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A Framework for Negotiating Service Level Agreement of Cloud-based Services

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Abstract

Cloud-based services have become the backbone of IT industry nowadays and the promising technology that offers a commoditized service to the software, the platform and the infrastructure where they are delivered as a service. Because several providers have started to offer a vast diversity of Cloud services, Cloud customers became unable to decide whose services they should use and what is the basis for their selection. Therefore, a legal contract is necessarily needed for negotiating these both Cloud parties. This contract is referred to Service Level Agreement (SLA). A SLA negotiation between Cloud parties assists in defining the Quality of Service (QoS) requirements of critical service-based processes. In addition, the role of third party in the negotiation process that is represented in Cloud broker will recommend customers to achieve the required service efficiently when negotiating with multiple providers. Currently, there is no framework that can allow customers to evaluate Cloud offerings and rank them based on their interests. Thus it is important to have a methodology that might map the customers' requirements referred as Service Level Objectives (SLO) with the most reliable Cloud service. In this work, we address this problem by presenting a proposed framework that intends to empower customers to evaluate and select between the different Cloud service offerings. This proposed framework aims to formalize the SLA with precise and unambiguous definition of services key performance indicators (KPIs) to support automated negotiation on the details of the agreement for both contracted parties. Our reasoning evaluation of proposed framework proved the importance of negotiation process for both Cloud parties in mapping the Cloud services with the customers' requirements.

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Keywords: Cloud services, SLA, QoS, Cloud Broker , SLO, KPIs

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1 Introduction

Cloud Computing is a new trend in IT field where the computing resources are delivered as a service. These computing resources are offered as pay-as-you-go plans and hence have become attractive to be cost effective for customers rather than the traditional infrastructures. [1] As customers delegate their tasks to more and more Cloud providers, it's important to have a SLA between customers and providers which makes it a key performance. With the high emergence of Cloud customers' requirements with variant specifications and the high emergence of Cloud service providers' offerings, thence SLA plays a central role in the Cloud services adoption by defining service requirements with providers' responsibilities to the service delivery to customers.

SLA refers to the contractual obligations between a service customer and a service provider, representing guarantees of QoS requirements which are defined in SLA as SLO that is priority of the service customer and promises of the Service provider. [2]

SLA should contain a) set of Services that provider will deliver with a complete and specific definition of each service, b) the terms of Agreement should be clearly defined and anticipate future problems e.g. (Upgrading Services) c) set of QoS metrics [3] to measure whether the provider is offering the services as guaranteed, d) an auditing mechanism to monitor the QoS and e) the remedies available to customer and provider if the terms are not satisfied.

The automated formation of SLA requires precise and unambiguous definition of the agreement as well as customizable engines to support automated negotiation on the details of the agreement for both contracted parties. Intelligent Agents [4] can perform SLA negotiation on behalf of customers and providers but, as humans, they need to converge on both a common meaning of the terms used in the communication and the offered services to have effective discussions on a SLA.

As the Cloud customers are not aware of the process of verifying the SLA, it's necessary to have trusted third party who manages and monitors the SLA verifications and assurance.

Many customers are still skeptical about Cloud providers' QoS promises because of the gap between these promises and the SLAs that these providers offer. Reducing this gab is the motivation of this study by contributing a framework that intends to empower customers in selecting the most reliable provider and aims facilitating wider adoption of Cloud services and enable providers to offer a wider set of services through approach that recommends customers with the service provider who match their interests specifications and enable the provision of QoS guarantees. Furthermore, formalizing the SLA which guarantees the customers' rights and maps their specifications through composing the SLOs with trustful KPIs in a higher precision to manage and bridge the gap between the QoS hype and SLA reality.

The paper is organized as follows: Section II introduces Cloud services and SLA negotiation; related work is described in Section III. Section IV deals in detail with the proposed framework and its mechanism, while Section V will observe the experimental study Section VI draws some final conclusions and future work.

