ISSN: 2414-1895 DOI: 10.6919/ICJE.202011_6(11).0031

# QoS-based Web Composite Service Selection Methods: A Review

Mengmeng Du

School of Computer Science & Technology, Tiangong University, TianJin, 300387, China.

17097491@qq.com

## Abstract

**With the popularization of technology such as service-oriented computing(SOC), and cloud computing, the services provided by suppliers can be invoked through standard Web services and provided to users. In recent years, owing to the exponential increase in the number of service providers, there are more and more services on the internet with the same function but different Qualifies of Service (QoS). Meanwhile, the increasingly complex user's needs for functionality and QoS can no longer be met by a single service. Therefore, how to integrate a large number of services into a comprehensive web service to satisfy users' QoS has attracted the attention of many scholars. In this paper, we introduce the web service composition model and the definition of relative QoS attributes and summarize the QoS-based web composite service selection methods according to the type of method. Finally, the shortcomings of each type of algorithm are shown.**

## Keywords

**Qualify of service; Service composition; Web service.**

## 1. Introduction

In recent years, as web service technology has been widely used in various fields, such as the Internet of Things (IoT), smart cities(SC), and safe-protection, web services have become an important way to solve complex functionalities. For the rapid increase in the number of web service providers, the web services' QoS in the network is also uneven, that is, there are millions of web services with the same function and different QoS. Additionally, users' requirements for web services are characterized by complexity. In the past, it was increasingly difficult for the web provided by a single service provider to meet the comprehensive user's demands. Therefore, service composite technology can better solve this problem.

In order to satisfy user needs and ensure high QoS at the same time, it is the current research hotspot that how fast develops web service composite algorithms within some of QoS constraints [1][2]. In this article, in order to facilitate understanding and reading, We summarized previous solutions related to QoS-based web service composition according to method categories and pointed out the shortcomings of these solutions.

The remaining chapters of this article are organized as follows. Section 2 introduces the composition model of web service. Section 3 shows the QoS model of web services. Section 4 summarizes web service composition optimization algorithms in recent according to their method categories. Section 5 gives some conclusions in this paper.

## 2. The model of web service composition

Currently, there are many web services with the same function and different QoS on the internet. It is very necessary to integrate these services into a comprehensive web composite service within user's

ISSN: 2414-1895 DOI: 10.6919/ICJE.202011_6(11).0031

demands based on the service-oriented computing (SOC) technology. Essentially, web service composition is an NP-hard problem, that is, a large-scale combinatorial optimization problem [3].

Generally, during web service composition, there are two of service as following:

1) The abstract service $As_i$: This service represents the service functionality, and this service contains multiple concrete services with the same functionality and different QoS.

2) The concrete service $Cs_{ij}$ : This service is provided by a web service provider, which can be directly invoked by the Internet.

Since a single web service cannot meet the comprehensive needs of users, web composite services successfully solve this problem. Generally, web composite services have multiple functions provided by the different service providers at the same time, that is, the web composite service is composed of multiple abstract services. In the process of web service composition, for each $As_i$, an optimal $Cs_{ij}$ is selected as the component of the final web service composition [4], as shown in Figure 1.

