Satisfaction aware QoS-based bidirectional service mapping in cloud environment

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Abstract

Due to large-scale growth in the number of service providers and consumers in cloud, their efficient mapping has become a complex undertaking. In most of the recent research works, quality of service (QoS) based selection of a service provider for a consumer has been recommended for service mapping. This is a unidirectional approach where the mapping of service is based on the service providers' evaluation in the context of QoS requirements of a consumer. But, in the business perspective of cloud, the bidirectional evaluation of the participating entities (service providers and consumers) in the mapping process is necessary for increasing their service satisfaction. Therefore, this paper proposes a mutual evaluation-based cloud service mapping (MECSM) framework which addresses the bidirectional evaluation of both the service providers and consumers. MECSM framework uses the Analytic Hierarchy Process method to evaluate the service providers and standard RFM (Recency, Frequency, and Monetary) model to evaluate the consumers. A mathematical model is evolved to draw the service satisfaction of the service provider and consumer involved in a service transaction. The process of service mapping is depicted through a case study. The stability of the MECSM framework is validated by performing the sensitivity analysis. For performance analysis, the scaling range of service providers and consumers in a controlled overhead is obtained through the extensive simulation experiments. A comparison of results with the existing service mapping frameworks proves its better performance in the cloud.

Keywords Cloud computing · Business model · Quality of service · Ranking · Service mapping

1 Introduction

Currently, cloud computing is a dominant, utility-based computing service model around the world. This is evidenced by the projection of 3.6 billion cloud consumers in the year 2018 which has been recorded 2.4 billion in the year 2013 [1]. Primary reasons for its widespread adoption are the ease of use of the cloud-based services freely in a quantifiable manner, any-time from anywhere and the availability of underlying technologies to set up and optimize high-end data centers [2]. Both the primary participating entities in cloud i.e. cloud service providers and consumers are duly benefitted from its service architecture. Service consumers obtain the benefits of higher scalability, availability, flexibility, and the low upfront cost [3], whereas, service providers obtain the benefits from the virtualization and time-sharing technologies, which enable them to accommodate enormous consumers. Virtualization technology partitions a physical resource into multiple virtual resources that are provisioned to the consumers as per their needs [4]. Time-sharing technology enables multiple consumers to share common resources concurrently.

Over the years, a big surge has been seen in the number of consumers as well as service providers and their resource capacities in cloud. Cloud has emerged as a big service market with the scope of large-scale revenue generation. Gartner reported 206.2 billion USD revenue generation from cloud in the year 2019 which is further expected to reach 278.3 billion USD by the year 2021 [5].

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Thus, the cloud has a strong business perspective [6, 7] where service providers earn from the services while consumers pay for the services. The relationship between the service provider and consumer is the primary trait for any business process and fundamentally governed from their mutual quality attributes. Therefore, there must be a mechanism for evaluating the quality of the participating entities in a business process before the inception of service between them. The identification and retention of the high value and potential customers are important for the competitive industry [8]. Sohrabi and Khanlari [9] stressed upon the importance of determining the profitability of customers before deploying the resources to them in accordance with their customer value. Further, for increasing the revenue, Zunk and Koch [10], suggested customer's ranking as a key factor to the business organizations where valuable customers are identified and promoted. The consideration of preference/choice of the service provider for the consumer has due importance which is clearly evident from different online commercial sites such as eBay, Zol, and Amazon [11] which are actively using different consumer evaluation strategies as part of their online business processes to enhance the revenues by classifying the potential consumers. Therefore, a service transaction governed through the mutual quality evaluation of the participating entities results in the improvement of their satisfaction level and establishes a long-term relationship between them. Similar strategies if followed in cloud will surely generate a strong faith and relationship between the participating entities and consequently, the objective of service satisfaction will be achieved at both end (provider and consumer).

The presence of a huge number of service providers and consumers complicates the process of service mapping in cloud [12]. Cloud service mapping is the process of selecting a suitable service provider for a consumer based on certain mutually acceptable parameters. Quality of service (QoS) is a highly used parameter for evaluating service providers [13–15]. For evaluating the QoS of the service providers, Cloud Service Measurement Initiative Consortium (CSMIC) has introduced Service Measurement Index (SMI) attributes which is a set of business-relevant Key Performance Indicators (KPIs) [16]. SMI attributes have been used in many existing research works [17–19] as standardized attributes to evaluate the QoS of the service providers for service mapping. Although this approach is proved to be useful for the consumers to obtain a satisfactory solution, it does not address the service satisfaction of the service providers. There is no consideration of the preference/choice of the service provider about the selection of a suitable consumer (i.e. to which consumer it wants to provide the service). For example, SMICloud [18] framework selects a suitable service provider among the

available by ranking them based on their QoS parameters. It is a unidirectional service selection process. Service providers have not been given the option to put the preference for the consumer. From literature, it is observed that very limited research work is contributed to evaluate the consumers along with service providers. For the first time, this issue has been discussed by Yadav and Goraya in paper [17], where authors have used three imaginary attributes Turnover, Duration, and Transaction to evaluate the quality of consumers along with evaluating the service providers using SMI attributes for their mutual mapping. Also, in [17], the service satisfaction of the service providers and consumers involved in a service transaction is not considered.

In this paper, we endeavor to achieve a mutual evaluation-based selection of service providers and consumers based on their mutual preference in terms of the required QoS parameters. To achieve this objective a bidirectional service mapping framework MECSM is proposed. During service mapping, the proposed framework uses the Analytical Hierarchy Process (AHP) for evaluating the ranking of service providers and RFM (recency, frequency, and monetary) [20] model for evaluating the ranking of consumers. RFM is a well-established marketing analysis tool for evaluating consumers. The attributes used by the RFM model are easily applicable to the online cloud environment where service transactions are recorded for cost management considerations [21]. Rank-based service mapping (RBSM) algorithm is developed to finalize the service mapping with the objective to map the suitable service providers to consumers. The service satisfaction of service providers and consumers is evaluated at the end of a service transaction. To prove the robustness of the service mapping through the MECSM framework, sensitivity analysis is performed on the case study data using *Super Decisions Software* [22]. The purpose of the sensitivity analysis is to identify the entities for which a small variation causes a drastic variation in the model's output measure [23].

1.1 Motivation and prime contributions of the research work

The prime motivating factors for the present research are: (a) dearth of explorations in parallel evaluation of service providers and consumers during their mapping, (b) evaluation of the consumers using standard RFM model applicable in the peer business processes, and (c) the expected improvement in the service satisfaction of both the service providers and consumers using mutual evaluation based service mapping. The primary contributions of the research work are

- A mutual evaluation-based cloud service mapping (MECSM) framework is proposed.
- A mathematical model is evolved for evaluating the service satisfaction of service providers and consumers in cloud.
- Sensitivity analysis is performed for the validation of service mapping through the proposed MECSM framework.
- Scalable service selection in cloud with controlled overhead in comparison to the existing SMICloud and TRCSM frameworks.

The rest of the paper is structured as follows. Section 2 includes the related work. Section 3 introduces the research background. A mathematical model is formulated in Sect. 4 to evaluate the service satisfaction of service providers and consumers during a service transaction. Section 5 describes the proposed MECSM framework. Section 6 depicts the process of service mapping using a case study and validates the robustness of the proposed framework through sensitivity analysis along with the evaluation of service satisfaction of service providers and consumers. Section 7 presents the ranking overhead through the simulation experiments. A comparative analysis of the proposed framework with existing frameworks is also presented in Sect. 7. The last section concludes the paper and presents some future directions.

2 Related study

This section is organized around QoS based service selection in the cloud and the evaluation of consumers in the cloud and other peer business models.

QoS based mapping has been proposed in many frameworks and algorithms in the literature. Garg et al. [18] proposed the SMICloud framework which uses the QoS based selection of an efficient provider for a consumer. Although, this framework selects an efficient provider for a consumer but does not consider the selection of a consumer for the provider. In paper [24], the NMCDA framework based on the AHP method is developed for estimating the performance of cloud services. For comparing the alternatives, a group of decision-makers is consulted and then the evaluation of decision-makers is aggregated. The estimation process is modeled using triangular neutrosophic numbers. Chan and Chieu [25] proposed a service selection method, Scalar Value Decomposition for ranking the service providers and consequently making a selection based on application matching. Shetty and D'Mello [26] proposed a ranking mechanism for selecting cloud-based services using the REMBRANDT approach. A flexible and dynamic ranked voting method for service selection is proposed by Baranwal and Vidyarthi [19] which selects the best service provider based on the user's requirement.

In the cloud, service level agreement is the key factor that decides the efficiency of service selection. In paper [27], a service level agreement aware ontology-based cloud service discovery method is proposed. Ontology to service discovery is used to improve the service semantic information. The proposed method selects the service which is closer to the consumer's requirement in the QoS aspect. Consumer selection along with provider selection is also important in the business perspective. Yadav and Goraya [17], proposed the TRCSM framework which evaluates both the participating entities i.e. provider and consumer in parallel during service mapping. QoS being an important selection parameter, many QoS monitoring tools such as CloudStone [28], CloudSleuth [29], CloudCmp [30], and CloudHarmony [31] are available to evaluate the QoS of the service providers. Some online websites[1] are also available for evaluating the QoS of the cloud service providers. QoS is also mostly used parameter in another area of research [32, 33]. The service providers offer performance of their services in terms of multiple QoS attributes. Multi-attribute driven QoS based evaluation and selection of service providers is a multi-criteria decision making (MCDM) problem. In literature many MCDM methods such as AHP [34], VIKOR [35], SMART [36], SVD [25], TOPSIS [37], PROMETHEE [38], ELECTRE [39], and Hypergraph based technique [40] are used to evaluate the ranking of service providers during service selection.

In the cloud, research is converged into two major trends i.e. Information Technology (IT) efficiency (better utilization of computing resources) and IT delivery (business being held to sell IT resources) [6]. In paper [41], Hoberg et al. focused on the wide understanding of cloud as an IT delivery model i.e. business perspective and concluded that there is a lack of research towards investigating its business perspective. RFM model has been widely used in business management for extracting valuable consumers so that the organizations can develop more feasible strategies (marketing programs) for different consumers [20, 42, 43]. In business, the identification of valuable consumers plays an important role for organizations to maximize their profit [44]. Many researchers worked on profit maximization problem [45, 46] and concluded that the profit of the service providers is directly proportional to the request arrival rate. Consumer satisfaction is one of the indirect factors that affect the request arrival rate. Research proposals are available in which consumer satisfaction is estimated for maximizing the profit [46, 47]. Consumer satisfaction is also used for solving many issues such as predicting the efficient cloud service selection [46] and availability zone selection [48].

