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RESEARCH ARTICLE

Combined Preference Ranking Algorithm for Comparing and Initial Ranking of Cloud Services

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Abstract: ***Background*:** With the immense significance of cloud computing over the decade, different IT companies offer varieties of cloud services.

***Objective*:** The selection of cloud services from the expanding range of Cloud Service Providers (CSPs) makes it difficult for the Cloud Consumers (CCs) to choose a CSP based on their preferences.

***Methods*:** In this context, this paper proposes an efficient trust management architecture for cloud service selection and put forward Combined Preference Ranking Algorithm (CPRA) for initial ranking of CSPs and their services before doing any transaction in the past based on CCs requirements.

***Results*:** The proposed trust management architecture prompts the CSPs to improve the Quality of Service (QoS) by adhering to Service Level Agreement (SLA).

***Conclusion*:** The experimental results show that compared with other ranking approaches CPRA generates the accurate ranking list of CSPs with minimal execution time.

Keywords: Cloud consumers, cloud services, cloud service providers, quality of service, service level agreement, service measurement index.

1. INTRODUCTION

Cloud computing is the transmission of services such as compute, storage, network or software over the Internet to Cloud Consumers (CCs). These services are provided on demand to the CCs. A Community which offers these types of expanding services is called Cloud Service Providers (CSPs). Since the CSPs market for handing out the computing services is on the rise, the CCs are facing the demand of selecting a reliable service provider that is appropriate for them. Considering that all the CSPs provide the same services and the confidence according to the CCs requirement [1]. It becomes difficult for the CCs to pick a quality CSP from a group of CSPs which provides the same services. For *e.g.*, if a Cloud Consumer (CC) wants a CPU Cloud service from a CSP. Let C = {CSP_1, CSP_2, CSP_n} be a set of CSPs which provides the same type of CPU service. The CSP_1 might provide the CPU service at 80 % better quality, CSP_2 may provide at 90 % improved quality and CSP_n may perhaps provide at 45 % quality of the same service. But a CC, you might land up using the CPU service with CSP_n without knowing its quality. Therefore a CC, must always measure the trustworthiness of a CSP and which CSP is more beneficial to them according to their requirements before availing the CPU service. In order to choose a quality and trustworthy CSPs from a competitive multi-cloud environment, the CCs have to compare all the competing CSPs with respect to multi-dimensional trust evaluation system such as Quality of Service (QoS), users feedback (direct), opinions (indirect), observations, Service-Level Agreement (SLA), performance, security, compliance, *etc.* These parameters are identified as building blocks to build up a trust relationship between the CCs and CSPs for the selection of a trustworthy CSP. The information about the specified parameters is often available with CSPs, CCs, Cloud Brokers and other entities participating in the selection of CSPs [2]. Generally, CCs enter into an agreement with CSPs to provide the QoS. This type of agreement is called the Service Level Agreement (SLA) [3]. SLAs typically hold account of service level parameters such as response time, reliability, availability, average throughput, accuracy, transparency, interoperability, scalability, up-time, *etc* [4]. One of the important parameters in building up the trust relationship between CCs and CSPs is the adherence (what a CSPs has promised to deliver to the CCs and what they have actually delivered) to the SLAs. To monitor the

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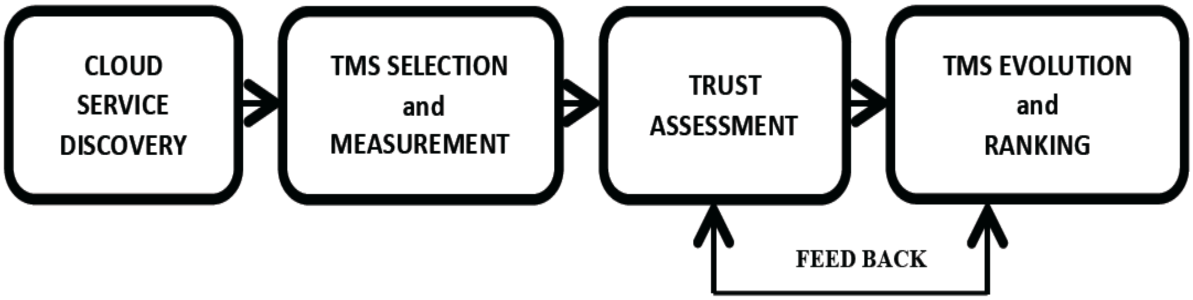

Fig. (1). Trust management system components.

dynamic nature of the QoS, SLA specifications and to detect and filter out the dishonest feedback's (Direct and Indirect) a trust management system model has to be introduced to allow the CCs to take a multi-dimensional decision for selecting a suitable CSP. The trust model will rank the CSPs based on different attributes and allow the CCs to select a suitable CSP. Until now, very little work has been done for evaluating and selecting a suitable CSP and ranking them based on multiple attributes. Hence, the growth of trust in selecting a CSP has drawn serious attention in the research study [5].

Trust Management System supports the CCs to choose an appropriate CSP with their respective QoS values [6]. The five Components of Trust Management system are as follows: i) cloud service discovery ii) trust selection and measurement iii) trust assessment iv) trust evolution and v) trust based ranking system to determine the trustworthiness of the CSPs Fig. (**1**) [7]. From the listed components, the ranking system which ranks the CSPs plays an important role in the Trust Management System. Therefore, given the diversity of CSPs offering the Cloud services, a critical threat for the CCs is to determine the right CSPs for their requirements. Different CSPs have distinct non-functional and functional requirements which make it challenging to measure the CSPs in a way where security, quality and reliability of the customer's application are established. Therefore, just to determine multiple CSPs is not sufficient, however, it is also crucial to assess which one is the most applicable CSP. In this regard, (CSMIC) - Cloud Service Measurement Index Consortium [8], has described QoS attributes that are connected in the frame of (SMI) – Service Measurement Index. This SMI could be used by CCs to evaluate different CSPs. Based on the described attributes of Cloud services in this paper, some encounters are dealt with understanding a prototype for estimating QoS attributes and ranking CSPs. The Primary is exactly how to evaluate several SMI QoS attributes of a CSP. A lot of these QoS attributes change over a period. For example, it has been found that the performance of virtual machines changes vastly from the agreed values in SLA by Amazon [9]. However, without having accurate evaluation standards for separate QoS attribute, it becomes difficult to analyze different services of Cloud or even determine them. So, SMICloud adopts old measurements and adds them with agreed values to determine the correct value of QoS attribute. Furthermore, we give actual QoS metrics for the respective quantifiable attribute.

The next task stands, in what way to rank the services of Cloud established on these QoS attributes. CCs can have two kinds of QoS requests: non-functional and functional. Few of them cannot be estimated with ease. User experience and security attributes are difficult to quantify. Furthermore, determining which service of Cloud with the best match with all non- functional and functional needs is a decision problem. It remains essential to consider seriously before choosing as it contains multiple measures and mutually dependent association among them. This stands a problem of MCDM (Multi-Criteria Decision-Making) [10]. Each separate factor disturbs the Cloud service selection procedure, and its effects the overall ranking be determined by its importance in the complete selection process. To tackle this problem, we propose an efficient trust management architecture and Combined Preference Ranking Algorithm (CPRA) which compare and rank the CSPs at every level initially without any transactions with the CCs based on CCs preferences. The CPRA would let CCs analyze distinct Cloud service offering, corresponding to their preferences and multiple dimensions, and choose whatsoever is suitable to their requirements therefore producing a desired quantitative foundation for the ranking the services of Cloud.

1.2. Paper Organization

The rest of the paper is organized as follows: Section 2 describes the related work in the area of ranking cloud services. Section 3 describes an overview of Service Measurement Index (SMI). Section 4 illustrates how the QoS metric for different quality features can be shown. Section 5 presents the framework of proposed trust management architecture for cloud service selection. Section 6 details the Combined Preference Ranking Algorithm (CPRA). Sections 7 show the stepwise working of CPRA with an example case study. Section 8 concludes this paper with future directions.

2. MATERIALS AND METHODS

2.1. Related Work

Cloud computing has been drawn as the consideration of several researchers as it gives numerous chances to organizations by providing a scope of various computing trust services. Saurabh *et al.* [11], proposed a structure and a methodology which measures the quality and ranks the cloud services using Analytical Hierarchal Process (AHP). When the level of complications are high it takes a lot of time to execute and generate the ranking list. Nivethitha *et al.* [12]

present a Hypergraph based Computational Model (HGCM) and Minimum Distance - Helly Property (MDHP) algorithm for ranking the cloud service providers. Helly property of the hypergraph has been utilized to allocate weights to the attributes and decrease the many-sided quality of the ranking model. The structure becomes complex when the number of CSPs increases with similar intersection points.

