# An Efficient Frame of Reference for the Selection of Best Cloud Service Provider

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Abstract: The recent technology term Cloud computing involves deployment of remote server groups and networks software, allowing data storage centralization and access to the online computer resources or services. The increasing demand for cloud services and also the increase in number of cloud service providers providing the same functionality have created a problem for cloud users to select the best cloud service providers as per their requirements. So there is a need for solution to help the cloud users. This paper identifies required Quality of Service (QoS) to be considered while selecting a best Cloud service provider and proposed a new methodology to rank the service provider using Analytical Hierarchical Process (AHP) with the help of Weighted Rankings.

Keywords: Cloud computing, remote server, network software, storage centralization, AHP, Weighted Rankings etc.

#### 1. Introduction

Cloud computing which is emerging as a new paradigm for the utility computing, is growing very rapidly and gaining attention not only by large organizations but also by academic organizations, government organizations, small and medium organizations. Like utility computing, the cloud computing also offers resources on demand.

It offers broadly three types of services:

- 1) Software as a service (SaaS)
- 2) Platform as a service (PaaS)
- 3) Infrastructure as a service (IaaS)

It also offers three deployment models:

- 1) Public Cloud
- 2) Private Cloud
- 3) Hybrid Cloud.

Big organizations and other users can reap the benefits of Cloud computing. Cloud customers have to pay only operational cost unlike traditional data center which reduces computing cost significantly. If company is growing, customer can rent more computing resources from Cloud without bothering to pay for unneeded resources. Since Cloud customers need not to bother about the infrastructure maintenance and consume resources on pay per use basis, organization becomes more agile. Also, Cloud computing can utilize resources more efficiently i.e. same infrastructure may be used by many customers resulting in less number of required servers. It makes Cloud greener and Cloud customers more eco-friendly. Other Cloud benefits include multi-tenancy, flexibility, disaster recovery etc. Though, key issues like security, interoperability, some standardization, SLA (service level agreement) etc. requires a deeper addressing in order for Cloud to be fully functional.

Many public Cloud service providers offer same service on low cost with better performance than others. Their customer support also may vary. Some providers charge higher for CPU but lower for RAM. From security point of view, they may have different certifications. Increasing number of Cloud service providers is making Cloud market more competitive day by day. Each service provider claims their best. This, in turn, makes the Cloud customers difficult to select a provider which fulfils their QoS requirement. May be an application was implemented with different needs but the needs might change over time like language, operating system etc. For such application, service provider with multilingual support will be a better option. It may be the case that an application is simple in its starting phase but after some time as company grows and scales, its application may become more complex. So Cloud customers have to find a Cloud service which not only satisfies its current need but will also adapt with future requirement.

For selection of a best Cloud provider, a customer must identify its QoS measures that are used to compare various service providers. But QoS measurement may be a difficult task because of lack of standard to understand it. For creating a standard to measure QoS in Cloud, Cloud Services Measurement Initiative Consortium (CSMIC) was formed in 2010 in Carnegie Mellon University. CSMIC is a group of globally established organizations. Professionals, from these organizations, have developed a standard measurement framework called SMI[1](Service Index). SMI Measurement includes seven major characteristics, each characteristic with 3 or more attributes. SMI clearly defines each attribute which helps decision makers to measure QoS requirement of customers, compare this to offerings of different Cloud service providers and to choose a best Cloud service provider.

Several challenges are to be tackled in realizing a model for evaluating QoS and ranking Cloud providers. The first challenge is to find a way to measure various SMI attributes of a Cloud service. Itâ<sup>TM</sup>s because many of the attributes vary over time. However, without having precise measurement models for each attribute, it is not possible to compare different Cloud services or even discover them. Therefore, SMI Cloud uses historical measurements and combines them with promised values to find out the actual value of an attribute.

The second challenge is to find a way to rank the Cloud services based on these attributes. There are two types of

QoS requirements which a user can have: functional and non-functional. Some of them cannot be measured easily given the nature of the Cloud. Attributes like security and user experience are not easy to quantify. Moreover, deciding which service matches best with all functional and nonfunctional requirements is a decision problem. It is necessary to think critically before selection as it involves multiple criteria and an interdependent relationship between them. This is a problem of Multi-Criteria Decision-Making (MCDM)[2]. Each individual parameter affects the service selection process, and its impact on overall ranking depends on its priority in the overall selection process. To address this problem, we propose a Analytical Hierarchical Process (AHP)[3] based ranking mechanism to solve the problem of assigning weights to features considering the interdependence between them, thus providing a quantitative basis for the ranking of Cloud services.

