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Cloud Service Provider Selection: A Complex Multi-Criteria Decision Making Problem

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Abstract: - Cloud computing is a large pool of virtualized resources that provides an on-demand, pay-as-you-go computing resources and scale economies. These advantages force many of organizations to migrate their in-house business to cloud based computing. It delivers the IT enabled capabilities as a service to any needed users over the internet. Contrasting several cloud service providers in terms of both price and quality has become challenging due to the growing number of cloud providers, their vast array of services, and their wildly disparate pricing models. Potential cloud consumers now have a more difficult time selecting a service and provider because of the variety of services and the abundance of alternatives accessible. Various multi-criteria decision making (MCDM) techniques have applied by researchers for service and provider selection. This paper focuses mainly on the different MCDM approaches that are existing, and comparative study of all the approach together as a literature survey.

Keywords: Cloud computing; Cloud service provider (CSP); Multi-criteria decision making(MCDM); Service selection; AHP; TOPSIS; ANP; SAW; BWM

I. Introduction

The cloud is a sizable collection of virtualized resources that offers consumers on demand, pay-as-you-go access to computing resources (including hardware, development platforms, and/or software applications). Due to these advantages, many organizations have migrated their in-house business to cloud based computing. Cloud services have been classified based on service availability (e.g. public cloud, private cloud, hybrid cloud, and community cloud) and application domain (e.g. Infrastructure as a Service IAAS - This also incorporates servers, networking, and storage specific bandwidth, Platform as a Service PAAS which provides an environment to create applications with the help of various tools provided by cloud provider without worrying the infrastructure facility and Software as a Service SAAS allows cloud user to use any software and associated data that is hosted on a cloud). Amazon EC2 and Rackspace cloud are examples of IAAS, Google App Engine is a example of PAAS and Salesforce, Zoho office suite, and Google Apps are examples of SAAS [1].

Cloud computing is a game of two players Cloud Service Providers (CSP) and Cloud Service Users (CSU). A cloud service provider provides various services and cloud service users consume those services as per requirements on a rental basis. A rising number of cloud service providers (CSPs), including Google, Microsoft, Amazon, IBM, Alibaba, and Oracle, among others, release comparable services with various feature sets at various pricing and performance levels [2].

Customers may find it challenging to choose which cloud service provider (CSP) is best suited to fulfil their unique demands due to the variety of CSPs that are now offered. The wrong choice of a cloud service provider (CSP) might result in a service failure, data security or integrity breaches, and future noncompliance with cloud storage standards [3]. We refer to this as a cloud service provider selection problem.

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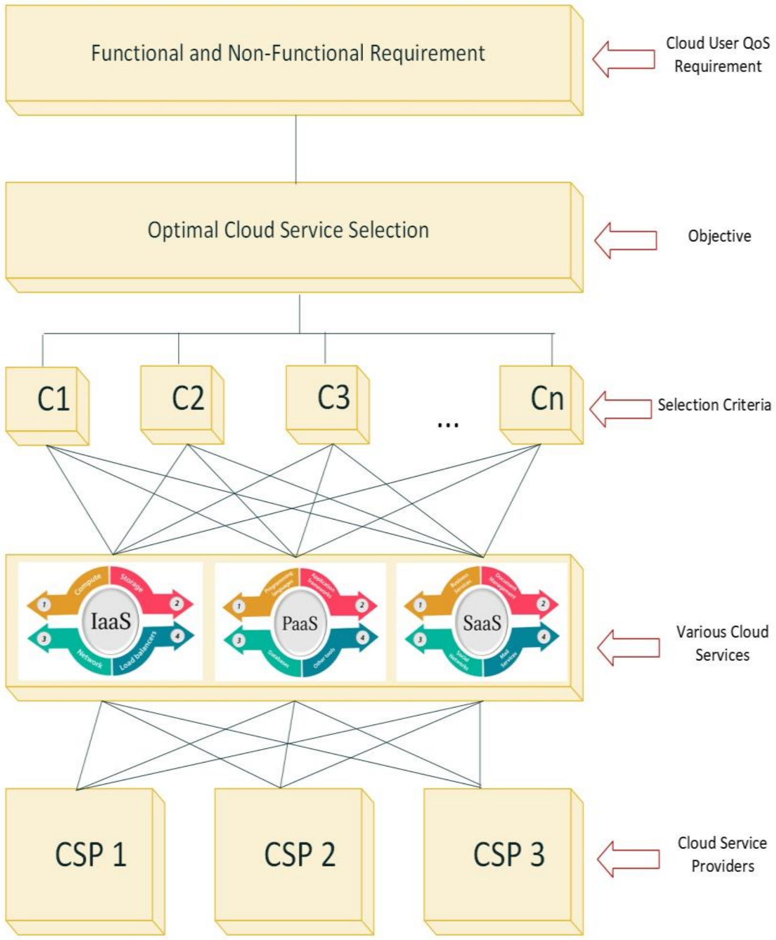

Fig. 1. A typical MCDM-based scenario for choosing a cloud service.