2 Cloud Services and SLA Negotiation

Cloud computing employs a service-driven business model. In other words, hardware, platform and software level resources are provided as services on an on-demand basis. [5] Cloud service models can be classified into three categories; a) Infrastructure as a Service (IaaS), b) Platform as a Service (PaaS) and c) Software as a Service (SaaS). [6]

In order for Cloud providers to supply customers with services that meet their quality constraints, they both need to negotiate the customer's request and the provider's infrastructure capabilities, and then agree to certain conditions.

SLA negotiation, consumers and providers establish an agreement specifying the service nature and the level of QoS which must be guaranteed to the customer. Therefore the importance of SLA negotiation is twofold: in a first phase, it allows the customer to discover/propose the important characteristics of the service; in a second and final phase, customer and provider sign a formal and clear agreement about the rights/obligations of provider and customer. [7] In the common practice, Cloud providers publish the characteristics of the offered Cloud services in a way that makes a comparison a boring and tedious task. As a consequence, the customer has to perform complex and boring converse tasks to compare different deals for Cloud services. Hence, this study proposed a framework that intends to enhance the process of searching the required service among the diversity of Cloud services offerings from different Cloud providers through a VCloud director solution that identify the customers' requirements before empowering customers to request services and sign the SLA.

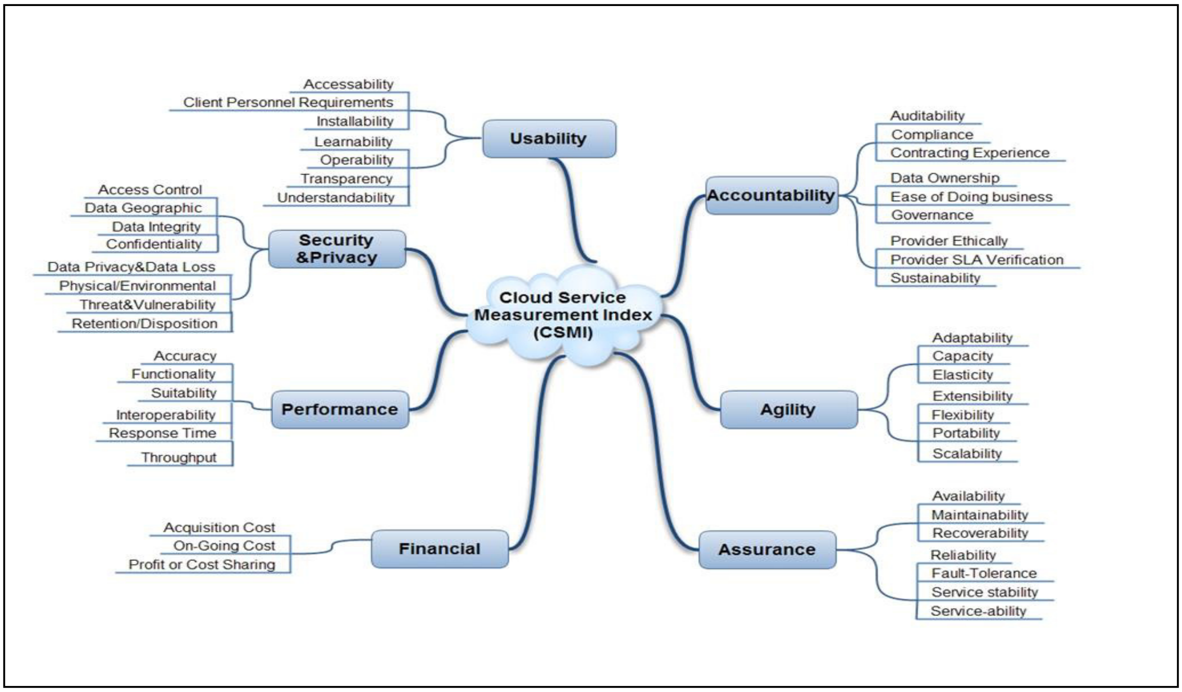

Fig. 1 Cloud Service KPIs

Figure 1 shows the SLA parameters (KPIs metrics) [8] that are usually inferred from functional and non-functional requirements. These parameters may be associated to one or more service type.