# 2. Service Measurement Index (SMI)

SMI attributes are designed based on the International Organization for Standardization (ISO) standards by the CSMIC consortium [1]. It consists of a set of businessrelevant Key Performance Indicators (KPIs) that provide a standardized method for measuring and comparing business services. The SMI framework provides a holistic view of QoS needed by the customers for selecting a Cloud service provider based on: Accountability, Agility, Assurance of Service, Cost, Performance, Security and Privacy, and Usability. There are currently no publicly available metrics or methods which define these KPIs and compare Cloud providers. SMI is the first effort in this direction. The following defines these high level attributes:

- Accountability: This group of QoS attributes is used to measure various Cloud provider specific characteristics. This is important to build the trust of a customer on any Cloud provider. No organization will want to deploy its applications and store their critical data in a place where there is no accountability of security exposures and compliance. Functions critical to accountability, which SMI considers when measuring and scoring services, include auditability, compliance, data ownership, provider ethicality, sustainability, etc.
- Agility: The most important advantage of Cloud computing is that it adds to the agility of an organization. The organization can expand and change quickly without much expenditure. Agility in SMI is measured as a rate of change metric, showing how quickly new capabilities are integrated into IT as needed by the business. When considering a Cloud services agility, organizations want to understand whether the service is elastic, portable, adaptable, and flexible.
- Cost: The first question that arises in the mind of organizations before switching to Cloud computing is whether it is cost effective or not. Therefore, cost is clearly one of the vital attributes for IT and the business. Cost tends to be the single most quantifiable metric today, but it is important to express cost in the characteristics which are relevant to a particular business organization.
- Performance: There are many different solutions offered by Cloud providers addressing the IT needs of different organizations. Each solution has different performance in

terms of functionality, service response time and accuracy. Organizations need to understand how their applications will perform on the different Clouds and whether these deployments meet their expectations.

- Assurance: This characteristic indicates the likelihood of a Cloud service performing as expected or promised in the SLA. Every organization looks to expand their business and provide better services to their customers. Therefore, reliability, resiliency and service stability are important factors in selecting Cloud services.
- Security and Privacy: Data protection and privacy are important concerns for nearly every organization. Hosting data under another organizations control is always a critical issue which requires stringent security policies employed by Cloud providers. For instance, financial organizations generally require compliance with regulations involving data integrity and privacy. Security and Privacy is multi-dimensional in nature and includes many attributes such as protecting confidentiality and privacy, data integrity and availability.
- Usability: For the rapid adoption of Cloud services, the usability plays an important role. The easier to use and learn a Cloud service is, the faster an organization can switch to it. The usability of a Cloud service can depend on multiple factors such as Accessibility, Installability, Learnability, and Operatibiliy.

## 3. SMI Cloud Architecture

The proposed Service Measurement Index Cloud framework (SMICloud) which helps Cloud customers to find the most suitable Cloud provider. The SMICloud framework provides features such as service selection based on QoS requirements and ranking of services based on previous user experiences and performance of services.



Fig. 1.SMICloud framework.

Customers provide their requirements and gets a sorted list of Cloud services. Fig. 1 shows the key elements of the framework:

- 1) Users: this the real users who register to coordinators to get the information of service providers for their requirements.
- Cloud Coordinator: this component is responsible for interaction with customers and understanding their application needs. It collects all their requirements and performs discovery and ranking of suitable services and display to the users.

- 3) Service Catalogue: stores the services and their features advertised by various Cloud providers.
- 4) Service Provider: this component is the real registered service providers who like to advertise about their services.

## 4. QoSMatrics

Cloud computing services can be evaluated based on qualitative and quantitative Key performance indicators (KPIs). Qualitative are those KPIs which cannot be quantified and are mostly inferred based on user experiences. Quantitative are those which can be measured using software and hardware monitoring tools. For example, providers<sup>™</sup> ethicality and security attributes are qualitative in nature. Since these KPIs represent generic Cloud services, only some of them are important for particular applications and Cloud services. For example, the installability attribute in usability is more relevant to IaaS providers than SaaS providers since in SaaS there is almost no installation on the customer end. In addition, the same KPI can have different definitions based on the service. Some of these parameters depend on customer applications and some are independent. For example, suitability is dependent on the customer while flexibility is determined by the provider. Therefore, it is complex to define precisely the SMI values for a provider, particularly when there are many parameters involved and parameter definitions also depend on many sub attributes. Here i have given definitions for the most important quantifiable KPIs, particularly in the context of IaaS. However, most of these proposed metrics are valid for other types of services too.