M.R. Gauthama *et al.* [13] introduce a Rough set κ -Helly property technique (RSKHT) to distinguish the key attributes to organize IDSs (Intrusion detection systems). John *et al.* [14] present a fuzzy-logic based approach that permits the cloud service users to decide the most reliable CSPs. Rules have been set up by CSPs that will be connected in the fuzzy inference system (FIS) to give the quantitative security list to the cloud service users. MZ Khan et al [15] propose a model named Cloud Service Evaluation and Ranking Model (CSERM), which uses SMI (Service Measurement Index) that examines the stability and gives the ranking list from which the cloud user can choose the appropriate services from the ranked option for their online services. Lie Qu *et al.* [16] introduce a TMS (Trust Management Services) where ranking is done by Cloud Service Providers (CSPs) assumes a crucial part in choosing the appropriate CSPs. As a rule, trust is registered utilizing objective and subjective attitude, acquired because of CSP's adherence to the SLA (Service Level Agreement) and the level of cloud user's expectation on the organization or services. Development in the field of cloud computing empowers the cloud users to concentrate towards the execution assessment of various CSPs. This outcomes in the improvement of cloud which benefits the assessment and to examine the tools for example, CloudCmp execution and cost [17, 18], Cloud Harmony performance [19], Cloud Monitoring performance [20], Cloud Rank Performance [21], Cloud Sleuth Performance [22] and Cloud Stone Performance [23]. H. Chan *et al.* [24] present an application and a cloud service provider (CSP) mapping system to rank the cloud services which is built on the Singular Vector Decomposition (SVD).

The cloud service provider provides a service quality standard measurement from the repository using which the cloud user selects an appropriate cloud service provider (CSP) based on cloud user requirements. P. Choudhury et al [25, 26] represent an architecture based on Service Ranking Services (SRS) which includes both qualitative and quantitative services. Qualitative services are negotiable whereas, for quantitative services, SMI metrics based on ISO organization is measured which are standardized key attributes to measure the cloud services. S.C Tejas et al [27, 28] introduce a CSP provision which compares the SLAs parameters with cloud consumer's requirements for ranking the cloud service providers. L. Qu [29] framed a design for both objective and subjective Quality of Services (QoS) as per the cloud users requirements and their experience. O.S Vaidya et al [30] used AHP which works on Multi Criteria Dimensional Model (MCDM) to integrate the complex structure and then aggregates these structures into the simple decision tree components.

From the related work, it is clear that to initially rank the cloud service providers there is no comprehensive ranking system that allows the CCs to rank the CSPs without doing any transaction with the CSPs in the past. Moreover, most of the ranking cloud service providers perform the data in the mode of the matrix and user preferences are ignored. When there is an increase in CSPs and CCs, matrix model becomes complicated and it affects the overall execution time. In the proposed work, the concept of initial ranking based on CPRA has been applied to rank the CSPs before any transaction begins with the CSPs. The reason for applying CPRA is CCs preferences are taken into account while ranking the CSPs and are given an additional weightage when the CSPs exceeds the expectations of the CCs preferences.

3. SERVICE MEASUREMENT INDEX (SMI)

Cloud Service Measurement Index Consortium (CSMIC) has set some attributes to measure the various cloud services in the form of Service Measurement Index (SMI). SMI attributes Fig. (**2**) are framed by International Organization for Standardization (ISO) [31]. These attributes are used by the CCs to evaluate the various CSPs. SMI attributes are classified into seven main attributes which are used for evaluating the cloud services. These attributes are further divided into two or more sub-attributes. Each sub-attribute is further nested into sub-attributes and so on. The attributes may be of quantitative behavior or qualitative behavior.

Quantitative metrics can be formulated using numeric values whereas qualitative metrics are measured in terms of nominal or ordinal values. Following are the seven main attributes of SMI which participate in evaluating the cloud service.

a. **Accountability**- this attribute is used to evaluate the CSP distinct characteristics. This QoS attribute is critical in building trust between CC and CSP. None of the organizations will deploy its sensitive data and their applications and store in a spot where there is no compliance and accountability. Critical functions which SMI considers for accountability when evaluating and scoring the cloud services include data ownership, sustainability, compliance, provider ethically, auditability, *etc.*

b. **Agility**- the most essential advantage of Cloud is that it can adjust and change fast at less cost. SMI measures agility by how fast a system adapts to a new environment if some changes are made by an organization. When examining the service agility of Cloud, organizations need to know whether the Cloud services are adaptable, elastic, flexible and portable.

c. **Assurance**- this metric illustrates the likeliness of a CSP performing as agreed in SLA. All organizations want to widen their enterprise and serve exceptional service to the Cloud consumers. Therefore, service stability, reliability and resiliency are essential factors in choosing the services of Cloud.

d. **Cost**- the query that appears to the organizations before migrating to Cloud whether it is less expensive or not. Therefore for IT and business, the cost is one of the important QoS attribute. This metric turns out to be the biggest quantifiable attribute today.

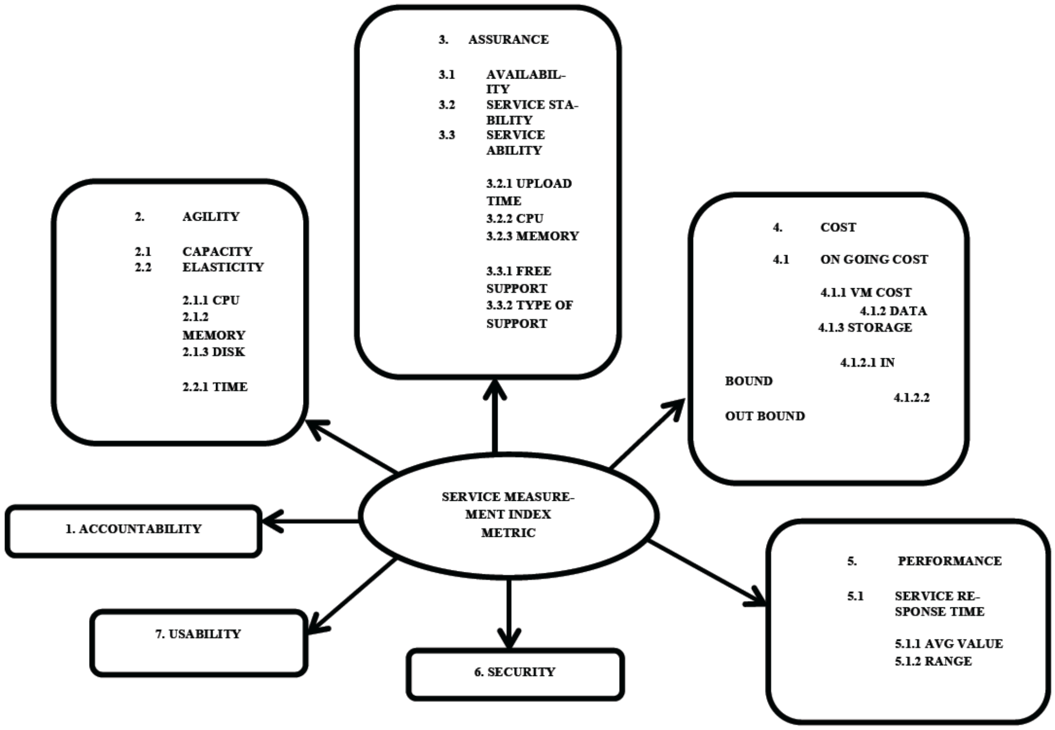

Fig. (2). SMI attributes.

a. **Performance**- several distinct solutions are offered by CSPs mentioning the IT demands of various organizations. Every solution holds a distinct performance based on accuracy, functionality and service response time. Organizations should know how their requests function on various Clouds and whether these requirements fit their likelihood.

b. **Security and Privacy**- privacy and data protection are very crucial for all organizations. Deploying data under some other organization authority is a vital issue which needs strict policies operated by CSPs. For example, financial business requires regulations and compliance demanding privacy and data integrity. This metric is multi-dimensional and consists of attributes like data integrity, privacy, availability and confidentiality.

c. **Usability-** this attribute is important for dynamic adoption of services in the Cloud. Services delivered to the CCs by the CSPs should be easy to use and understand. This metric depends on various factors like Learnability, Accessibility, Operatibility and Installability.

4. QOS MODEL FOR IAAS SERVICE PROVIDER

Cloud services can be measured based on quantitative and qualitative Key Performance Indicators (KPIs). Quantitative KPIs can be evaluated using hardware and software estimating tools. Qualitative KPIs which are not quantified are measured based on Cloud consumer experiences. For instance, CSPs security and ethicality metric are qualitative. These Key Performance Indicators serve generic services of Cloud, only a few are crucial for distinct Cloud services and application. For instance, installablity QoS metric based on usability is important to IaaS CSP than SaaS CSP considering in SaaS mostly there is no installation on Cloud consumer's side. The similar KPIs may have various definitions depending on Cloud services. Few of these specification banks on Cloud consumer's application and few are self-reliant. For instance, flexibility is analyzed by CSP while suitability is inclined to Cloud consumer. Therefore, it becomes difficult to decide accurately the service measurement index values for a CSP when there are numerous attributes involved and attributes definitions confide with various sub-attributes. Few example explanations for quantifiable KPIs are presented in Section 4.1 with their QoS metric and formulation [31] specifically with respect to IaaS. Qualitative QoS KPIs is outside the scope of this paper.

4.1. Cloud Key Performance Indicators QoS Metric

4.1.1. Availability

It is the proportion of time a CC can utilize the Cloud service.

