CHAPTER

A HYBRID COMPUTATIONAL INTELLIGENCE DECISION MAKING MODEL FOR MULTIMEDIA CLOUD BASED APPLICATIONS

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7.1 INTRODUCTION

In the age of Information technology, ICT has become a mainstay for everyday survival of majority of the companies and is gaining its importance in the rest of the business world. The blooming of cloud computing is a basic and path breaking modification in ICT. With the rapid growth of Cloud Computing applications a number of cloud service providers have launched diverse B2B and B2C cloud services namely: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). A number of global and regional players have dived into the endless opportunities provided by the current scenario. Big players like Amazon, Google, Microsoft, Oracle, etc. have started providing commercial cloud computing services. Also government agencies from all over the world have a very positive response towards cloud based services due to the fact that the services do not need any in house infrastructure or experts, is relatively cheap and highly scalable to deploy [1]. On the other hand the enhancement of mobile computing with the support of cloud based services has opened new avenues for the Mobile Cloud Computing (MCC). Mobile Cloud Computing (MCC) which is defined as the combination of cloud computing into the mobile domain [2]. It provides new services and facilities to mobile users ubiquitously by attaining the benefits of cloud data centers. In addition to this the service providers are interested in providing services for multimedia communication and applications.

In recent years, cloud services will provide extensive opportunities for the business to grow and flourish. The companies will be able to deliver a network of virtual services to other users and companies irrespective of their location in the world which eliminates the need to adopt ICT infrastructure and ICT experts. Thus, both providers and consumers will be benefited in terms of monetary gains and access to technology.

The emergence of variety of service providers and different platforms for cloud computing in the market has resulted into a class of clouds providing similar services. Thus, migrating the same application may require different amount of computing and execution time due to the difference in cloud's cost, speed and resource availability. So, it is necessary to choose an ideal cloud service from a set of cloud service providers satisfying the user requirements in less cost and with improved throughput performance. Optimal cloud selection requires analysis of large variety of data and parameters making it a cumbersome process.

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Being a critical issue, lot of studies have been conducted to address the problem of selecting a suitable cloud matching requirements, but many of them take into consideration implementation techniques and cost benefit analysis. Only a few of them have gone into the aspect of practical transformation strategies, like cloud service selection and cloud service adoption technologies, etc. However there is an immense need of a practical procedure for transforming an existing IT platform of a company to a Cloud based one.

The conflicting nature of quantitative and qualitative criteria in cloud services creates a hurdle in choosing an appropriate cloud service. Due to the involvement of a spectrum of variables the cloud selection problem becomes a Multi-Criteria Decision Making (MCDM) problem. Also due to the uncertain nature of data and ambiguous decision making process, techniques based on fuzzy set theory has also been applied to MCDM in a number of studies. AHP has proven to be ineffective to give promising results when applied to problems having high vagueness [3]. Many researchers have tried to overcome this by using a FAHP (Fuzzy AHP) technique over traditional AHP and have tried to handle uncertainty and vagueness on order to overcome the short comings of AHP [4].

In this paper, the FDM and FAHP are used as the hybrid computational intelligence decision making techniques for best cloud path selection and are compared with existing techniques for providing better quality of solution to resolve those issues. The proposed technique varies from the existing methods as it adopts FDM and FAHP to deal with the vagueness of decision making process for cloud path selection. FDM approach is used to select the important decision-making criteria's based on the opinion of different experts. Further FAHP method is incorporated to compare and determine the importance of different criteria's. It is also used to choose the best cloud service among different service providers based on the weights of different decision making factors. Our proposed computational intelligence decision making model can enable users to use cloud services during mobility accurately, cost effectively and in systematic way.

The remainder of this paper is structured as follows: Section 7.2 describes the literature review. Section 7.3 discusses the research background. In Section 7.4, proposed hybrid MCDM model for cloud service selection is presented by explaining different stages of the proposed approach. Section 7.5 describes a real-world application to choose the optimal cloud service using the hybrid technique. Finally, Section 7.6 concludes the paper by giving future direction.