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3 Research background

The ranking of service providers and consumers is intuitively different than the others because of dynamism in the market demand. In this section, QoS based ranking of service providers using the AHP method and transaction attribute-based ranking of consumers using the RFM method is explored.

3.1 QoS based ranking of service providers

The ranking of service providers is one of the key features of the MECSM framework. The ranking of service providers is based on QoS attributes accountability, agility, assurance, cost, performance, and security. The QoS attributes are evaluated by many sub-attributes. The sub-attributes evaluation matrix is given in paper [16, 49] and QoS attributes are defined as follows:

3.1.1 Accountability

Accountability ensures the consumers that their data is handled by the provider as per their expectations. It is estimated in terms of auditability, compliance, governance, ownership, and sustainability, etc.

3.1.2 Agility

Agility of the cloud organization shows how quickly the resources are scaled with less expenditure. It is composed of adaptability, elasticity, extensibility, flexibility, probability, and scalability, etc.

3.1.3 Assurance

It assures that the performance of the delivered service is the same as promised in service level agreement. Assurance is evaluated in terms of availability, maintainability, recoverability, reliability, resiliency, etc.

3.1.4 Cost

It is the most important attribute whose value is dependent on all the attributes. It refers to transition cost, recurring cost, and the usage cost of a service or group of services.

3.1.5 Performance

It defines the functions and features of the provider. Performance is evaluated in terms of reliability, response time, suitability and functionality.

3.1.6 Security

It is defined as the control of the service provider to the user's data. Security depends on access control, data geographic, data integrity, and data privacy, etc.

Service providers are ranked using well established AHP method [34]. Using AHP the hierarchal structure of offered QoS attributes is prepared at each level. The steps to rank the service providers are as follows

Step 1   Construct the relative value vector matrix (RVVM):

If there are n number of service providers, k number of attributes, w_i^k and w_j^k are the weights of kth QoS attribute for the provider i and j respectively. The RVVM matrix is defined as

$$x_{ij}^k = \frac{w_i^k}{w_j^k} \,|\, i,j = 1,2,\ldots n \tag{1}$$

$$RVVM_k = \begin{pmatrix} x_{11}^k & \cdots & x_{1n}^k \\ \vdots & \ddots & \vdots \\ x_{n1}^k & \cdots & x_{nn}^k \end{pmatrix}$$

where x_{ij}^k denotes the weight of provider i over provider j for the kth attribute.

Step 2   Construct the relative value vector (RVV) matrix: RVV is evaluated in two phases
First, normalize the RVVM matrix

$$y_{ij}^k = \frac{x_{ij}^k}{\sum_{i=1}^n x_{ij}^k} \tag{2}$$

where, y_{ij}^k is the normalized RVVM matrix for the kth attribute.
Second, normalize score of service providers for each attribute

$$Z_{ik} = \frac{\sum_{j=1}^n y_{ij}^k}{n} \tag{3}$$

where, Z_{ik} is the relative score for kth attribute of provider i relative to rest other competitive service providers.
The RVV for weighted criteria is defined as

$$RVV_k = \begin{bmatrix} Z_{1k} \\ Z_{2k} \\ Z_{3k} \\ \vdots \\ Z_{nk} \end{bmatrix}$$

Step 3   Construct the option performance matrix (OPM): The OPM matrix is given by

$$\begin{bmatrix} RVV_0 & RVV_1 & \ldots & RVV_k \end{bmatrix}$$
$$= \begin{bmatrix} Z_{11} & \cdots & Z_{1k} \\ \vdots & \ddots & \vdots \\ Z_{n1} & \cdots & Z_{nk} \end{bmatrix}$$

Step 4   Value for Money (VFM): VFM is the final ranking score generated from multiple criteria of the service providers including the user's requirement. The VFM is derived as

$$VFM = OPM \times RVV_{required} \tag{4}$$

where $RVV_{required}$ is the relative weights of the attributes required by the consumer.

3.2 RFM model-based ranking of consumers

The research in cloud computing is moving beyond its technical perspective to the business perspective. Valuable consumers play an important role to earn more profit. Therefore, the proposed framework in this paper uses the RFM model [20] to evaluate the consumers. Using the RFM model, consumers are segmented to find out the valuable consumers. The RFM model is constituted from recency, frequency, and monetary which are defined as

(a)   *Recency* Recency shows the last transaction period of the consumer. It is assumed that the consumer who has made a transaction recently will have the next transaction soon.
(b)   *Frequency* It is the number of transactions a consumer has made in a certain period. The high value of frequency is assumed to be very beneficial to the service providers.
(c)   *Monetary* Monetary is defined as the direct measurement index for the benefit given by the consumer to the provider. A consumer whose transaction amount is high is supposed to be very beneficial to the provider.

The steps for ranking consumers using the RFM model are as follows:

Step 1   Sort the consumers in descending order based on recency, frequency, and monetary value.
Step 2   For each attribute, classify the consumers into 5 groups such as G_1, G_2, G_3, G_4, and G_5 where G_1 contains the top consumers $80\% < G_1 \le 100\%$, second group contains $60\% < G_2 \le 80\%$, third group contains $40\% < G_3 \le 60\%$, the fourth group contains $20\% < G_4 \le 40\%$ and the fifth group contains $0\% < G_5 \le 20\%$.

Step 3   Assign a number to each group in 1 to 5 scales. First group G_1 is given number 5, and second group G_2 is given number 4 and so on
Step 4   Calculate the RFM score using the equation given below

$$RFM_i = 100 \times RT_{G_i} + 10 * F_{G_i} + 1 \times M_{G_i} \tag{5}$$

where, RT_{G_i}, F_{G_i}, and M_{G_i} is the group value of ith consumer for recency, frequency, and monetary respectively.

In the RFM model, the consumers are classified into five quantiles (20% in each group) and presented by 555, 554, 553, …, 111. Thus, 125 unique scores ($5 \times 5 \times 5$) are created. If the consumers are more than 125 at a time, then some consumers will obtain the same score. Dealing with consumers having the same score is more complex. In the cloud environment, the number of consumers easily increases beyond 125. The proposed MECSM framework efficiently deals for more than one thousand consumers at a time by extracting the competitive consumers and hence reduces the solution space for each provider.

4 Mathematical model for service satisfaction evaluation

The satisfaction of participating entities in a service affects the market share of the business organizations. The performance and cost are two factors that lead to a high impact on satisfaction. Both factor's performance and cost are dependent on each other such that if the cost of service is high then performance should also be high in comparison to the other alternatives and vice versa. Satisfaction measures the level of discrepancy between the offered performance attributes and received performance attributes per unit cost [50]. If after getting the service, the received performance surpasses the offered performance then the performance is considered as high. The high performance makes satisfaction high and vice versa. Thus, the key factor that affects satisfaction is the discrepancy between the received and offered performance. Based on the *Oliver Theory of Expectancy Disconfirmation* [50] the satisfaction is formulated as

$$S_{ij}^k = e^{-\left| \frac{R_{ij}^k - O_i^k}{O_i^k} \right|} \tag{6}$$

where S_{ij}^k denotes the satisfaction of jth entity for the kth attribute after taking service from the ith entity, R_{ij}^k is the received performance by jth entity for kth attribute after taking the service from ith entity, and O_i^k is the offered performance by the ith entity for kth attribute.

In the cloud, the performance of services is measured by QoS parameters. The QoS offered by different service

providers may be represented in different data formats such as *Numeric*, *Boolean*, *Unordered set*, *Range*, etc. The QoS attribute can also be different in tendency such as positive (higher data value is better) or negative (lower data value is better) e.g. response time 0.5 ns is better than 0.7 ns which shows that the tendency of better response time is negative while availability 99% is better than 97% which shows that the tendency of better availability is positive. Using Eq. 6, the evaluation of consumer satisfaction for different data types used in representing the QoS attributes with their tendency is defined as follows.

Boolean These type of data values is estimated by the subjective assessment whose numeric value is either 0 or 1. Satisfaction for the boolean data type is estimated as:

$$S_{ij}^k = \begin{cases} 1 & if \ R_{ij}^k \cong O_i^k \\ 0 & elsewhere \end{cases} \tag{7}$$

Numeric It is used for both in the subjective and objective assessment. If the values are evaluated by the subjective assessment, then the values are defined within a scale of 1 to 9. If the values are evaluated by the objective assessment, these must be with some unit e.g. 3 ns, 2 \$/h. The service satisfaction level of numeric data type is computed as

If the tendency of QoS attribute is negative, then

$$S_{ij}^k = \begin{cases} 1 & if \ R_{ij}^k \leq O_i^k \\ e^{-\left|(R_{ij}^k - O_i^k)/R_{ij}^k\right|} & elsewhere \end{cases} \tag{8}$$

If the tendency of QoS attribute is positive, then

$$S_{ij}^O = \begin{cases} 1 & if \ R_{ij}^k \geq O_i^k \\ e^{-\left|(R_{ij}^k - O_i^k)/O_i^k\right|} & elsewhere \end{cases} \tag{9}$$

Range If the QoS attributes are represented in a range by defining the lower and upper boundary. Then the service satisfaction is defined as:

$$S_{ij}^k = \begin{cases} 1 & if \ L\_R_{ij}^k \geq L\_O_i^k \\ 0 & if \ U\_R_{ij}^k \leq L\_O_i^k \\ e^{-\left|(R_{ij}^k - O_i^k)/O_i^k\right|} & elsewhere \end{cases} \tag{10}$$

where, $L\_R_{ij}^k$, $U\_R_{ij}^k$ is the lower and upper boundary of kth QoS attribute value received by the jth entity after taking service from the ith entity and $L\_O_i^k$ is the lower boundary of kth QoS attribute value offered by the ith entity.

4.1 Service satisfaction of consumers

In the cloud environment, the services are offered in terms of multiple QoS attributes, therefore, the overall satisfaction S_{ij} of the consumer for a provider is evaluated by the cumulative product of the required weights w_k of the attribute with the satisfaction value of consumer (using Eq. 6) based on each QoS attributes.