- Accountability: As defined in SMI this group of QoS attributes is used to measure various Cloud provider specific characteristics. Here i am considering Availability and Reliability factor of the cloud service.
  - 1) Availability: Availability is the degree to which a system or component is operational and accessible when required for use. Different applications require different availability rating. Online tools are available which run benchmark on different providers and provides an idea about availability of different providers such as Global Provider View. CLOUDSLEUTH application Global Provider View brought by Compuware is a near real-time visualization tool, which provides availability and response time of different service providers. It uses Gomez Performance Network (GPN) to measure the performance of an identical sample application running on several popular Cloud service providers. GPN is a benchmark which has been created unambiguously by Gomez. User can collect data of availability and response time at different time frame and at different locations or worldwide.
  - 2) Reliability: Using virtualization technology, Cloud computing utilizes resources more efficiently. A physical server can deploy many virtual machines and operating systems. However, with the increase in software and hardware components, more failures are likely to occur in the system. Thus, one should understand failure behavior in the Cloud environment in order to better utilize the Cloud resources. In this

work, MTBF (mean time between failures) is considered for reliability measure. It is assumed that MTBF will be provided by the service provider for each Cloud service. MTBF applies to a service that is going to be repaired and returned to operate, and is defined as

# $MTBF = \frac{Totaltime}{Number of failures}$

A practical definition of reliability is the probability that a service operating under specified conditions shall perform satisfactorily for a given period of time. It is assumed that failures occur randomly so reliability for a certain time period t can be described by the given exponential distribution.

 $R(t) = e \frac{\Box t}{MTBF}$ 

- 3) Accuracy: The accuracy of the service functionality measures the degree of proximity to the users actual values when using a service compared to the expected values. For computational resources such as Virtual Machines, accuracies first indicator is the number of times the Cloud provider deviated from a promised SLA. It is defined as the frequency of failure in fulfilling the promised SLA in terms of Compute units, network, and storage.
- Security: Cloud providers take different types of security measures. Different application may have different requirement for security measures. Here Crypto algorithms and Certifications are considered as attribute of QoS metric under security.
- Certification: Different providers have different certifications for industry regulatory compliance e.g. Amazon has certification of SAS 70 TYPE II, ISO 27001, and HAPP etc. Windows Azure has certifications of Safe Harbor policy, ISO 27001 etc. A user may prefer one certification over other. This factor helps in determining the quality of the service provider since certification helps in standardization.
- 2) Crypto algorithms used: Cryptography is the art or science of keeping data secure by converting the data into non readable forms. Different providers use different crypto algorithms like Data Encryption Standard (DES), Triple-DES, Advanced Encryption Standard (AES), Blowfish Algorithm any many other algorithms to secure the customers data. Here whether they are using any encryption method to secure the data is considered as a metric for ranking.
- Agility: Agility in SMI is measured as a rate of change metric, showing how quickly new capabilities are integrated into IT as needed by the business. Here following attributes are considered.
  - 1. Scalability: Scalability is important to evaluate in order to determine whether a system can handle a large number of application requests simultaneously. The ability to scale resources is an essential part of the elasticity provided by Cloud computing. However, this metric is more applicable from the performance perspective of user applications. The scalability has two dimensions: horizontal Cloud scalability and vertical Cloud scalability. Horizontal Cloud

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scalability means increasing Cloud resources of the same types such as initiating more virtual machines of the same type during peak load. Some of the aspects of horizontal scalability, we have already discussed during our discussion of measuring the elasticity of Cloud services. Therefore, to avoid overlap, here we consider only the vertical scalability that is defined as the ability to increase the capacity of a Cloud service such as a virtual machine by increasing resources such as the physical memory, CPU speed, or network bandwidth. Vertical scalability is an important quality measure for organizations who want to move to the Cloud. If the Cloud does not allow an application to scale well vertically, it can increase the costs of using Cloud services, particularly at peak times. The vertical scalability can be calculated as the maximum available increase in the resources of a Cloud service. Let rij be resource *j* that needs to be enhanced on Cloud service *i*. Let *n* and *m* be the number of resources assigned to a particular Cloud service and the number of Cloud services used by the user, respectively. The formulation of vertical m ni