In a simplified SLA negotiation protocol, the provider sends to the customer a "template" with the proposed values for several different SLA parameters, which is eventually signed by the customer in a revised form.

3 Related Work

There is a wide-range of works around the SLA for Cloud Computing. Thus in this section, we compare and contrast our work with previous research work for evaluating and comparing the performance of different Cloud services.

With the increasing popularity of Cloud computing, many researchers studied Web-based SLA. For instance, Keller, A., & Ludwig, H. [9] presented a Web Service Level Agreement (WSLA) that intended to develop flexible SLA specification and monitoring framework that focuses on web-services. The negotiation process has already been established between the Service customer and the Service provider. The management deployment is used to monitor the SLA parameters from metric functions. WSLAs are usually defined and described by a service description language, and providing an efficient way for service- advertising and discovering. On the other hand Torkashvan, M., & Haghighi, H [10] proposed Cloud based SLA Management (CSLAM) that is built based on WSLA but with some additions and changes to fit into Cloud environment. It supports specific life cycle of Cloud SLA management. The life cycle of CSLAM starts from SLA parameters of major Cloud services that has been defined in the established SLA document going through the deployment phases to monitor and measure the service parameters then verify if there any violations or not from the Service provider Side. It differs from WSLA that CSLAM did not require standard language for Cloud service description that can be published on the internet.

Unlike these previous works in which the negotiation process has already been established and the SLA has been signed and then going through the deployment of SLA assessment, our proposed framework intends to monitor and deploy the assessment of providers' services before the SLA negotiation process .

Nie, G., Xueni, E., & Chen, [11] enhanced the CSLAM which is based on WSLA with the coordination model and management model by adding the third parties agent who is responsible for the negotiation for the service-composition either is the coordination of negotiation for multiple services to ensure end-to-end QoS or the negotiation between the service customer and one or many Service providers. This framework didn't clearly observe if the role of third-party was confined on negotiation process only or combined with development, deployment, measurement, assessment, and management to fit the nature of Cloud Service.

Yan, S., Chen, C., Zhao, G., & Lee, B. S. [12] proposed a framework for enterprises to recommend and select Cloud services according to business requirements, company policies, standards, and the specifications of Cloud offerings.

Our work complements this previous study by presenting the VCloud director solution which enables customers to define their QoS requirements in order to be verified and mapped with the providers' services and their regulations.

4 Proposed Framework Conceptual design

With the expansion of Cloud Computing, there's high emerge of Cloud providers and Cloud resources; therefore, it is troublesome for Cloud customers to pick out the most reliable providers or service resources. It's vital to possess a technique that maps the customers' requirements and their SLO outlined within the SLA.

The main intention of this work is to introduce an approach that recommends the Cloud providers' catalogue of services and assists the Cloud customers to select the most reliable one through integrating the automatic SLA negotiation with the measurement of service quality parameters to make sure that they're secured from the Cloud Service provider through the SLA that is accountable for mapping the customers' SLOs and their specifications. In addition, indexing and ranking the Cloud providers according to their offerings. Fig.2 will show the proposed framework that consists of five main agents modules; a) Cloud provider module b) VCloud director module c) Cloud customer module d) Cloud auditor module e) Cloud broker (SLA negotiation and Selection of Cloud provider) module