It is defined as:

$$\frac{(\text{total operating time of Cloud service})-(\text{overall time for which Cloud service was unavailable})}{\text{total operating time of Cloud service}}$$

4.1.2. Interoperability

It is the capability of a Cloud service to communicate with different Cloud services provided through the same CSP or different CSPs. This metric is qualitative and defined by means of user skills. Since it is a vital parameter for CCs, estimation is given by: $\frac{\text{Total No.of platforms provided by CSP}}{\text{Total No.of platforms needed by CCs}}$

4.1.3. Stability

Stability is described as uncertainty within the act of a Cloud service. For *e.g.*, Storage is the variance of average write time and read time. For *e.g*, a computational resource is given by: $\Sigma\frac{\alpha_{avg,i} - \alpha_{sla,i}}{\frac{T}{n}}$, where α is storage, computational or network unit. $\alpha_{avg,i}$ is the detected mean performance of the CC i who hired the Cloud service, $\alpha_{sla,i}$ is the agreed values, T is the Cloud service time; and n is the overall CC.

4.1.4. Reliability

Reliability reveals in what way a Cloud service functions deprived of failure during a specified condition and time. It is established on the MTTF (Mean Time To Failure) assured by the CSP and earlier failures encountered by the CCs. It is given by: probability with respect to violation × P_{MTTF}

$= (1 - \frac{num\_failure}{n}) * P_{MTTF}$, Where num_failure is a count of CCs who experienced a decline in a time period less than agreed by the CSP, n is count of CCs, and P_{MTTF} stands for the agreed Mean Time To Failure.

4.1.5. Service Response Time

The performance of availability in Cloud services can be calculated with respect to response time (RT), *i.e.* in terms of IaaS, how quickly the Cloud service can be accessible for usage. For instance, if CC requests a VM from a CSP, then the Cloud service RT is measured by time acquired by the CSP to attend CC request. This consists of VM provisioning, VM booting, starting of application deployment and IP address assigning. This metric is reliant on several sub-factors like average RT, maximum RT guaranteed by the CSP, and fraction of time RT level is neglected.

• Average RT is defined by $\Sigma_i \frac{R_i}{c}$, where R_i is time from when CC *i* intended an IaaS Cloud service and at what time it is really accessible and c is the overall count of IaaS Cloud service requirements.

• Maximum RT is defined as maximum guaranteed RT by the CSP for the Cloud service.

• RT Failure is defined as the percentage of occurrence when the RT time was greater than the agreed maximum RT. Hence, it is specified as 100[c′/c], where c′ is the sum of occurrence when the CSP did not satisfy their assurance.

4.1.6. Elasticity

Elasticity is outlined as, how much scaling of Cloud services can be done in case of peak hours. Two attribute defines this metric: average time it takes to increase or decrease the Cloud service size and full size of Cloud service. The size is given by maximum count of computational units which can be provided during peak times.

4.1.7. Cost

Cost is determined by two characteristics: on-going cost and acquisition. It is difficult to compare various costs of Cloud services as they deliver distinct features with several dimensions. The same CSP provides distinct virtual machines which fulfills CCs necessities. For example, Cloud services of Amazon provides small virtual machine at less price when compared to Rackspace, however the amount of compute unit, data storage and bandwidth are distinct among two CSPs . To address this issue, volume-based metric is defined, *i.e.* the price of a unit of RAM, CPU, storage and network bandwidth. Hence if a virtual machine is rated at X for network units, CPU units, RAM units, and data units. So the virtual machine price is given by $\frac{X}{RAM^{l} * CPU^{m} * data^{y} * net^{z}}$, Where l, m, y and z are weights of respective attributes and l + m + y + z = 1. The Weights differs for each application.

4.1.8. Adaptability

Adaptability is defined as the capability of the CSP to adapt changes in Cloud service when the CCs request an upgradation. It is outlined as a period of time it takes to upgrade to the greater level.

4.1.9. Suitability

Suitability is illustrated as the extent to which CCs requisite is met by a CSP. Firstly, it filters outs the CSPs based on non-essential and essential requests of the CCs, if more than one CSP exist after the filtering process then all of them are considered acceptable. Otherwise, if filtering leads to an empty list of CSPs then those CSPs are chosen that meet the essential requirements. It is given as:

$$=\frac{\text{No.of non−essential requirements offered by the CSP}}{\textit{No.of non−essential requirement required by the CC}}$$

if only necessary features are fulfilled

= 1 if every requirement is fulfilled

= 0 else.

4.1.10. Accuracy

This metric is described as the rate of failure in providing the agreed SLA in terms of storage, network and computational units. Accuracy is given as $\Sigma_i \frac{a_i}{c}$ where a_i is the total count the CSP fails to please the agreed values for the consumer n over the Cloud service period T and c is the total no of previous CCs.

5. PROPOSED TRUST MANAGEMENT ARCHITECTURE FOR CLOUD SERVICE SELECTION

We propose an efficient trust management architecture for cloud service selection which helps CCs to evaluate the different CSPs and rank them accordingly. The Combined Preference Ranking Algorithm (CPRA Algorithm) has been proposed in the architecture which does the ranking of the overall cloud services and individual cloud services initially before any transaction takes place in the system based on user preferences. Once the transactions begin, our architecture ranks the CSPs based on multi criteria decision making approach which makes it more efficient and less time consuming for the CCs to access the different CSPs. The framework helps the user to find suitable CSPs as per the CCs requirement. The initial ranking of the CSPs is done based on SMI metrics as discussed in section 3. This architecture also provides a pre- SLAs to the CCs through which they can access the previous record of each CSP's perfor-

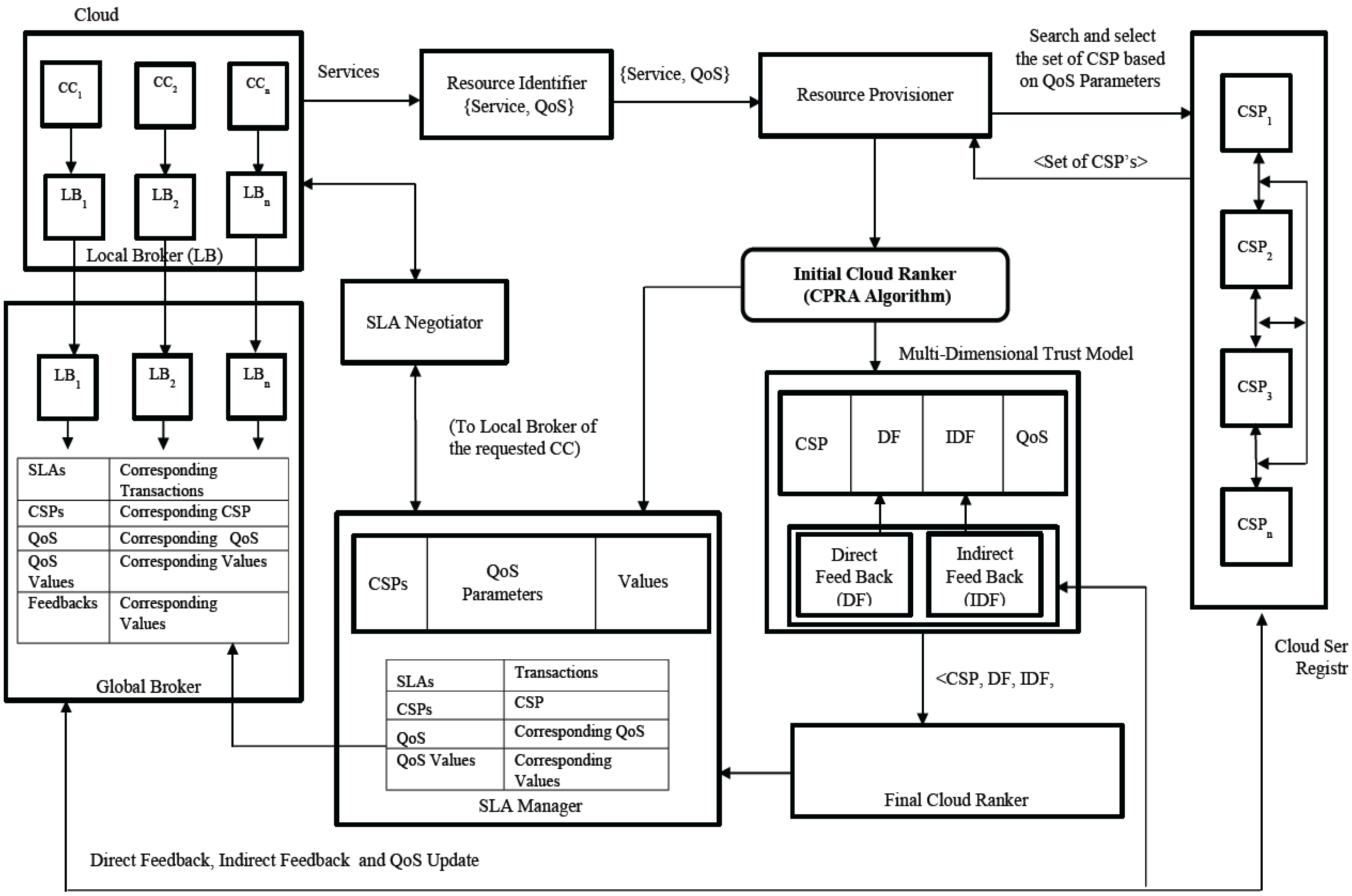

Fig. (3). Proposed trust management architecture for cloud service selection.