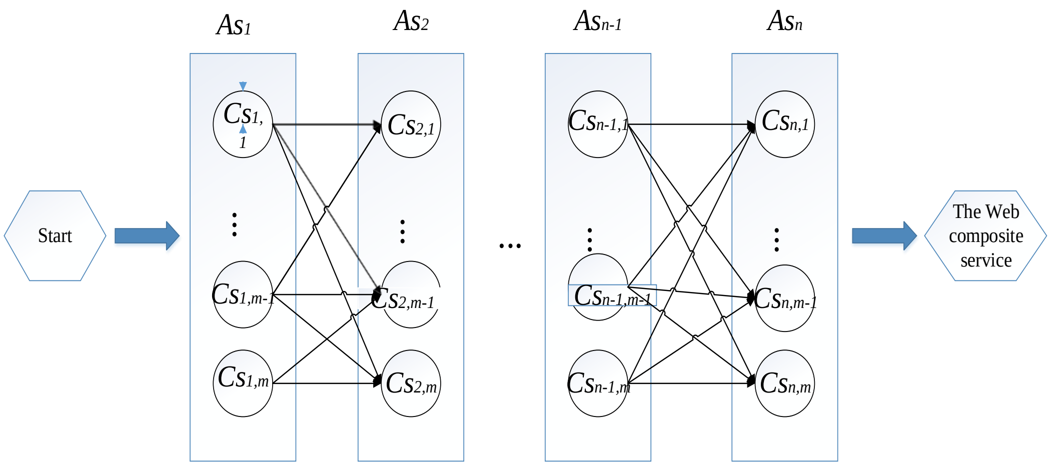


Figure 1. The model of web service composition

## 3. The related attribute definitions about web QoS

QoS is an index, which measures the degree of satisfaction of a service, proposed by the International Telephone and Telegraph Consultative Committee (CCITT) [5]. In the process of web service composition, the QoS attributes that are often considered are shown in table 1.

Table 1. The Common QoS attributes for web service

| The QoS attributes | The definition |
|---|---|
| Cost (C) | The price that should be paid for using the service is provided by the supplier. |
| Response time (RT) | The time interval between service request and service response. |
| Reliability (RE) | The probability of the service being executed correctly within a certain time interval |
| Availability(AV) | The probability that the service is available in a certain time interval |
| Reputation(Re) | The average value of users' evaluation for the service. |

Web service attributes can be divided into benefit-attributes, such as availability and reputation, and cost-attributes, such as cost and response time, according to their own characteristics. As the value of cost-attributes increases, QoS will decrease. At the same time, as the value of benefit-attributes increases, QoS will increase. Therefore, in order to promote QoS, in the process of web service

ISSN: 2414-1895 DOI: 10.6919/ICJE.202011_6(11).0031

composition, the benefit-attribute will be maximized, and the cost-attribute attribute will be minimized [6-7].

The QoS attribute of the web composite service is consistent with that of the web service. However, the QoS of web composite services is affected by its own structure [8]. The common structures are sequential, parallel, conditional, and circular [8-9] as shown in figure 2. Under different structures, the aggregation function of QoS attributes is shown in table 2.