7.2 LITERATURE REVIEW

Already there are techniques to choose cloud services based on logic, MCDM, optimization and other parameters. An AHP based technique was proposed by Godse and Mulik to select a SaaS service [5]. An ANP based procedure to select IaaS service has been proposed by Menzel et al. [6]. Zeng et al. proposed an architecture based on cloud service and an algorithm to select an ideal cloud service [7]. Simple additive weighted-based approaches for ranking different cloud service have been proposed by Saripalli and Pingali [8]. A greedy technique for a cloud service selection problem using B+ trees has been proposed by Sundareswaran et al. [9]. In [10], researchers had used multiplicative priority rating techniques for the AHP. In this paper, authors had focused on evaluating the consistency of different decision maker judgments in decision support systems [11]. In [12], authors had described that eigen-vector of pair-wise comparison matrix shows the local priority criteria weights, sub-criteria and alternatives. In [13], sequential decision-making method was used by conducting the question response process and developed a dynamic programming for it. According to [14], authors have proposed AHP and TOPSIS technique to evaluate airlines service quality. An AHP based technique was proposed by Godse and Mulik to select a SaaS service [5]. An ANP based procedure to select IaaS service has been proposed by Menzel et al. [6]. Zeng et al. proposed architecture based on cloud service and an algorithm to select an ideal cloud service [7]. Simple additive weighted-based approaches for ranking different cloud service have been proposed by Saripalli and Pingali [8]. [15] discussed different approaches to ERP selection problem using FAHP and Fuzzy TOPSIS method. Wang et al. described a dynamic model of cloud service selection by using an adaptive learning mechanism for multi-cloud computing purpose [16]. [17] used AHP and Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Cloud) method to select an optimal cloud in cloud offloading systems.

Although most of the work has been done on cloud service selection for offloading in MCC environment but that is limited only on single criterion. However in this study, both single and multiple decision analysis approaches are performed by considering different criteria's such as accuracy, performance, security, availability and maintenance cost in selection problem.

7.3 RESEARCH BACKGROUND

7.3.1 CLOUD COMPUTING

Cloud Computing (CC) directs to configuring, accessing and manipulating the application through the Internet. It focuses on sharing of resources to achieve consistent and economic scale as similar to a utility over a network [18]. Cloud computing is an extensive concept of shared services and infrastructure which relies on maximizing the performance of distributed resources. It has been one of the booming technologies among various researchers and industrialists in education and business fields [19,20]. Cloud resources are dynamically allocated to multiple users in an on-demand fashion according to their requirements. This approach reduces the implementation cost and thus maximizes the use of computing services across the Internet. Cloud has larger storage capacity and can handle much more data with no any infrastructure investments [21].

Cloud Computing relies on projects which varies their businesses rather than infrastructure and thus allows companies to avoid infrastructure costs [22]. Cloud computing improves manageability and enables ICT to grow rapidly by fulfilling dynamic requirements of multiple users in an appropriate time. It provides different services and resources to mobile device such as Software as a Service (SaaS), Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Testing as a Service (TaaS), etc. through various service providers and customers can access these resources through rich-resourceful data centers. Fig. 7.1 demonstrates various aspects of Cloud Computing which was proposed by NIST including five essential characterizes, three service models and four deployment models of cloud [23]. Cloud Computing has the following key characteristics:

- Maintenance: It is easy to maintain as the services provided by different service providers can be accessed ubiquitously and need not to be installed on each user's computer.
- Virtualization: It allows sharing of storage devices and servers where applications can be easily migrated from one server to another physical server. In virtualization a single piece of hardware is being managed by numerous guest operating systems [24].