mance and their service guaranteed. Following are the main modules of our proposed architecture represented in Fig. (**3**).

a. **Cloud Consumers (CCs)** – CCs is the entity who submits the request to the resource identifier for the execution of the IaaS, PaaS or SaaS services.

b. **Local Broker (LB)** - Every CC has a local broker associated with it which keeps tracks of each transaction with the CSP in regard to all the specification with respect to SLA and later it decides after transacting whether the CSP has satisfied or violated the SLA. The LB monitoring of SLA metric is considered as CC side monitoring.

c. **Resource Identifier (RI)** - It identifies the type of service and its QoS parameters requested by CC and forward the request to the resource provisioner.

d. **Cloud Service Registry (CSR)** – The CSPs register the type of services and its QoS it provides in the CSR.

e. **Resource Provisioner (RP)** – It collects all the requirements of the CC from the RI and searchers in the CSR and retrieves the list of all the CSPs based on CC requirements and forwards the CC requirements and the retrieved list of CSP or CSPs to initial cloud ranker.

f. **Initial Cloud Ranker** – The retrieved list of CSPs are ranked based on CC requirements using Combined Preference Ranking Algorithm (CPRA) which is the main focus of this paper discussed detail in section 6.

g. **Multi-Dimensional Trust Model (MDTM)** - MDTM gets the CSPs rank obtained from CPRA algorithm and then it combines the multi criteria decision making approach using various sources of trust information, to generate the final ranking of the CSPs after the transaction happens initially in the system with the requested CC. The various sources of MDTM model include the direct feedback, indirect feedback, CPRA CSPs ranking and the QoS values.

Direct Feedback: Is the satisfaction level of the CC after transacting directly with the respective CSP.

Indirect Feedback: Is the satisfaction level of the other CCs and the CSPs who have transacted with the same CSP for the requested service by the CC in the past.

Final Cloud Ranker - It aggregates the values of the direct feedback, indirect feedback, CSPs ranking obtained from CPRA algorithm, QoS and generates the final CSP ranking. The obtained value after aggregation is presumed as final trust value of the CSP which will be used in ranking the CSPs.

a. SLA Manager-Once the respective CSP has been selected by the final cloud ranker, the CC and the CSP enter into a contract known as Service Level Agreement (SLA). The SLA manager performs the negotiation between CC and the selected CSP using SLA negotiator. SLA manager finalizes the SLA metric like response time, availability, reliability, throughput, performance, *etc.* and keeps tracks of the promised metric between the CC and the CSP. SLA manager tracking of SLA metric is considered as server side monitoring.

b. Global Broker (GB) – In our proposed architecture the monitoring of the SLA metric is done by the CCs side through the LB and server side by SLA manager. The GB keeps tracks of all the Local Brokers CCs side specifications with respect to SLAs made between all the CCs and CSPs and server side. The individual CC SLA metric values are then compared with the respective server side SLA metric values for reconfirmation by the GB. Any deviations found between CC SLA metric and server SLA metric, the GB negotiates between them and the final values are taken for direct feedback, indirect feedback by the CCs, CSPs and QoS update for final ranking in MDTM.

6. INITIAL RANKING OF CLOUD SERVICES USING COMBINED PREFERENCE RAKING ALGORITHM

Ranking of CSPs is one of the utmost essential component of our proposed architecture. Our framework assesses the initial ranking of CSPs based on QoS requirements of the CCs and the services provided by the cloud. Comparison of cloud services amongst different CSPs without doing any transactions before with the CSPs and ranking them accordingly to the users preferences is not an easy task to perform for CCs. A scenario arises when a CC wants to compare each QoS parameters where they might be looking for low cost efficient CSPs and additionally they also want good assurance of the CSPs. This creates lot of confusion among CCs while selecting which services are suitable for them. To avoid such situations, we propose an optimal ranking algorithm which provides the CCs the details of ranking list for individual and overall QoS parameters. Since there are different levels of SMI metrics and each attributes further have sub- attributes. One must consider all these metrics, as each parameters plays its crucial role for the selection of the suitable cloud service provider (CSP) based on CCs preferences. The CPRA algorithm is setoff when initial ranking of the CSPs list and CCs requirements are retrieved by the resource provisioner. CPRA is best utilized when the system starts without having the CSPs transaction history of the past. The CPRA ranks the CSPs based on CCs requirements and CSPs offering the cloud services.

Algorithm 1: Combined Preference Ranking Algorithm (CPRA)

<u>Input:</u>

(x_0): Cloud Consumer(CC) user preference value

(s_i): Service values of CSP at each level

(α): Initial Assignment of weight at level 3(α > 0.1)

<u>Output:</u>

Ranking of SMI attributes at L_3, L_2 and L_1.

Overall Ranking of CSPs - $Rank_i \leftarrow \{R_1, R_2 \ldots R_n\}$

<u>Generating Algorithm:Begin:</u>

<u>Step1: To compute the ranking for SMI sublevel attributes (l_3)</u>

for each l_3 attribute: i=1 to n

Determine L_s ← List which contains weighted ues (x_0) of SMI attribute and its services(s_i).

$L_a = Compare\ (x_0, s_i)$

<u>Step1.1: Impute the missing values for (x_0, s_i)</u>

$if(x_0)\ : Vt\ = Range$,
$x_0 = ([Mean(\ x_0)\ services]\ CC\ preference\ value)$

$if(s_i)\ : Vt = Range\ \ s_i\ = ([Mean(\ s_i)\ services])$, i=1 to n

$if(x_0)\ : Vt = Boolean, \qquad x_0\ = 1$

$if(x_0)\ : Vt = us$,
$x_0 =\ no\ of\ services\ CC\ requires$

$if(s_i)\ : Vt = us,$
$s_i\ =\ no\ of\ services\ CSP\ provides$,

Where i =1 to n.

$if(x_0)\ : Vt = numeric,$

$$x_0 = \left([Mean(\ s_i)\ services]\left[\frac{1}{2}\ln\frac{1-E^t}{E^t}\right]\right), E^t \leftarrow \alpha$$

where $Value\ type(Vt), unordered\ set(us), E^t$ is Error Rate

<u>Step2: To compute the ranking for SMI superlevel attributes (l_2)</u>

for each l_2 attribute : Determine L_s ← List which contains the corresponding l_3 SMI attributes

Compute new CC user preference value (x_0)

$l_n(x_0)\ = \sum_{i=1}^{n} \alpha * \ x_0$, where n is the level

from the L_a SMI computed list, determine the service value

if SMI attributes is measured in time and cost:

Efficiency of time and cost is computed: $\mathrm{EoA}(s_i) = \sqrt{A_n - A(s_i)}$,

where $A_n = \sum_{i=1}^{n} A(s_i)$, i = 1 to n ., Efficiency of Attribute (EoA)

Compute the new $(s_j)\ values\ for\ l_2$, for each service j=1 to n :

$z\ = \sum_{j=1}^{n} L_a(s_j)$

Store in a list $L_b \leftarrow (z, s_j, l_n(x_0))$

for each service (s_j) from the list L_b , do : ,fetch service value z and $l_n(x_0)$

$$L_c = \ Compare\ (l_n(x_0), z)$$

<u>Step3: To compute the ranking for SMI mainlevel attributes (l_1)</u>

Repeat step2 by varying the level and list

MAIN LEVEL ATTRIBUTES - Level 1 (WEIGHT)	SUPER LEVEL ATTRIBUTES - Level 2 (WEIGHT)	SUB LEVEL ATTRIBUTES – Level 3 (WEIGHT)		SERVICE 1	SERVICE 2	SERVICE 3	SERVICE 4	SERVICE 5	Value Type	CC USER PREFERENCE VALUE
ACCOUNTABILITY (0.05)	LEVEL: 0-10 (1)			4	8	4	6	7	Numeric	4
AGILITY (0.2)	CAPACITY (0.6)	CPU	0.5	9.6	12.8	8.8	10.8	8.8	Numeric	6.4 GHz
		MEMORY	0.3	15	14	15	13	15	Numeric	10
		DISK	0.2	1690	2040	630	700	850	Numeric	500GB
	ELASTICITY (0.4)	TIME	0.4	80-120	520-780	20-200	90-140	130-190	Range	60-120 Sec
ASSURANCE (0.2)	AVAILABILITY (0.7)			99.95	99.99	100	99.85	99.92	Numeric	99.9%
	SERVICE STABILITY (0.2)	UPLOAD TIME	0.3	13.6	15	21	14	12	Numeric	
		CPU	0.4	17.9	16	23	13	14	Numeric	
		MEMORY	0.3	7	12	5	15	13	Numeric	
	SERVICEABILITY (0.2)	FREE SUPPORT	0.7	0	1	1	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	24/7, Diagnostic Tool, Phone	24/7, Phone	Unordered Set	24/7, Phone
COST (0.3)	ON-GOING COST (1)	VM COST	0.6	0.68	0.96	0.96	0.83	1	Numeric	<1 $/hr
		DATA (0.2)	IN - BOUND	10	10	8	9	9	Numeric	100 GB/month
			OUT - BOUND	11	15	18	13	13	Numeric	200 GB/month
		STORAGE	0.2	12	15	15	13	14	Numeric	1000 GB
PERFORMANCE (0.3)	SERVICE RESPONSE TIME (1)	RANGE	0.5	80-120	520-780	20-200	100-130	120-200	Range	60-120 Sec
		AVERAGE VALUE	0.5	100	600	30	140	140	Numeric	
SECURITY (0.05)	LEVEL: 0-10 (1)			4	8	4	4	4	Numeric	4

Fig. (4). Evaluation Data Set of Amazon EC2 (S1), Windows Azure (S2), Rackspace (S3) and Private Cloud Setup – OpenStack (S4) and Eucalyptus (S5).