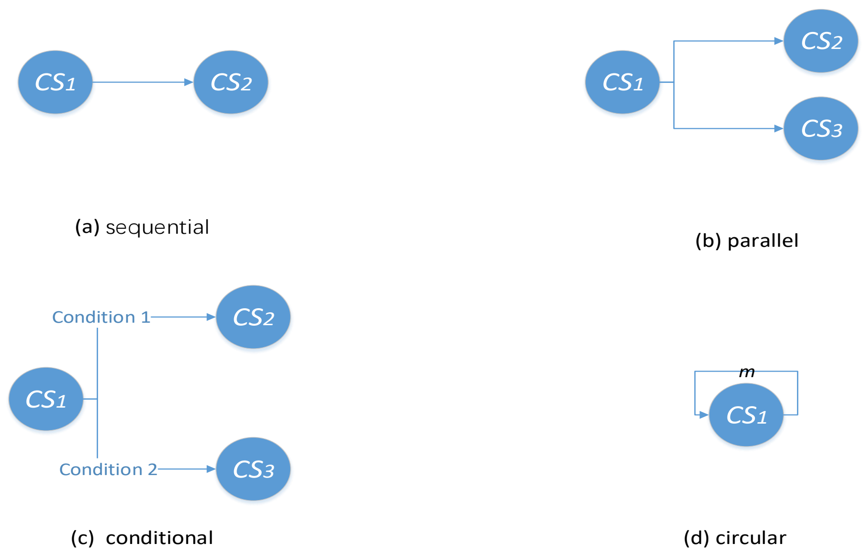


Figure 2. The common structure of web composite service

Table 2. The calculation methods for different structures

| Composition structure | Cost (C) | Response time (RT) | Reliability (RE) | Availability (AV) | Reputation(Re) |
|---|---|---|---|---|---|
| Sequential | $\sum_{i=1}^{n} Q_i(P)$ | $\sum_{i=1}^{n} Q_i(RT)$ | $\prod_{i=1}^{n} Q_i(RE)$ | $\prod_{i=1}^{n} Q_i(AV)$ | $\sum_{i=1}^{n} Q_i(Re)/n$ |
| Parallel | $\sum_{i=1}^{n} Q_i(P)$ | $max\{Q_i(RT),...,Q_n(RT)\}$ | $\prod_{i=1}^{n} Q_i(RE)$ | $\prod_{i=1}^{n} Q_i(AV)$ | $\sum_{i=1}^{n} Q_i(Re)/n$ |
| Conditional | $\sum_{i=1}^{n} P_i Q_i(P)$ | $\sum_{i=1}^{n} P_i Q_i(RT)$ | $\sum_{i=1}^{n} P_i Q_i(RE)$ | $\sum_{i=1}^{n} P_i Q_i(AV)$ | $\sum_{i=1}^{n} P_i Q_i(Re)$ |
| Circular | $k*Q_i(P)$ | $k*Q_i(RT)$ | $(Q_i(RE))^k$ | $(Q_i(AV))^k$ | $Q_i(Re)$ |

## 4. QoS-based web service composition optimization algorithm

In the process of web service composition, there are multiple abstract services, and each abstract service is composed of multiple concrete services, which have the same function and different QoS. Therefore, the essence of QoS-based web service composition is to select a web service with optimal QoS for each abstract service to form the final composite service meeting the complex needs of users. Based on the method type, this section will summarize the previous QoS-based web service composition optimization algorithm.

### 4.1 The exhaustive method

The exhaustive method, also known as the enumeration method, is the simplest search algorithm [10]. It's essence is that all possible web service composite solutions are listed in sequence according to the needs of users. Then, according to a certain evaluation standard, evaluate all the candidate web

ISSN: 2414-1895 DOI: 10.6919/ICJE.202011_6(11).0031

composite services, and use the scheme closest to the evaluation standard as the final web composite service [3].

The exhaustive method has a series of advantages as follows:

1) It is convenient to operate and understand.

2) It can list all possible solutions, and there is no problem of missing partial solutions.

However, this method also has some weakness, that is, as the scale of web services and the scale of composition increases, the time complexity of the algorithm increases exponentially, resulting in low efficiency and low scalability. Therefore, for large-scale web service composite problems, the exhaustive method is only applicable to small-scale web service composite problems.

### 4.2 The genetic algorithm

Genetic algorithms (GA) is a biological self-heuristic algorithm. It is an adaptive global optimization method based on the genetic and evolutionary phenomena of organisms in nature [11]. GA transforms the combinatorial optimization problem into an optimization problem based on a fitness function. Comparing with other methods, it is more suitable to solve NP-hard problems.

The advantages of GA are as follows:

1) The genetic algorithm does not use other auxiliary knowledge, and only selects the final solution through fitness function, which is simple to operate.

2) Use the random mechanism to search for the best solution, and search for all possible solutions more comprehensively.

However, GA also has some disadvantages as follows.

1) As the scale of the problem increases, the efficiency will be greatly reduced.

2) The time-consuming of the algorithm searching is relatively high.

3) Premature maturity and early proficiency are prone to occur.

4) The algorithm is very sensitive to the setting of evolutionary operating parameters, such as crossover rate and mutation rate, and relevant parameters need to be set reasonably.