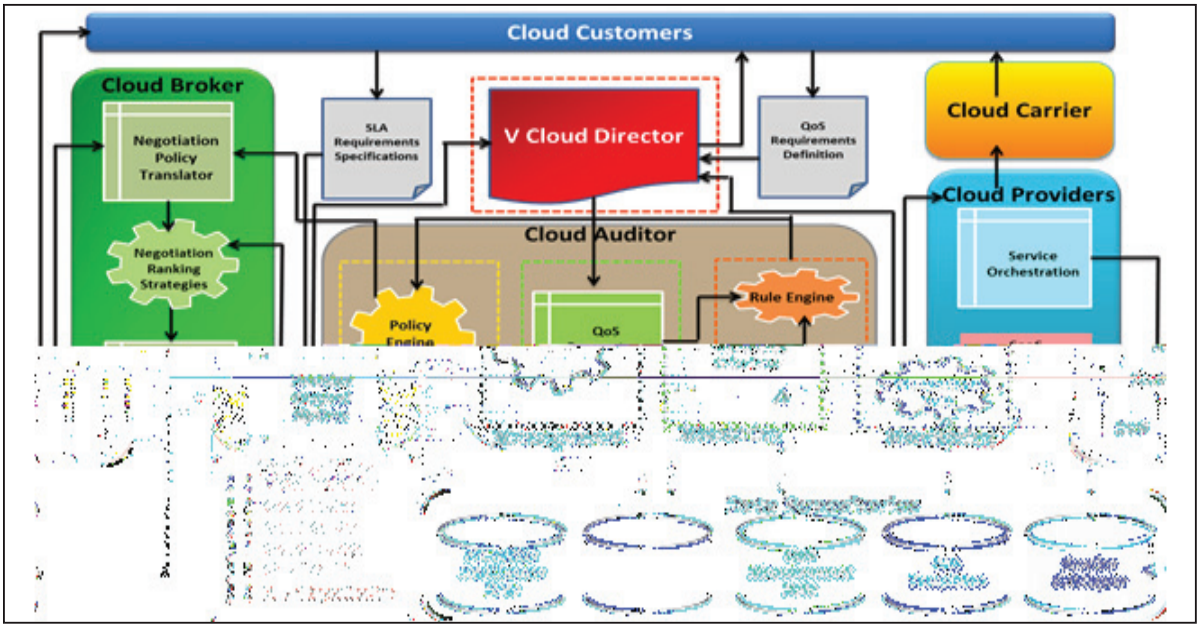

Fig. 2 Proposed Framework Conceptual Design

4.1 Cloud provider Module

Cloud Service provider is responsible for making a service available to interested parties. It acquires and manages the computing infrastructure required for providing the services, runs the Cloud software that provides the services, and makes arrangement to deliver the Cloud services to the Cloud customers through network access. Cloud provider conducts its activities through a service orchestration

The Cloud Service provider agent comprises the following components.

- *Resource Abstraction:* entails software elements, such as hypervisor, virtual machines, virtual data storage supports software components, realizes the infrastructure upon which a Cloud service can be established.
- *Service Orchestration:* refers to the arrangement, coordination and management of Cloud infrastructure to provide different Cloud services to meet IT and business requirements.
- *Service Catalogues*: a repository to store all the specifications of various Cloud service offerings from Cloud providers which can be in either private or public Cloud.

The Cloud provider agent normally communicates with other parties.

- *VCloud director interface:* The Cloud provider announce its service level capability as an advertisement in a VCloud directory as it is considered the service registry
- *Inventory Management interface*: Set up and manage service catalogues, involves creating and maintaining a service catalogue. It ensures that the information in the service catalogue is accurate and up-to-date. It ensures that the service description is unambiguous and valuable to customers.
- *Contract Management interface:* Manage service contracts, setup, negotiate, close, terminate contract.
- *SLA broker as interface:* Creates a SLA between Cloud provider and SLA Carrier in order to transport Cloud services to the customers.
- *Cloud carrier as interface:* sends the SLA to the SLA templates repository in order to be monitored and managed.

4.2 VCloud Director Module

VCloud Director orchestrates the provisioning of software-defined datacentre services as complete virtual datacentres that are ready for consumption in a matter of minutes. Software-defined datacentre service and the virtual datacentres fundamentally simplify infrastructure provisioning, and enable IT to move at the speed of business. [13]

VCloud Director is a software solution that enables Cloud User access management. It allows creating and publishing service offerings, such as virtual machines, with specific configurations and applications via a service catalogue. It allows Cloud service customers to request for a service through a Web-based User interface. Customers may select a service from a service catalog that is available through the User interface. VCloud Director also provides an authentication mechanism to verify customer identities before empowering them to request for services. The VCloud director solution comprises the following components.

