An Efficacious Decision Support System for the Migration of Application to the Cloud

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***Abstract*— The aim of this work is the selection of most suitable cloud service provider for the migration of existing applications. Here the cloud provider selection is not only based on the quantitative and qualitative requirements of the application, but also based on cost minimization. For this purpose, this work proposes a decision support system that makes decisions with the help of a migration framework, which consider both the quantitative and qualitative factors. The proposed framework is then compared against the existing works.**

***Index Terms*— Cloud migration; decision support system; migration framework; usage pattern; Quality of Service**

I. INTRODUCTION

Cloud computing is one of the widely used computing terminologies in now a day. It is mainly intended for the delivery of computing as a service, based on utility billing model. The advantages of cloud computing was not get fully explored, even though the concept was introduced in 1950s. Now a day, the cloud becomes more and more popular and has become interesting for commercial exploitation. Cloud computing market grows day by day and a very large number of cloud service providers are there in the market. In order to reap the benefits of cloud, the existing applications need to migrate to the cloud [1]. But selection of suitable cloud service provider, which satisfies all the functional and qualitative requirements of an application, is a puzzling riddle. Selection process of suitable cloud service requires the analysis and comparison of different quantitative and qualitative parameters, which is difficult to done manually [2], [3].

The selection of cloud service which best suits an application is complicated by different factors [4]. This is because different cloud providers have different standards for their services and for the similar services itself their pricing policies are different. The absence of standard measures that allow for the comparison of various cloud services puts cloud customers at risk of missing the full value of cloud services. Another important concern while selecting cloud service is the quality of service. Satisfaction of non-functional requirements plays an important role in cloud service selection [5].

To address this problem and to define measures those are globally appropriate for the cloud services, we propose a quality model based decision support system that focus on provider selection and cost calculation. In peculiar:

- We present a set of requirements for making a decision about migration of application.
- We propose a quality model based decision support system architecture which incorporates migration framework and service selector.
- We narrate a prototypical implementation of the recommended approach that we evaluate in practice.

In order to find the quality of service, different approaches are present such as SLA matching, SRS approach, Aggregation approach, Cloud ranking approach etc [6]. Another important method for the prediction of quality of service is the analysis of user feedbacks or user experiences [7]. In this paper, we follow SLA matching and analysis of user feedbacks for the evaluation of quality of service.

The rest of this paper is organized as follows: Section II summarizes the related work. Section III describes our proposal for Quality Model Based Decision Support System and its key components. Section IV gives details of implementation. Section V discusses evaluation and section VII concludes the work.

II. RELATED WORK

During the selection of cloud services, quality of service and cost are two major concerns. Different frameworks and systems are developed for this selection process. For the estimation of cost for using public IaaS cloud, a cost modeling tool was proposed [8]. This allows the cloud customers to model their application and infrastructure requirements by considering the usage pattern also. Its main limitation is that it only discusses infrastructure costs of using public IaaS clouds. Since the selection process requires the analysis of various parameters and factors, this is a problem of Multiple Criteria Decision Making (MCDM). Different MCDM methods are present, such as Analytic Hierarchy Process (AHP), Analytic Network Process, fuzzy AHP etc.

The Cloud Service Measurement Initiative Consortium proposed a framework called SMICloud [9], which analyzes the most important Quality of Service (QoS) attributes for the s election of cloud services. It does service selection using AHP. CloudGenius [10], based on $((mc^2)^2)$ framework [11], is another approach for cloud service selection, which also uses AHP as the decision making method. It focuses on virtual machine image selection and cloud infrastructure service selection and finally the most suitable combination of them are provided. Based on $((mc^2)^2)$ framework, CloudGenius describes a formal model to define requirements, alternatives and scenarios which are then analyzed by Analytic Hierarchy Process. Both CloudGenius and SMICloud does not support analysis based on service cost and usage pattern. Another systematic comparator of the performance and cost of cloud providers' is CloudCmp [12]. It focuses on the comparison of three main cloud services: elastic computing, networking services and persistent storage. Based on these services, CloudCmp performs a comprehensive measurement study over four popular cloud providers, namely, Amazon Web Services, Google AppEngine, Microsoft Azure, and Rackspace Cloud Service.