Step 4: Compare Function

Compare (x_0, s_j), j=1 to all services

Begin:

$if\ \left(Value(x_0) < Value(s_j)\right) \leftarrow$ (β = α + 0.1), $elseif\ (Value(x_0)\ > Value(s_j)) \leftarrow$ (β = α - 0.1),

$else\ \ (Value(x_0)\ =\ Value(s_j)) \leftarrow$ (β = α),

where β is new weight

Endif

$\varphi\ (s_j) =\ \beta\ * Value(s_j)$, where φ is the SMI attribute

$return(\varphi\ , s_j)$

End

Step 5: To compute overall ranking of the services

for each service i=1 to n from the l_1 list , do

$S(i) = \sum_{i=1}^{n} Values\ of\ Main\ Attribute\ (L_1)_i$

End

7. EVALUATION AND EXPERIMANTAL RESULTS AND DISCUSSION OF INITIAL RANKING OF CSPS USING COMBINED PREFERENCE RANKING ALGORITHM

In this segment, evaluation of the proposed CPRA ranking methodology is discussed. The informational data taken for the evaluation of the cloud services are from five CSPs. The comparison and initial ranking of five CSPs are done using CPRA. Collectively one CC requirement and five CSPs were considered for ranking the CSPs. The left out values for the CC were imputed using step1.1 of CPRA algorithm. Five CSPs were evaluated for six main attributes of QoS groups namely Accountability, Agility, Assurance, Cost, Performance and Security, 9 super attributes and 15 sub attributes. For each attribute, the weightage is assigned from [31] with modification of agility and serviceability. The first three QoS data is gathered from three different IaaS cloud service providers namely Amazon EC2, Windows Azure, and Rackspace [32-34]. The fourth and fifth QoS dataset was collected from the private cloud setup using OpenStack and Eucalyptus at VIT University. Fig. (**4**) shows the five IaaS cloud service providers of QoS dataset organized in the ordered format of SMI metric. CPRA presents the procedural steps of the calculation for cloud service ranking of SMI. It pairs each SMI values of the services (s_j) with respect to CC user preference values (x_0). From each pair of attributes, new weightage (β) is computed based on (Algorithm1: Step 4).

7.1. Accountability

Following are the pair values of CC user preference (x_0) and accountability services (s_j) respectively: (x_0, s_1) = (4, 4), (x_0, s_2) = (4, 8), (x_0, s_3) = (4, 4), (x_0, s_4) = (4, 6), (x_0, s_5) = (4, 7) and α= 0.05**.**

Computation of individual ranking of the accountability services is evaluated using step4 of CPRA.

$$\varphi\ (s_j) =\ \beta\ * Value(s_j) \quad (1)$$

$\varphi\,(s_1) = \beta * (s_1) = 0.05*4 = 0.2$, $((x_0) = (s_j), \beta = \alpha)$

$\varphi\,(s_2) = \beta * (s_2) = 0.15*8 = 1.2$, $((x_0) < (s_j), \beta = \alpha + 0.1)$

$\varphi\,(s_3) = \beta * (s_3) = 0.5*4 = 0.2$

$\varphi\,(s_4) = \beta * (s_4) = 0.15*6 = 0.9$

$\varphi\,(s_5) = \beta * (s_5) = 0.15*7 = 1.05$

Fig. **(5).** shows the service comparison in terms of accountability: $S_2 > S_5 > S_4 > (S_1 = S_3)$.

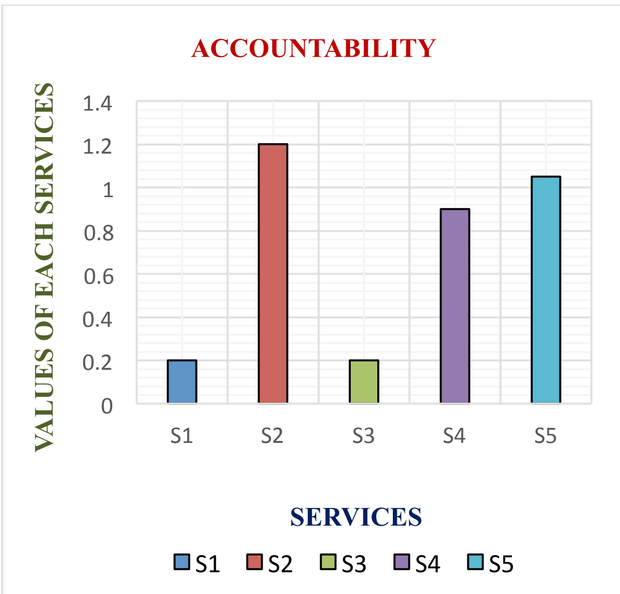

Fig. (5). Service ranking of main level attribute accountability. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

7.2. Agility

Ranking of agility is computed by correlating its associated sub level attributes and super level attributes.

7.2.1. Capacity

Sub level attributes - CPU, memory and disk is evaluated to compute capacity.

7.2.1.1. CPU

The service pair of CC user preference value (x_0) and CPU (s_j) are S_1= (6.4, 9.6), S_2= (6.4, 12.8), S_3= (6.4, 8.8), S_4= (6.4, 10.8), S_5= (6.4, 8.8) and α= 0.5.

The individual rankings of CPU are as follows:

$\varphi\,(s_1) = \beta * (s_1) = 0.6*9.6 = 5.76$,

$\varphi\,(s_2) = \beta * (s_2) = 0.6*12.8 = 7.68$,

$\varphi\,(s_3) = \beta * (s_3) = 0.6*8.8 = 5.28$,

$\varphi\,(s_4) = \beta * (s_4) = 0.6*10.8 = 6.48$,

$\varphi\,(s_5) = \beta * (s_5) = 0.6*8.8 = 5.28$

$S_2 > S_4 > S_1 > (S_3 = S_5)$, shows the service ranking in terms of CPU.

7.2.1.2. Memory

Memory service pairs values are: S_1= (10, 15), S_2= (10, 14), S_3= (10, 15), S_4= (10, 13), S_5= (10, 15) and α= 0.3. The Individual rankings of memory: $\varphi\,(s_1)$ = 0.4*15 = 6, $\varphi\,(s_2)$ = 0.4*14 = 5.6, $\varphi\,(s_3)$ = 0.4*15 = 6, $\varphi\,(s_4)$ = 0.4*13 = 5.2 and $\varphi\,(s_5)$ = 0.4*15 = 6. $(S_1 = S_3 = S_5) > S_2 > S_4$

7.2.1.3. Disk

Constructed values of disk service pairs S_1= (500, 1690), S_2= (500, 2040), S_3= (500, 630), S_4= (500, 700), S_5= (500, 850) and α= 0.2. The individual rankings of disk $\varphi\,(s_1)$ = 0.3*1690 = 507, $\varphi\,(s_2)$ = 0.3*2040 = 612, $\varphi\,(s_3)$ = 0.3*630= 189, $\varphi\,(s_4)$ = 0.3*700= 210 and $\varphi\,(s_5)$ = 0.3*850= 255.The service ranking in terms of disk: $S_2 > S_1 > S_5 > S_4 > S_3$.

To assess the ranking of capacity, new values of (x_0, s_j) is determined using step2 of CPRA. To obtain the value of (s_j) sub level attributes of capacity is added in terms of CPU, memory and disk of the services: S_1= (5.76+ 6+ 507) = 518.76, S_2 = (7.68+ 5.6+ 612) = 625.28, S_3 = (5.28+ 6+ 189) = 200.28, S_4 = (6.48+ 5.2+ 210) = 221.68 and S_5 = (5.28+ 6+ 255) = 266.28.Computation of (x_0) in terms of capacity is done using Eq. (2).

$$l_n(x_0) = \sum_{i=1}^{n} \alpha * x_0 \tag{2}$$

x_0 = ((6.4*0.5) + (10*0.3) + (500*0.2)) = 106.2.Capacity service pair values S_1= (106.2, 518.76), S_2= (106.2, 625.28), S_3= (106.2, 200.28), S_4= (106.2, 221.68), S_5= (106.2, 266.28) and α = 0.6. The individual rankings for capacity: $\varphi\,(s_1)$ = 0.7*518.76 = 363.132, $\varphi\,(s_2)$ = 0.7*625.28 = 437.696, $\varphi\,(s_3)$ = 0.7*200.28 = 140.196, $\varphi\,(s_4)$ =0.7*221.68 = 155.176 and $\varphi\,(s_5)$ = 0.7*266.28= 186.396. Indicates the service comparison in terms of capacity: $S_2 > S_1 > S_5 > S_4 > S_3$.

7.3. Elasticity

Ranking of elasticity is computed in terms of sub level attribute time.