scalability is:  $\sum_{i} \sum_{j} (\text{proportion of increase in } rij).$ 

- 2. Adaptability: Adaptability is the ability of the service provider to adjust changes in services based on customersâ<sup>™</sup> requests. It is defined as the time taken to adapt to changes or upgrading the service to a higher level (e.g. upgrading from a small Amazon VM to a medium size Amazon VM)
- 3. Elasticity: Elasticity is defined in terms of how much a Cloud service can be scaled during peak times. This is defined by two attributes: mean time taken to expand or contract the service capacity, and maximum capacity of service. The capacity is the maximum number of compute units that can be provided at peak times.
- 4. Usability: The ease of using a Cloud service is defined by the attributes of Usability. The components such as operability, learnability, installability and understandability can be quantified as the average time experienced by the previous users of the Cloud service to operate, learn, install and understand it respectively.
- 5. Interoperability: Interoperability is the ability of a service to interact with other services offered either by the same provider or other providers. It is more qualitative and can be defined by user experience.
- Capacity: Capacity means maximum amount of resources that a service provider can provide at peak times. Capacity of a service provider can be quantified by following attributes:
- 1) Number of data centers: The number of data centers helps in parallel computing, also increases the reliability of the services since if any one data center is down other can somehow manage the traffic.

- 2) Operating system support: Providers support different OS like Mac OS X, Windows, and Open SUSE Linux etc. It is possible that one provider support some OS and other provider supports some other OS like Windows Azure supports only Windows operating system, while GoGrid supports Windows server 2003/2008, Red hat Linux 5.1/5.4 etc. Different applications require different OS support. Application can rank providers based on decision whether provider provides required platform or not.
- 3) Platform support: Same as operating systems, different providers support different type of platforms. For example, CloudSigma supports Java, PHP, WinDev, Dot Net. While Firehost supports Ruby, Java, PHP, and Dot Net. Different application requires different platform support. Application may rank providers like it ranks providers based on Operating System.
- Virtualization technique: Today, any application can be 4) deployed using any virtualization platform. This work considers that if one is going to deploy a new application, one can use any virtualization platform according to its requirements. Unlike platforms, generally a provider supports only one virtualization platform. But each virtualization technique has its own advantages. If any one does not require advance features it may seek Hyper-V. Xen is Linux based and its management and administration is difficult but it has its advantage for experienced Linux user. VMware provides robust features. There are many vendors with application to fulfill the need in Vsphere. Hyper-V is freeware but one has to buy windows server. So choice of hypervisor very much depends on applications requirement.
- 5) Memory (RAM): Random-access memory is a form of computer data storage. A random-access memory device allows data items to be read and written in roughly the same amount of time regardless of the order in which data items are accessed. In contrast, with other directaccess data storage media such as hard disks, CD-RWs, DVD-RWs and the older drum memory, the time required to read and write data items varies significantly depending on their physical locations on the recording medium, due to mechanical limitations such as media rotation speeds and arm movement delays.
- 6) Storage (Disc): Disk storage is a general category of storage mechanisms where data are recorded by various electronic, magnetic, optical, or mechanical changes to a surface layer of one or more rotating disks. This is the main attribute which cloud user expects from service provider.
  - a) Cost:Cost depends on two attributes: acquisition and on-going. It is not easy to compare different prices of services as they offer different features and thus have many dimensions. Even the same provider offers different VMs which may satisfy users<sup>TM</sup> requirements. We can use different weights for each attribute based on the user application. Generally users need to transfer data which also incurs cost. Therefore, the total on-going cost can be calculated as the sum of data communication, storage and compute usage for that particular Cloud provider and service.
  - b) Performance: There are many different solutions offered by Cloud providers addressing the IT needs of different organizations. Each solution has different

performance in terms of functionality, service response time and accuracy. Organizations need to understand how their applications will perform on the different Clouds and whether these deployments meet their expectations. Attributes considered is Average response time, CPU speed and Location.

1) Average Response Time: It is given by  $\sum_{i} \frac{T_i}{n}$  where  $T_i$  is

time between when user i requested for an IaaS service and when it is actually available and n is the total number of IaaS service requests.