In [12], the author transformed the problem of web service composition optimization into a multi-attribute decision-making problem. First, the compromise ratio method (CRM) is used to delete candidate services with lower QoS, for reducing the search domain. Then, GA is used to find the global optimal solution that ultimately meets the demand Web composite service. In [13], the author selects the web composite service that meets the user's preference based on the distance from the solution group to the positive and negative ideal points, and then uses the adaptive genetic algorithm to find the optimal web composite service. In [14], the author used chaos theory to generate an initial solution population and then combine GA and chaotic small disturbance method (CSDM) to search for the final best web composite service. In [15], the author adopted a multi-scale crossover genetic algorithm and an information-sharing factor to select a solution that meets the needs within QoS constraints. In [16], the author transformed the service selection problem in a polymorphic environment into a single-objective optimization problem with uncertain QoS constraints and then used GA with a community partition method to find the final candidate service.

### 4.3 Ant colony algorithm

Ant Colony Algorithm (ACA) is a stochastic optimization algorithm proposed by Italian scholar M.Dorigo et al., and ACA is invented based on the behavior phenomenon of ant colonies in the process of finding food [17]. It can solve complex Optimization problem.

ACA has the following advantages:

1) Using a positive feedback mechanism, the algorithm search process continues to converge until the optimal solution position is approached.

2) Using a probabilistic search mechanism, it is easy to find the global optimal solution.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202011_6(11).0031

3) The search process adopts a distributed method, that is, a parallel search solution.

However, there are also the following disadvantages [18]:

1) In the search process, ACA is easily affected by the optimal solution found in the early stage, and it is easy to fall into the local optimal solution.

2) As the scale of the problem increases, the search time for CAC is longer.

3) During the search process, population diversity is difficult to guarantee.

In [19], the author proposed a QoS-aware web service optimization method. This method uses the ant colony algorithm and introduces the concept of chaotic disturbance to avoid local optimal solutions. In [20], the author proposed an improved ant colony algorithm (IACA), which contains an initial pheromone distribution strategy and a local optimization strategy to search for web composite services within QoS constraints. In [21], the author transformed the web service composite problem into a multi-objective optimization problem and proposed a multi-objective dynamic web service selection algorithm based on QoS global optimization. The algorithm optimizes multiple objective functions in parallel to determine the final web composite service.

### 4.4 Particle swarm algorithm

A particle swarm algorithm (PSA) is a global stochastic optimization algorithm based on a swarm heuristic. This method finds the global optimal solution by constantly adjusting the positions of the current solution and the temporary optimal solution [22]. PSA has the characteristics of simple operation, convergence speed, and wide application range. But there are also some disadvantages, such as premature convergence, low optimization accuracy, and easy to fall into local optimal solutions.

In [23], the author transformed the dynamic web service selection problem into a single-objective optimization problem and proposed a QoS global optimal service selection algorithm based on PSA. Through using this algorithm, a composite service that satisfies the global QoS constraints is discovered. In [24], the author proposed an improved PSA, which finds web composite services from the optimal local solution generated in each iteration. In [25], the author proposed a new web service recommendation strategy based on the discrete binary particle swarm algorithm.

### 4.5 Hybrid algorithm

Since each optimization algorithm has shortcomings and advantages, in order to solve more complex web service composition problems, combining different algorithms is a good idea. In [26], the author put forward a hybrid algorithm with a particle swarm algorithm and genetic algorithm to find the global best web composite service. In [27], in order to overcome the difficulty of traditional optimization algorithms in high-latitude spaces, the author combines the gravitational search algorithm with the PSA and proposes a hybrid algorithm to find the global optimal solution. In [28], for solving the problem of the low diversity of traditional PSA and easy to fall into local optimum, the author will combine PSA and firework algorithm to propose a firework particle swarm algorithm to find the global optimal composition plan.

### 4.6 Other algorithms

In the past, many scholars have used other optimization algorithms to solve the web composite service selection problem. For example, in [29], the author transformed the QoS-aware service composition problem into a multi-objective optimization problem, using rough set theory and fuzzy hierarchy analysis to automatically calculate the corresponding QoS weight. Then, the cuckoo multi-objective optimization algorithm is used to find the global optimal solution. In [30], the author proposed a web service composition schedule based on a multi-objective gray wolf optimization algorithm. In [31], in order to overcome the shortcomings of traditional single-objective service selection algorithms that tend to fall into local optimality, the author adopted the artificial fish group algorithm selects the global optimal web composite service within a limited number of iterations. In [32], for improving the diversity and QoS of combined services, and improved multi-objective bee colony algorithm was

ISSN: 2414-1895 DOI: 10.6919/ICJE.202011_6(11).0031

proposed to solve the composite problem of web services. The algorithm uses direction learning factors, elite guidance strategies, and combination mutation strategies to increase the diversity of service portfolios while ensuring the QoS of web composite services.