The overall satisfaction of the jth consumer after taking service from the ith provider is given by:

$$S_{ij} = \sum_{k=1}^{n} \left(w_k \times e^{-\left|\frac{R_{ij}^k - O_i^k}{O_i^k}\right|} \right) \tag{11}$$

4.2 Service satisfaction of service providers

The service satisfaction of service provider is evaluated based on the mapped consumer's score generated using the RFM model. Let S_{ij} denotes the satisfaction of the ith provider for the jth consumer, R_{ij} is the received score of the mapped consumer and T_j is the top possible score (in case of RFM model it is 555) of the jth consumer. The satisfaction of the ith provider from the jth consumer is given as:

$$S_{ij} = e^{-\left|\frac{R_{ij} - T_j}{T_j}\right|} \tag{12}$$

5 Mutual evaluation-based cloud service mapping (MECSM) framework

The proposed mutual evaluation-based service mapping framework (MECSM) is shown in Fig. 1. The MECSM framework represents the complete cloud environment where consumers obtain cloud services from the available service providers. The service transactions between service providers and consumers are decided by service broker based on the QoS attributes. The service broker may be implemented as a third party in the real cloud environment. Service broker performs the mapping as "best fit" consumers to the "best fit" service providers. The framework uses the cloud adoption service model similar to IBM's framework for cloud adoption [51]. The scope of IBM's framework is limited to the individual organization, where the usage of the public cloud is assumed to be exclusive or open for the consumers within the organization. The exclusive public cloud provides the shared services exclusively to the members of the same organization on the pre-negotiated terms. Therefore, the relationship between a service provider and consumer is perceived to be one to

one. The open public cloud provides services to an organization but the individual consumers within the organization are permitted to do service level negotiations. Therefore, the relationship is perceived to be one to many.

The presently proposed MECSM framework has a wider scope where a consumer can obtain the services from one of the multiple service providers based on its required QoS. Similarly, a service provider can decide to offer the service to one of the multiple consumers. In the presence of multiple consumers and service providers in the cloud environment, the concept of service mapping is applied based on the QoS attributes of service providers and consumers. MECSM framework consists of the entities-service consumers, service broker, service provider–consumer relationship, public cloud, and service provider. Figure 1 depicts the layered architecture of the proposed MECSM framework. Layer 1 represents the service consumer(s) entity that submits the requests for cloud services. Layer 2 corresponds to the service broker and service relationship entity. The service broker receives the service requests from the service consumers and performs service mapping based on the QoS attribute values of consumers and service providers. The broker consists of the following components

- *Observer* The observer component contains the provider's directory and consumer's directory. The provider's directory contains all the information of service providers such as provider id, offered QoS attributes value, the status of being free, etc. and consumer's

directory contains the information about the consumers such as consumer id, past transaction history, etc.

- *Ranking evaluator* This component evaluates the ranking score of service providers and consumers using AHP and RFM method respectively.
- *Mapping logic* The service mapping logic is implemented through the RBSM algorithm. The probable relationships between service providers and consumers (1:1, 1: m, n:1, and n:m) are realized through the service mapping logic
- *Satisfaction evaluator* It evaluates the satisfaction of service providers and consumers at the end of a service transaction in the cloud.

During service mapping between service providers and consumers, the broker set up the probable relationship between them in the following ways

- *One to one (1:1)* The relationship between provider and consumer is said to be *1:1* if one consumer is requesting service and only one service provider is available to provide the service (no competitive consumers for a provider and vice versa). This cloud service scenario comes under an exclusive public cloud.
- *One to many (1:m)* The relationship between provider and consumer is said to be *1: m* if many consumers are requesting a service from a provider. This service scenario comes under an open public cloud.
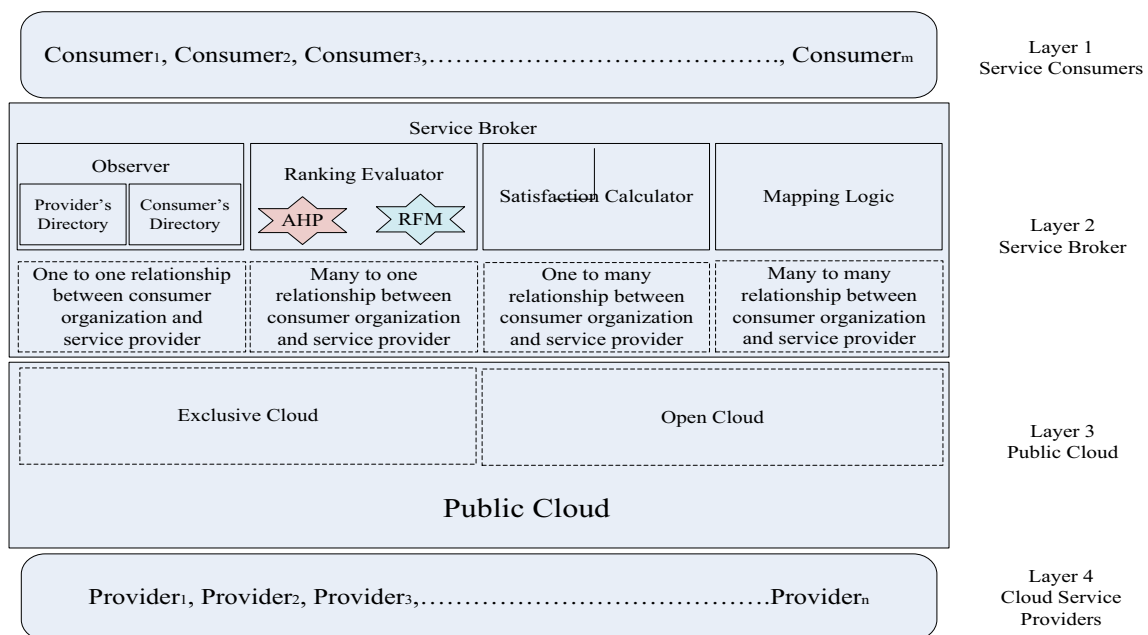- *Many to one (n:1)* In this relationship, the multiple service providers are in competition for providing the

Fig. 1 Proposed MECSM framework

requested service to a consumer. This service scenario comes under an exclusive public cloud.

- *Many to many (n:m)* In this relationship, multiple consumers submit the request for the cloud service and multiple service providers are available to provide the requested service. This scenario is very complex and exists in the open public cloud.

Layer 3 represents the public cloud. The public cloud may be accessed as an exclusive cloud or open cloud. Layer 4 represents the available cloud service providers.

5.1 Proposed RBSM algorithm

This section represents the RBSM algorithm which is used during service mapping.

Algorithm 1 Base Algorithm RBSM for service mapping

Input: List of Service providers and Consumers;

Output: Efficient mapping of Service providers and Consumers;

1:    For all the service providers set flagProvider ← 1;
2:    **IF** the number of service providers ==1 and number of consumers == 1 **THEN**
3:       map the consumer to service provider;
4:       flagProvider ← 0;
5:    **END IF**
6:    **IF** the number of service providers >1 and number of consumers == 1 **THEN**
7:       calculate the ranking score of service providers by using Eq. 1,2,3,4;
8:       sort the ranking score of service providers in decreasing order and get the top rank provider id for the consumer;
9:       map the consumer to service provider;
10:      flagProvider ← 0;
11:   **END IF**
12:   **IF** the number of service providers ==1 and number of consumers > 1 **THEN**
13:      calculate the RFM score of competitive consumers using Eq. 5;
14:      rank the consumers and get the top rank consumer;
15:      map the consumer to service provider;
16:      flagProvider ← 0;
17:   **END IF**
18:   **IF** the number of service providers >1 and number of consumers > 1 **THEN**
19:      **FOR** each consumer **DO**
20:        calculate the ranking score of service providers by using Eq. 1,2,3,4;
21:        sort the ranking score of service providers in decreasing order and get the top rank provider id for the consumer;
22:      **END FOR**
23:      **FOR** each provider **DO**
24:        get the list of competitive consumers;
25:      **END FOR**
26:      **FOR** each provider **DO**
27:        **IF** list of competitive consumers is empty **THEN**
28:          continue;
29:        **ELSE IF** the number of competitive consumers == 1 and flagProvider ==1**THEN**
30:          map the consumer to service provider;
31:          flagProvider ← 0;
32:        **END IF**
33:        **ELSE** flagProvider ==1 **THEN**
34:          calculate the RFM score of competitive consumers using Eq. 5;
35:          rank the consumers and get the top rank consumer;
36:          bind (consumer, provider);
37:          flagProvider ← 0;
38:      **END FOR**
39:   **END IF**
40:   After completion of the service the flagProvider is set to 1;
41:   For remaining consumers, the next top rank provider is considered where flagProvider == 1 and the process is repeated until all the service providers and consumers are mapped.
42:   If at any time all the flagProvider == 0, then consumer wait for the provider until the flagProvider is set to 1.

The algorithm takes multiple passes to complete the service mapping process. In the first pass, the flag of all service providers is set to 1 (see line 1) to show that initially all the service providers are available to deliver the service. The number of participating service providers and consumers are counted. For a single If the number of service providers are one and the number of consumers are also one. The scenario comes under one to one mapping. The algorithm maps the service provider to the consumer directly and sets the flag of provider to 0 (see lines 2 to 4). If the number of consumers are one and the number of service providers are greater than one. The scenario comes under one to many. The proposed algorithm ranks the service providers using AHP method and maps the top-ranked provider to consumer and after mapping, the flag of provider is set to Zero (see line 6 to 11). If the number of consumers are greater than one and the number of service providers are only one, then the RFM score of the consumers is calculated. The top rank consumer is mapped to the provider and after mapping the flag of provider is set to 0 (see line 12 to 17). If the number of consumers are greater than one and the number of service providers are also greater than one, then for each consumer compute the ranking of service providers and get the list of competitive consumers for each provider (see line 19 to 25). If there are no competitive consumers for a provider, then the algorithm verifies the competitive list of consumers for the next provider. If there is only one consumer and flag of provider is one then it maps the consumer to the service provider and after mapping, the flag of provider is set to zero (see line 26 to 32). If the number of competitive consumers are more than 1 then the algorithm ranks the consumers using the RFM model and maps the top rank consumer to the service provider and after mapping the flag of provider is set to 0 (see line 33 to 38). In the next pass of mapping, the second top rank service provider is mapped to the consumer and this process is repeated until all the service providers are mapped to the consumers (see lines 40 to 42).

5.2 The time complexity of the RBSM algorithm

In this section, the time complexity of the proposed RBSM Algorithm is discussed. The time complexity of the proposed RBSM algorithm depends on the complexities of ranking the service providers using AHP, the ranking of consumers using RFM, and the mapping process. Algorithmic time complexity is described through distinct phases as

Phase 1 The complexity of ranking the service providers using AHP The complexity of AHP depends on four parameters which are number of levels in QoS hierarchy, number of elements in each level, number of elements in

each group (at the same level the number elements whose parent node is same), and the number of service providers. The operations deriving the time complexity of AHP are computing QoS property weighting (relative, absolute, and arbitrary), computing the relative ranking of service providers, aggregating relative ranking for QoS properties, and QoS groups [52].