- CPU speed: The CPU speed, or processor speed, is the amount of cycles that a CPU can perform per second. Here i consider the average CPU speed of the processor used by the service providers.
- 3) Location: Performance is highly affected by the speed of light latency, TCP latency, (both of which are directly correlated to circuit distance between user and files), as well as packet loss. By placing the files closer to the user, both speed-of-light latency and TCP latency are minimized. Packet loss is also minimized because the probability of packet loss increases as distance increases. Hence this location parameter has greater weightage compared to other parameters. Using the location of users and the locations of datacenters once can get the distance between them and the shortest distance get the more priority over the other while ranking.
- Support
- Customer support facility: Type of support, response time for support and the charge for customer support are important factors which define customer support facility. Generally new users prefer a provider with a good support system. Some providers offer free customer support service, but mostly the providers charge accordingly. GoGrid provides free 24/7 phone support and free 24/7 premium support. Amazon AWS provides premium Support (Urgent - 1 hour, High - 4 business hours, Normal - 1 business day, Low - 2 business days). So to measure customer support facility metric, the metric is assumed as unordered set which may contain elements like Free 24/7 phone support, Urgent support, Basic support, Low support, Diagnostic tools etc.
- 2) Free trial: Some Providers provide free trial to test their services. It is very beneficial for users. User can test services before deployment. Definitely, provider with free trial service will get higher rank.

# 5. Quality Model Assessment

In this section, we assess usefulness and practicability of the metrics proposed in this paper by using four criteria which are identified from IEEE Standard 1061[4]

• Correlation: The metrics proposed in this paper are derived from quality attributes, i.e., KPIs required by the users application. There is a strong linear association between quality attributes and their metrics. For example, Elasticity of a Cloud service depends on how fast the Cloud can grow and how much it can grow. Each of these values can affect the elasticity of an application. If a Cloud provider takes hours to increase the number of

virtual machines, it will directly affect the QoS expected by the users.

- Practical and computable: According to this criterion, the proposed metrics should be computable practically with ordinate effort or time. Except for sustainability, the metrics proposed in this paper are easily computable by using various publicly available performance tools[10-12].
- Consistency: Similar to the criterion correlation, the values among quality attributes also have a strong linear association. If quality attribute values A1, A2, An, have the relationship A1 > A2 >An, then the corresponding metric values shall have the relationship M1 > M2 >Mn. It can be observed that each of the metrics is calculated based on numerical values of various performance characteristics of the Cloud service, therefore consistency is self-evident from the metrics.
- Discriminative power: The metric is capable of discriminating between high-quality Cloud services (e.g., short response time) and low-quality Cloud services (e.g., long response time). The set of metric values associated with the former should be significantly higher (or lower) than those associated with the latter. Let us assume there are three values of throughput for three Cloud services, i.e., Th1, Th2, Th3,. Since each of these values are numerical in nature, we can have the relationship Th1 > Th2 > Th3. Hence, in terms of the throughput, i can conclude that the first Cloud service can be ranked as the service which can handle the highest amount of workload.

# 6. Cloud Service Ranking

Ranking of Cloud services is one of the most important features of the SMICloud framework. The Ranking System computes the relative ranking values of various Cloud services based on the QoS requirements of the customer and features of the Cloud services. The ranking system helps to take the ranked service providers in to account before deciding from where to lease Cloud resources. Process of ranking follows (a) Selection of data based on cost, storage and services (b) User experience based ranking considerations (c) the service quality analysis based on AHP.

- a) Selection of data based on cost, storage and services To rank the Cloud services that can fulfill the users requirements, the cost of service plays a key role in the ranking process. In the literature [19], it is called the cost value trade off. A good ranking system should suggest to the user the Cloud service which gives the best QoS at the minimum cost. Therefore, in the first step, the service and the storage capacity along with the cost specified by the user is considered to retrieve the specific data sets which considers all user requirements.
- b) User experience considerations To rank the Cloud services based on previous users experience had a great advantage in selection of best service providers so for user rating also some weight to be given while ranking.
- c) Service quality ranking using AHP

As discussed previously, Cloud services have many KPIs with many attributes and sub-attributes which makes the

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ranking process a complex task. This problem in the literature is defined as multiple criteria decision making (MCDM)[13]. The traditional weighted sum-based methods cannot be directly applied in such a hierarchical structure of attributes. In addition, some of the attributes do not have any numerical value, for example, security.

Without a structured technique, the evaluation of the overall quality of different Cloud services would be very difficult given the number of attributes involved. In addition, the challenge is to compare each Cloud service based on each attribute, how to quantify them and how to aggregate them in a meaningful metric. In general, such problems fall into the category of MCDM, where decision makers choose or rank alternatives on the basis of an evaluation of several criteria. Decision making involves managing trade-offs or compromises among a number of criteria that are in conflict with each other. There are three fundamental approaches to solving MCDM problems: Multiple Attribute Utility Theory (MAUT), outranking and Analytic Hierarchy Process (AHP). Most of the approaches proposed in the literature are variations of these three basic methods.