## 5. Conclusion

The QoS-based web composite service problem is a classic Np-hard problem. Moreover, the QoS of web composite services affects user experience. In this paper, we detailed the web service composition model and related parameters commonly used to evaluate web QoS. Finally, according to the method type, we summarize and illustrate the previous QoS-based web service composition algorithms.

## References

[1] Xiaoqin Fan, Changjun Jiang, et al.: Dynamic Web Service Selection Based on Discrete Particle Swarm Optimization[J], Journal of Computer Research and Development, 2010,47(1):137-156. (In Chinese).

[2] Liu Shulei, Liu Yunxiang, Zhang Fan, et al.: A Dynamic Web Services Selection Algorithm with QoS Global Optimal in Web Services Composition[J]. Journal of Software, 2007, 18(3): 646-656. (In Chinese).

[3] Li Jinzhong, Xia Jiewu, Tang Weidong, Zeng Jintao, Wang Xiang, Wu Lanying: Survey on Web services selection algorithms based on QoS [J]. Application Research of Computers, 2010,27(10):3622-3627+3638. (In Chinese).

[4] Liu Heng, Zhang Gongrang, Wu Man: Web Service Composition Optimization Based on Estimation of Distribution Algorithm [J]. Chinese Computer Technology and Development, 2014, 24(06):10-14.

[5] Tang Chong: Survey on Web Services QoS Optimization Problem [J], Information Technology and Informatization,2015(04):223-225. (In Chinese).

[6] Xia Yamei, Cheng Bo, Chen Junliang, Meng Xiangwu, Liu Dong: Optimizing Service Composition Based on Improved Ant Colony Algorithm[J], Journal of Computers, 2012, 35(02):2270-2281. (In Chinese).

[7] Zhang Li: Research on QoS-driven Service Composition Optimization Algorithm in Internet of Things[D]. Xi'an Shiyou University, 2018. (In Chinese).

[8] Feng Yan: Study on Web Service Composition on the Basis of QoS multi-attributes decision making[D]. Tianjin University, 2014. (In Chinese).

[9] Zhang Chengwen, Su Sen, Chen Junliang: Genetic Algorithm on Web Services Selection Supporting QoS[J], Journal of Computers, 2006,29(07):1029-1037. (In Chinese).

[10] Wang Deyan: Comparison of Exhaustive Method and Particle Swarm Algorithm [J], Journal of Wuxi Institute of Technology,2008(01):44-45. (In Chinese).

[11] Ge Jike, Qiu Yuhui, Wu Chunming, Pu Guolin: Summary of genetic algorithms research [J], Application Research of Computers, 2008(10): 2911-2916. (In Chinese).

[12] Feng Yan, Chen Fuzan: Web Service Composition Optimization Method Based on QoS Multi-attribute Decision Making [J], Computer Engineering, 2015, 41(06):33-37+42. (In Chinese).

[13] Lu Chenghua, Kou Jisong: Multi-attribute Decision Making and Adaptive Genetic algorithm for Solving QoS optimization of Web service composition[J], Computer Science, 2019, 46(02):187-195. (In Chinese).

[14] Tan Wenan, Zhao Yao: Web service composition based on chaos genetic algorithm [J], Computer Integrated Manufacturing System,2018,24(07):1822-1829. (In Chinese).

[15] Xu Tian, Liu Lingxia: Optimization of Web Service Composition Based on improved Genetic Algorithm [J], Computer Applications and Software, 2016, 33(05):24-27. (In Chinese).

