International Journal of Technology (2016) 4: 643-653
ISSN 2086-9614 © IJTech 2016

FRAMEWORK FOR RANKING SERVICE PROVIDERS OF FEDERATED CLOUD ARCHITECTURE USING FUZZY SETS

L. Aruna[1*], M. Aramudhan[2]

[1] *Department of Computer Science, School of Mathematics, Periyar University, Salem 636011, Tamil Nadu, India*
[2] *Department of Information Technology, Perunthalaivar Kamarajar Institute of Engineering and Technology (PKIET), Karaikal 609603, Puducherry, India*

(Received: July 2015 / Revised: September 2015 / Accepted: January 2016)

ABSTRACT

Federated Cloud Architecture is a heterogeneous and distributed model that provides infrastructures related to the cloud by aggregating different Infrastructure-as-a-Service (IaaS) providers. In this case, it is an exciting task to select the optimal service cloud provider for the customer and then deploy it. In this paper, a new provider discovery algorithm and fuzzy sets ranking model is proposed in the modified federated architecture and then the performance is evaluated. The proposed discovery method shortlists the provider based on the Quality of Service (QoS) indicators suggested by the Service Measurement Index (SMI) with the Service Level Agreement (SLA) that provides improved performance. In addition to that, the cost is also included that represents the fulfillment at the level of the end user. The ranking mechanism is based on a Fuzzy set approach, having three general phases, such as problem decomposition, judgment of priorities and an aggregation of these priorities. With some simple rules, the fuzzy set may be combined with the QoS indicators. The Weighted Tuned Queuing Scheduling (WTQS) Algorithm is proposed to resolve the issue of starvation in the existing architecture and manage the requests effectively. Experimental results show that the proposed architecture has a better successful selection rate, average response time and less overhead, compared to the existing architecture that had supported the Cloud environment.

Keywords: Cloud ranking; Differentiated scheduling; Federated cloud architecture; Provider discovery

1. INTRODUCTION

Cloud computing is a promised paradigm that offers simple, flexible, scalable and a cost-effective outsourcing type of services, such as application development and hosting to customers on demand and who then pay per utilization. The Service Level Agreement (SLA) is an agreement that illustrates the level of performance assured by the provider on the user's side (Lu et al., 2016). In the current scenario, the SLA technique plays a major role that brings the confidence to the user, prompts business policies and ensures the Quality of Service (QoS) on the user's side. SLA management is provided in three phases, including SLA establishment, SLA negotiation, SLA monitoring and detecting violations. In terms of QoS, a cloud provider, in an agreement known as a SLA establishment, makes a commitment to the user; whereas during the SLA negotiation, the user discusses with the provide the required level of services.

*Corresponding author's email: arunaloga@gmail.com, Tel. 09843159445
Permalink/DOI: http://dx.doi.org/10.14716/ijtech.v7i4.1498

Any of these services consumed by the user are monitored by the provider, who is involved with detecting if there is any abnormality, which is then marked as violation. SLA is implemented between the cloud member (the user) and the cloud service provider for efficient processing of the federated cloud architecture (Aljawarnesh, S., 2011). SLA management is maintained in the proposed architecture by discovering and ranking the service providers for the user based on fuzzy sets.

Federated Cloud Architecture is a heterogeneous and distributed model that provides infrastructure related to the cloud by aggregating different Infrastructure-as-a-Service (IaaS) providers. In this case, it is an exciting task to select the optimal service cloud provider for the customer and deploy it. The Cloud Service Measurement Index Consortium (CSMIC) (http://www.beta.cloudcommons.coms) has identified some metrics in the form of the Service Measurement Index (SMI) that helps to evaluate and compare the services of different cloud providers. Based on these SMI metrics, ranking the cloud service providers is a challenging task, because the value of the metrics is determined and selected by the algorithm used for ranking the performance of the selected provider. In the proposed architecture, the Cloud Broker Manager is responsible for selecting the best cloud providers, in addition to performing QoS monitoring, SLA verification and ranking the matched service providers. The SLA is comprehensive for the user and the agreement encompasses discovering the appropriate service provider, describing and defining their services properly, negotiating and delivering the service as persuant to the agreement (Jrad et al., 2012). SLA level policies are monitored by the cloud Broker Manager for the specific user. If there is any violation found, then a penalty will be imposed.