Decision-making is an aspect of life, However, selecting a cloud service is a difficult endeavor since different degrees of QoS qualities, such as performance, security, dependability, and service costs, are used by cloud service providers to differentiate their services [4]. A wide variety of assessment criteria known as QoS parameters for various cloud services from various CSPs must be taken into account in order to identify which cloud service provider (CSP) is the best fit for a cloud user's needs [5]. To standardize the QoS measurements used to gauge the QoS offered by CSPs, the world's top organizations came together to create the Cloud Services Measurement Initiative Consortium (CSMIC) [6]. The Service Measurement Index (SMI) methodology that CSMIC presented comprises seven key QoS measures, including accountability, financial, usability, performance, agility, assurance, security, and privacy. In order to specify the metrics at a low level, they further separated each metric into a number of sub-metrics. Cloud users compare different CSPs using these metrics. To choose the best options, a number of alternatives must be assessed based on several criteria. Choosing a cloud service provider is considered as a MULTI-CRITERIA DECISION MAKING (MCDM) problem [7].Figure 1 depicts a typical MCDM based scenario for choosing a cloud service.

The rest of the parts of the article are structured as follows: Section 2 Briefs about various decision making methods. Section 3 provides relevant work. In Section 4, we provide open research issues and Section 5 contains conclusions.

II. DISCUSSION

Various algorithms and techniques such as optimization based [8], [9], [10], [11], [12], [13], trust based [14], [15], [16], [17], logic-based [18], [19], [20], [21] and multi-criteria decision making [22] is used to assess, evaluate, and ultimately choose the best service out of the available options. Approaches based on optimization by minimizing or maximizing specific performance parameters while meeting certain restrictions, find the ideal CSP. It uses greedy method, dynamic programming and integer programming to select best CSP depending on heuristics.

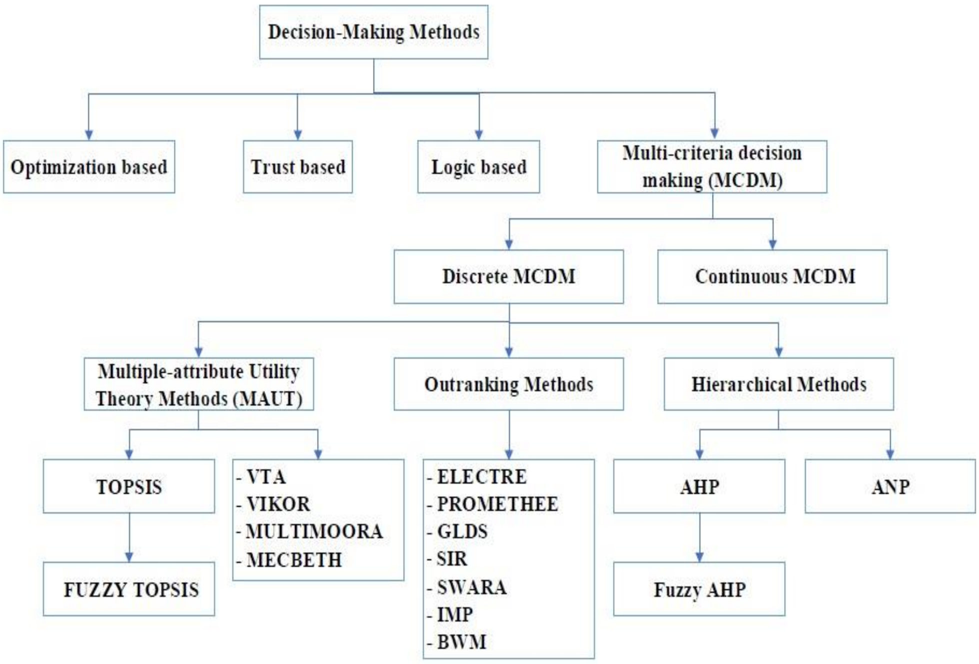

Fig. 2. Classification of decision-making methods.