[16] Zhu Xilu, Wang Bai: Web service selection algorithm based on uncertain quality of service [J], Computer Integrated Manufacturing System, 2011, 17(11):2532-2539. (In Chinese).

[17] Wu Qinghong, Zhang Jihui, Xu Xinhe: Ant Colony Algorithm with Mutation Characteristics[J],Journal of Computer Research and Development,1999(10):3-5. (In Chinese).

[18] SERDYUKOV P,RODE H,HIEMSTRA D, Modeling multi-step relevance propagation for expert finding[C] //Proc of the 17th Conference on Information and Knowledge Management. New York: ACM Press, 2008: 1133-1142.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202011_6(11).0031

[19] Cheng Song, Zhou Jingquan, Chang Ruiyun: Investigation on Optimization of Web Service Composition Employing Chaos Ant Colony Algorithm [J], Computer Technology and Development,2017,27(02):178-181+186. (In Chinese).

[20] Ni Zhiwei, Fang Qinghua, Li Rongrong, Li Yiming: The application of improved ant colony algorithm in the optimization of Web service composition based on service quality[J], Journal of Computer Applications, 2015, 35(08):2238-2243+2279. (In Chinese).

[21] Fang Qiqing, Liu Qinghua, Peng Xiaoming, Hu Yahui: Global QoS optimizing and multi-objective Web service selection algorithm [J], Application Research of Computers,2009,26(12):4442-4445+4448. (In Chinese).

[22] Xue Hongbo, Lun Shuxian: A review on appliaction of PSO in multi-objective optimization [J], Journal of Bohai University (Natural Science Edition),2009,30(03):265-269. (In Chinese).

[23] Kang Guosheng, Liu Jianxun, Tang Mingdong, Xu Yu: Dynamic Web Services Selection Algorithm with Globally Optimal QoS [J], Journal of Chinese Computer Systems,2013,34(01):73-76. (In Chinese).

[24] Yang Song, Shi Liwei, Liu Yaozhao, Bai Nan, Chen Rui: Application of Particle Swarm Optimization Algorithm in Web Service Selection[J], Computer Programming Skills & Maintenance, 2014(22):30-31. (In Chinese).

[25] Cai Huali, Liu Lu, Fan Kun, etc: Web service recommendation strategy based on BPSO[J], Journal of Shenzhen University (Science and Technology Edition), 2010, 27(1): 49-55. (In Chinese).

[26] Hu Chunhua, Wu Min, Liu Guoping, et al.: An Approach to Constructing Web Service Workflow Based on Business Spanning Graph[J], Journal of Software, 2007, 18(8): 1870-1882. (In Chinese).

[27] Yuan Bo,Ma Li: Web Service Selection for Gravitation Search Algorithm [J], Computer & Digital Engineering, 2019, 47(02):289-295. (In Chinese).

[28] Guo Xing, Chen Shanshan, Zhang Yiwen, Li Wei: Application of Fireworks Particle Swarm Optimization Algorithm in Web Service Composition [J], Journal of Chinese Computer Systems, 2018, 39(06):1312-1316. (In Chinese).

[29] Hongbing Wang,Danrong Yang,Qi Yu,Yong Tao. Integrating modified cuckoo algorithm and creditability evaluation for QoS-aware service composition[J]. Knowledge-Based Systems,2018,140.

[30] Han Min, Duan Yanzhong: QoS optimization of Web services composition incorporating with credibility evaluation [J], Control and Decision, 2020,35(08):1859-1865. (In Chinese).

[31] Liu Xuan, Liao Mingchao: On Web Services Selection with QoS Global Optimum based on Artificial Fish Swarm Algorithm[J], Computer Applications and Software,2013,30(08):87-90. (In Chinese).

[32] Song Hang, Wang Yali, Liu Guoqi, Zhang Bin: Web Service Composition Optimization Method based on Improved Multi-objective Bee Colony Algorithm[J], Journal of Northeastern University (Natural Science), 2019, 40(06):777-782. (In Chinese).