Initially, differential treatment is applied to identify the category of the user, to maintain the SLA based on the user profile, to apply the concept of the fuzzy set to rank the Cloud providers and to allocate the top provider to the user. Strict differential treatment leads to starvation, but it is resolved using the proposed scheduling algorithm called Weighted Turned Queuing Scheduling (WTQS). The Cloud Broker Manager (CBM) is responsible for resource provisioning in the proposed Federated Cloud. Each provider has interconnections with the Cloud Broker Manager. The SLA is verified with the information available in the Cloud Broker registry for the user. In this paper, a new selection method is suggested that combines Quality of Service (QoS) indicators with the SLA that provides better performance. In addition to the new selection method, the cost is included that represents fulfillment at the level of the end user. It also describes how the SLA management is effectively designed for the users by enabling them to integrate the service levels and efficient interoperability is achieved using cloud brokers. This paper is organized as follows: Section 2 describes the related work of ranking the providers; Section 3 illustrates the architecture, discovery of providers and fuzzy set ranking technique; Section 4 reveals the performance of the proposed architecture and Section 5 discuss with conclusion.

2. RELATED WORK

Describe market-based provisioning policies for flexible allocation of resources to applications in the Cloud. (Buyya et al., 2009) Resource allocation was carried out based on the support for customer-driven service management based on customer profiles, Quality of Service requirements, risk management with respect to applications and sustainability of the SLA. This work was effectively implemented using the Aneka platform. Rule-based resource managers (Grewal et al., 2013) were proposed to utilize the private cloud resources, considering the security requirements of applications and data. The resource manager is the component that allocates the resources on demand, even when the cloud is overloaded. In the proposed approach, the user request is categorized by critical data processing and security. Based on the type of requests, priority is assigned and redirected to the suitable cloud.

A new framework is proposed for the Cloud that maintains the SLA by means of distinguishing the incoming requests, either as a SLA-based member or a SLA-based non-member, (Rajarajeswari & Aramudhan, 2014). This policy brings about starvation that can be avoided by introducing a new algorithm called Distributed Loose Priority- based scheduling. Additionally, the cloud providers are ranked, based on the plot care method and the average response time of the requests were calculated, analyzed and compared with the existing method. Ganghishetti et al. (2011) used the concept of rough set theory to allocate the best service provider to the cloud users with minimum searching time. A Cloud Broker was used in this architecture that helps to allocate resources based on the Service Level Agreement between users and providers for Infrastructure-as-a-Service (IaaS). Cloud providers publish their service along with all types of QoS parameters in the Cloud Registry and later the MCQoS algorithm is used to invoke it.

Discussed the framework, which (Buyya et al., 2009; 2011) measures the quality, prioritizes and selects the cloud services based on SMI metrics and ranks the services using the Analytic Hierarchy Process (AHP). It is one of the flexible ways for solving and adapting any number of attributes to any number of sub-attributes. The AHP model has three phases, such as forming an hierarchy structure, pairwise comparisons and to find aggregated value to generate the services ranking. Various authors have proposed a mapped service that contains a technique called Singular Value Decomposition (SVD), which is used for ranking the services in a statistical manner. Bathla et al. (2014) proposed a system called a Service Ranking System (SRS). This system has two types of ranking: static and dynamic. In the static ranking, all available cloud service providers are ranked without considering user requirements. But in dynamic ranking, suitable services are ranked based on user requirements. Czarnul (2013) has developed a simulator implemented in C and "...its goal is to model cloud provider offers over time and simulate execution of a ranking algorithm that would output certain scores for particular offers at particular moments in time." (Qu et al., 2014) proposed a system that evaluates a trust of clouds according to users' fuzzy Quality of Service (QoS) requirements and services for dynamic performance optimization to facilitate service selection. This framework used for ranking and reservation in the cloud service is based on a set of cloud computing specific performances and QoS attributes.