A Migration Decision Support System [13] was proposed which include selection of cloud services based on cost minimization. It considers functional requirements and usage pattern o f the application along with the cost of services for cloud provider selection. It uses AHP as the ranking method but the problem is that it never considers t he QoS attributes of cloud services during the selection. There is an amount of work on selection of Cloud services, but each one of them lacks any one of the important criteria for cloud service selection.

III. QUALITY MODEL BASED DECISION SUPPORT SYSTEM

A. Overview

In this work, we propose a quality model based decision support system, which select a cloud service provider by considering all the quantitative and qualitative requirements. Qualitative requirements are analyzed based on SLAs, S LA fulfillment history and user feedbacks. Cost minimization and usage pattern are also taken into account during the decision making process.

The proposed system has the following abilities:

1. Ability to match functional requirements of an application with available cloud service provider offerings and calculate the cost for each cloud provider's offerings.
2. Ability to evaluate the qualitative requirements of cloud user during cloud service provider s election.
3. Ability to select cloud provider based on Service Level Agreement (SLA) analysis and user feedback analysis.
4. Ability to support variable requirements of users by analyzing the usage patterns.

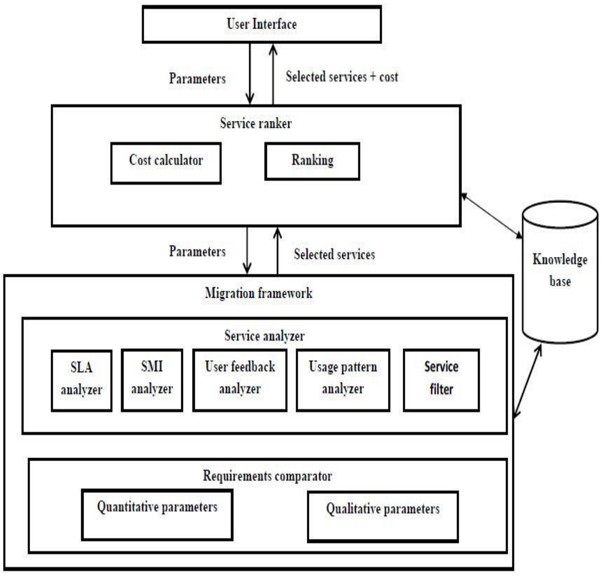

Figure 1: Overview of QMDSS

5. Ability to rank t he selected cloud service providers based o n minimum cost.
6. Existence of knowledge base, which contain cloud service providers' offerings, pricing models and SLAs.

Figure 1 shows the architecture for Quality Model Based Decision support System that addresses the above requirements. The three tiered architecture model includes:

1. User interface as the front end of the system.
2. Migration framework and service selector for implementing the main functions of the system: identifying the cloud providers, which satisfy all the functional requirements, quality criteria and usage pattern along with minimum cost.
3. A knowledge base which stores information about cloud offerings, pricing policies and Service Level Agreements.

Architectural components of the system are discussed in detail as follows.

A. User Interface

The user interface allows the users to provide their requirements and usage pattern and to view the selected services along with their service cost. Functional requirements can be band width, number of cores, operating system, speed , memory etc. Qualitative requirements can be response time, availability, service sustainability, suitability etc. So the input parameters can either numerical (memory, bandwidth etc.) or non-numerical (name of operating system). Usage pattern helps to specify the needs of application in future. For example, consider an application which helps the users to book the rooms in popular hotels in tourist places. The application may be used by a large number of customers in holidays. If the application depends on a cloud, it may require additional resources in holidays in order to meet the traffic, such as 10GB increase in storage for the next 2 months. Usage pattern helps to demand such needs earlier.