Methods based on trust Choose the best CSP based on the provider's trust value, which is calculated using a mix of both objective (third-party monitoring tool) and subjective (user experience or expert opinion) assessments of the CSP's QoS values. To decrease the computing complexity, logic-based approaches are utilized to remove services that do not satisfy user needs. It enables service providers to make their services discoverable using ontologies or machine readable languages like Owl or WSML. In order to execute logic-based matching and choose the optimum CSP, it transforms user requirements into machine readable languages. MCDM methods involve comparing each CSP's QoS metric with others and aggregating them to find the best suitable service provider. The categorization of decision making techniques is shown in Figure 2. Figure 3 shows the use of the approaches by various researchers. From that we conclude that MCDM is most preferred.

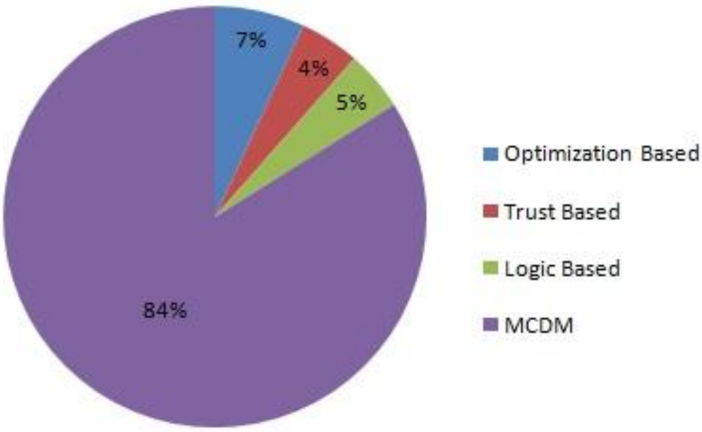

Fig. 3. Various approaches applied by researchers

A. Multi-Criteria Decision Making (MCDM)

As seen in Figure 2 based on the number of alternatives accessed MCDM problems are classified as Continuous MCDM problems also called multi objective decision making (MODM) methods and discrete MCDM problems also called multi attribute decision making (MADM) methods. Discrete MCDM challenges are those in which the decision maker must rank and order a finite collection of possibilities in order to determine which the best option is. Issues with an unlimited number of choices are referred to as continuous MCDM issues [22]. MADM approaches can be classified into three groups: Multi-attribute Utility Theory (MAUT) methods, outranking methods, and hierarchical-based methods. In MAUT techniques, experts rank options in preference to criteria to create a decision matrix. The scores of each option on all criteria, together with the weights of the criteria, may then be combined using some aggregation functions to determine the overall ranking of the alternatives. Based on pairwise comparisons between the alternatives, outranking algorithms calculate the relative preferences of alternatives with respect to each criterion. The outranking relations, which show the dominance of one choice over others, are then acquired by averaging the relative preferences. A decision problem is divided into a hierarchy of sub problems using a hierarchical approach. A decision-maker then evaluates the relative importance of its several components using pairwise comparisons, converts them into numerical weights, and uses those weights to determine a score for each option [23].

B. QoS Parameters

QoS are quantifiable, non-functional characteristics that define and distinguish services and serve as the foundation for service choice [24], [25]. However, the nature of QoS qualities is often varied and they might be either quantitative or qualitative (or categorical).When evaluating the quality of service (QoS) of cloud services, which is determined by a mix of quantitative and qualitative data, the Service Measurement Index (SMI) [26] specifies seven primary criteria to take into account. These include usability, security and privacy, financing, performance, agility, and accountability. Numerous features that might be either quantitative or qualitative are included for each group. In contrast to qualitative attributes like usability, flexibility, suitability, operability, elasticity, etc., quantitative attributes such as service response time, accuracy, availability, and cost can be quantitatively measured using the right software and hardware monitoring tools. They largely result from user experience.

III. RELATED WORK

This paper’s goal is to provide a thorough overview of several MCDM-based methods for choosing cloud services. Several methods and strategies are used for ranking the cloud services and cloud provider which facilitates the decision maker in identifying the optimal services that fit into the necessity of user and business. Below, many studies employing MCDM methodologies that have been published are described.

In [5] the best cloud services with the best QoS values are provided for consumers using the newly introduced cloud service selection algorithm, which uses principal component analysis (PCA) and the best-worst method (BWM) to minimize the size of the selection criteria and eliminate correlations between QoS. However, using PCA results in a considerable loss of information.

[27] Presented the best only approach (BOM), which is more effective and trustworthy than AHM and BWM in terms of computing complexity and consistency. However, the decision maker’s estimates of the pairwise comparison values for the qualitative criteria determine the final ranking of the CSPs and, consequently, the confidence in the conclusion.