- *QoS Requirement Repository:* it is a repository that contains all customers' requirements specifications that are mapped to the Service QoS parameters which will be measured to check its validity.
- *Reputation System:* it is an intelligence system that collects the reputation about the Cloud providers either from social media, users' preferences, or feedback rating. (Collective Intelligence)
- *Provider Service Catalogues:* a repository to store all the specifications of various Cloud service offerings from Cloud providers which can be in either private or public Cloud.

The VCloud director normally communicates with other parties.

- *Cloud auditor interface:* provides a valuable inherent function by conducting the independent monitoring of Cloud services.
- *Cloud customer interface:* an individual or small enterprise or organization that request acquires and uses Cloud products and services.
- *Cloud provider interface:* represents the supplier of Cloud products and services.

4.3 Cloud customer Module

The Cloud customer comprises the following components in the proposed framework as follows

- *The VCloud Director:* as discussed before, it's a web-based User interface that enable customers to define their QoS requirements in order to empower them to select and request the service from the most reliable provider.
- *QoS Requirement Repository*: is the repository that contains all of QoS requirement that are translated to QoS Parameters that are collected from service catalogue repository and calculated in the monitoring phase in order to generate the QoS reports and recommending the ranked providers and create the SLA.
- *Negotiation Policy Translator*: Maps customers' QoS requirements according to Cloud provider service catalogues.
- *Monitoring & Reporting interface:* Discover and monitor the virtual resources, monitor Cloud operations and events, and generate performance reports.

The Cloud customer is also communicates with other parties as follows;

- *Cloud auditor as interface:* provides the monitoring of QoS requirements results to the decision support system which provides the VCloud director with the ranked providers with the required services
- *Cloud broker as interface:* After the customer gets the result about the ranked providers. They send their decision to the broker to create the SLA with their measured specifications.

4.4 Cloud auditor Module

As discussed earlier, the comprehensive SLA management over the lifetime of SLA includes monitoring process in order to make the SLA formation between customer and provider. Figure 5 will be illustrated the components of TP Cloud auditor interfaces with them.

- *QoS Parameters Calculator:* retrieve the QoS parameters from the QoS Measurement Data Repository in order to be calculated to accomplish the validation of these parameters.
- *Comparison Rule:* are the conditions used to trigger an alarm if there any violations in the SLA.
- *Rule Engine:* compares the QoS data calculated by QoS Calculating Layer with appropriate SLA contract and Comparison Rules, to detect if the QoS is in conformity with that in SLA.
- *SLA management Interface:* Encompasses the SLA contract definition (basic schema with the quality of service parameters), SLA monitoring, and SLA enforcement, according to the defined policies.
- *Monitoring & Reporting interface:* Discover and monitor the virtual resources, monitor Cloud operations and events, and generate performance reports.

4.5 Cloud broker Module (SLA negotiation and Selection of Cloud provider)

After listing all of the proposed framework modules that interface with other framework components, the selection process will be deployed and fig.6 shows how the selection process can be fulfilled and how the component parties interface with it and the SLA formation between the Cloud provider and Cloud customer. The Module comprises the following constraints.

- *Negotiation policy Translator:* is the set of references to remote the SLA providers' services catalogues to be mapped with the Cloud customers' QoS requirements.
- *Negotiation Ranking Strategies:* fitches additional information about the Cloud Service provider's reputation in order to rank it and provide the VCloud Director with the feedback.
- *Decision Support System:* when the customers receive the feedback information about ranked providers, they send their selection to the broker decision support system to create the SLA between the Cloud provider and the Cloud customer. In addition, the provider requests from broker to create SLA between Cloud carrier and Cloud provider in order to transform the Cloud services from the provider to customers.