Computing weighting of QoS property: Suppose QoS hierarchy has l levels and each level has N_l number of attributes. The number of attributes for group i at kth level is n_{ki} then in case of relative weighing there is no need of calculating the relative weighting of QoS property, therefore, the time complexity is linear. For absolute weighting, the time complexity of normalizing the weight vector for the kth level of the ith group is $O(n_{ki})$ and for the group i at level k is $O\left(\sum_{i=1}^{k-1} n_{ki}\right)$. Then, for all levels for all groups, the time complexity is $O\left(\sum_{k=1}^{l} \sum_{i=1}^{N_{l-1}} n_{ki}\right)$. For arbitrary weighting, the time complexity of normalizing the weight vector for the kth level of the ith group is $O(n_{ki})^3$ and the time complexity for all groups at kth level is $O\left(\sum_{i=1}^{N_{l-1}} \left((n_{ki})^3\right)\right)$. Then, for all levels and for all group the time complexity is $O\left(\sum_{k=1}^{l} \sum_{i=1}^{N_{l-1}} \left((n_{ki})^3\right)\right)$.

Computing relative ranking of service providers: The relative ranking of m service providers is calculated by estimating the eigenvector of m size whose complexity is derived as $O(m^3 N_l)$.

Aggregating relative ranking for QoS properties and QoS groups: The time complexity of aggregating a group i at level k is $O(mn_{ki})$, then time complexity for all groups at level k is $O\left(\sum_{i=1}^{N_{k-1}} n_{ki}\right) = O(mN_k)$. For all levels and all groups, the time complexity is $O\left(m \sum_{k=1}^{l} N_k\right)$.

Phase 2 The complexity of ranking consumers using RFM Let p number of consumers are requesting the cloud service with each request having q number of parameters. Then the time complexity of the RFM model (sorting each parameter value in decreasing order, assigning rating) is $O(pq \log p)$.

Phase 3 The complexity of the Mapping process The complexity of the mapping process depends on getting a competitive consumer for the service providers is $O(pm \log m)$ and a number of passes to map the service providers to consumers (in worst case m passes). The worst-case time complexity of the mapping process is $O(m^2 p \log m)$.

Therefore, the worst-case time complexity of RBSM algorithm over three phases is computed as

For relative ranking: $O\Big(m^3 N_l + m \sum_{k=1}^{l} N_k + pq \log p + m^2 p \log m\Big)$.

For absolute ranking: $O\Big(\sum_{k=1}^{l} \sum_{i=1}^{N_{k-1}} n_{ki} + m^3 N_l + m \sum_{k=1}^{l} N_k + pq \log p + m^2 p \log m\Big)$.

For arbitrary ranking: $O\Big(\sum_{k=1}^{l} \sum_{i=1}^{N_{k-1}} \big((n_{ki})^3\big) + m^3 N_l + m \sum_{k=1}^{l} N_k + pq \log p + m^2 p \log m\Big)$.

6 Case study

In the case study, the offered QoS data of the three IaaS public service providers: Amazon EC2, Rackspace, and Windows Azure is considered. The standard QoS attributes accountability, agility, assurance, cost, performance, and security, as proposed in SMI, are considered for ranking the service providers. The QoS data is collected from the paper [18]. The unavailable data such as accountability and security are randomly assigned to each provider. The QoS data comparison rules are taken from the paper [52]. The QoS data offered by provider$_1$, provider$_2$, provider$_3$ and relative weights of consumer's requirement is depicted in Table 1. For the ranking estimation of consumers, the transaction attributes recency, frequency and monetary are considered and data values are assigned randomly as presented in Table 2. After applying the AHP method, the relative performance of service providers as shown in Fig. 2a, relative required QoS attribute as shown in Fig. 2b, the ranking score of service providers as shown in Fig. 2c, and the ranking of service providers are shown in Fig. 2d. The performance of provider$_1$ is better in terms of Assurance and Cost, provider$_2$ is better in terms of Accountability and Security, and provider$_3$ is better in terms of performance and agility as shown in Fig. 2a. Attribute preference requirement of the consumers is considered during service mapping. In business perspective, every consumer follows a cost-quality tradeoff [53, 54]. Thus cost-quality based service ranking is considered as the final stage of selection of service providers. In this case study, the cost offered by the service providers is different based on their offered QoS. In this work, the value of quality (QoS attribute value) for the per-unit cost is computed. The ranking of service providers per unit cost is considered at the final stage of mapping. The ranking score of service providers per unit cost (Fig. 3a) and the ranking of service providers (Fig. 3b) are shown in Fig. 3. From Fig. 3, it is seen that provider$_1$ is ranked as the first choice for consumer$_6$, provider$_2$ is ranked as the first choice for

consumer$_3$, and for provider$_3$ multiple consumers are competing. For provider$_1$ and provider$_2$, there is no consumer in competition. Thus, there is no need of considering RFM scores of consumer$_3$ and consumer$_6$. For provider$_3$ the competitive consumers are consumer$_1$, consumer$_2$, consumer$_4$, consumer$_5$, consumer$_7$, consumer$_8$, consumer$_9$, and consumer$_{10}$. A valuable consumer for provider$_3$ is selected by evaluating the ranking of consumers using the RFM model based on the transaction values given in Table 2. Each transaction value (recency, frequency and monetary) is divided into quantiles and given a score in the scale 1 (low) to 5 (high). RFM score of the consumers is evaluated using Eq. 5 as shown in Table 3. The RFM Score of consumer$_8$ is highest among competitive consumers. Therefore, consumer$_8$ is mapped to provider$_3$.

6.1 Service satisfaction of consumers and service providers

At the completion of cloud service mapped through the proposed framework, the service satisfaction of consumers for a single attribute is evaluated using the Eq. 11. The overall service satisfaction of consumer by considering all QoS attributes is evaluated using Eq. 12. The offered QoS parameter of the provider is presented in Table 1 and the actual QoS parameter received by the consumer from the provider during the service transaction is presented in Table 4. The satisfaction of consumers and service providers using the ranking of their counterpart and without using the ranking of their counterpart is presented in Fig. 4. From Fig. 4a, it is observed that the satisfaction of consumer$_3$ is increased by 0.60%, the satisfaction of consumer$_6$ is increased by 13.8%, and the satisfaction of consumer$_8$ is increased by 21.33% after using the ranking of their counterpart. Figure 4b shows that after considering the consumer's ranking the satisfaction of provider$_3$ is increased from 81.87% to 95.94% while there is no change in satisfaction of provider$_1$ and provider$_2$ due to the absence of any competing consumers.

6.2 Sensitivity analysis of service providers

The sensitivity analysis is performed on the case study data to show the stability (i.e. robustness) of the proposed framework. The term stability is measured by observing the variation in ranking corresponding to the variation in the required attributes of consumers. The higher variation in ranking score indicates the lower stability of the framework and vice versa. To observe the sensitivity analysis in the present research work, a step size in variation in the attribute value is set to 0.1 (i.e. 0.0001, 0.11111, 0.22222, …, 0.9999). The sensitivity analysis is performed for service providers with respect to the mapped consumers

Table 1 Offered QoS of the cloud service providers

QoS attributes	Top-level QoS attributes required by the consumers										First level attributes (weights)	Second level attributes (weights)		Service 1	Service 2	Service 3	Value type
	1	2	3	4	5	6	7	8	9	10							
Accountability	0.05	0.25	0.10	0.25	0.05	0.05	0.05	0.05	0.30	0.05	Level 0–10			4	8	4	Numeric
Agility	0.10	0.20	0.20	0.10	0.15	0.10	0.10	0.10	0.10	0.30	Capacity (0.6)	CPU	0.5	9.6	12.8	8.8	Numeric
												Memory	0.3	15	14	15	Numeric
												Disk	0.2	1690	2040	630	Numeric
Assurance	0.30	0.10	0.15	0.20	0.20	0.20	0.45	0.20	0.20	0.20	Elasticity (0.4)	Time	1	80–120	520–780	20–200	Range
											Availability (0.7)	0.7	0.7	99.95%	99.99%	100%	Numeric
											Service stability (0.2)	Upload Time	0.3	13.6	15	21	Numeric
												CPU	0.4	17.9	16	23	Numeric
												Memory	0.3	7	12	5	Numeric
											Serviceability (0.1)	Free support	0.7	0	1	1	Boolean
												Type of support	0.3	24/7, diagnostic tools, phone, urgent response	24/7, diagnostic tools, phone, urgent response	24/7, phone, urgent response	Unordered set
Cost	0.30	0.05	0.30	0.10	0.25	0.50	0.05	0.10	0.05	0.10	On going cost (1)	VM Cost	0.6	$0.68	$0.96	$0.96	Numeric
												Data	Inbound	10	10	8	Numeric
													Outbound	11	15	18	
												Storage	0.2	12	15	15	Numeric
Performance	0.30	0.30	0.10	0.30	0.30	0.10	0.30	0.30	0.30	0.30	Service response time (0.1)	Range	0.5	80–120	520–780	20–200	Range
												Average value	0.5	100	600	30	Numeric
Security	0.05	0.10	0.15	0.05	0.05	0.05	0.05	0.25	0.05	0.05	Level: 0–10 (1)			4	8	4	Numeric

Table 2 The transaction values of consumers

Consumer Id	Recency (day)	Frequency (number)	Monetary (Rs)
Consumer$_1$	18	10	520
Consumer$_2$	4	1	190
Consumer$_3$	12	6	65
Consumer$_4$	7	3	2000
Consumer$_5$	9	4	25
Consumer$_6$	55	8	726
Consumer$_7$	17	14	580
Consumer$_8$	35	6	150
Consumer$_9$	23	1	325
Consumer$_{10}$	3	15	140

(consumer$_3$, consumer$_6$, and consumer$_8$) for each of the attributes- accountability, agility, assurance, cost, performance, and security.