Multiple Attribute Utility Theory (MAUT) [14] is the simplest method that combines various preferences in the form of multiple attribute utility functions. In MAUT, utility functions for each criterion are combined with weighting functions of criteria. The primary advantage of using MAUT is that the problem is constructed as a single objective function after successful assessment of the utility function. Thus, it becomes easy to ensure the achievement of the best compromise solution based on the objective function.

The outranking approach is based on the principle of the degree of one alternatives dominance over another [15], rather than considering that a single best alternative can be identified. Outranking, thus, compares the performance of alternatives for each criterion and identifies the extent of a preference of one alternative over another without using a prescribed scale from the user. Outranking models are generally applied when aggregation of criteria metrics is not easy and measurement units are incommensurate or incomparable. The drawback of this approach is that many times it does not reach a decision and it is relatively complex to implement compared to other MCDM approaches. Analytic Hierarchy Process (AHP) is one of the most widely used mechanisms for solving problems related to MCMD. AHP is a multi-criteria decision making approach that simplifies complex, ill-structured problems by arranging the decision factors in a hierarchical structure. Unlike MAUT, AHP is based on pair wise comparisons of decision criteria rather than utility and weighting functions. The pairwise comparison allows the decision maker to determine the trade-offs among criteria. The advantages of AHP over other multi-criteria methods are its flexibility, intuitive appeal to the decision makers and its ability to check inconsistencies [16]. In addition, AHP decomposes a decision problem into its constituent parts and builds hierarchies of criteria similar to KPIs in the SMI framework. AHP also helps to capture both subjective and objective evaluation measures. While providing a powerful mechanism for checking the consistency of the evaluation measures and alternatives, AHP reduces bias in decision making.

Therefore, to rank Cloud services based on multiple KPIs, i make use of a ranking mechanism based on Analytic Hierarchy Process (AHP) [17]. There are three phases in this process: problem decomposition, judgment of priorities, and aggregation of these priorities. AHP gives a very flexible way for solving such problems and can be adapted to any number of attributes with any number of sub-attributes. In the first phase, the ranking of a complex problem is modeled in a hierarchy structure that specifies the interrelation among three kinds of elements, including the overall goal, QoS attributes and their sub-attributes, and alternative services. The second phase consists of two parts: a pair wise comparison of QoS attributes is done to specify their relative priorities; and a pair wise comparison of Cloud services based on their QoS attributes to compute their local ranks. In the final phase, for each alternative service, the relative local ranks of all criteria are aggregated to generate the global ranking values for all the services.

Therefore, to rank Cloud services based on multiple KPIs,a ranking mechanism based on Analytic Hierarchy Process (AHP) is used. There are three phases in this process: problem decomposition, judgment of priorities, and aggregation of these priorities. AHP gives a very flexible way for solving such problems and can be adapted to any number of attributes with any number of sub-attributes. In the first phase, the ranking of a complex problem is modeled in a hierarchy structure that specifies the interrelation among three kinds of elements, including the overall goal, QoS attributes and their sub-attributes, and alternative services. The second phase consists of two parts: a pairwise comparison of QoS attributes is done to specify their relative priorities; and a pairwise comparison of Cloud services based on their QoS attributes to compute their local ranks. In the final phase, for each alternative service, the relative local ranks of all criteria are aggregated to generate the global ranking values for all the services.

# 7. Time complexity of AHP

In this section, i discuss the time complexity of the AHP based-ranking algorithm, which is used by SMI Cloud for each user request. The ranking mechanism consists of multiple phases. The first phase, the data have to be retrieved based on user specific requirements and then to construct a hierarchy structure for cloud services, is a onetime computation and will remain the same for all other requests. Thus, the time complexity of AHP depends mainly on the other three phases. Let there be *m* number of services to be compared, and L levels of attributes; each level has  $N_1$ number of attributes and  $n_{li}$  is the number of sub-attributes at level *l* of the *i*th attribute at level  $l \Box 1$ .