5 Experimental Study

There are many different services offered by Cloud providers addressing the IT needs of different organizations. Each service has different performance in terms of efficiency, response time, resource utilization, accuracy, and stability. Organizations (customers) need to understand how their applications will perform on the different Clouds and whether these deployments meet their expectations.

The study is based on the proposed framework. Figure 3 shows the testing environment that have been implemented in EMC2 Co. [14] through their testing lab which consists of two physical Dell servers that are connected through Storage Area Network “SAN” with the Fibre Channel Switch to EMC VNX Storage Array in addition to the vSphere customers.

V Sphere clients are the interface that allows customers to connect remotely to V Center Server from any Windows PC [15]. It is used to configure the host and to operate its virtual machines. The V Sphere clients are connected via Ethernet Switch to access the hosts.

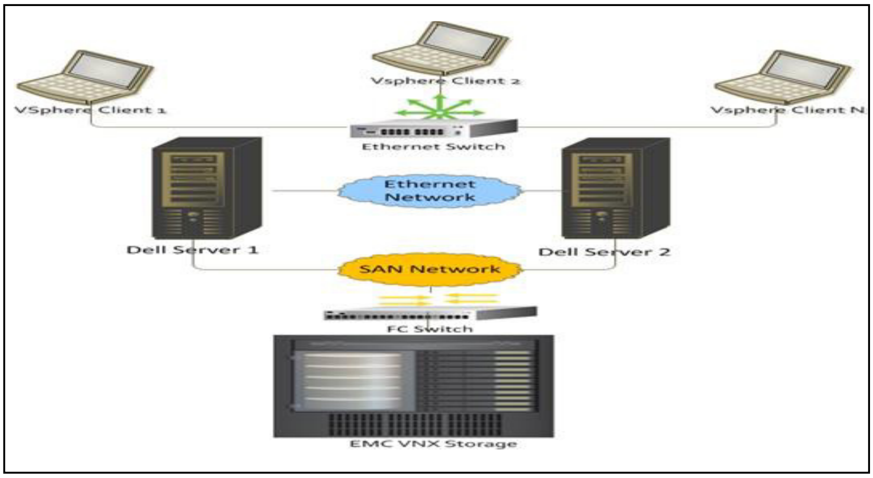

Fig.3 Testing Environment

Till now, there is no standard benchmark for Cloud environment. It is still an open research area to build our benchmark that considers SAP, SQL, and Oracle are the customers' applications they own and they request infrastructure and platform as a service with the following specifications in the table.1 for measuring the utilization of requested resources (CPU, Memory, and Network) provided by EMC2 and running a testing scenario to measure the response time of the three applications running on the Cloud to evaluate the performance of the service provider and ensure the Cloud efficiency.

Table1. Specifications of customer's Requirements

OS	*CPU*	*Memory*	*Network*
Windows 7 64bit	1 VCPU= 3GHz	2GB RAM	1 Ethernet Adaptor with 1000Mb/s Base T

The basic requirements of infrastructures are represented in CPU, RAM, and Network. In addition, the windows OS is required for the platform.

We tested the three applications I/O Characteristics by using Iometer application [16] applied on the testing Cloud in order to measure the Cloud efficiency.

The efficiency and monitoring the performance of Cloud service are measured by Resource utilization and Response Time. The Cloud system efficiency as shown in eq.1 indicates the effective utilization of leased services and how fast the service is provided. [18]

$$\text{Efficiency} = W_{\mathrm{RU}}.\,\mathrm{RU} + W_{RT}.\mathrm{RT} \tag{1}$$

Resource utilization [18] measures a ratio number of assigned resources for the pre-defined resources as referred in Eq.2.this provides imagination about how much of the VM is being utilized and this data helps in analyzing the resource utilization by applications on the scaling requirements. This can be computed as;

$$\mathrm{RU} = \frac{\text{Number of allocated resources}}{\text{Number of predefined resources}} \tag{2}$$

Equation.3 shows the Application Response time (ART) which is the key metric in application performance management which actually calculates the time taken when the Database Query Application sends a request to the server to the time it receives a response packet. [19]