Firstly, the sensitivity of service providers is observed by varying the required value of the attributes for consumer$_3$. For the attribute accountability, it is observed that the ranking score of provider$_1$ decreases by 0.001 in each step, the ranking score of provider$_2$ is increased by 0.002 in each step and the ranking score of provider$_3$ decreases by 0.001 in each step. Thus, the attribute accountability negatively impacts provider$_1$ and provider$_3$ and positively impacts the provider$_2$. But their ranking remains the same as shown in Fig. 5a. For the attribute agility, it is observed that the ranking score of provider$_1$ remains the same in each step, the ranking score of provider$_2$ decreases by 0.001 in steps 4, 6, 9, and the ranking score of provider$_3$ increases by 0.001 in each step. Thus, the attribute agility doesn't impact provider$_1$, negatively impact provider$_2$, and positively impact provider$_3$. But the ranking of service providers remains the same as shown in Fig. 5b. For the attribute assurance, the ranking score of provider$_1$ increases by 0.001 in some steps, the ranking score of provider$_2$ decreases by 0.001 in each step and the ranking score of provider$_3$ increases by 0.001 in some steps. Thus, the attribute assurance positively impacts provider$_1$ and provider$_3$, and negatively impacts provider$_2$. But the ranking of service providers is not affected as shown in Fig. 5c. For the attribute cost, the ranking score of provider$_1$ increases by 0.001 in each step, the ranking score
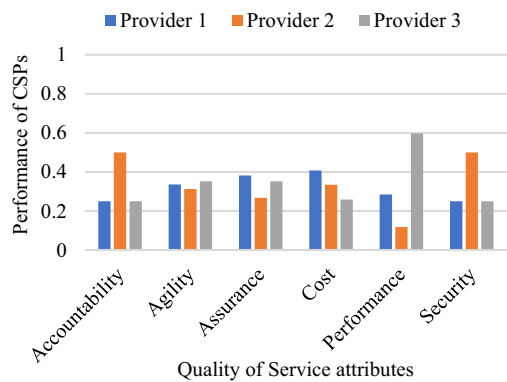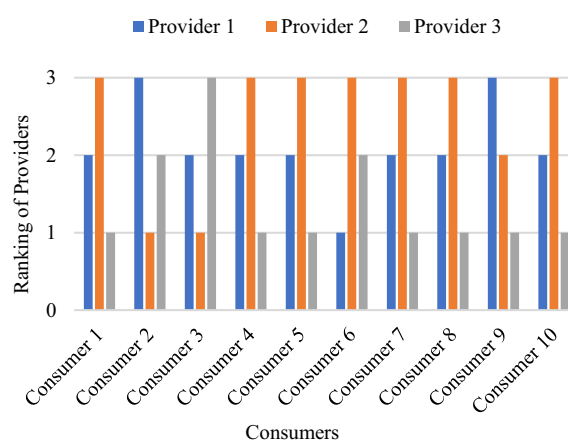

(a) Performance of service providers
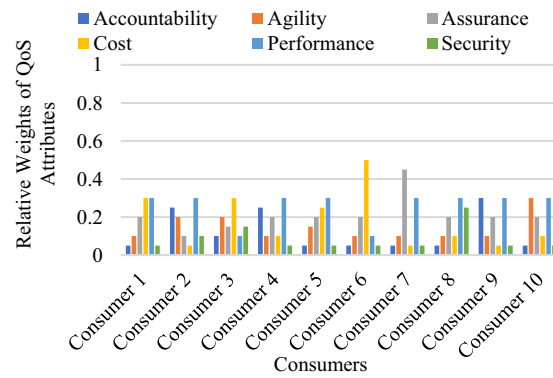
(b) QoS attributes weight
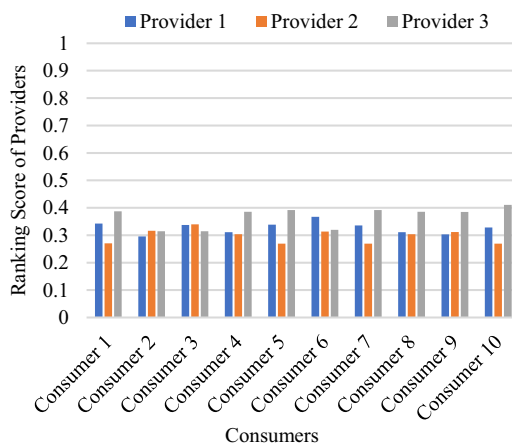
(c) Ranking score of service providers

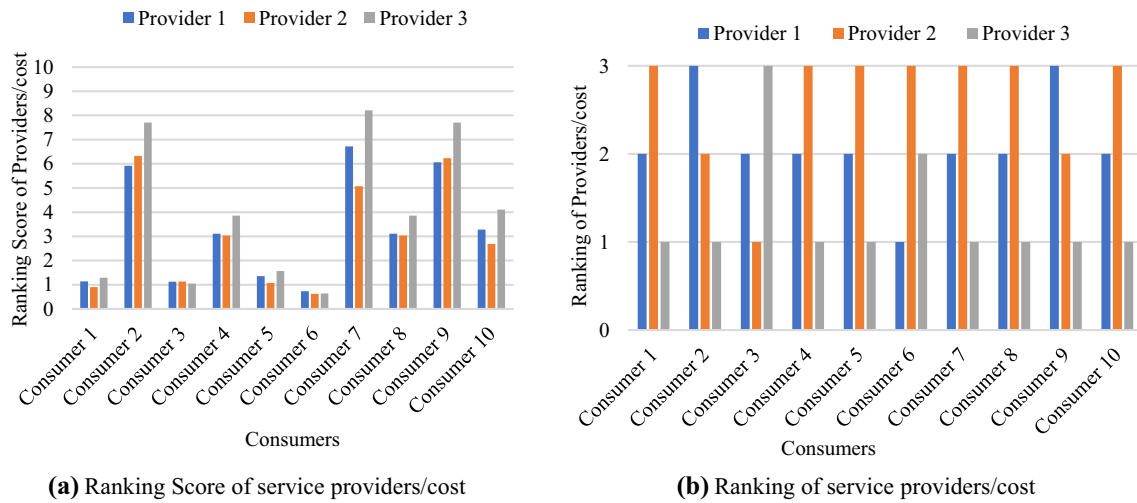**(d)** Ranking of service providers

Fig. 2 Ranking of service providers

(a) Ranking Score of service providers/cost

(b) Ranking of service providers/cost

Fig. 3 Ranking of service providers per unit cost

Table 3 RFM score of consumers

| Consumer Id	Recency	R	Consumer Id	Frequency	F	Consumer Id	Monetary	M	Consumer Id	RFM
$Consumer_6$	55	5	C_{10}	15	5	$Consumer_4$	2000	5	$Consumer_1$	444
$Consumer_8$	35	5	C_7	14	5	$Consumer_6$	72	5	$Consumer_2$	113
$Consumer_9$	23	4	C_1	10	4	$Consumer_7$	580	4	$Consumer_3$	331
$Consumer_1$	18	4	C_6	8	4	$Consumer_1$	520	4	$Consumer_4$	225
$Consumer_7$	17	3	C_3	6	3	$Consumer_9$	325	3	$Consumer_5$	221
$Consumer_3$	12	3	C_8	6	3	$Consumer_2$	190	3	$Consumer_6$	545
$Consumer_5$	9	2	C_5	4	2	$Consumer_8$	150	2	$Consumer_7$	354
$Consumer_4$	7	2	C_4	3	2	$Consumer_{10}$	140	2	$Consumer_8$	532
$Consumer_2$	4	1	C_2	1	1	$Consumer_3$	65	1	$Consumer_9$	413
$Consumer_{10}$	3	1	C_9	1	1	$Consumer_5$	25	1	$Consumer_{10}$	152

of $provider_2$ decreases by 0.001 in some steps and the ranking score of $provider_3$ decreases by 0.001 in each step. Thus, the attribute cost negatively impacts $provider_2$ and $provider_3$ and positively impacts $provider_1$. But the ranking of service providers is not affected as shown in Fig. 5d. For the attribute performance the ranking score of $provider_1$ decreases by 0.001 in some steps, the ranking score of $provider_2$ decreases by a maximum of 0.003 in each step, and the ranking score of $provider_3$ increases by a maximum of 0.004 in each step. Thus, the attribute performance negatively impacts $provider_1$ and $provider_2$ and positively impacts $provider_3$. But the ranking of service providers is not affected as shown in Fig. 5e. For the attribute security, the ranking score of $provider_1$ decreases by 0.001 in each step, the ranking score of $provider_2$ increases by 0.002 in each step, and the ranking score of $provider_3$ decreases by 0.001 in each step. Thus, the attribute security negatively impacts $provider_1$ and $provider_3$ and positively impacts

$provider_2$. But the ranking of service providers is not affected as shown in Fig. 5f. The impact (i.e. negative or positive or no change) of attributes in the ranking of service providers is shown in Table 5. The negative impact of attribute decreases the ranking score of the service provider, the positive impact of attribute increases the ranking score of the service provider, and no change impact of the attribute does not affect the ranking score of the service provider.

Similarly, the sensitivity of service providers is observed by varying the required values of the attributes for $consumer_6$ as shown in Fig. 6 and $consumer_8$ as shown in Fig. 7. The variations in the required attribute value have marginal positive and negative impacts on the provider's ranking scores as shown in Table 6 (for $consumer_6$) and Table 7 (for $consumer_8$).

Table 4 Received QoS

QoS attributes	First level attributes (weights)	Second level attributes (weights)		Service 1	Service 2	Service 3	Value type
Accountability	Level 0–10			6	4	8	Numeric
Agility	Capacity (0.6)	CPU	0.5	5 × 1.6 GHZ	4 × 1.6 GHZ	12 GB	Numeric
		Memory	0.3	15 GB	12 GB	12 GB	Numeric
		Disk	0.2	630 GB	800 GB	800 GB	Numeric
	Elasticity (0.4)	Time	1	20–200	60–120	60–120	Range
Assurance	Availability (0.7)	0.7	0.7	100%	99.9%	99.9%	Numeric
	Service stability (0.2)	Upload time	0.3				Numeric
		CPU	0.4				Numeric
		Memory	0.3				Numeric
	Serviceability (0.1)	Free support	0.7				Boolean
		Type of support	0.3	24/7, phone, urgent response	24/7, Phone	24/7, Phone,	Unordered set
Cost	On going cost (1)	VM cost	0.6	$0.96/h	$0.68/h	$0.96/h	Numeric
		Data	Inbound	8	400 GB/month	400 GB/month	Numeric
			Outbound	18	400 GB/month	400 GB/month	
		Storage	0.2	15	500 GB	500 GB	Numeric
Performance	Service response time (0.1)	Range	0.5	20–200	60–120	60–120	Range
		Average value	0.5	30	600	30	Numeric
Security	Level: 0–10 (1)			4	8	4	Numeric