7.3.1. Time

Imputing of missing values of (x_0, s_j) for time in range value type is evaluated using Eqs. (3, 4).

$$x_0 = ([Mean(x_0)\ services]\ CC\ preference\ value) \tag{3}$$

$$s_i = ([Mean(s_i)\ services])\text{ , i=1 to n} \tag{4}$$

The individual ranking for Time is: $\varphi\,(s_1)$ = 50, $\varphi\,(s_2)$ = 325, $\varphi\,(s_3)$ = 55, $\varphi\,(s_4)$ = 57.5 and $\varphi\,(s_5)$ = 80, shows the service ranking for time: $S_1 < S_3 < S_4 < S_5 < S_2$. As elasticity is measured in terms of time, the ranking are $\varphi\,(s_1)$ = 25, $\varphi\,(s_2)$ = 162.5, $\varphi\,(s_3)$ = 27.5, $\varphi\,(s_4)$ = 28.75 and $\varphi\,(s_5)$ = 40. The service comparison in terms elasticity is: $S_1 < S_3 < S_4 < S_5 < S_2$.

Estimation of agility is done using the computed values of Capacity and elasticity. To evaluate the ranking of agility the values of (x_0, s_j) is determined. To obtain the value of (s_j), Efficiency of Elasticity (EoE) is calculated using Eqs. (5, 6).

$$\mathrm{EoE}(s_i) = \sqrt{E_n - E(s_i)}\,, \tag{5}$$

$$E_n = \sum_{i=1}^{n} E(s_i), \text{ i=1 to n} \tag{6}$$

Computed values of EOE are $EoE(s_1)$ =16.08, $EoE(s_2)$ =11.01, $EoE(s_3)$ =16.00, $EoE(s_4)$ =15.96 and $EoE(s_5)$ =15.61. Agility of (s_j) is evaluated agility by adding its associated super level attributes in terms of capacity and efficiency of elasticity of the services: S_1= (363.132+16.08) = 379.212, S_2 = (437.696 + 11.01) = 448.706, S_3 = (140.196 + 16) = 156.196, S_4 = (155.176 + 15.96.) = 171.136 and S_5 = (186.396 + 15.61) = 202.006. Computation of (x_0) for agility is done using (2), x_0 = ((36 * 0.4) + (106.2*0.6)) = 78.12. For agility the service pairs are, S_1= (78.12, 379.212), S_2= (78.12, 448.706), S_3= (78.12, 156.196), S_4= (78.12, 171.136), S_5= (78.12, 202.006) and α = 0.2. The individual rankings for agility are: φ (s_1) = 113.763, φ (s_2) = 134.611, φ (s_3) = 46.858, φ (s_4) = 51.340 and φ (s_5) = 60.601, Fig. (**6**) displays the service ranking in terms of agility: $S_2 > S_1 > S_5 > S_4 > S_3$.

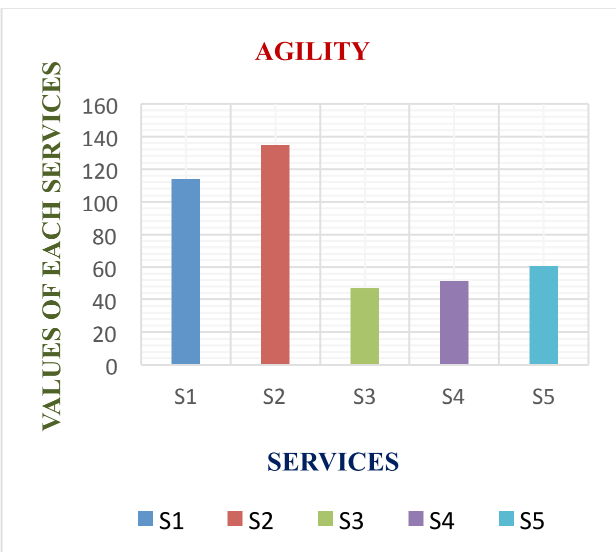

Fig. (6). Service Ranking of Main Level Attribute Agility. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

7.4. Assurance

To get the ranking of assurance, calculation of sub level attributes of assurance is computed.

7.4.1. Availability

As there are no sub level attributes for availability, its super level attribute is measured. For availability the following are the service pairs, S_1 (99.9, 99.95), S_2 (99.9, 99.99), S_3 (99.9, 100), S_4 (99.9, 99.85), S_5 (99.9, 99.92) and α = 0.7. The individual ranking for availability is φ (s_1) = 0.8*99.95=79.96, φ (s_2) = 0.8*99.99=79.99, φ (s_3) = 0.8*100=80, φ (s_4) = 0.6*99.85=59.91 and φ (s_5) = 0.8*99.92= 79.93. The service ranking for availability is: $S_3 > S_2 > S_1 > S_5 > S_4$.

7.4.2. Service Stability

To assess service stability, computation of upload time, CPU and memory is computed.

7.5. Upload Time

Imputing of missing value of (x_0) for upload time in numeric value type is evaluated using Eq. (7).

$$x_0 = [Mean(\,s_i)\ services] - [\tfrac{1}{2}\ln \tfrac{1-E^t}{E^t}] \tag{7}$$

where E^t is Error Rate, $E^t \leftarrow$α . $[Mean(\,s_i)\ services]$ is calculated as 15.12 and α = 0.3, the measured value of x_0 = 14.7, constructed service pair of upload time is: S_1= (14.7, 13.6), S_2=(14.7, 15) , S_3=(14.7, 21), S_4=(14.7,14), and S_5= (14.7, 12). The individual rankings are: φ (s_1) = 0.2*13.6=2.72, φ (s_2) = 0.4*15= 6, φ (s_3) = 0.4*21= 8.4, φ (s_4) = 0.2*14= 2.8, φ (s_5) = 0.2*12= 2.4, Service comparison in terms of upload time is: $S_5 < S_1 < S_4 < S_2 < S_3$.

7.5.1. CPU

Similarly, x_0 of CPU is computed using (7). x_0 = 16.57 and α is 0.4, CPU ranking is φ (s_1) = 8.95, φ (s_2) = 4.8, φ (s_3) = 11.5, φ (s_4) = 3.9 and φ (s_5) = 4.2, hence $S_3 > S_1 > S_2 > S_5 > S_4$.

7.5.2. Memory

For Memory the value of x_0 is evaluated as 9.98 and α = 0.3, the service values are φ (s_1) = 1.4, φ (s_2) = 4.8, φ (s_3) = 1, φ (s_4) = 6, φ (s_5) = 5.2, $S_4 > S_5 > S_2 > S_1 > S_3$. To obtain the s_j value of Service Stability, the Efficiency of UpLoadTime (EoUT) is assessed using Eqs. (8) and (9).

$$\mathrm{EoUT}(s_i) = \sqrt{UT_n - UT(s_i)} \tag{8}$$

$$UT_n = \sum_{i=1}^{n} UT(s_i), \text{ i = 1 to n} \tag{9}$$

Service stability (s_j) is, S_1= (4.427+ 8.95+ 1.4) = 14.777, S_2= (4.03+ 4.8+ 4.8) = 13.63, S_3= (3.730+ 11.5+ 1) = 16.23, S_4= (4.418+ 3.9+ 6) = 14.318 and S_5 = (4.463+ 4.2+ 5.2) = 13.863, x_0 as 14.03 and α = 0.2, The individual ranking is φ (s_1) = 4.433, φ (s_2) = 1.363, φ (s_3) = 4.869, φ (s_4) = 4.295 and φ (s_5) = 1.386, the ranking of service stability is: $S_3 > S_1 > S_4 > S_5 > S_2$.

7.6. Serviceability

Similarly, serviceability is measured with its second level attributes in terms of free support and type of support.

7.6.1. Free Support

To obtain (x_0) according to CPRA algorithm the Boolean value is assumed to be true because CCs always wants the free support to be provided. Therefore x_0 is given as 1 and α = 0.7, the ranking are φ (s_1) =0, φ (s_2) = 0.7, φ (s_3) = 0.7, φ (s_4) = 0.7 and φ (s_5) = 0.7, hence ($S_2 = S_3 = S_4 = S_5$).

7.6.2. Types of Support

The values x_0 and s_j is figured out by counting the number of services the CC requires and number of service the CSPs are offering and α is given as 0.3, we get φ (s_1) =1.6, φ (s_2) =1.6, φ (s_3) = 1.2, φ (s_4) = 1.2 and φ (s_5) = 0.6, hence ($S_1 = S_2$) > ($S_3 = S_4$) > S_5. For serviceability x_0 = 1.3, s_j values are S1=1.6, S2=2.3, S3=1.9, S4=1.9, S5=1.3 and α= 0.2, φ (s_1) = 0.48, φ (s_2) = 0.69, φ (s_3) = 0.57, φ (s_4) = 0.57 and φ (s_5) = 0.26, shows the service ranking of serviceability: S_2> ($S_3 = S_4$) > S_1 > S_5.

The value of s_j in terms of availability, service stability and serviceability is: S_1= 84.873, S_2=82.043, S_3= 85.439, S_4= 64.775, S_5 = 81.576, x_0 = 72.996 and α is given as 0.2. Assurance ranking stand: φ (s_1) = 25.461, φ (s_2) = 24.612, φ (s_3) = 25.631, φ (s_4) = 6.477, φ (s_5) = 24.472, Fig. (**7**) shows the service comparison in terms of assurance: S_3> S_1 > S_2 > S_5 > S_4.