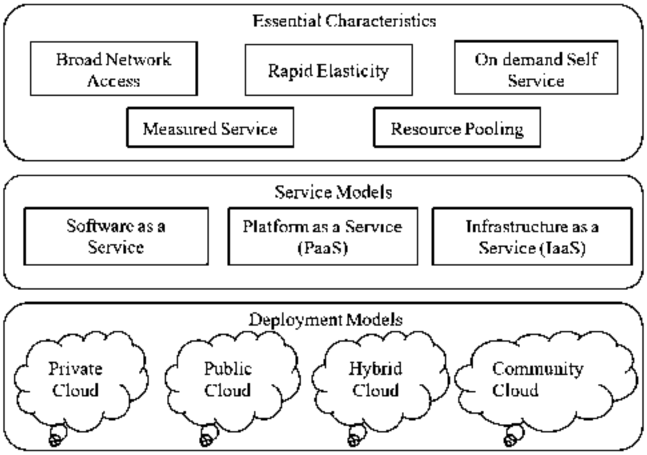

FIGURE 7.1

Aspects of Cloud Computing.

- Location and device independence: It enables users to access the system ubiquitously through a web browser.
- Performance: It is consistent which is constructed using web services as the system interface [25,26].

7.3.2 FUZZY DELPHI METHOD

The Delphi method is a repetitive process to collect and extract the specific opinions of various decision-makers. When the domain knowledge is incomplete, Delphi method is used as a research instrument. The limitations of conventional Delphi method includes high enforcing cost, low consistency of decision-makers judgments and changes in decision-makers individual judgment to reach overall judgment of decision-making process. To overcome these limitations, Ishikawa et al. [27] combined expert judgments with fuzzy numbers based on generalized cumulative frequency distribution and fuzzy integral. This process is called as Fuzzy Delphi Method (FDM) which is the combination of the fuzzy set theory with the Delphi method. FDM is one of the effective methods which enable forecasting to converge a possible value with the feedback mechanism, based on the judgment of decision-makers [28]. It uses triangulation statistics for determining the uncertainty and fuzziness in decision-making process.

Commonly, FDM method is more effective than Delphi method on the basis of following advantages [29]:

- Minimum number of analysis required.
- Apply fuzzy theory for clarifying the invertible fuzziness in interviews with decision-makers for obtaining more valid and reasonable responses.

- By FDM, we can achieve higher economic effectiveness in terms of costs and time that needs to conduct evaluation.
- Easy evaluation process.
- Managing multiple level and multi-solution decision problems.

7.3.3 FUZZY ANALYTIC HIERARCHY PROCESS (FAHP)

Due to uncertainty and insufficient statistics, sometimes it becomes quite difficult for the experts to take the appropriate decision within the decision environment. So, to solve these issues a fuzzy set theory is used which is based on user perceptions. FAHP is a fuzzy extension of conventional AHP. Fuzzy set theory is introduced to solve issues involving the absence of sharply defined criteria by Zadeh [30]. A triangular fuzzy representation is very common in fuzzy applications. The logic of fuzzy set theory is that the truth values are fuzzy sets and the rules of inferences are approximate rather than exact [31]. The function value μ_a as described in Eq. (7.1) represents membership function of x and triangular membership function is represented by a triplet (a_1, a_2, a_3).

$$\mu_a = \begin{cases} (x-w)/(m-w), & w \le x \le m \\ (u-x)/(u-m), & m \le x \le u \\ 0, & \text{otherwise} \end{cases} \tag{7.1}$$

Here w and u represent the lower and upper bounds of the fuzzy number and m describes the modal value for a.

7.4 THE PROPOSED HYBRID MCDM MODEL

In this study, the FDM and FAHP are used as the hybrid computational intelligence decision making techniques to select an IaaS among various cloud services. Our proposed technique gives better results and accuracy when it compared with AHP and fuzzy TOPSIS method [21] as existing literature lacks a systematic procedure aggregating customer's feedback (subjective) and real world performance assessment (objective) data, while incorporating fuzziness of different criteria's. FDM is used to choose the list of optimal decision making factors which are prepared through literature surveys and based on the opinion of different experts. Further, FAHP method is used to obtain the relative importance of different decision making factors and to select an optimal alternative with the maximum value is selected as the best cloud service.