For Phase 2, we need to compute relative weights for each QoS KPI. If the user assigns weights to KPIs between 0 and 1, then the time complexity of computing relative weights is linear. However, if the user assigns weights using AHP's standard method, then the time complexity of calculating the normalized weight vector for a group of sub-attributes is equivalent to the time taken for computing an eigenvector of

size  $n_{li}$ , i.e.,  $O((n_{li})^3)$  [17]. Therefore, the time complexity of

computing relative weights for each level and each attribute

is 
$$O(\sum_{l=1}^{L} \sum_{i=1}^{N_l \sqcup 1} ((n_{li})^3))$$
.

For Phase 3, we calculate the relative weights of each Cloud service for the lowest level attributes. Since there are m services, the time complexity is  $O(m^3 N_I)$ .

For Phase 4, aggregation of all relative ranking is done from bottom to top of the hierarchical structure constructed in the first phase. Each level has  $N_l \hat{a}^{*1}$  groups of attributes and

each group has  $n_l i$  attributes that need to be aggregated for each service. The time complexity of aggregating all attributes at a level is the multiplication of two matrices, i.e.  $O(N_l m)$ . For all attributes at all levels, the time complexity is

$$O(m\sum_{l=1}^L N_l) \, .$$

# 8. Related Work

In the table 1 values of Scale up, Scale out, API, Free trial and certification are considered to be Boolean and while calculations if yes it is considered 1 and if no it is considered as 0.

Also values for Sustainability, Reliability, Encryption technique used, Virtualization technique used are also Boolean with good, average and bad. They are considered as 1, 0.5 and 0 respectively during calculations.

By considering an example result is shown in below steps. Step 1: User register with user name and password with his location as Bangalore, Karnataka

Step 2: User login using his credentials.

Step 3: Click on services and enter the requirements

OS = Windows

Cost = 200\$

Service = IAAS Capacity = 100GB

Step 4: Dataset is processed with a query to fetch service provider's data which corresponds to user query where cost is less than and capacity is greater than the specified value is fetched and executed further.

Step 5: For each attribute Max value of that attribute is fetched like max in sustainability is 1 and all the values is divided by that max value. But in case of distance max value is 8825.015 here if we consider this, it will give wrong result since the rating for near distance should be higher than that of far distance so here after dividing by max it is subtracted 1.

Step 6: Then all the values are multiplied by respective weights as in the Table 2. And results will be added to get the sum and based on the sum it is arranged in descending order to get the ranked list of service providers. Results are shown in Table 3.

### 9. Result and Discussion

With the result I can conclude that for the user requirements AT&T is the best option.







Graph 3: Cost Graph



Graph 9.5: Performance Graph

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Graph 4: Assurance Graph



Graph 5: Security Graph

Table 1: Complete data set												
NAME	Amazon	Rackspace	GoGrid	Terremark	AT&T	Google	OpSource	Softlayer	HP	Microsoft Azure	Bit Refinery	DigitalOcean
SUSTAINABILITY	good	good	good	good	good	good	good	good	good	good	good	good
USER RATING	5	4	4	5	5	5	5	5	5	5	5	5
SERVICE	IAAS	IAAS	IAAS	IAAS	IAAS	IAAS	IAAS	IAAS	IAAS	IAAS	IAAS	IAAS
PLATFORM	Java	Java	Java	Java	Java	Java	Java	Java	Java	Java	Java	Java
os	Windows, Linux	Windows, Linux	Windows, Linux	Windows, Linux	Windows, Linux	Windows, Linux	Windows, Linux	Windows, Linux	Windows, Linux	Windows,Linux	Windows,Linu x	Linux
NOD	10	6	5	10	26	11	5	7	3	10	7	4
RAM	7.5	8	5	8	8	8	4	4	8	8	8	4
DISK	160	120	200	50	200	200	40	60	100	120	120	80
API	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
SCALE UP	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
SCALE OUT	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
COST	66.43	292	116.8	138.9	121.3	42.42	95.63	182.5	87.6	267.84	279.6	80
DATA TRANSFER OUT	0.12	0.18	0.29	0.17	0	0	0.15	0.1	0.05	0.02	0	0
DATA TRANSFER IN	0	0	0	0.17	0	0	0	0	0	0	0	0
ART	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CPU SPEED	2.6	2.3	2.9	3	2.4	2.75	2.1	2	2.7	1.6	2.1	3
LOCATION	Virginia, California, Oregon, Brazil, Ireland, Germany, Singapore, Tokyo, Beijing, Sydney	Texas, Illinois, Virginia, the United Kingdom, Australia, Hong Kong	San Francisco, California, Ashburn, Virginia, Amsterda m, The Netherland S	United States, Europe, Latin America	Ashburn, Austin Texas, Batiment, Chai Chee, Dallas, Frankfurt, Hawthorme, Hong Kong, Bangalore, London, New York, Sydney, Tokyo, Shanghai	Douglas County, Quilicura,Saint Ghislain, Hamina,Jurong West,Changhu a County	California, Virginia, the United Kingdom	Hong Kong, Jurong, Amsterdam, Chantilly, Dallas, Plano, Houston, Santa Clara, Seattle, Frankfurt	California	California, Brazil, Beijing, Shanghai, Hong Kong, Singapore, Dublin, Ireland, Netherlands, Saitama, Osaka, Melbourne	Denver, Seattle, Chicago, New York, England, Atlanta	New York, Amsterdam, San Francisco, London, Singapore, Frankfurt
AVAILABILITY	99.99	100	100	99.9	99.95	99.95	100	100	99.95	99.95	100	99.9
RELIABILITY	good	good	good	good	good	inadequate	good	good	good	inadequate	good	good
SLA	99.95	99.9	100	100	99.9	99.95	100	100	99.95	99.95	100	99.99
FREE TRIAL	Yes	No	No	No	Yes	Yes	No	No	No	Yes	No	Yes
CERTIFICATION	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
ENCRPTION TECHNIQUE	good	good	good	good	good	good	good	good	good	good	good	good
Virtualization Technique	good	good	good	good	good	good	good	good	good	good	good	good