(a) Satisfaction of mapped consumers

(b) Satisfaction of mapped service providers
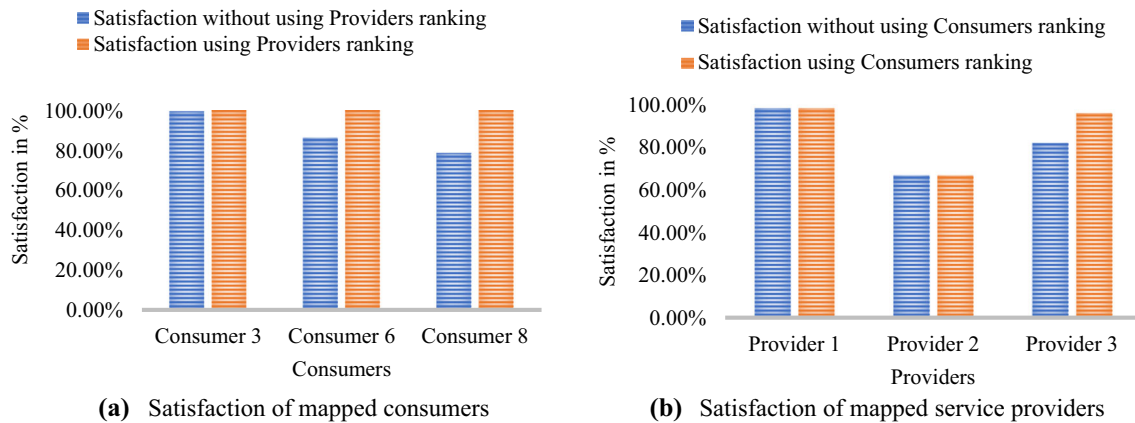
Fig. 4 Satisfaction of the participating entities

7 Experimental results and discussion

For performance evaluation of the proposed framework, results are obtained in terms of its ranking overhead. Time to make the hierarchy of the performance parameters is structure dependent and cannot be predicted. Therefore, it is difficult to analyze the exact execution time of the proposed framework [52]. However, we attempt to calculate the execution time of the framework through simulation experiments using CloudSim 3.0 toolkit on the Intel Core i7-2.60 GHz having 8 GB RAM. The data for each QoS

attribute and their relative weights are uniformly distributed. Variation in the number of service providers and consumers with constant QoS attributes for each provider is considered. In the proposed framework, worst-case time complexity highly depends on the number of service providers and consumers. For the performance evaluation, the number of service providers and consumers is varied while their attributes are fixed. In the existing SMICloud framework [18], the overhead of 10 s has been justified as the ideal overhead for the online selection of cloud services. Taking the overhead of 10 s as a benchmark, we

(a) Accountability

(b) Agility

(c) Assurance

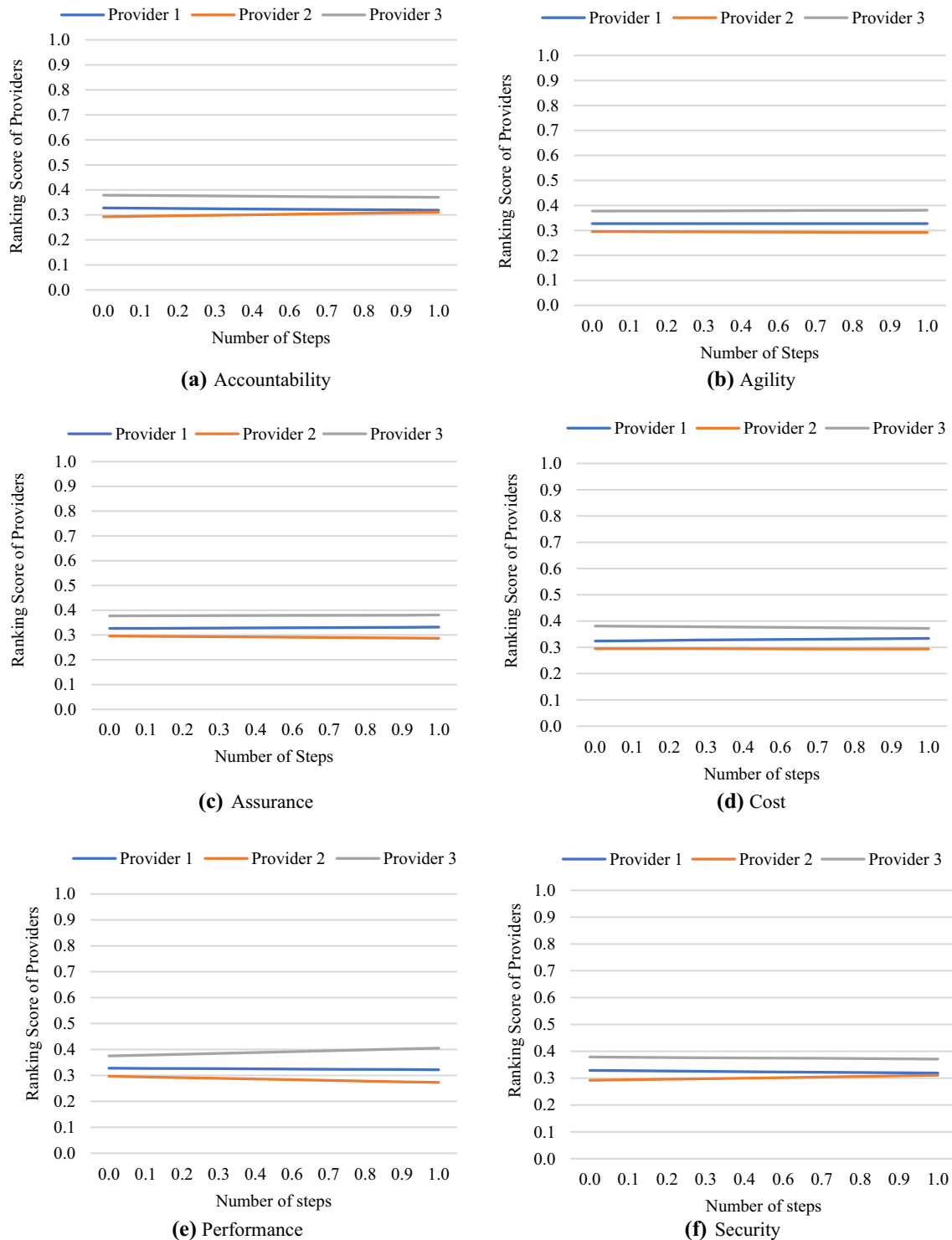(d) Cost

(e) Performance

(f) Security

Fig. 5 Sensitivity analysis of service providers considering the priorities of consumer₃

perform a comparative analysis of the proposed MECSM framework with TRCSM [17] frameworks on the account of scalability in the number of service providers and

consumers during service mapping. For 10 s overhead (benchmark) results are observed for the following cases

Case 1   Scaling in service providers for the fixed number of consumers (Fig. 8a)

Table 5 Impact on provider's ranking for variation on required attributes of consumer₃

Attributes→ Provider↓	Accountability	Agility	Assurance	Cost	Performance	Security
Provider₁	Negative	No change	Positive	Positive	Negative	Negative
Provider₂	Positive	Negative	Negative	Negative	Negative	Positive
Provider₃	Negative	Positive	Positive	Negative	Positive	Negative

(a) Accountability

(b) Agility

(c) Assurance

(d) Cost

(e) Performance

(f) Security
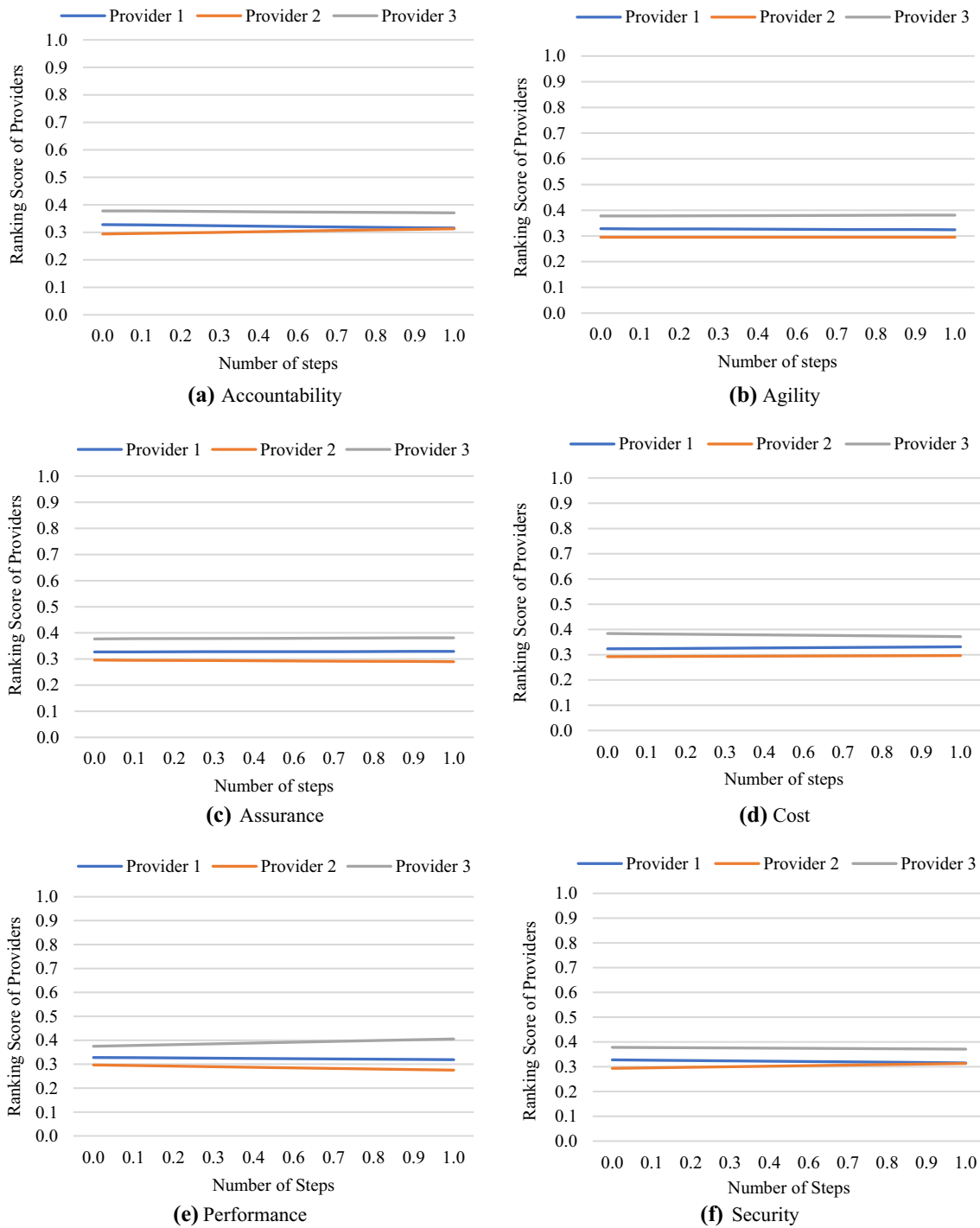
Fig. 6 Sensitivity analysis of service providers considering the priorities of consumer₆
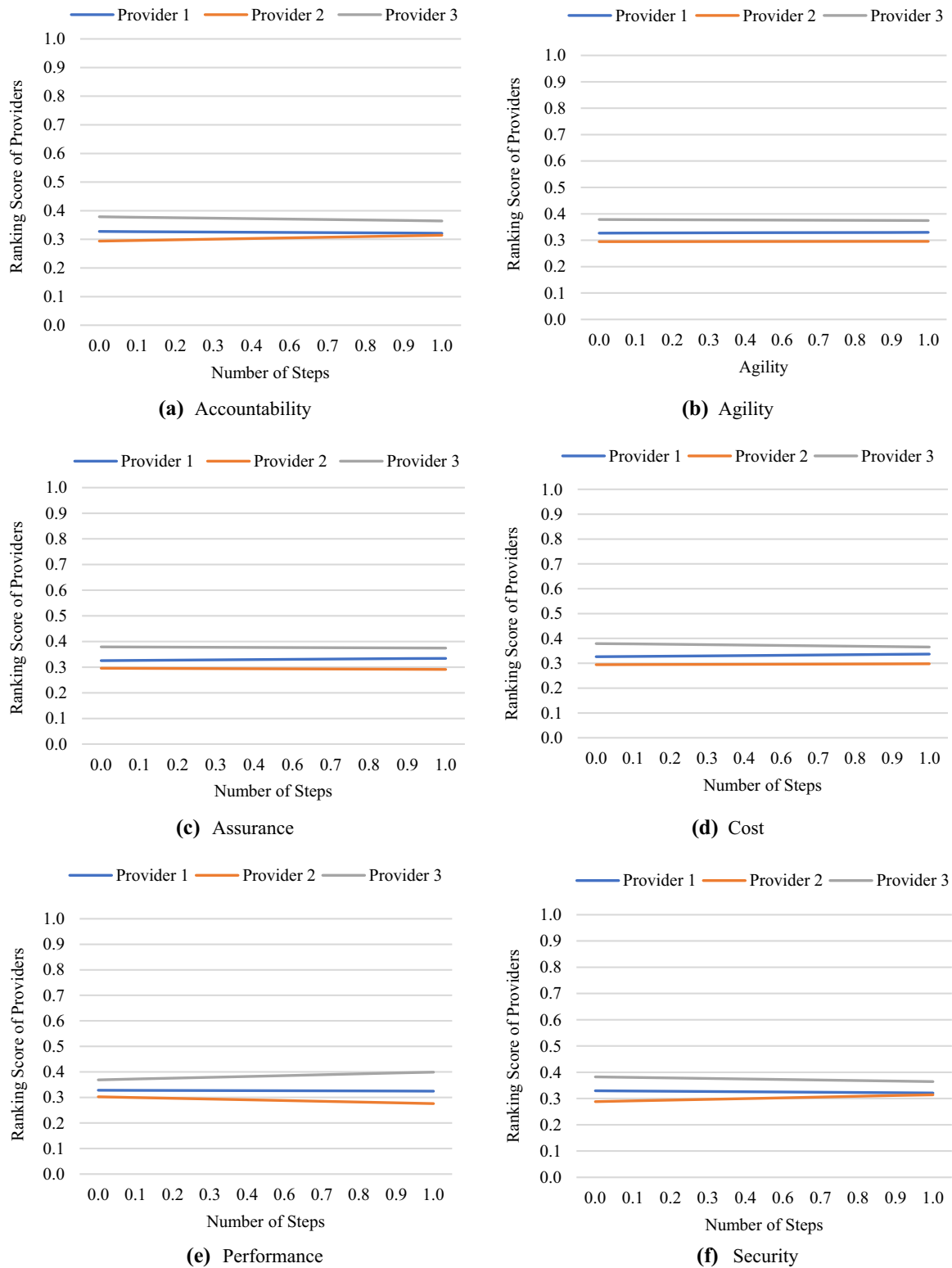
Fig. 7 Sensitivity analysis of service providers considering the priorities of consumer$_8$