3. PROPOSED RANKING BASED ON FEDERATED CLOUD ARCHITECTURE

A modified Federated Cloud Architecture resource provisioning model consists of three phases, namely (i) Discovery of service providers (ii) Rank the selected service provider using Fuzzy logic sets (iii) Assign the service to the best service provider. The customized Federated Cloud Architecture is shown in Figure 1. The Broker Manager (BM) collects the various levels of services offered by the cloud service providers based on their different performance values through broker learning algorithms. Brokers manage the cloud service resources; the BM communicates with brokers and shortlists the providers. The Broker-based Learning Algorithm (BLA) is used to study the workload of the providers, necessary user tasks and resource requirements.

The Differential Service Module (DSM) in the Federated Cloud Architecture helps to identify whether the category of the user accessing the service belongs to either SLA or non-SLA with the help of the information available in the Profile Manager. Non-SLA requests are not considered for resource computation until there is a request that belongs to SLA in the queue (Garg et al., 2011). Instead of using this strict differential treatment, Weighted Turned Queuing Scheduling (WTQS) is proposed for differentiating and managing the requests fairly without starvation.

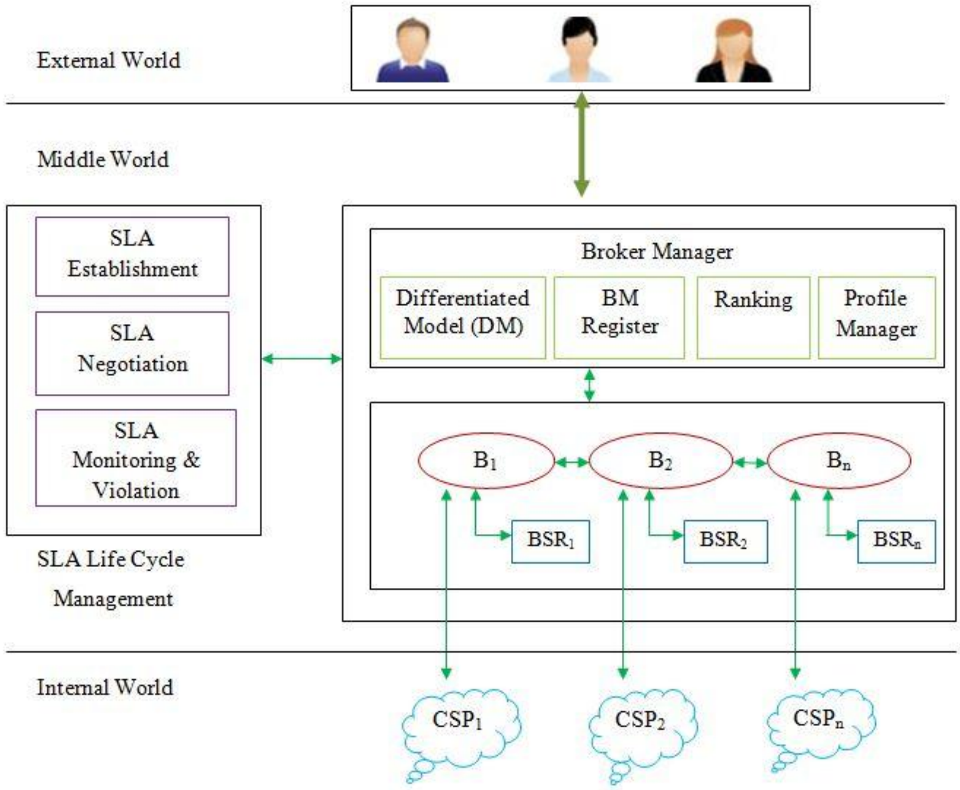

Figure 1 Customized Federated Cloud Architecture

Two queues are maintained at the application level and initially weight is assigned for the queue based on the priority. Weight denotes the number of requests that are to be considered for computation continuously from that queue. Later, the next queue requests are computed and vice versa. Cloud traffic is unpredictable and by its nature in a rush. Hence, the value of the weight assigned may be turned dynamically either increased or decreased, depending on the number of requests in that queue. When the number of requests in the queue is higher than normal, and then the weight to that queue is increased. The number of requests in the i^{th}queue is 'N_i'. From this example, the request in the queues are 35 and 20 respectively.

Then, deviation of the queue is calculated as D_i= (2 * 35)/55 = 1.272(>1) and D_j = (2 * 20)/55 = 0.727(<1). As given in the example, the weight for the queues is assigned as 10 and 3 respectively the new weights of the queues 13 and 2. This weighting is computed from the algorithm in Step 3. The summary of the steps for Weighted Turned Queuing Scheduling(WTQS) is shown below.

