Cloud Service Selection Using Fuzzy ANP

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Abstract. In current scenario cloud computing has become emerging technology, as it provides services on computing (C) and non-computing (NC) resources to the government, private organization and also individuals based on pay-for-utility policy. Hardware and software resources are delivered as virtualized services. But selecting a best cloud provider is a challenging and complex task for consumers as it includes more providers with diverse configurations. Since it involves multiple criteria towards consumer perception of QoS, in-depth research is required. To provide solution for multi criteria decision making in nature, we propose ANP (Analytic Network Process) method integrated with fuzzy perception. The experimental studies shows the improved results and validity of proposed method.

Keywords: Cloud computing · Fuzzy inference · ANP · Customer feedback · Multi Criteria Decision Making

1 Introduction

A utility computing [1] called cloud computing provides a huge collection of services to customers on pay-as-you-go [2] phenomena. Many organizations are migrating their IT applications from static environment to dynamic environment where provisioning resources using virtualization. It provisions virtualized resources like CPU, storage, network, databases, application server, and internet server, etc. Cloud service providers like Rackspace, Google, IBM, Amazon etc. are offering pool of different services based on demand. Basically, customers have different requirements to develop their applications. Different configurations of VMs from Azure required (based on workload) for different applications as shown in Table 1.

Choosing the right mix of services is a challenging task for the customers as it includes heterogeneity [3]. Due to heterogeneity of configurations, selecting QoS optimized cloud service isn't an easy task [4]. A high end Amazon EC2 CPU response is 20% less expensive than the comparable low-end Microsoft Azure. But its speed of processing application's workload is very high. This configuration information is available in provider's website for reference. Due to combination of inconsistent criteria, the information provided by website is not sufficient for comparison. And also the provider's published data is not trustworthy as they overemphasize their services. However, this

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Table 1. Azure data configuration

Application type	CPU	Memory	Database	Network
General purpose	Low	Low	Low	Moderate
Compute optimized	High	High	Moderate	High
Memory optimized	Moderate	Low	Moderate	Low
Storage optimized	Low	Low	High	Low
High performance compute	Very high	High	High	Very high

is awfully difficult job for users to associate their QoS needs to configuration given by the provider. Migration from one provider to another is not only a risky process but also costly. This implies the significance of service selection framework. Application stack dependency or platform (Microsoft SQL) dependency occurs if the provisioning process implementation is not superlative. More technical problems faced to solve these challenges in cloud environment for its establishment. So, in near future cloud community not likely become reality while QoS requirements and available service configurations taken in to consideration.

A reliable service selection framework is needed for consumers to select best suitable (as per QoS) services. For this we proposed a novel fuzzy ANP framework which considers individual customer's QoS criteria based service selection. Even though huge research models and frameworks exists for making best selection of services, many of those approaches could not capture the QoS information and lack of validation. Hence, the existing methods are prejudiced with the uncertainty in information given by cloud providers, ambiguous specification of requirements by consumer and also fictitious estimation of QoS [4] based on actual measurement on time and existing QoS of previous services. The proposed work can be organized as follows.

- Validating the specified service's configuration information by a third party validator.
- Actual measurement of QoS is taking by using monitoring tools.
- Taking into consideration, the customer reviews on performance of services in the provisioning process.
- The consumer's fuzzy estimation of Qos is simplified by designing Fuzzy ANP approach which is a Multi Criteria Decision Making Process.

The proposed framework can deal with indefinite consumer's requirements based on the QoS parameters.

2 Related Work

Different areas of research like virtualization, datacenter hardware design, software development, and resource provisioning are included in cloud computing. However, this paper [9] focuses on to improve the service selection [10] which is a part of re- source provisioning research [11].

Here, we mainly consider selection for IaaS services, which is a provider independent classification model [7]. Here, we compare and classify the cloud providers. From consumer's perspective, the main criteria behind IaaS provider's selection are determined by cloud provider's market analysis, international literature review and expert analysis. Gaurg et al. in [8], developed a software based framework which can automatically compute the quality attributes and hierarchize cloud services. The case study in this paper includes QoS parameters as well as cost, capacity and performance of customer's applications.

They proposed and used AHP based ranking algorithm to define key performance metrics of QoS parameters in SMI. But, they didn't consider exact customer's requirements. [22] introduced wide-ranging service QoS measurement Index (SMI) which consist of business related key performance indicators (KPIs) and this is a typical method for comparing and measuring service providers.