B. Knowledge Base

Knowledge base is one of the important parts of decision support system. It stores the details of services provided by the cloud service providers, together with the service cost. It al so stores the user feedback details about each of th e cloud services. Service Level Agreement details are the basis for quality of service analysis. The important details about the selected qualitative attrib utes are extracted from SLAs. Migration framework re ceives the details of cloud service offerings from kn owledge base for the selection of appropriate cloud provider offering. Cost calculator component takes pricing information from knowledge base for cost calculation of selected services.

C. Migration Framework

Migration framework includes requirements comparator and service analyzer. Requirements comparator has two sub components – one for the analysis of quantitative parameters and another for the analysis of qualitative parameters. Since the selection of cloud provider is based on different criteria, this is a multiple criteria decision making (MCDM) problem. For the selection and ranking of cloud services based on quantitative or functional parameters Analytic Hierarchy Process (AHP) can be used. It is a structured technique for making complex decisions. AHP decomposes the problem into different sub problems, find solutions for each of these sub- problems and finally merge the results to find the ultimate solution. Figure 2 shows how we utilize AHP for the decision making process in this work. Here the goal is to choose the cloud and to find a solution we have to consider different functional requirements such as memory, storage, bandwidth etc. So each of these requirements are considered as different sub problems. For each sub problem different alternatives or solutions are present such as Amazon web services, Go ogle App Engine, Windows Azure etc. From these alternatives, through AHP, the best solution can be determined.

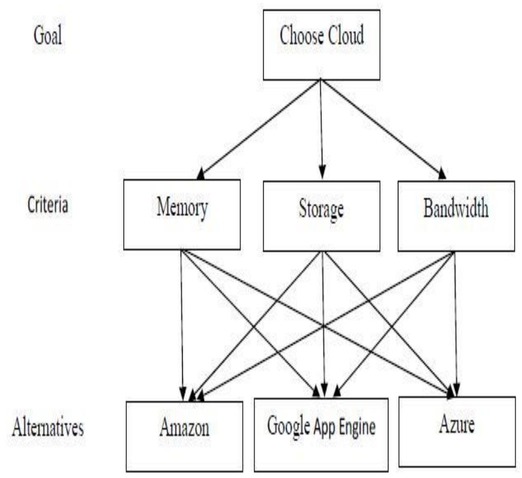

Figure 2: Application of AHP for the selection of functional requirements

For the selection and ranking of cloud services based on qualitative parameters Fuzzy Analytic Hierarchy Process

(FAHP) can be used. The main problem associated with AHP is that, it is unable to handle the uncertainties. In addition to this, AHP requires exact values for decision making, which is difficult in case of qualitative parameter analysis. Fuzzy analytic hierarchy process finds the results for each of the sub problems based on a range of values. Figure 3 shows the application of FAHP for the analysis of qualitative requirements. For each quality factor, a range of values are considered and the best solution is selected from the available alternatives.

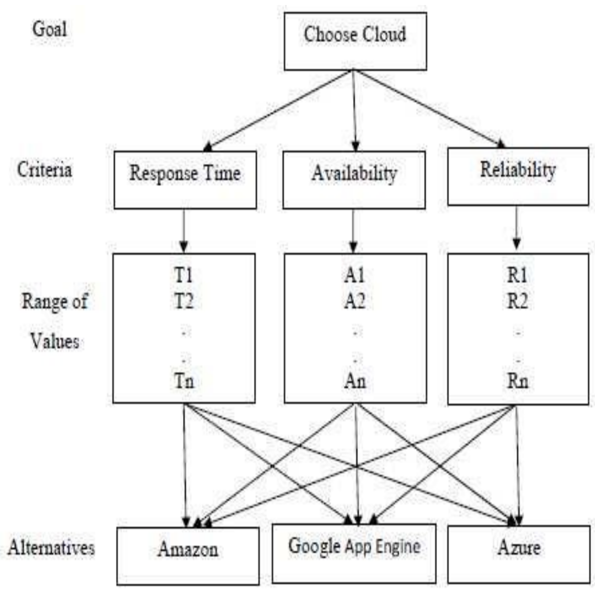

Figure 3: Application of FAHP for the selection of qualitative requirements

Quality of service analysis c an be done by Service analyzer which includes SL A analyzer, SMI analyzer, user feedback analyzer, usage pattern analyzer and service filter. SLA analyzer compares and evaluates the qualitative requirements of the user against the qualitative factors ensured through the SLAs by various cloud service providers. Analysis of considerable number of SLAs of a particular cloud provider gives an overview about their services and quality attributes.