Response time = Execution Time + Waiting Time (3)

We run our testing for 6 hours and the following table.2 will show the input I/O characteristics of the benchmark applications workload. [17]

Table2. Applications I/O Characteristics

In Terms of	*SAP*	*SQL*	*Oracle*
Max. IOPs	11200	11200	11200
Read Ratio %	88	88	88
IO Size (Byte)	20500	8192	16000
Testing Duration (hours)	6	6	6
IO Alignment	1 MB		
Burst Length	1 IO		

The process of ranking, selecting and recommending customers with the most reliable Cloud provider is implemented through the following steps;

Step1: collecting the required data for performance KPI metrics regarding Cloud efficiency from the evaluation of benchmark

Step 2: calculating the Cloud efficiency for each available Cloud provider

Step3: assigning weights to the requested resources utilization and response time. These weights are assigned based on each customer's own scale

Step4: assigning weights to the top level of QoS performance KPIs and e) ranking and selecting the service provider through Analytical Hierarchy Process (AHP) methodology by comparing each value Cloud Performance KPIs metric at more than one provider as shown in fig.4

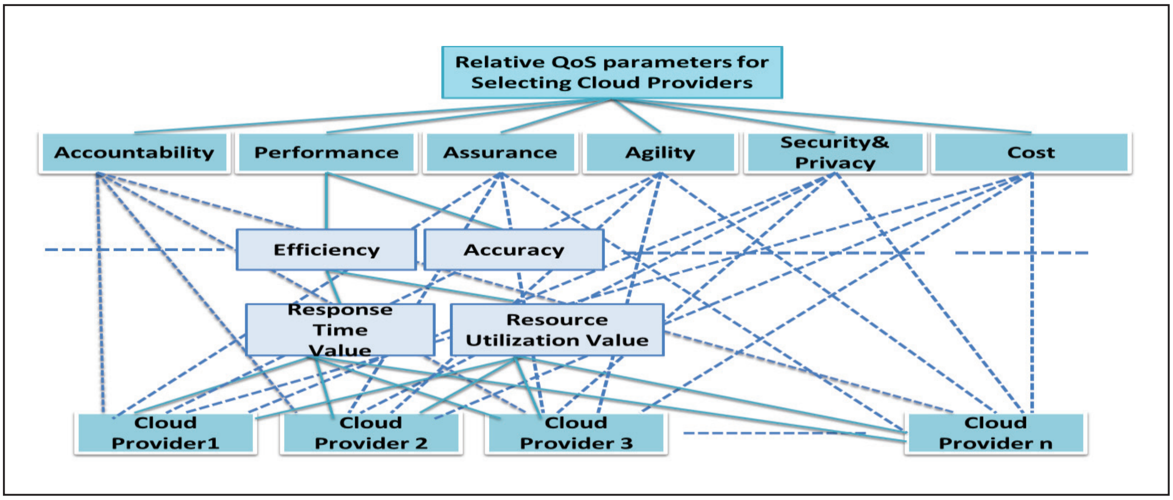

Fig.4 AHP for Cloud Service Provider

The results as shown in fig 5 clarifies that all customers' specifications of virtual CPU, Memory, and Network that are required to run their applications SAP, SQL, and Oracle are met with the defined criteria in the SLA but in different utilization performance average according to each application.

