet with Multiple QoS model.

Table 1. Comparison of Time

No. of web services	Time (secs)	
	Petrinet model	*Petrinet with Multiple QoS model*
50	11	8
100	14	10
150	17	15
200	21	18
250	25	21

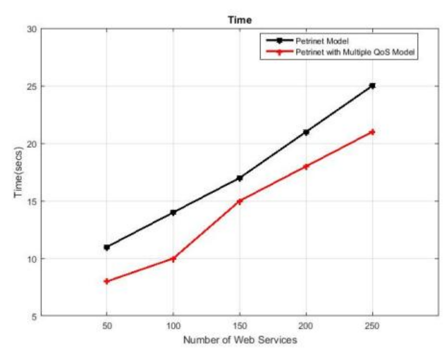

Figure 1. Comparison of Time

Figure 1 shows the comparison of time between existing Petrinet model and proposed Petrinet with Multiple QoS model for web service composition. X axis denotes the number of web services and Y axis denotes the time in sec. When the number of web services is 250, the execution time of Petrinet with multiple QoS model is 16% less than Petrinet model. From the analysis, it is proved that the proposed Petrinet with multiple QoS model has better execution time than the Petrinet model.

B. Availability

The availability factor Ava_{pq} can be calculated by the services which are responded to the total number of services as,

$$Ava_{pq} = \frac{respond_{pq}}{total\ request_{pq}}$$

Table 2. Comparison of Availability

No. of web services	Availability	
	Petrinet model	***Petri net with Multiple QoS model***
50	73	78
100	74	80
150	77	82
200	80	85
250	82	88

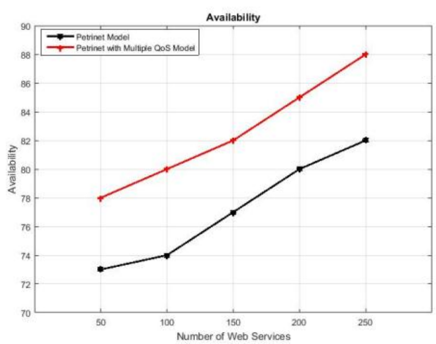

Figure 2. Comparison of Availability

Figure 2 shows the comparison of availability between existing Petrinet model and proposed Petrinet with Multiple QoS model for web service composition. X axis denotes the number of web services and Y axis denotes the availability. When the number of web services is 250, the availability of Petrinet with multiple QoS model is 7.3% greater than Petrinet model. From the analysis, it is proved that the proposed Petrinet with multiple QoS model has better availability than the Petrinet model.

C. Reliability

Reliability is the capability of upholding the service and service quality. This measure is used to define the ability of a service which it function correctly and consistently. It can be calculated as,

$$R_{pq} = e^{-\int_0^{timepq} \gamma(t)dt} * e^{-\gamma * time_{pq}}$$

Table 3. Comparison of Reliability

No. of Web Services	Reliability	
	Petrinet model	***Petri net with Multiple QoS model***
50	0.606	0.612
100	0.608	0.619
150	0.609	0.622
200	0.614	0.63
250	0.619	0.636

Figure 3 shows the comparison of reliability between existing Petrinet model and proposed Petrinet with Multiple QoS model for web service composition. X axis denotes the number of web services and Y axis denotes the reliability. When the number of web services is 250, the reliability of Petrinet with multiple QoS model is 2.7% greater than Petrinet model. From the analysis, it is proved that the proposed Petrinet with multiple QoS model has better reliability than the Petrinet model.

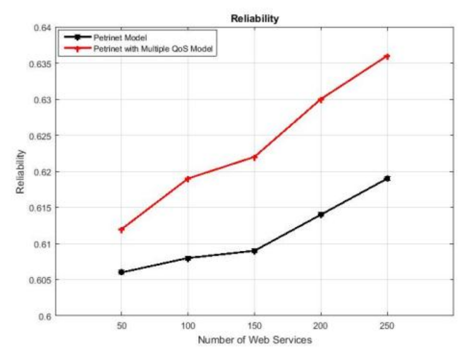

Figure 3. Comparison of Reliability

D. Cost

Cost is the amount that a service requester needs to pay to execute a service using task.

Table 4. Comparison of Cost

No. of web services	Cost	
	Petrinet model	***Petri net with Multiple QoS model***
50	60	52
100	67	60
150	75	69
200	82	74
250	98	87

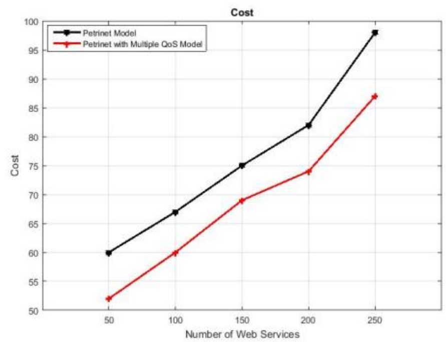

Figure 4. Comparison of Cost

Figure 4 shows the comparison of cost between existing Petrinet model and proposed Petrinet with Multiple QoS model for web service composition. X axis denotes the number of web services and Y axis denotes the cost. When the number of web services is 250, the cost of Petrinet with multiple QoS model is 11.2% less than Petrinet model. From the analysis, it is proved that the proposed Petrinet with multiple QoS model has better cost than the Petrinet model.

V. CONCLUSION

In this paper, Petrinet with multiple QoS is proposed for efficient selection of web services for web service composition. In the planning, verification and execution phase of the automatic web service composition framework the plans are generated by getting input from the discovery phase and it is verified using Petri net based algebra approach for its correctness. For the optimal selection of composition plans multiple QoS parameters are included in the Petri net based approach. Thus the selection of qualitatively different services from multiple functionally identical services is achieved by using Petrinet with multiple QoS model. The experimental results show that the proposed Petrinet with multiple QoS model is better than the Petrinet model in terms of time, availability, reliability and cost.

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