Fig. 7.2 presents the systematic process of the hybrid computational intelligence technique. Different stages of the proposed hybrid approach are as follows:

Step I: Classification of different decision making parameters through expert survey and literature review. Step II: Identification of important decision making factors using FDM method. FDM method is used to choose the most important decision making criteriaś based on opinion of different experts and questionnaires. The steps are as follows [32]:

1. Employ a questionnaire by consulting different experts and find the evaluation score of each decision factor based on linguistic values of questionnaire.

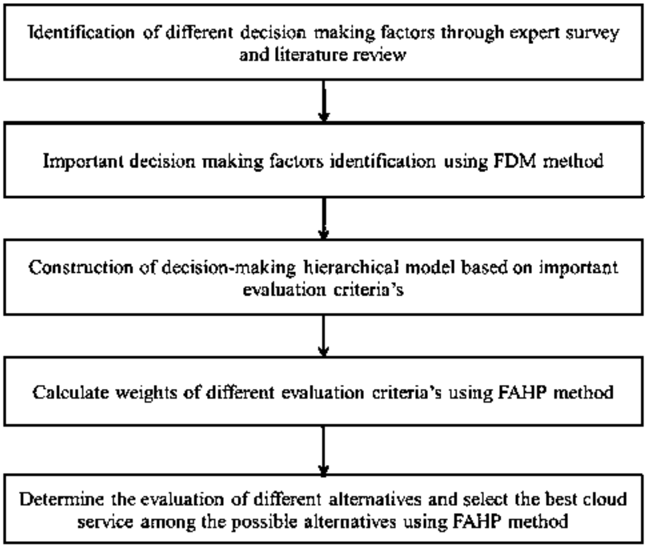

FIGURE 7.2

Hybrid technique for service selection in cloud.

2. Calculate the triangular fuzzy number for the minimum (pessimistic) value, maximum (optimistic) value and geometric mean of important decision making factors.

$$\begin{cases} \textit{Pessimistic value},\ a_j = \min(a_{ij}) \\ \textit{Optimistic value},\ b_j = \max(b_{ij}) \\ \textit{Geometric mean},\ c_j = 1/n \sum_{i=1}^{n} c_{ij} \end{cases} \tag{7.2}$$

3. Defuzzify the fuzzy weight of each alternative for obtaining the significance value D_j which is as follows:

$$D_j = a_j + b_j + c_j/3 \tag{7.3}$$

4. Set up the threshold value α. If $D_j \geq \alpha$ then evaluation criteria is accepted else it is rejected.

Step III: Construct decision-making hierarchical model based on important evaluation criteria's.
Step IV: Obtain the weights of different evaluation criteria's using FAHP method.
FAHP is a fuzzy extension of conventional AHP and it consist the following six steps [4].

1. Construct pair-wise comparison matrix among all the elements and express it by using nine-point scale defined by Satty [12].

Table 7.1 Fuzzy pair wise comparison scale and its description

Fuzzy pairwise scale	Description
0.5	equally important
0.55	slightly important
0.65	important
0.75	strongly important
0.85	very strongly important
0.95	extremely important

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & x_{22} & a_{23} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nn} \end{bmatrix} \tag{7.4}$$

Here $a_{ii} = 1$ and $a_{ij} = 1/a_{ji}$.