3 Fuzzy ANP Approach

For web based applications and SOA like grid computing [14] service selection has been introduced in many research works. So, more methods are available for solving the selection problem in others models [15]. A fuzzy cloud selection framework [13], proposed a model which consists of 4 modules (i) User Interface, (ii) Management of QoS component, (iii) Service Selection Module, and (iv) Cloud Service Repository component. We have customized the same model by using ANP (Analytical Network Process) as illustrated in Fig. 1. The existing model proposed by Tajvidhi et al. used AHP MCDM ranking algorithm, but it doesn't consider inter feedbacks of selection criteria.

Our proposed framework consists of 3 modules (i) User Interface, (ii) User feedback, and (iii) Cloud Service Repository as input sources for calculating the metrics. The first module called user interface collects the needed criteria and their relative important costs directly from consumers. This data may not be exactly concise, because the complexities and consumer's unclear perception of QoS parameters. Hence, a specific approach is defined as shown in Fig. 1. This is used for getting fuzzy based linguistic weights of criteria, and then the triangular fuzzy numbers are converted into simplified numbers, which can then be used in ranking algorithm called ANP.

This module consists of two other components (i) Metrics calculation and (ii) Ranking using ANP. The input for metric calculation is from two sources one is cloud service repository, which consists of data gathered from different sources and is published with a certification by third party vendor. This component's output is redirected to ranking algorithm called ANP which is shown in Fig. 2. At last the result will be displayed by user interface. For resolving this selection problem we should consider service attributes to be compared, make them comparable to choose a best structure.

3.1 QoS Management

In order to select the best service first we should select required service attributes and is a challenging task. This QoS management eases this task and is liable to model the most required criteria; QoS needs are mapped to available service configurations [13].

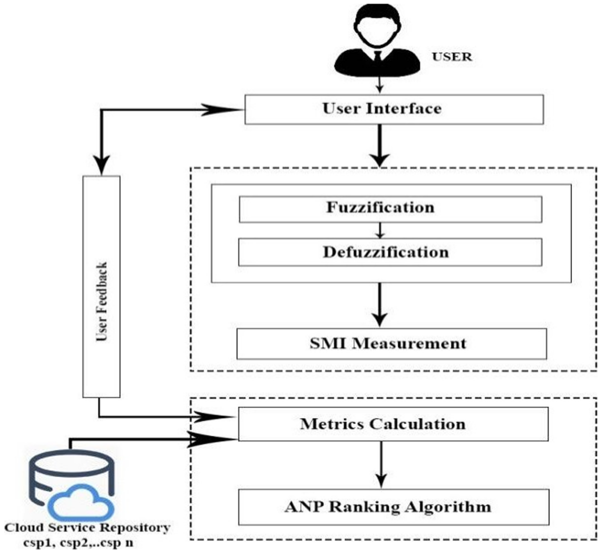

Fig. 1. Fuzz ANP framework

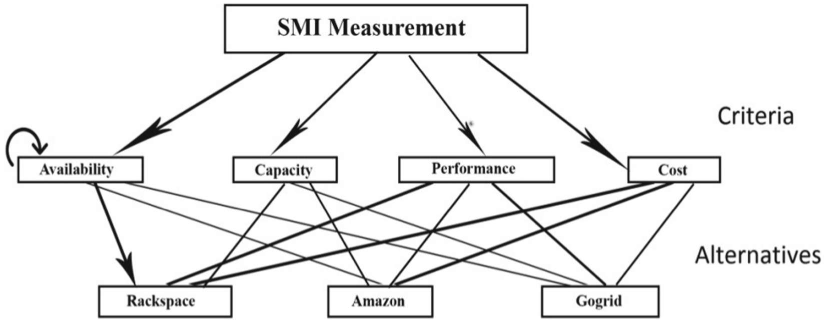

Fig. 2. ANP architecture among criteria

We need to choose one of the most appropriate model comparisons and service selection, because designing the QoS is trivial task for making optimal decisions in decision making systems [16]. To ease this task we have used the model SMI (Service Measurement Index) [4]. It is hierarchical view of service attributes that customer required in selection process [17].

3.2 Metrics Calculation

In proposed framework we consider AMI measurement. For many services, SMI approach is not available to define and capture QoS parameters dynamically [17, 18]. Service providers provide the service configuration statically. But they might not give accurate information due to competitive market. So, there is uncertainty in decision making. To handle this uncertainty, we have used cloud repository which has the cloud provider's data given in their own websites and it is maintained in a standard XML format. It is managed by cloud service broker [19], who is responsible for verifying the service provider's QoS violations to make data reliable.