[3] combines ANP and VIKOR to create the hybrid multi criteria decision making (HMCDM) model, which aids cloud customers in selecting a CSP that always provides the highest level of service by enhancing decision making and choosing the best CSP or alternative. However, the problem with ANP is complexity is high when more criteria are introduced and VIKOR is suffering with the linear normalization process.

[28] Suggested a hybrid strategy using BWM and TOPSIS algorithms to rank cloud services. The outcome produced by combining the BWM and TOPSIS methods was reliable and shown high consistency when subjected to sensitivity analysis. This method’s flaw was its inability to take into account how different decision-making factors interacted with one another.

[29] Offered a bench marking tool for a nation with few CSPs and few criteria. This tool used the AHP approach to analyze five criteria and assist novice users in selecting the best CSP from the list of five options.

[30] Proposed an easy-to use assessment technique for choosing the best cloud service among the available services based on the user's preferences that uses an AHP-based integer multiplication (IM) method by changing geometric mean. The proposed method requires fewer calculations and multiplications compared to a geometric mean method and provides accuracy. However Computational complexity of the approach is high due to pairwise comparison.

[23] Offered an MCDM approach that combines the approach for Order of Preference by Similarity to the Ideal Solution (TOPSIS) and the Best Worst Method (BWM) to rank CSPs using assessment criteria describing their services. Utilizing relative preferences of criteria and options, the suggested strategy is practicable, effective, and consistent. Compared to AHP, it is more dependable and effective in terms of computing complexity. Work can be expanded by integrating BWM with different MCDM methods.

[4] Proposed an MCDM model that systematically represents the QoS attributes of cloud services using a 3-tier architecture. The suggested technique is utilized to gather QoS data from three sources, including user evaluations, third-party monitoring tools, and cloud service providers. For rating the cloud services, they blended AHP and Simple Additive Weighting (SAW). It is built as a simulation tool that ranks and chooses cloud services in accordance with the QoS needs of cloud service customers while taking into account three QoS characteristics (Security, Usability, and Performance). The selection of CSP is credible and accurate since it draws from a variety of sources. The simulation results demonstrate how the suggested approach enhances, assures, and simplifies the CSPs selection process.

Using smart data, a hybrid Multi-Criteria Decision Method (MCDM) has been proposed by [31] to assess and rank cloud service providers. The hybrid approach combined the k-means algorithm with the Analytical Network Process (ANP) to rank the clusters of cloud service providers with similar attributes. This approach also took into account the connections and relationships between the performance metrics. The weighted technique, however, degrades performance when used for grouping and ranking.

[32] Offered a framework for cloud service matching, selection, and composition based on Semantic Web and QoS criteria including availability, response time, throughput, and cost. The authors attempted to integrate many cloud service providers in a multi-cloud environment. The suggested system is now more sophisticated overall as a result. The interoperability of various services from a multi cloud context is also not fully handled.

[33] Provided a methodology for choosing the top candidate cloud services by utilizing the AHP and TOPSIS. The method's pairwise comparison class is used to calculate how similar the services are, and the TOPSIS technique is used to rank the services. Pairwise comparisons are not appropriate for identifying comparable services when taking into account the vast array of services.

[34] Provided a framework for choosing a cloud service in a fuzzy environment based on the fuzzy TOPSIS approach. Although their suggested approach is resilient to the rank reversal problem, it is incompatible with inter-dependent QoS.

[35] Handled both qualitative and quantitative aspects while choosing CSPs by using fuzzy-AHP. When comparing options and criteria using linguistic scales, they used fuzzily triangulated numbers. Data from Cloud Harmony is used to evaluate this method; however, sensitivity analysis is not done to ensure that the results are consistent.

A fuzzy AHP technique was utilized by [36] to rate cloud services. Fuzzy AHP was developed to provide decision makers the option of using fuzzy classification rather than precise classification. The final choice in your work is modelled as the intersection of the background fuzzy sets using the fuzzy operator" and," and QoS parameters are modelled as fuzzy sets. Fuzzy AHP has the drawback that each alternative must have a membership value within the range [0, 1], making it challenging to precisely quantify the values that are selected.

IV. RESEARCH CHALLENGES

Great efforts have been made by various researchers for CSP selection still some of the following issues are open for investigation.