User feedback analyzer evaluates the feedback of users about the service quality, which can also be used as a criterion for cloud service selection. Usage pattern analyzer compares the pat tern of usage of cloud customer against the usage pattern options provided by the cloud service providers. Cloud Service Measurement Initiative Consortium (CSMIC) proposed Service Measurement Index (SMI), which is a benchmarking for Cloud service quality. Here Service Measurement Index is calculated by Service Measurement Index Analyzer (SMI analyzer) based on selected qualitative parameters such as response time, service sustainability, availability etc. SMI is calculated for each cloud service provider and it stands as an indication for cloud service quality. Results from requirements comparator, SLA analyzer, SMI analyzer, user feedback analyzer and
usage pattern analyzer can be used by the service filter component for the selection of cloud service provider. The migration framework returns the selected services to the service ranker component.

D. Service Ranker

Service ranker receives the selected services from migration framework and for each selected services the cost calculator component calculates the cost. The cost of service is provided by the knowledge base. Ranking system rank th e selected cloud services based on minimum cost. Finally the service selector returns the selected services and their cost as the QMDSS decisions.

IV. IMPLEMENTATION

The QMDSS architecture was implemented as a web application. In particular, the Knowledge base was implemented in Microsoft SQL Server 2008 Express. The User Interface was implemented as a collection of ASP.NET web pages, with the Migration Framework and Service Ranker components as the logic behind serving the pages. Microsoft Visual C# classes and SQL queries are used to implement the cloud service selection process. The QMDSS prototype was implemented in Microsoft Visual Studio 2010 based on Microsoft .NET Framework 4.0.

The knowledge base which stores the information about cloud services and t heir pricing is implemented with a relational database. The information necessary to match the offerings an calculate the cost can be obtained through queries from database.

In migration frame work, service comparator compares both functional or quantitative parameters and qualitative parameters. Here we consider bandwidth, memory, storage, speed, number of cores and operating system as t he functional requirements. These requirements are compared and selected by the Analytic Hierarchy Process. The Qualitative factors considered are response time, service sustainability, suitability, availability, transparency and reliability. Based on these requirements a basic level filtering is done in the service comparator itself.

A. Proposed Quality Attributes

1) *Service Response Time:* The elapsed time between the end of an inquiry or demand on a service and the beginning of a response is known as the response time.
2) *Service sustainability:* Sustainable services as components of sustainable strategies and operations basically are offerings that decrease negative environmental impact while providing improved social and environmental benefits to consumers and producers. Here the service sustainability is obtained as a ratio of number of features provided by the service to the number of features required by the customer.
3) *Suitability:* Suitability of a service indicates the quality of having the properties that are right for a specific user needs. It can be calculated as the ratio of number of non-essential features provided by the service to the number of non-essential features required by the service.
4) *Transparency:* It is one of the important quality factors of cloud service. It can be evaluated based on the time for which the customer's application is badly affected by any changes in services provided by the cloud.
5) *Availability:* It indicates the time in which the customer can access the service without any interruption. It can be defined as the ratio of difference of total service time and total time for which service was not available to that of the total service time.
6) *Reliability:* It mainly depends on three factors – accessibility, continuity and performance. Accessibility means the service should be accessible when the customer desired. Continuity means the customer should obtain uninterrupted service during a given time and condition. Performance can be evaluated by checking whether the service meets customer's expectation or not.