Table 6 Impact on provider's ranking for variation on required attributes of consumer$_6$

Attributes → Providers ↓	Accountability	Agility	Assurance	Cost	Performance	Security
Provider$_1$	Negative	Negative	Positive	Positive	Negative	Negative
Provider$_2$	Positive	No change	Negative	Positive	Negative	Positive
Provider$_3$	Negative	Positive	Positive	Negative	Positive	Negative

Table 7 Impact on provider's ranking for variation on required attributes of consumer$_8$

Attributes → Providers ↓	Accountability	Agility	Assurance	Cost	Performance	Security
Provider$_1$	Negative	Negative	Positive	Positive	Negative	Negative
Provider$_2$	Positive	No change	Negative	Positive	Negative	Positive
Provider$_3$	Negative	Positive	Negative	Negative	Positive	Negative
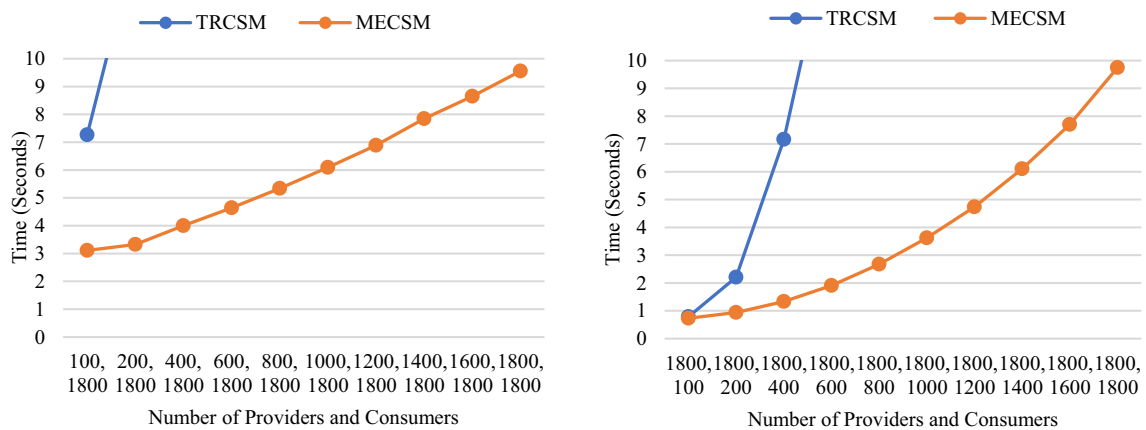
(a) Ranking overhead by fixing the consumers at 1800 and varying service providers

(b) Ranking overhead by fixing the service providers at 1800 and varying consumers
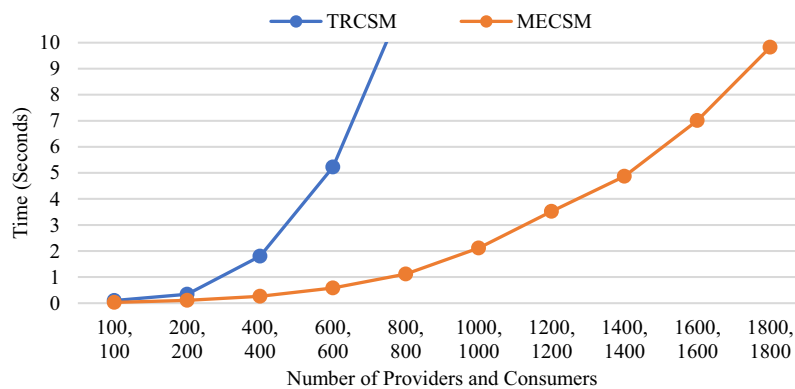
(c) Ranking overhead by varying both the consumers and service providers up to 1800

Fig. 8 Ranking overhead of MECSM framework

| Case 2 | Scaling in consumers for the fixed number of service providers (Fig. 8b) |
| Case 3 | Scaling in both service providers and consumers (Fig. 8c) |

The results clearly prove better scalability of the proposed MECSM framework in comparison to the existing TRCSM framework. Scalability indicates the number to which the participating service providers and consumers can be increased for their mapping under the controlled

overhead. In the first case within the controlled overhead of 10 s, the TRCSM framework achieves the scaling of 150 service providers and 1800 consumers while MECSM framework achieves the scaling of 1800 service providers and consumers each. In the second case, TRCSM framework achieves the scaling of 1800 service providers and 500 consumers while MECSM framework achieves the scaling of 1800 service providers and consumers each. In the third case, TRCSM framework achieves the scaling of 700 service providers and consumers each while MECSM framework achieves the scaling of 1800 service providers and consumers each.

The improvement in scaling in MECSM framework is attributed to the use of RFM model (simple in computation) for evaluating the service consumers, the use of AHP only for evaluating the service providers, and the use of less iterative RBSM algorithm for service mapping. TRCSM framework uses AHP method (which is complex in computation) to evaluate both the service providers as well as consumers. Further, TRSM algorithm used in TRCSM framework for service mapping is more iterative. The controlled overhead of 10 s is considered as a benchmark which is suggested by the SMICloud framework (unidirectional service mapping framework). The scaling range in the controlled overhead of 10 s shows the better efficiency of the proposed MECSM framework (bidirectional service mapping framework) in comparison to the existing TRCSM framework (bidirectional service mapping framework).

8 Conclusion

In this paper, a mutual evaluation-based cloud service mapping (MECSM) framework is presented. This research work is an endeavor to find a valuable service partner for both the service providers and consumers to their satisfaction. The rank-based organization of the service providers and consumers is carried out to complete their mutual mapping for the service transaction. AHP method is applied to rank the service providers in the context of consumers who submit the service requests and the RFM model is used to rank the consumers in the context of the available service providers. The service satisfaction of both the service providers and consumers is evaluated at the end of a service mapping. Sensitivity analysis is performed on the outcome of the service mapping performed through MECSM to prove its stability. The feasibility of the proposed MECSM framework in the selection of online services is established through ranking overhead. Results show that for a ranking overhead of 10 s the proposed MECSM framework scales up to 1800 service providers and 1800 consumers which is quite better than the existing SMICloud and TRCSM frameworks. Since MECSM framework tries to map the service providers and consumers as per their QoS based ranking, thus they can be self-motivated for performance improvement. In the future, a reputation-based service mapping framework will be developed by considering both the subjective and objective assessment of service providers. A punishment mechanism will also be implemented for identifying malicious service providers and consumers who pretend to provide enhanced QoS.