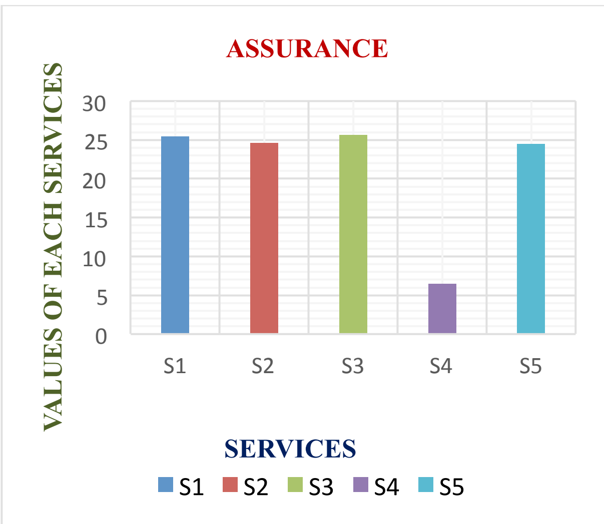

Fig. (7). Service ranking of main level attribute assurance. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

7.7. Cost

For VM cost the value of x_0 is assumed as 0.6 dollar/hour, the following pairs are, S_1 (0.6, 0.68), S_2 (0.6, 0.96), S_3 (0.6, 0.96), S_4 (0.6, 0.83), S_5 (0.6, 1) and α= 0.6, Ranking is: φ (s_1) = 0.47, φ (s_2) = 0.67, φ (s_3) = 0.67, φ (s_4) = 0.58 and φ (s_5) = 0.7, therefore, S_1 < S_4< ($S_2 = S_3$) < S_5.

For Data cost, it further has two sub-attributes, data inbound and data out-bound. Following are the values for data in-bound: φ (s_1) = 1, φ (s_2) = 1, φ (s_3) = 0.8, φ (s_4) = 0.9, and φ (s_5) = 0.9 and for data out- bound the values are evaluated as, φ (s_1) = 1.1, φ (s_2) = 1.5, φ (s_3) = 1.8, φ (s_4) = 1.3 and φ (s_5) = 1.3. Adding inbound and outbound together to evaluate the value of data: φ (s_1) = 2.1, φ (s_2) = 2.5, φ (s_3) = 2.6, φ (s_4) = 2.2, and φ (s_5) = 2.2, hence S_1< ($S_4 = S_5$) < S_2 < S_3.

Likewise, Storage cost is computed as: φ (s_1) = 1.2, φ (s_2) = 1.5, φ (s_3) = 1.5, φ (s_4) = 1.3, and φ (s_5) = 1.4, ranking is S_1< S_4 < S_5 < ($S_2 = S_3$). For ongoing cost the ranking value are φ (s_1) = 3.393, φ (s_2) = 4.203, φ (s_3) = 4.293, φ (s_4) = 3.672 and φ (s_5) = 3.87. Shows the ranking of ongoing cost: S_1 < S_4 < S_5 < S_2 < S_3 and cost (x_0) is identified as 260.36 and α = 0.3. Cost ranking are: φ (s_1) = 0.678, φ (s_2) = 0.840, φ (s_3) = 0.858, φ (s_4) = 0.734 and φ (s_5) = 0.774, Fig. (**8**) demonstrates the service comparison in terms of cost: S_1 <S_4< S_5 < S_2 < S_3.

Fig. (8). Service ranking of main level attribute cost. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

7.7.1. Performance

Ranking of range and average value are φ (s_1) = 60, φ (s_2) = 390, φ (s_3) = 66, φ (s_4) = 69, φ (s_5) = 96. Where, S_1 < S_3 < S_4 < S_5 < S_2. Average value is computed as φ (s_1) = 40, φ (s_2) = 360, φ (s_3) = 12, φ (s_4) = 56 and φ (s_5) = 56, S_3 < S_1 < ($S_4 = S_5$) < S_2.

Fig. (9). Service ranking of main level attribute performance. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

Table 1. Service comparison ranking of sub level SMI attributes.

Sub Level SMI Attributes	S1	S2	S3	S4	S5	Service Comparison
CPU	5.76	7.68	5.28	6.48	5.28	$S_2 > S_4 > S_1 > (S_3 = S_5)$
Memory	6	5.6	6	5.2	6	$(S_1 = S_3 = S_5) > S_2 > S_4$
Disk	507	612	189	210	255	$S_2 > S_1 > S_5 > S_4 > S_3$
Time	50	325	55	57.5	80	$S_1 < S_3 < S_4 < S_5 < S_2$
Upload Time	2.72	6	8.4	2.8	2.4	$S_5 < S_1 < S_4 < S_2 < S_3$
CPU	8.95	4.8	11.5	3.9	4.2	$S_3 > S_1 > S_2 > S_5 > S_4$
Memory	1.4	4.8	1	6	5.2	$S_4 > S_5 > S_2 > S_1 > S_3$
Free Support	0	0.7	0.7	0.7	0.7	$(S_2 = S_3 = S_4 = S_5)$
Type of Support	1.6	1.6	1.2	1.2	0.6	$(S_1 = S_2) > (S_3 = S_4) > S_5$
VM Cost	0.47	0.67	0.67	0.58	0.7	$S_1 < S_4 < (S_2 = S_3) < S_5$
Data In- Bound	1	1	0.8	0.9	0.9	$S_3 < (S_4 = S_5) < (S_1 = S_2)$
Data Out- Bound	1.1	1.5	1.8	1.3	1.3	$S_1 < (S_4 = S_5) < S_2 < S_3$
Data	2.1	2.5	2.6	2.2	2.2	$S_1 < (S_4 = S_5) < S_2 < S_3$
Storage	1.2	1.5	1.5	1.3	1.4	$S_1 < S_4 < S_5 < (S_2 = S_3)$
Range	60	390	66	69	96	$S_1 < S_3 < S_4 < S_5 < S_2$
Average Value	40	360	12	56	56	$S_3 < S_1 < (S_4 = S_5) < S_2$

Summation of all the second level attributes is done to get the values for Service Response Time (s_j). Services s_j is calculated as S_1= (60+ 40) = 100, S_2= (390+ 360) = 750, S_3 = (66+ 12) = 78, S_4= (69+ 56) = 125, S_5= (96+ 56) = 152, x_0 = 146 and α=1. The pairs formed are S_1 (146, 100), S_2 (146, 750), S_3 (146, 78), S_4 (146, 125) and S_5 (146, 152).The following service response time rank values obtained is, $\varphi(s_1)$ = 90, $\varphi(s_2)$ = 825, $\varphi(s_3)$ = 70.2, $\varphi(s_4)$ = 112.5 and $\varphi(s_5)$ = 167.2, the ranking of service response time is: $S_3 < S_1 < S_4 < S_5 < S_2$. To evaluate performance, the Efficiency of Service ResponseTime (EoSRT) is computed using Eqs. (10, 11).

$$\text{EoSRT}(s_i) = \sqrt{SRT_n - SRT(s_i)} \quad (10)$$

$$SRT_n = \sum_{i=1}^{n} SRT(s_i),\ i = 1 \text{ to } n \quad (11)$$

Performance is evaluated using EoSRT and its individual ranking are as $\varphi(s_1)$ = 6.854, $\varphi(s_2)$ = 4.194, $\varphi(s_3)$ = 6.912, $\varphi(s_4)$ = 6.788 and $\varphi(s_5)$ = 6.626, Fig. (**9**) displays its ranking: $S_3 > S_1 > S_4 > S_5 > S_2$. Table **1** summarizes all the sub level SMI attributes at level 3 with their respective service values and their individual ranks.

7.7.2. Security

For security, the following pairs are S_1(4, 4), S_2(4, 8), S_3(4, 4), S_4(4, 4), S_5(4, 4) and α= 0.05. Evaluating the security services their individual rank is, $\varphi(s_1)$ = 0.05*4 = 0.2, $\varphi(s_2)$ = 0.15*8 = 1.2, $\varphi(s_3)$ = 0.05*4 = 0.2, $\varphi(s_4)$ = 0.05*4 = 0.2 and $\varphi(s_5)$ = 0.05*4= 0.2, Fig. (**10**) represents the ranking of security: $S_2 > (S_1 = S_3 = S_4 = S_5)$. Table **2** summarizes all the super level SMI attributes at level 2 with their respective service values and their comparison.

After computing the ranking of SMI metric individually of l3, l2 and l1 all the SMI main level attributes (l1) are added with the efficiency of cost. Efficient of Cost (EoC) is evaluated using Eqs. (12 and 13). Table **3** summarizes all the

Table 2. Service comparison ranking of super level SMI attributes.

Super Level SMI Attributes	S1	S2	S3	S4	S5	Service Comparison
Capacity	363.13	437.69	140.19	155.17	186.3	$S_2>S_1>S_5>S_4>S_3$
Elasticity	25	162.5	27.5	28.75	40	$S_1<S_3<S_4<S_5<S_2$
Availability	79.96	79.99	80	59.91	79.93	$S_3>S_2>S_1>S_5>S_4$
Service Stability	4.433	1.363	4.869	4.295	1.386	$S_3>S_1>S_4>S_5>S_2$
Service Ability	0.48	0.69	0.57	0.57	0.26	$S_2>(S_3=S_4)>S_1>S_5$
On- Going Cost	3.393	4.203	4.293	3.672	3.87	$S_1<S_4<S_5<S_2<S_3$
Service Response Time	90	825	70.2	112.5	167.2	$S_3<S_1<S_4<S_5<S_2$

Table 3. Service comparison ranking of main level SMI attributes.