Based on the evaluation of these quality attributes SMI value is calculated for each of the cloud service by the SMI analyzer. Details of qualitative attributes are taken from the SLAs for the analysis and are done by SLA analyzer. Information about service fulfillment is obtained through the user feedback analysis. Then the service filter component analyzes these analysis results to select the best service provider.

V. EVALUATION

For the purpose of evaluation of the proposed system we have done a comparison of our work with the existing frameworks those have the similar goals. We consider SMICloud framework, CloudGenius, Cloud Adoption Toolkit and Migration Decision Support System for comparison.

In the first stage of comparison we focus on the selection of cloud services. In CloudGenius, the selection of cloud service is mainly based on infrastructure service selection and virtual machine image selection. It does not consider quality of service as well as cost of service as the criteria for cloud service selection.

For the suitability analysis for cloud service selection, cloud adoption toolkit was proposed. It focused only on the analysis but not on the selection of cloud services. Analysis areas of cloud adoption toolkit are restricted to technology suitability analysis, cost modeling, stake holder impact analysis, energy consumption analysis and responsibility modeling. Analysis of quality factors are not done here. But it differs from another works in the sense that it has considered socio-political factors and energy consumption as some of the major areas of consideration.

SMICloud is another framework for the selection of cloud services and is proposed by Cloud Service Measurement Initiative Consortium (CSMIC). The purpose of formation of CSMIC is to ensure the quality of cloud services. Even though it deals with quality factors properly, it does not consider cost of services, which is one of the major criteria in cloud service selection. But it evaluates the quality of service by thoroughly analyzing service level agreements and by calculating a Service Measurement Index (SMI) value for each of the cloud services.

Migration Decision Support System (MDSS) is the latest among all of these works. But MDSS concentrates on the selection of cloud based on requirements of application, cost of various services and usage pattern. It does not consider quality of service for selection of cloud services. Its major advantage is that it calculate the cost not only by considering the cost of various cloud offerings but also the future usage pattern of these offerings. Since the option for usage pattern is provided here, customers can specify their varying demands and they can come to know about the cost of these varying demands.

By considering quality of service as one of the main criteria we improve Migration Decision Support System as Quality Model based Decision Support System. It differs from all the previous works since it consider the important concerns of cloud service selection - functional requirements, cost, quality of cloud services and usage pattern. An important advantage of QMDSS is that it retrieves results mainly based on user requirements. That is, it considers user requirements for the basic level filtering of services. As a result, the selected list of cloud services never includes any unwanted services. Since the results are sorted based o n cost, users can easily make decisions on selection of cloud service offerings. Table I shows the comparison of QMDSS with the above specified frameworks.

TABLE I: COMPARISON OF QMDS S WITH EXISTING FRAMEWORKS

Frameworks	Goals	Factors considered
QMDSS	Selection of suitable cloud services, cost calculation, ranking of cloud services	Functional requirements, cost, usage pattern, quality of service
MDSS	Selection of suitable cloud Services, Cost calculation, Ranking of cloud services	Cost, Functional requirements, Usage pattern
CloudGenius	Selection of combinations of cloud infrastructure and VM image services, ranking of cloud services	Functional requirements
Cloud Adoption Toolkit	Suitability analysis, stake holder impact and energy consumption analysis	Functional requirements, cost, energy consumption, social and political factors
SMI Cloud	Selection and ranking of cloud services	Functional requirements, quality of service

VI. CONCLUSION

For the existing applications i t is beneficial to move to the cloud to fully utilize its benefits. But for the selection of suitable cloud service a number of parameters are to be considered. In order to analyze these parameters and to make a suitable decision we propose a Quality Model Based Decision Support System. It includes a user friendly interface with migration framework and service ranker as the back - end logic. Using ASP.NET, Micros oft Visual C# and Microsoft SQL Server a prototype of this approach was implemented as a Web application. It supports the selection of cloud service based on application's functional requirements, qualitative requirements, cost and usage pattern. Security is a major concern in selection of cloud service which is not considered here. In order to improve the system security factors can also be included.

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