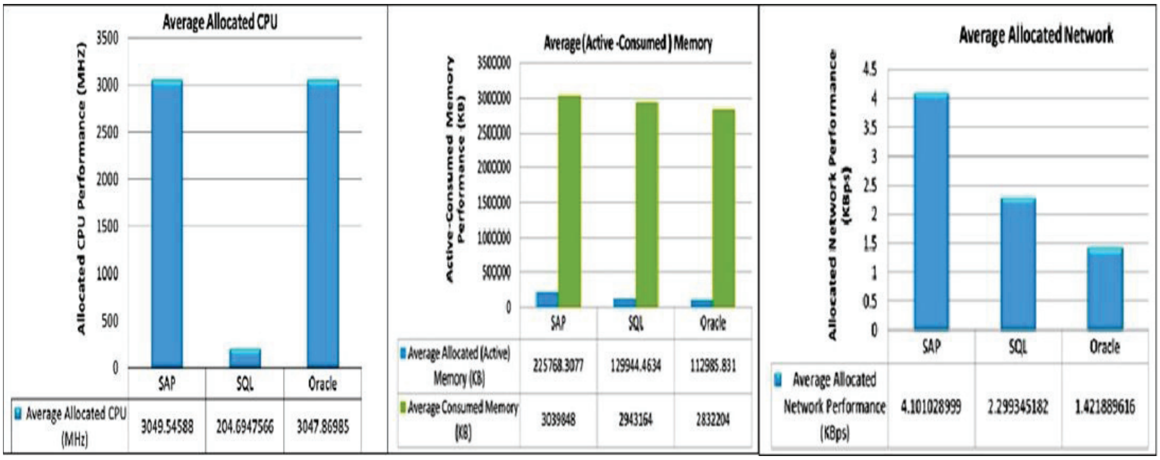

Fig.5 Allocated Resource Utilization Performance

The computation of the service provider indexing is done using the QoS data of efficiency that collected from the evaluation study of benchmark applications that run over the testing Cloud.

In the following, we show step by step the ranking computation process for Cloud service provider. Customers' weights are randomly assigned to each QoS KPI. The top level QoS groups are resource utilization and response time. They are also randomly assigned. For each attribute, a relative ranking matrix is constructed using the following method.

Computing the Relative Service Ranking Vector (RSRV) for the resource utilization.

$RSRV_{RU} = [0.700234 \quad 0.0744976 \quad 0.00000261]$

Combining the RSRV of (CPU, Memory and Network), then multiply it with the resources weights. We get Relative Service Ranking Matrix (RSRM) for the resource utilization

$RSRM_{RU} (0.700234 \quad 0.0744976 \quad 0.00000261) (0.4)$

Therefore, we get $RSRV_{\text{resource utilization}}$ Value = [0.238]

Computing the average response time from the testing scenario that given by Figure 4-11. Therefore, we get the $RSRV_{\text{Response Time}}$ = [0.0161]

Finally, aggregating all the RSRVs of all efficiency KPIs and multiplying them with the weights of the top level of QoS KPIs to get the relative service ranking matrix for the available Cloud provider.

Therefore, RSRV value for the Cloud provider = 0.1428

The relative ranking of Cloud provider can be decided on the resultant RSRV which based on the customers' requirements.

The observed low values can be explained by the fact that customers did not utilize the allocated resources completely as they over request resources.

6 CONCLUSION AND FUTURE WORK

In this Work, we presented a framework for choosing the most reliable Cloud providers who can satisfy customers' requirements through the high emerging and diversity of their services' offerings. The proposed framework involves the context of SLA assessment that presents systematically the measurement of the QoS KPIs; which is represented in the resources utilization efficiency and the response time. The Analytical Hierarchy Process (AHP) has been applied in order to evaluate the Cloud services and ranking the providers by comparing each value result with efficient KPIs. Since there was no recommendation for the customers by the decision support system (Cloud broker), they unnecessarily over requested some of the resources and hence they were not fully utilized. The customers' requirements have been met by the provider despite of the fact that some of resources were not fully utilized. This study concludes the importance of the third party Cloud broker and auditor who can best match the requirements with the resources so that there will be no waste of resources and lower efficiency.

Future prospects include ranking methodology that will be enhanced by further investigation to comprise more than one Cloud provider in order to select the best one from the customers' perspectives to cope with the variations in the QoS parameters. The Quality model will be extended to include; the rest of QoS measurement KPI metrics and to involve the non-quantifiable QoS parameters. The Cloud "Software as a Service" will be extended to utilize services of the proposed framework; while provisioning resources and scheduling execution of applications. The proper Cloud services verification technique will further be investigated to be implemented by third party broker; in order to formalize and standardize the SLA.

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