During selection process, run time QoS attributes like reliability, performance etc. and past QoS performance considerations are another major issue. These run time QoS attributes information has not given by service providers [20]. In order to handle this, the best approach is user feedback, where the cloud consumers gave their live experiences. These cloud users information is more reliable than website information. This component is introduced based on [21]. Hence, data is taken from two trustworthy sources; Cloud Service Repository and User Feedback.

4 Service Selection in Cloud Environment

To our proposed ANP-based [12] ranking method, criteria's comparative weight is one of the important inputs. It is given by fuzzy perception. Hence, first we describe fuzzy inference for getting comparative weights of the criteria and then describe the ANP algorithm used in this paper.

4.1 Fuzzy Logic

Cloud consumers give their weights by linguistic terms. Based on these terms we have to assign weight to each criterion by considering relative importance of the attribute. Then fuzzy sets convert these into simplified numbers.

Triangular Weight Matrix: Cloud users are giving their requirements and constraints as weights for each criterion as shown in Table 1 using linguistic terminology. Because these terms cannot be used in ANP algorithm, as it requires weights in numerals. Hence we used Defuzzification, in order to get the simplified numbers. So, each term is allocated with the triangular fuzzy numbers, suppose if customer chooses criterion called more important, its corresponding fuzzy set is (5, 7, 9) as shown in Table 2.

Table. 2. Triangular fuzzy numbers of linguistic terms

Linguistic terms	Triangular fuzzy number
Not important	(1, 1, 1)
Less important	(1, 3, 5)
Definitely important	(3, 5, 7)
More important	(5, 7, 9)
Extremely important	(7, 9, 9)

Cost matrix is defined as shown in (1), where 'cap' symbol represents the triangular numbers.

$$A_i = \begin{pmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{m1} & \cdots & d_{mn} \end{pmatrix} \quad (1)$$

Cost matrix is defined as shown in (1), where 'cap' symbol represents the triangular numbers. The row of the matrix in (1) represents triangular numbers of all sub-criteria, i.e. d_{ij} denotes the significance of ith criterion and jth number.

Geometric Mean Calculation: Using [25] the geometric mean of sub criteria fuzzy value is calculated as defined in (2).

$$p_i = \left(\prod_{i=1}^{n} d_{ij}\right)^{1/n}, \ \mathrm{i} = 1, 2, \ldots, \mathrm{n}(\mathrm{n} = 3) \quad (2)$$

Final fuzzy weight is defined as Final fuzzy weight is defined as

$$\hat{w}_i = \hat{p}_i \times (\hat{p}_1 + \hat{p}_2 + \ldots \hat{p}_n)^{-1} = (1w_i, mw_i, uw_i) \quad (3)$$

Defuzzification: To get non fuzzy numbers we need to defuzzify the above using center of area method [26] as follows:

$$df_i = \frac{1w_i + mw_i + um_i}{3} \quad (4)$$

We need to do normalization here as follows:

$$Nr_i = \frac{df_i}{\sum_{i=1}^{n} df_i} \quad (5)$$

These values are given as input to ANP ranking algorithm.

4.2 ANP Algorithm

Cloud consumers have given their requirements and constraints. ANP analyses and select the service which meets such requirements [12]. The ANP orders these chosen services based on their ranking procedure described in the following 3 steps.

- Solution for selection problem: It is specified in ranking objective (level 1), QoS attributes ordering with feedback (level 2) and cloud service providers like Rack-Space, Amazon EC2 and GoGrid (level 3).
- Pair wise comparison: Here, the relative importance of criteria over other criteria as well as with self can represented. Consider c_i and c_j be the values of criteria k for cloud services i and j respectively. Consider a_i and a_j be the cloud services then a_i/a_j, indicates the relative rank of a_i over a_j [3].

For each attributes, we calculated numeric and Boolean values differently by using proposed ranking method. Based on context, the numeric value has two types; those are in case of performance higher value is preferable where as in case of cost lower value is preferable. And if we consider higher value is better, then the value of specific QoS is $a_i/a_{j,}$ or else a_j/a_i (if lower is better). The pairwise comparison matrices obtained as follows:

$$a_i/a_j = 1 \text{ if } a_i = a_{j,}\ a_i/a_j = w_k \text{ if } a_{i=1} \text{ and } a_{j=0,}\ a_i/a_j = 1/w_k \text{ if } a_0 = 0 \text{ and } a_j = 1 \quad (6)$$

- Aggregation of each criterion's relative importance: In this step, the relative ranking of matrices of each attribute are aggregated with their previous related weights. This process is repeated for all attributes which is helpful in ranking cloud services.