2. Analyze consistency in the comparison matrix

$$A = \begin{bmatrix} \frac{w_1}{w_1+w_1} & \frac{w_1}{w_1+w_2} & \frac{w_1}{w_1+w_3} & \cdots & \frac{w_1}{w_1+w_n} \\ \frac{w_2}{w_2+w_1} & \frac{w_2}{w_2+w_2} & \frac{w_2}{w_2+w_3} & \cdots & \frac{w_2}{w_2+w_n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_n+w_1} & \frac{w_n}{w_n+w_2} & \frac{w_n}{w_n+w_3} & \cdots & \frac{w_n}{w_n+w_n} \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} & s_{13} & \dots & s_{1n} \\ s_{21} & s_{22} & s_{23} & \dots & s_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ s_{d1} & s_{d2} & s_{d3} & \dots & s_{nn} \end{bmatrix} \tag{7.5}$$

If it is consistent it must satisfies:

$$s_{ii} = 0.5, \qquad s_{ij} + s_{ji} = 1, \qquad 1/s_{ij} - 1 = (1/s_{ik} - 1) \times (1/s_{ki} - 1) \tag{7.6}$$

3. Evaluate positive fuzzy matrix to convert scores of pair-wise comparison matrix into fuzzy variables having values between 0 and 1. The fuzzy pair-wise comparison scale is given in Table 7.1 which when compared with Sattyś scale must satisfies the following equation.

$$s_{ij} = a_{ij}/(a_{ij} + 1) \tag{7.7}$$

4. Calculate the fuzzy weights of decision elements as shown in Eq. (7.8).

$$W = (w_1, w_2, \dots, w_n) \tag{7.8}$$

$$w_i = z_i / \sum_{i=1}^{n} z_i \tag{7.9}$$

where $z_i = 1/[\sum_{j=1}^{n} 1/s_{ij} - n]$.

5. Integrate the decision of all experts by calculating Geometric mean of it.

Table 7.2 Values of RI

Matrix-size	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

6. Obtain final ranking by calculating the Consistency Index (CI) as shown in Eq. (7.10)

$$CI = [\sum_{i=1}^{n} (AW)_i / nw_i]/(n-1) \tag{7.10}$$

and, Consistency Ratio (CR) is obtained according to Eq. (7.11)

$$CR = CI/RI \tag{7.11}$$

where RI is Random Consistency Index and its values are shown in Table 7.2.

Step V: Determine the evaluation of different alternatives and select the best cloud service among the possible alternatives using FAHP method.

7.5 A NUMERIC APPLICATION OF THE PROPOSED HYBRID APPROACH

The applications of Cloud have various requirements for configuration and deployment. It is very difficult to check the performance of these applications on real Cloud. For the purpose of implementation, CloudSim and MATLAB are used as simulation tools which help in evaluating different applications without investing in the purchase of real time Cloud infrastructure. It enables decision makers to better understand the whole evaluation process and thus increases the efficiency of decision making process in cloud service selection. Due to fast growth in cloud computing, many companies introduce cloud services for better performance and efficiency. In this paper, we construct a list of decision-making factors to select an IaaS among different cloud services on the basis of experts survey and literature review. Here we consider five different cloud services to select the best cloud service among possible alternatives. In this section, proposed work is numerically analyzed by considering real-time mobility environment by considering various parameters based on experts opinions and criteria ranking is done using FDM method as listed in Table 7.3. Fig. 7.3 represents the hierarchical model based on important decision-making factors which are selected using FDM approach. Finally FAHP approach is applied to calculate the weights of different decision-making factors as described in Table 7.4 and Table 7.5 represents the ideal cloud service among possible alternatives using proposed technique.

From Table 7.3, it can be concluded that Security, availability, accuracy, maintenance cost and performance are the most important decision making factors among other criteria's. From Table 7.4, it can be analyzed that availability of resources and Maintenance cost are the most important criteria's. Also, consistency ratio is $0.05 < 0.1$. Thus, we can say that the weights are consistent under FAHP method.