Step 1: Compute the number of requests in the queues.

Step 2: Calculate the deviation (D) of the queues using the formula in Equation 1 shown below:

$$Di= (n * R_i)/ N \tag{1}$$

'n' refers the number of queues. N denotes the total number of requests in the queues. R_i refers the number of requests in that queue.

Step 3: Calculate the new weight for the queue as shown in Equation 2 below:

$$New\_ weight_i =.Old\ \_weight_{\ i} * D_i \tag{2}$$

3.1. Layered Architecture of the Federated Cloud

Cloud computing may be delineated because the new era within the world of computing is composed of many layers, all of which may be accessed by users connected to the cloud. Understanding what functions every layer includes and how these layers interact with one another, as well as the necessity for numerous technological skills to form how the cloud weather will work along the way are all essential. This can be the foremost used layer of cloud computing. The cloud provides the desired responsibility within the management of the packages and databases, as well as installation, updates and removal. Cloud developers ought to have information in Java script, XML and Perl languages. The Layered Architecture is shown in Figure 2. Brokering functions in federated clouds at the IaaS layer may be rotten into two aspects, i.e. resource provisioning and resource adaptation. In resource provisioning, the foremost applicable mixture of resource categories and therefore the variety of nodes of every resource category are calculable based on the match of the desires of the appliance with confirmation of the user objectives (e.g., throughput) and constraints (e.g., precision). In SLA life cycle management, Layered Architecture is used most often in these activities, i.e. discovering the service supplier, defining the SLA and SLA violations, establishing the agreement level, and SLA termination operations (Buyya et al., 2009). The Broker Management Layer acts as a member between the users and the cloud providers. It also has the responsibility of resource provisioning in federated cloud.

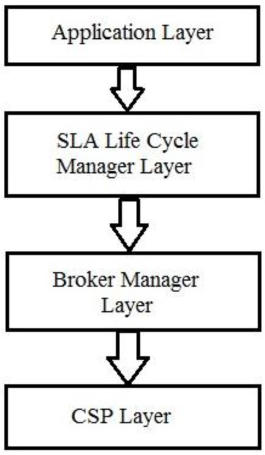

Figure 2 Layered architecture of federated cloud

There are four layers in the Federated Cloud Architecture. Layer 1 deals with the different cloud service providers and their resources. Layer 2 discusses the role of the brokers and their collected information from the CSPs. Layer 3 describes the level of SLA and its related functionalities. Layer 4 explains about the details of the applications and their requirements.