References

1. Consumer cloud computing users worldwide 2018. (n.d.). https://www.statista.com/statistics/321215/global-consumer-cloud-computing-users/
2. Thakur, A., Goraya, M.: A taxonomic survey on load balancing in cloud. J. Netw. Comput. Appl. **98**, 43–57 (2017)
3. Hayyolalam, V., Kazem, A.: A systematic literature review on QoS-aware service composition and selection in cloud environment. J. Netw. Comput. Appl. **110**, 52–74 (2018)
4. Aluvalu, R.K., Muddana, L.: Access control model with enhanced flexibility and scalability for cloud. In: Proceeding of the 2015 IEEE International Conference on Green Computing and Internet of Things (ICGCIoT), Noida, India, 2015
5. Gartner Says Global IT Spending to Grow 1.1 Percent in 2019. (n.d.). https://www.gartner.com/en/newsroom/press-releases/2019-04-17-gartner-says-global-it-spending-to-grow-1-1-percent-i
6. Marston, S., Li, Z., Bandyopadhyay, S., Zhang, J., Ghalsasi, A.: Cloud computing—the business perspective. Decis. Support Syst. **51**(1), 176–189 (2011)
7. Yongsiriwit, K., Assy, N., Gaaloul, W.: A semantic framework for configurable business process as a service in cloud. J. Netw. Comput. Appl. **59**, 168–184 (2016)
8. Huang, S.C., Chang, E.C., Wu, H.H.: A case study of applying data mining techniques in an outfitter's customer value analysis. Exp. Syst. Appl. **36**(3), 5909–5915 (2009)
9. Sohrabi, B., Khalnari, A.: Customer lifetime value (CLV) measurement based on RFM model. Iran. Acc. Aud. Rev. **14**(47), 7–20 (2007)
10. Zunk, B.M., Koch, V.: Customer ranking model for project businesses: a case study from the automotive industry. Int. J. Eng. Bus. Manag. **6**, 10 (2014)
11. Shen, H., Liu, G.: An efficient and trustworthy resource sharing platform for collaborative cloud computing. IEEE Trans. Parallel Distrib. Syst. **25**(4), 862–875 (2014)
12. Garg, N., Goraya, M.S.: Task deadline-aware energy-efficient scheduling model for a virtualized cloud. Arab. J. Sci. Eng. **43**(2), 829–841 (2017)
13. Sun, L., Dong, H., Hussain, F., Hussain, O., Hang, E.: Cloud service selection: state-of-the-art and future research directions. J. Netw. Comput. Appl. **45**, 134–150 (2014)
14. Zheng, Z., Zhang, Y., Lyu, M.R.: Investigating QoS of real-world web services. IEEE Trans. Serv. Comput. **7**(1), 32–39 (2014)
15. Wang, Z.E., Liu, J.L.: A QoS evaluation model in the environment of cloud computing. Adv. Mater. Res. **488**, 1094–1100 (2012)

16. The Cloud Service Measurement Initiative Consortium, Service Measurement Index (SMI), Carnegie Mellon, Silicon Valley, http://www.cloudcommons.com/about-smi

17. Yadav, N., Goraya, M.S.: Two-way ranking based service mapping in cloud environment. Future Gener. Comput. Syst. **81**, 53–66 (2018)

18. Garg, S.K., Versteeg, S., Buyya, R.: A framework for ranking of cloud computing services. Future Gener. Comput. Syst. **29**(4), 1012–1023 (2013)

19. Baranwal, G., Vidyarthi, D. P.: A framework for selection of best cloud service provider using ranked voting method. In: Proceedings of the 2014 IEEE International Advance Computing Conference (IACC), Gurgaon, India (2014)

20. Jo-Ting, W., Shih-Yen, L., Hsin-Hung, W.: A review of the application of RFM model. Afr. J. Bus. Manag. **4**(19), 4199–4206 (2010)

21. Erl, T., Puttini, R., Mahmood, Z.: Cost metrics and pricing models. In: Erl, T., Puttini, R., Mahmood, Z. (eds.) Cloud Computing: Concepts, Technology & Architecture, pp. 380–390. Prentice Hall, Upper Saddle River (2013)

22. Adams, W.J.L., Saaty, R.: Super Decisions Software Guide. Creative Decisions Foundation, Pittsburgh (2003)

23. Song, E., Nelson, B.L., Staum, J.: Shapley effects for global sensitivity analysis: theory and computation. SIAM/ASA J. Uncertain. Quantif. **4**(1), 1060–1083 (2016)

24. Abdel-Basset, M., Mohamed, M., Chang, V.: NMCDA: a framework for evaluating cloud computing services. Future Gener. Comput. Syst. **86**, 12–29 (2018)

25. Chan, H., Chieu, V.: Ranking and mapping of applications to cloud computing services by SVD. In: Proceeding of the 2010 IEEE/IFIP Network Operations and Management Symposium Workshops, NOMS Wksps, Osaka, Japan (2010)

26. Shetty, J., D'Mello, D. A.: Quality of service driven cloud service rank and selection algorithm using REMBRANDT approach. In: Proceedings of the 2015 IEEE International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM), Chennai, India (2015)

27. Liu, L., Yao, X., Qin, L., Zhang, M.: Ontology-based service matching in cloud computing. In: Proceedings of the 2014 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), Beijing, China (2014)

28. Sobel, V., Subramanyam, S., Sucharitakul, A., Nguyen, J.: Cloudstone: MultiPlatform, multi-language benchmark and measurement tools for web 2.0. In: First Workshop on Cloud Computing and Its Application (2008)

29. Abubakr, T.: Cloud Sleuth (2011). https://www.cloudsleuth.net

30. Li, A., Yang, X., Kandula, S., Zhang, M.: CloudCmp: Comparing public cloud providers. In: Proceedings of the 10th ACM SIGCOMM Conference on Internet measurement (2011)

31. CloudHarmony: (2009). http://www.cloudharmony.com

32. Khattak, H.A., Farman, H., Jan, B., Din, I.U.: Toward integrating vehicular clouds with IoT for smart city services. IEEE Netw. **33**(2), 65–71 (2019)

33. Din, I., Kim, B., Hassan, S., Guizani, M., Atiquzzaman, M., Rodrigues, J.: Information-centric network-based vehicular communications: overview and research opportunities. Sensors **18**(11), 3957-1–3957-13 (2018)

34. Saaty, T.L.: The analytic hierarchy and analytic network processes for the measurement of intangible criteria and for decision-making. In: Greco, S., Figueira, J., Ehrgott, M. (eds.) Multiple Criteria Decision Analysis, pp. 363–419. Springer, New York (2016)

35. Mardani, A., Zavadskas, E., Govindan, K., Amat Senin, A., Jusoh, A.: VIKOR technique: a systematic review of the state of the art literature on methodologies and applications. Sustainability **8**(1), 1–38 (2016)

36. Patel, M. R., Bhatt B.V., Vashi M. P.: SMART-Murli-criteria decision-making technique for use in planning activities. In: Proceedings of New Horizons in Civil Engineering (NHCE-2017), Surat India (2017)

37. Yuniwati, I.: Correlation test application of supplier's ranking using TOPSIS and AHP-TOPSIS method. Cauchy **4**(2), 65 (2016)

38. Brans, J.P., Vincke, P., Mareschal, B.: How to select and how to rank projects: the PROMETHEE method. Eur. J. Oper. Res. **24**(2), 228–238 (1986)

39. Govindan, K., Jepsen, M.B.: ELECTRE: a comprehensive literature review on methodologies and applications. Eur. J. Oper. Res. **250**(1), 1–29 (2016)

40. Somu, N., Kirthivasan, K., Shankar, S.S.: A computational model for ranking cloud service providers using hypergraph based techniques. Future Gener. Comput. Syst. **68**, 14–30 (2017)

41. Hoberg, P., Wollersheim, J., Krcmar, H.: The business perspective on cloud computing—a literature review of research on cloud computing. In: Proceedings of the 2012 AMCIS 18th Americas Conference on Information Systems, Seattle, Washington (2012)

42. Jianping, W.: Research on VIP customer classification rule base on RFM model. In: Proceedings of the 2011 IEEE International Conference on Management Science and Industrial Engineering (MSIE), Harbin, China (2011)

43. Jianping, W.: Research on customer classification rule extraction base on RFM model and rough set. In: Proceeding of the 2010 IEEE 2nd International Conference on Information Science and Engineering, ICISE, Hangzhou, China (2010)

44. Junwei, C., Hwang, K., Li, K., Zomaya, A.Y.: Optimal multi-server configuration for profit maximization in cloud computing. IEEE Trans. Parallel Distrib. Syst. **24**(6), 1087–1096 (2013)

45. Jing, M., Li, K., Li, K.: Customer-satisfaction-aware optimal multiserver configuration for profit maximization in cloud computing. IEEE Trans. Sustain. Comput. **2**(1), 17–29 (2017)

46. Chen, J., Wang, C., Zhou, B.B., Sun, L., Lee, Y.C., Zomaya, A.Y.: Tradeoffs between profit and customer satisfaction for service provisioning in the cloud. In: Proceedings of the 20th International Symposium on High Performance Distributed Computing, HPDC'11, ACM, New York, NY, USA pp. 229–238 (2011)

47. Ding, S., Wang, Z., Wu, D., Olson, D.O.: Utilizing customer satisfaction in ranking prediction for personalized cloud service selection. Decis. Support Syst. **90**, 1–10 (2017)

48. Unuvar, M., Tosi, S., Doganata, Y., Steinder, M., Tantawi, A.: Selecting optimum cloud availability zones by learning user satisfaction levels. IEEE Trans. Serv. Comput. **8**(2), 199–211 (2014)

49. Choi, S.W., Her, J.S., Kim, S.D.: QoS metrics for evaluating services from the perspective of service providers. In: Proceedings of IEEE International Conference on e-Business Engg., ICEBE'07 (2007)

50. Oliver, R.L.: Effect of expectation and disconfirmation on post-exposure product evaluations: an alternative interpretation. J. Appl. Psychol. **62**, 480–486 (1977)

51. Defining a framework for cloud adoption: How common ground can help enterprises drive success with cloud computing [White paper]. IBM Global Technology Services: https://fcw.com/~/media/A548A7862DF64227B223FFD3EEE3C617.PDF. Accessed May 2010

52. Tran, V.X., Tsuji, H., Masuda, R.: A new QoS ontology and its QoS-based ranking algorithm for Web services. Simul. Model. Pract. Theory **17**(8), 1378–1398 (2009)

53. Pfister, H.: Conflict and tradeoffs in decision making, Elke U. Weber, Jonathan Baron and Graham Loomes (Eds.), Cambridge: Cambridge University Press, 2001, 347 pp., ISBN 0-521-77238-9 (hb). J. Behav. Decision Making **16**(1), 73–75 (2002)

54. Naha, R.K., Othman, M.: Cost-aware service brokering and performance sentient load balancing algorithms in the cloud. J. Netw. Comput. Appl. **75**, 47–57 (2016)

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