5 Example

Here, we use simple case study to implement this fuzzy ANP approach. The data regarding this QoS is collected from 3 IaaS cloud providers viz Rackspace [27], Amazon EC2 [28] and GoGrid [29]. In this example, we have considered few criteria for easy calculation as follows (i) Capacity, (ii) Cost and (iii) Performance. The data collected from official websites is shown in Table 3. Here, we explained the proposed fuzzy perception and ANP ranking method on real time data.

Table 3. QoS attributes for Azure, Amazon EC2 and GoGrid Cloud Services

First-level criteria	Second-level criteria	Value type	Microsoft azure	Amazon EC2	GoGrid
Capacity	CPU	Numeric	9.6	18.8	12.8
	Memory	Numeric	15	15	14
Cost	VM cost	Numeric	0.68	0.96	0.96
	Data (GB)	Numeric	10	10	8
	Storage	Numeric	12	15	15
Performance	Network availability	Numeric	99	99.99	100
	Urgent response	Boolean	0	1	1

5.1 Fuzzy Perception

Triangular Weight Matrix. Here, the input is taken from Table 4 and for each criterion the weight matrix is calculated based on (1). For first level criteria attribute called capacity

Table 4. QoS attributes for azure, amazon EC2 and GoGrid cloud services

First-level criteria	Second-level criteria	Importance	Triangular values	Geometric mean
Capacity	CPU	Extremely important	(7, 9, 9)	(4.6, 6.7, 7.9)
	Memory	Definitely important	(3, 5, 7)	
Cost	VM cost	Extremely important	(7, 9, 9)	(2.7, 5.12, 6.8)
	Data	Less important	(1, 3, 5)	
	Storage	Definitely important	(3, 5, 7)	
Performance	N/W availability	Extremely important	(7, 9, 9)	(2.6, 5.2, 6.7)
	Urgent response	Less important	(1, 3, 5)	

is calculated as matrix, here rows represent the sub criteria triangular numbers (CPU, Memory). So, the related matrix for capacity will be

$$\hat{V} = \begin{bmatrix} 7\ 7\ 9 \\ 3\ 5\ 7 \end{bmatrix} \tag{7}$$

For other criteria called cost with 3 sub criteria (VM cost, data, storage), the relative matrix is

$$\hat{C} = \begin{bmatrix} 7\ 9\ 9 \\ 1\ 3\ 5 \\ 3\ 5\ 7 \end{bmatrix} \tag{8}$$

Similarly, for performance, the relative matrix is

$$\hat{P} = \begin{bmatrix} 7\ 9\ 9 \\ 1\ 3\ 5 \end{bmatrix} \tag{9}$$

Calculating Geometric Mean. For each criterion the geometric mean based on (2) is as follows.

$$\hat{p}_1 = \left[(7 * 3)^{1/2}; (9 * 5)^{1/2}; (9 * 7)^{1/2}\right] \tag{10}$$

$$\hat{p}_2 = \left[(7 * 1 * 3)^{1/2}; (9 * 3 * 5)^{1/2}; (9 * 5 * 7)^{1/2}\right] \tag{11}$$

$$\hat{p}_3 = \left[(7 * 1)^{1/2}; (9 * 3)^{1/2}; (9 * 5)^{1/2}\right] \tag{12}$$

Table 5 shows geometric mean values of the available criteria. In addition to this, it also shows sum value and reverses value.

Calculating Fuzzy Value. By using sum and inverse of sum which is in last row of Table 5, fuzzy weight of capacity criteria is calculated based on (3) as follows

$$\mathrm{W1} = (4.6 * 0.1);\ (6.7 * 0.05);\ (7.9 * 0.04) = (0.46,\ 0.335,\ 0.316) \tag{13}$$

Similarly, other two criteria fuzzy weights are determined and shown in Table 5.