1) It is yet to be determined if combining the most recent MCDM approaches, such as COPRAS, MOORA, MULTIMOORA, ARAS, WASPAS, and SWARA with the previous MCDM methods would improve outcomes

in the service selection context. Combining recent Multi-Criteria Decision Making (MCDM) approaches with previous methods can potentially enhance outcomes in the service selection context. This combination can leverage the strengths of different methods, address their weaknesses, and provide a more comprehensive decision-making framework. Combining recent MCDM approaches with previous methods in the service selection context can lead to more informed, accurate, and robust decision making. This integrated approach can handle diverse criteria, balance subjectivity and objectivity, and provide a flexible framework adaptable to various decision-making scenarios.

2) The majority of MCDM-based approaches use predefined values for various QoS criteria. However, consideration of a gradual shift in QoS criterion in cloud service selection is still under investigation due to the dynamic nature of computer networks and the varying performance of CSPs, which may be brought on by bursty workloads or DDoS assaults. Addressing the dynamic nature of QoS criteria in cloud service selection requires a multi-faceted approach that combines real-time monitoring, adaptive MCDM methods, predictive analytics, and robust SLAs. By integrating these strategies, it is possible to enhance the reliability and effectiveness of cloud service selection processes in the face of varying performance due to bursty workloads, DDoS attacks, and other dynamic factors.

3) To get better results, fuzzy MCDM approaches can be used with other MCDM techniques. Additionally, none of the current fuzzy MCDM systems employ type-2 fuzzy sets; the majority of them apply type-1 fuzzy sets. So, the application of a type-2 fuzzy set has not yet been studied. Fuzzy Multi-Criteria Decision Making (Fuzzy MCDM) approaches are particularly useful in handling the uncertainty and imprecision associated with decision-making processes. By combining fuzzy MCDM with other MCDM techniques, and exploring the application of type-2 fuzzy sets, it is possible to achieve better results in complex decision contexts such as cloud service selection. The application of type-2 fuzzy sets in MCDM represents a promising area of research that can significantly enhance the handling of uncertainty and imprecision in decision-making processes. By combining fuzzy MCDM approaches with other MCDM techniques and incorporating type-2 fuzzy sets, it is possible to achieve more accurate, robust, and reliable outcomes, particularly in dynamic and complex environments like cloud service selection.

4) When choosing the best QoS criterion, the application of feature selection methods might be helpful. Feature selection methods can play a crucial role in improving the selection of the best Quality of Service (QoS) criteria in Multi-Criteria Decision Making (MCDM) processes. By identifying the most relevant and impactful criteria, feature selection methods can streamline the decision-making process, reduce complexity, and enhance the overall quality of the decisions. Applying feature selection methods in the selection of QoS criteria for MCDM processes can significantly enhance the quality and reliability of decision-making. By reducing dimensionality, addressing redundancy, and focusing on the most relevant criteria, feature selection methods help streamline the decision making process and improve outcomes. Integrating filter, wrapper, and embedded methods provides a comprehensive approach to selecting the best QoS criteria, ensuring that the decision-making model is robust, efficient, and accurate.

5) We still need to investigate the implications and relationships between service selection methods and QoS prediction algorithms. Investigating the implications and relationships between service selection methods and QoS prediction algorithms is essential for enhancing the reliability and effectiveness of cloud service selection. By integrating prediction algorithms with MCDM frameworks, implementing feedback loops, and performing scenario analysis, organizations can make more informed, accurate, and adaptive decisions. This integrated approach helps mitigate uncertainty, optimize resource allocation, and ensure robust service performance over time.

6) Another key area that must be considered is security. To choose a more secure service that better provides privacy, integrity, and authentication in this situation, a number of security-related considerations should be taken into account. Integrating security considerations into the service selection process is essential for choosing cloud services that provide robust privacy, integrity, and authentication. By developing a comprehensive set of security criteria, using MCDM methods to evaluate these criteria, and incorporating real-time data and expert input, organizations can make more informed and secure decisions. This approach ensures that security remains a top priority in the decision-making process, helping to mitigate risks and protect sensitive data and resources.

V. CONCLUSION

The choosing of a cloud service provider is regarded as an MCDM (MULTICRITERIA DECISION MAKING) challenge. Various MCDM methods are applied for cloud service provider selection. In-depth analyses of MCDM based cloud service provider selection are provided in this study. To evaluate the MCDM-based service selection approaches, several datasets including QWS, Cloud Harmony, Cloud Climate, Synthetic, Random dataset, NBA, MSE-BING, and WS-DREAM are employed. Also, various environments and simulators such as CloudSim, MATLAB, JAVA, C++ and Python are applied for the evaluation of the methods. Further Various QoS Parameters such as execution time, accessibility, reliability, adaptability, response time, cost, security, reputation, throughput, performance, and availability are considered by various researchers for selection of Cloud service provider.

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