	Т	Table 2: Weights			
LEVEL 1	ACCOUNTABILITY(0.05)	AGILITY(0.2)	COST(0.2)		
LEVEL 2	Sustainability(0.5) User Rating(0.5)	Service(0.1) Platform(0.1) OS(0.1) N O Data Centers(0.1) RAM(0.1) Disk(0.2) API(0.1) Scale up(0.1) Scale out(0.1)	Cost per month(0.4) Data Transfer out (0.3) Data Transfer in(0.3)		
LEVEL 1	PERFORMANCE(0.3)	ASSURENCE(0.2)	SECURITY(0.05)		
LEVEL 2	Average response time(0.2) CPU time(0.2) Distance(0.6)	Availability(0.2) Reliability(0.2) SLA(0.5) Free trial(0.1)	Certification(0.4) Encryption technique used(0.3) Virtualization technique used(0.3)		

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NAME	AT&T	Google	HP	Amazon	GoGrid
SUSTAINABILITY	0.025	0.025	0.025	0.025	0.025
USER RATING	0.025	0.025	0.025	0.025	0.02
SERVICE	0.01	0.01	0.01	0.01	0.01
PLATFORM	0.01	0.01	0.01	0.01	0.01
OS	0.02	0.02	0.02	0.02	0.02
NOD	0.02	0.008462	0.002308	0.007692	0.003846
RAM	0.02	0.02	0.02	0.01875	0.0125
DISK	0.04	0.04	0.02	0.032	0.04
API	0.02	0.02	0.02	0.02	0.02
SCALE_UP	0.02	0.02	0.02	0	0.02
SCALE OUT	0.02	0.02	0.02	0.02	0.02
COST	0	0.052023	0.022226	0.036188	0.002968
DTO	0.06	0.06	0.049655	0.035172	0
DTI	0	0	0	0	0
ART	0	0	0	0	0
СТ	0.010345	0.003103	0.004138	0.006207	0
DISTANCE	0.18	0.140041	0	0.139907	0.082823
AVAILABILITY	0.03998	0.03998	0.03998	0.039996	0.04
RELIABILITY	0.04	0.02	0.04	0.04	0.04
SLA	0.0999	0.09995	0.09995	0.09995	0.1
FT	0.02	0.02	0	0.02	0
CERTIFICATION	0.02	0.02	0	0.02	0
ET	0.015	0.015	0.015	0.015	0.015
VT	0.015	0.015	0.015	0.015	0.015
SUM	0.730225	0.703559	0.478257	0.655862	0.497137

#### Table 3: Calculated values

#### **10.** Conclusion

This work focused on helping the user in selection of those service providers which will serve their requirement. The Ranked list of eligible service providers will be the result given to the user and it is designed using AHP (analytical hierarchical process) with weighted ranking method.

### **11. Future Work**

This work made use of static data sets which were taken from different providers site. Hence future work can focus on dynamically capturing those data sets or giving a real time platform for service providers to update and advertise their services. Also future work can focus on adding new quality of service attributes which may be main criteria in choosing service providers.

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