3.2. Discovery of Cloud Service Providers

The cloud provider selection algorithm uses quality metrics according to the Service Measurement Index (SMI). A shortlist of the matched providers depends on the SLA and its functional requirements. Let CP = {CP_1, CP_2….CP_n}, which is the list of cloud providers in the Federated Cloud (FC). Let CB = {CB_1, CB_2….CB_n), which is the list of cloud brokers that are connected to the Cloud Providers (CP), which in turn are connected to the Cloud Manager (CM) in the proposed Federated Cloud Architecture. The Cloud Broker considers the list of QoS indicators Q_i = {Q_1, Q_2, Q_3….Q_n} for the service requests submitted by the user, and then the cloud broker initiates the processing and shortlists the providers based on the value of the assured quality indicators. Then ranking is applied on the shortlisted cloud providers, using the fuzzy sets approach. In order to normalize the value of QoS indicators, the following characteristics are considered: QoS metrics are measured uniformly, qualities of the cloud providers are analyzed using a uniform index and a threshold value is assigned for the quality indicators, based on their priority. The matching cloud provider is identified by the representation of the given set as shown below in Equation 3:

$$MP = \{QI, FA, RCP, CCP, SLAF\} \tag{3}$$

MP denotes the Matching Provider. QI is the list of Quality Indicators recognized by the SMI. FA discusses the functional requirements. RCP refers to the resource demand by the service and released by the Cloud Provider. SLAF means Service Level Agreement Factor, which is computed from the RCP. Cloud providers are clustered based on the type of service referred to as the Clustered Cloud Providers (CCP). The functionality of selection provider discovery is shown in Figure 3. Information such as user desired performance and the corresponding price are registered in the Profile Manager and Cloud Broker calculates the ratio of desired performance to price and updates the value in the registry of the Broker Manager.

The user layer consists of users accessing the cloud services. The broker layer performs the selection of providers for the user. The layer consists of the Broker Manager; the combination, based on the service levels, performance and cost, of brokers, who are connected with providers, are clustered together In the Broker Registry, the broker manages information about the provider and helps to select the matching provider based on Equation 3. The Broker Manager shortlists the cloud providers and rank them, using fuzzy logic sets. The Resource Layer is comprised of cloud providers and brokers, using Service Mapping (SM).