The evaluation matrix for cloud service selection problem is shown in Table 7.5. From Table 7.5, it can be analyzed that we should select cloud service 4 to offload data when we consider these criteria's

Table 7.3 Evaluation criteria by FDM method

Sr. No.	Decision making factors	Pessimistic value a_j	Optimistic value b_j	Geometric mean c_j	Significance value d_j	Ranking
1.	Maintenance cost	4	9	8.108	7.036	4
2.	Support channel	3	9	6.556	6.185	6
3.	Availability	4	9	8.489	7.163	2
4.	Accuracy	4	9	8.428	7.143	3
5.	Network expenses	4	9	5.485	6.162	7
6.	Performance	4	9	7.915	6.972	5
7.	Security	4	9	8.497	7.166	1
8.	Programming Languages	2	9	6.620	5.873	8

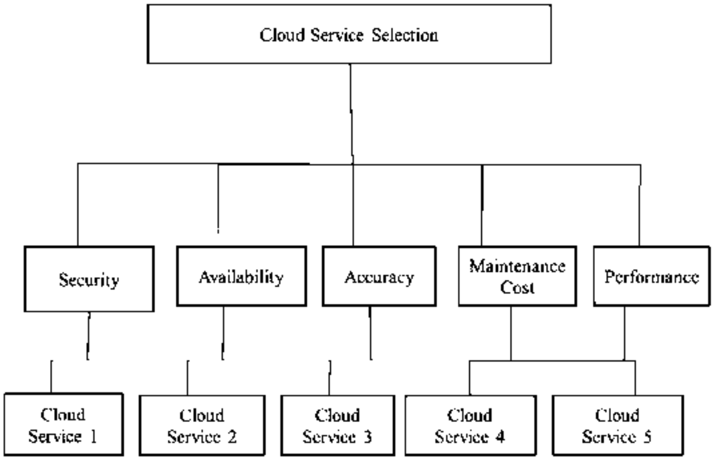

FIGURE 7.3

Hierarchical model for cloud service selection problem.

Table 7.4 Results obtained by FAHP (CR = 0.05)

Criteria	Weights	Rank
Availability	0.3708	1
Performance	0.1528	3
Security	0.0609	5
Maintenance cost	0.348	2
Accuracy	0.0673	4

simultaneously. In other words, we can say that cloud service 4 is the best cloud service for offloading the multimedia application.

Table 7.5 Final results for best cloud service selection

Cloud Services	Availability	Performance	Security	Maintenance cost	Accuracy	Results
Cloud service 1	0.0	0.1	0.0	0.2	0.2	–
Cloud service 2	0.1	0.2	0.2	0.0	0.1	–
Cloud service 3	0.3	0.0	0.2	0.1	0.2	–
Cloud service 4	0.5	0.0	0.1	0.5	0.3	–
Cloud service 5	0.2	0.2	0.0	0.1	0.0	–
Weights	0.3708	0.1528	0.0609	0.348	0.0673	–
Cloud service 1	0.0	0.01528	0.0	0.0696	0.01346	0.098
Cloud service 2	0.03708	0.03056	0.01218	0.0	0.00673	0.086
Cloud service 3	0.1112	0.0	0.01218	0.0348	0.01346	0.172
Cloud service 4	0.1854	0.0	0.0061	0.174	0.0202	0.386
Cloud service 5	0.07416	0.03056	0.0	0.0348	0.0	0.139

7.6 CONCLUSION AND FUTURE STUDY

This study presents a Hybrid Computational Intelligence Decision Making (HCIDM) model for multimedia cloud based services using Fuzzy Delphi Method (FDM) and Fuzzy Analytic Hierarchy Process (FAHP). FDM method is used to select the list of different decision making factors to solve the fuzziness of common understanding of different expert opinions. A FAHP approach is then proposed to determine the importance of decision making criteria's and to select the best cloud service for migrating large multimedia applications which will be a critical issue. The proposed hybrid approach enables decision makers to better understand the whole evaluation process and thus increases the efficiency of decision making process in cloud service selection. As a future study, the proposed hybrid model can also be applied to other MCDM problems to ensure more comparative or integrated study.

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