Main Level SMI Attributes	S1	S2	S3	S4	S5	Service Comparison
Accountability	0.2	1.2	0.2	0.9	1.05	$S_2>S_5>S_4>(S_1=S_3)$
Agility	113.76	134.61	46.85	51.34	60.60	$S_2>S_1>S_5>S_4>S_3$
Assurance	25.461	24.612	25.63	6.477	24.47	$S_3>S_1>S_2>S_5>S_4$
Cost	0.678	0.840	0.858	0.734	0.774	$S_1<S_4<S_5<S_2<S_3$
Performance	6.854	4.194	6.912	6.788	6.626	$S_3>S_1>S_4>S_5>S_2$
Security	0.2	1.2	0.2	0.2	0.2	$S_2>(S_1=S_3=S_4=S_5)$

main level SMI attributes with their respective service values and their comparison among the five IaaS service providers.

$$\mathrm{EoC}(s_i) = \sqrt{C_n - C(s_i)} \tag{12}$$

$$C_n = \sum_{i=1}^{n} C(s_i),\ \text{i=1,2,3,..n.} \tag{13}$$

Computed values of EoC are EoC(s_1) =1.790, EoC(s_2) =1.744, EoC(s_3) =1.739, EoC(s_4) =1.744 and EoC(s_5) =1.763.Evaluate the overall ranking of the services based on the computed attributes using Eq. (14)

$$\text{S(i)}=\sum_{i=1}^{n} Values\ of\ Main\ Attribute\ (L_1)_i \tag{14}$$

S(1) = 0.2+ 113.763+ 25.461+ 1.790+ 6.854+ 0.2 = 148.268

S(2) = 1.2+ 134.611+ 24.612+ 1.744+ 4.194+ 1.2 = 167.561

S(3) = 0.2+ 46.858+ 25.631+ 1.739+ 6.912+ 0.2 = 81.54

S(4) = 0.9+ 51.340+ 6.477+ 1.774+ 6.788+ 0.2 = 67.479

S(5) = 1.05+ 60.601+ 24.472+ 1.763+ 6.626+ 0.2 = 94.712

Hence, final ranking of services are $S_2 > S_1 > S_5 > S_3 > S_4$. Fig. (**11**) represent the overall ranking of CSPs with their values. From the above discussion we have seen that selection of suitable individual and overall cloud services is an important step while selecting a CSP when CCs opts for certain services. This paper proposes an effective mathematical method to generate the individual and final ranking list based on SMI attributes for the CSPs and its QoS values using SMI without doing any transaction with the CCs in the past.

Based on the evaluation, the proposed CPRA simplifies the selection of Cloud Service Providers (CSPs) and it also provides an efficient way to calculate the missing default user value x_0.This approach is much more dynamic in nature as it deals with both functional and nonfunctional requirements of CCs. We analyze that the efficient factor of CPRA ranking algorithm with the previous existing ranking AHP and MDHP algorithms.

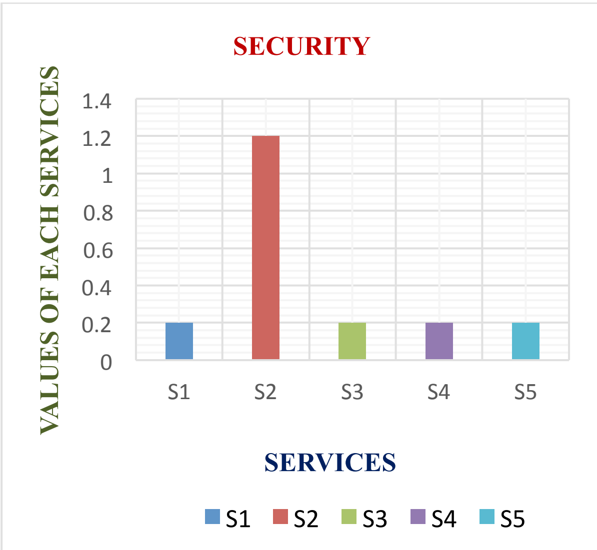

Fig. (10). Service Ranking of Main Level Attribute Security. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

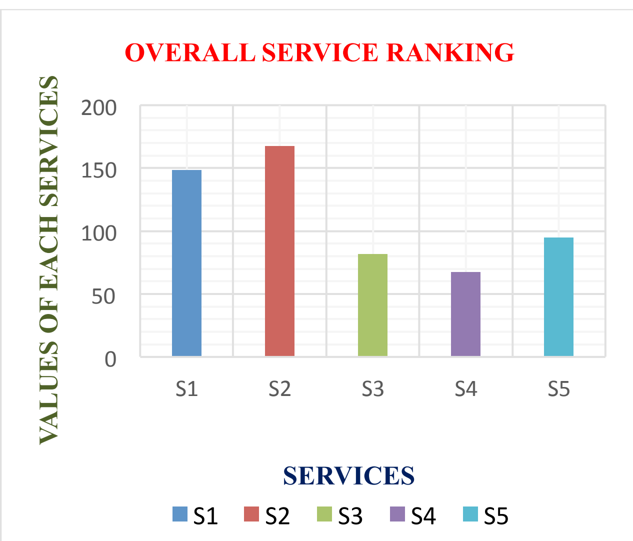

Fig. (11). Overall ranking of services using SMI attributes. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

To evaluate the proposed CPRA in terms of execution time, an empirical model based on CloudSIM was used. The CPRA was evaluated by altering the number of Cloud consumers and Cloud service providers throughout the time without changing the SMI attributes. Fig. (**12**) depicts the performance of proposed CPRA with existing AHP and MDHP ranking algorithm with reference to the execution time. CPRA ranks and retrieves the list of best cloud service providers amidst 1000 CSPs with minimal execution time. CPRA accuracy list of retrieved CSPs has been increased because it takes into account CCs preferences while ranking the CSPs.

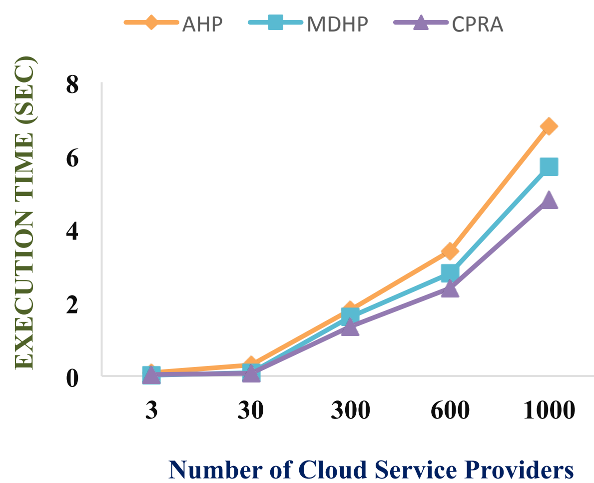

Fig. (12). Execution time AHP, MDHP and CPRA. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

CONCLUSION

Cloud computing has seen an increase in endorsement of cloud services among IT industries. Presently, there are different CSPs who are providing various cloud computing services with distinct SLAs and QoS. It becomes difficult for the CCs to choose the best cloud services in terms of QoS requirements. Hence (CSMIC) recommended a framework model based on standard characteristics of cloud computing services. The objective of CSMIC is to specify each QoS attribute inclined in the framework for measuring the various cloud services. In this frame of reference, CPRA was proposed to methodically evaluate all the SMI QoS attributes suggested by CSMIC and rank the cloud computing services at each level of SMI to choose a suitable cloud service provider based on CCs requirements. The proposed CPRA takes CCs requirements in consideration when comparing and ranking the different CSPs. To validate the efficiency of our method, we conduct comprehensive simulation and the results show that CPRA outperforms AHP and MDHP ranking methods with more reliable ranking with minimal time complexity for each SMI attribute. Our proposed approach can evaluate the services of cloud based on various cloud applications depending upon Quality of Service requirements and addresses the problem of CCs missing preference values. We consider the CPRA represents an important step for enabling precise Quality of Service measurement and selection of cloud services for CCs. By applying the technique suggested in this paper, CSPs can recognize how they provide the cloud services when compared to other CSPs and as a result they can enhance their cloud services.

To achieve improved performance, for the future work, we will like to enhance the CPRA accuracy by taking advantage of additional methods (*e.g.*, matrix factorization, random walk, data smoothing, utilizing content information, *etc.*). In this way, the CPRA technique will achieve more accurate ranking list and obtain reliable rankings of cloud service. As the CPRA method only ranks SMI QoS attributes independently, we will further conduct a study on the combinations and correlations of distinct QoS attributes.

LIST OF ABBREVIATION

CPRA	=	Combined Preference Ranking Algorithm
QoS	=	Quality of Service
SLA	=	Service Level Agreement
CSPs	=	Cloud Service Providers
SLA	=	Service-Level Agreement

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

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