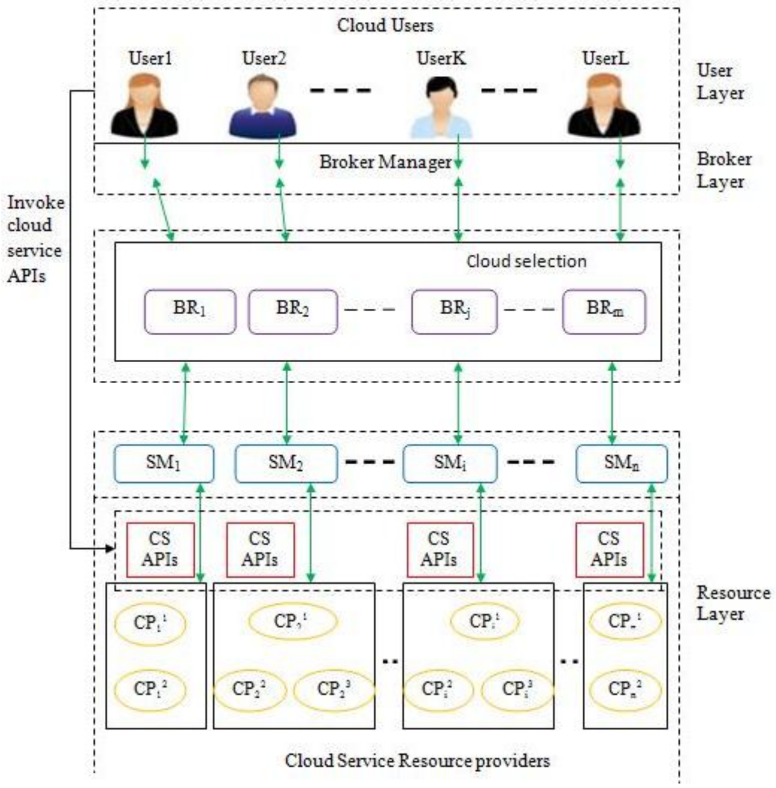

Figure 3 Discovery of the Service Provider (SP) in federated cloud architecture

Service Mapping(SM) can help the respective broker register the status of its connected provider in its registry, including the failures of some services. Each provider defines the API (Application Programming Interface) as a means invoked by the broker and used after finishing the process of cloud service selection. Cloud providers are clustered together based on the level of service group. The number of available and matched providers are shortlisted for ranking using fuzzy set logic. The detailed Service Selection Algorithm for cloud service provider selection is shown below.

Input: Registering and monitoring the availability of providers for selection.
Output: shortlisted provider for ranking.
1: SLA-Value= Max-Value; /*Register the value of SLA */
2. If there is any cloud providers register for the selection then
3. Broadcast the message from Broker Manager to the Brokers .
4.for each $Broker_i$ and $i \in [1,n]$ do
5. $Broker_i$ communicate with the provider
    5.1 compute $C\text{-}SLA\text{-}Value_j \leftarrow$ available (performance, security, usability, cost)
    5.2 update the value $BrokerRegistry_{i,j} \leftarrow C\text{-}SLA\text{-}Value_j$;
    5.3 Invoke Broker-selection algorithm.
    5.4 Study the $C\text{-}SLA\text{-}Value_j$ in broker information registry and form $Broker_j$ as clustered.
    5.5 Sends a register message from the $broker_j$ to Broker Manager along with $C\text{-}SLA\text{-}Value_j$;
    5.6 The $C\text{-}SLA\text{-}Value_j$ is updated in the table information of Broker Manager.
Endfor
6. At Broker Manager, compare if SLA-Value >C-SLA-Value then
7: Reject that provider, unsatisfied the SLA, confirm message is send to the broker for its unavailability in the selection list.
8 else
9 send confirm message to the broker for its availability in the selection list.
10. end if
11. end for
12endfor
13 endif
14. If cloud $provider_i$ is found to be a failure, the information is registered in the $BrokerRegistry_i$.
15 Auto message is send by the broker to Broker Manager
16. Update the status as unavailable for the selection.
17. end if

3.3. Ranking of Providers using Fuzzy Set

Classical set theory requires that each element of a set is included entirely within the set. Fuzzy set theory, a generalization of classical set theory, allows set elements to have partial membership and therefore allows representation of imprecise and qualitative information in an exact manner. There are numerous methods for establishing the proportion of membership between two adjoining sets. The appropriate method is determined by the context of a particular application. The Sigmoidal Membership Function is used to rank the cloud providers based on the following metrics, such as service response time, sustainability, suitability, interoperability, availability, reliability, stability and cost. Service response time is computed by means of how fast the service/resources can be assigned for usage. The Membership Function (MF) is mapped to a membership value between 0 and 1. Sustainability refers the environmental impact of the cloud service used. Suitability indicates the requirement of user met by the cloud provider. Accuracy denotes the service functionalities measured to suit the user's actual values when using a service compared to the expected values. Interoperability is defined as the ability of a service to interact with other services offered either by the same cloud provider or other providers. Availability refers the percentage of time a user can access the service. Reliability denotes how a service operates without failure, during a given time and condition. Adaptability means the ability of the service provider to adjust changes in services based on user requests. The effect of the sigmoidal membership function is to provide the maximum separation between those serials in the middle of the ranking system, while those serials at either extreme are bunched together closely.