Defuzzyfication. Using center of area method (4) and normalization (5) we can defuzzify the value obtained in previous step as shown in Table 6. Attribute weights are required for ANP algorithm. Hence, we can use ANP algorithm in this context by considering each attribute's weight as matrix below

$$w_k = \begin{matrix} Capacity \\ Cost \\ Performance \end{matrix} \begin{bmatrix} 0.4 \\ 0.31 \\ 0.28 \end{bmatrix} \tag{14}$$

Table 5. Geometric mean

Criteria	$\hat{p}_i$		
Capacity	4.6	6.7	7.9
Cost	2.7	5.1	6.8
Performance	2.6	5.2	6.7
Sum	9.9	17.0	21.4
Reverse Sum	0.10	0.05	0.04

Table 6. Each criteria final fuzzy value

Criteria	W			$\mathrm{df_i}$	$\mathrm{Nr_i}$
Capacity	0.46	0.335	0.316	0.37	0.4
Cost	0.27	0.26	0.272	0.285	0.31
Performance	0.26	0.26	0.268	0.26	0.28

5.2 ANP Ranking Algorithm

1. *Design the problem as a network structure*: It is also like hierarchical structure but includes feedback with 3 first level criteria and 7 second level criteria as shown in Table 3.
2. *The pair wise comparison matrix*: Here, the comparison matrix for capacity attribute with sub criteria is calculated based on Table 1 as follows.

$$CM_{CPU} = \begin{matrix} Sp_1 \\ Sp_2 \\ Sp_3 \end{matrix} \begin{bmatrix} 1 & \frac{18.8}{9.6} & \frac{12.8}{9.6} \\ \frac{9.6}{18.8} & 1 & \frac{12.8}{18.8} \\ \frac{9.6}{12.8} & \frac{18.8}{12.8} & 1 \end{bmatrix} \tag{15}$$

Then the normalize vector for CPU and Memory capacity are:

$$nCM_{CPU} = \begin{bmatrix} 0.44 \\ 0.23 \\ 0.33 \end{bmatrix} \tag{16}$$

$$nCM_{Memory} = \begin{bmatrix} 0.33 \\ 0.33 \\ 0.32 \end{bmatrix} \tag{17}$$

By combining the above two we get the relative matrix for capacity attribute as follows:

$$RM_{Capacity} = \begin{bmatrix} 0.44\ 0.33 \\ 0.23\ 0.33 \\ 0.33\ 0.32 \end{bmatrix} \tag{18}$$

The normalized vector for this capacity is calculated as follows

$$nRM_{Capacity} = \begin{bmatrix} 0.38 \\ 0.29 \\ 0.32 \end{bmatrix} \tag{19}$$

Similarly, for cost and performance the resultant normalized matrices are as follows

$$nRM_{Cost} = \begin{bmatrix} 0.05 \\ 0.76 \\ 0.05 \end{bmatrix} \tag{20}$$

$$RM_{Performance} = \begin{bmatrix} 0.25 \\ 0.44 \\ 0.25 \end{bmatrix} \tag{21}$$

3. *Aggregating the relative importance of criteria*: To get the single matrix, we need to combine all the above relative matrices as follows:

$$\begin{bmatrix} 0.38\ 0.05\ 0.25 \\ 0.29\ 0.76\ 0.44 \\ 0.32\ 0.06\ 0.25 \end{bmatrix} \tag{22}$$

Now multiply this matrix with weights of QoS attributes which are calculated from fuzzy perception values (15)

$$\begin{bmatrix} 0.38\ 0.05\ 0.25 \\ 0.29\ 0.76\ 0.44 \\ 0.32\ 0.06\ 0.25 \end{bmatrix} \begin{bmatrix} 0.4 \\ 0.31 \\ 0.28 \end{bmatrix} = \begin{matrix} Sp_1 \\ Sp_2 \\ Sp_3 \end{matrix} \begin{bmatrix} 0.26 \\ 0.47 \\ 0.21 \end{bmatrix} \tag{23}$$

Hence the service providers are ranked as Sp2 > Sp1 > Sp3, Amazon EC2 (Sp2) got highest rank followed by Rack Space (Sp1) followed by GoGrid (Sp3).

6 Conclusion and Future Enhancement

Here, we proposed a cloud service selection approach called fuzzy ANP. The existing methods are not considering uncertainty of customer requirements. They only refer the data published by cloud service providers in their web sites and consumers vague conception of requirements. They also used AHP ranking algorithm [5] which is best for ranking services but it doesn't consider feedback among criteria. To get realistic QoS requirement, we have considered fuzzy perception of QoS and ranking the service providers using ANP algorithm which gives accurate results. We can also extend this for more QoS parameters to get better results which are applicable for real time scenario.

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