A ranking mechanism is proposed, based on a fuzzy set approach, having three general phases, such as problem decomposition, judgment of priorities and aggregation of these priorities. A fuzzy set may be combined by some simple rules. For example, the intersection of sets A and B is defined to be the minimum of the two fuzzy set membership functions, while the union of sets A and B is defined to be the maximum of the two fuzzy membership functions. The following membership fuzzy set function is shown in Equations 4 and 5 below:

$$\text{Fuzzy membership} = 1 - 2\left(\frac{(x-\alpha)}{(\gamma-\alpha)}\right)^2 \quad \text{for } \alpha < x < \gamma \tag{4}$$

$$\text{Fuzzy membership} = 2\left(\frac{(x-\alpha)}{(\gamma-\alpha)}\right)^2 \quad \text{for } \beta < x < \gamma \tag{5}$$

There are several methods for establishing the quantity of membership between two connecting sets. In this paper, a sigmoid-shaped fuzzy membership function can be characterized by three set of classes of parameters, such as Class A, Class B, and Class C. Class A corresponds to a fuzzy membership value of 1.0 and it is referred as α. Class B corresponds to a fuzzy membership value of 0.5 and it is referred as β and Class C corresponds to a fuzzy membership value of 0.1 and it is referred as γ. Between these, the exact value of the fuzzy membership function is determined by the Equations 4 and 5. The effect of the membership function provides the maximum separation between the providers in the ranking system. Fuzzy sets may be combined by some basic rules, such as union and intersection.

To rank the service providers, the service functionality attributes are classified into three categories, such as Class A, Class B and Class C. Class A refers to high level attributes, such as accountability, assurance, security and privacy. Class B refers to the next level of attributes, such as usability, reliability and Interoperability. Class C denotes low level attributes, such as user interest, stability, cost, throughput and efficiency. The broker is responsible for interaction with users and understanding their request needs. The ranking system considers two aspects, such as (i) the service quality ranking based on fuzzy set and (b) the final ranking based on the cost and quality ranking. Each one of the attributes is combined with weight functions and it becomes easy to ensure the achievement of the best compromise solution based on the objective function. Ranking of cloud services is one of the most challenging tasks in the framework of cloud. The Ranking System computes the relative ranking values of various cloud services based on the QoS requirements of the user and features of the cloud services. To calculate the selection of ranking, the service provider, using two distinct threshold values, recalculates the values using a fuzzy set membership function to assign membership values for each of the individual cloud provider ranking criteria and then the service provider uses fuzzy composition rules to combine these data. Finally, the overall ranking of the cloud providers are considering by Class C level attributes.

The cloud provider selection model is based on three steps of evaluation. The first step is to identify the suitability of each service provider for the service rendered by the user. A suitability evaluation carried out by considering a reduction in the effect of any particular measure in Class A. In the second step, the user confirms that provider can extend services to the user’s “Render Service Request.” The third step compares the cost and lists the service providers. Cloud providers are selected based on the overall and individual cut off threshold values of the attributes considered for evaluation.

4. SIMULATION RESULTS AND DISCUSSION

Simulation experiments were implemented on the JADE 4.3.0 platform's average response time and throughput was computed and the performance was also analyzed. The parameters considered for the simulation are the number of users, the number of cloud service providers, the deadline of tasks, etc.

The execution time for each task is assigned randomly between 0.1 ms to 0.5 ms. The number of users considered are 1,000, 5,000 and 10,000 at a time. An assumption is made that each request is considered as one user. The number of service providers available is fixed as 10, and the deadline for each request is fixed as 0.5 ms. Every cloud service provider has 50 computing hosts and a time-shared VM scheduler. The cloud broker's request, on behalf of the user, consists of 256 MB of memory, 1 GB of storage, 1 CPU, and time-shared Cloudlet scheduler. The cloud broker requests instantiation of 25 VMs and associates one Cloudlet with each VM to be executed. Two experiments were conducted and performance was analyzed according to the existing approach. The experimental results prove that the proposed scheduling algorithm performs better in terms of average response time. The average response time, using a Strict Differentiated Model (DM) and WTQS, is shown in Table 1 for SLA members and Table 2 for Non SLA members and it is reflected in the simulation that is shown in Figures 4 and 5. The second experiment results analyzed the success rate of the selection algorithm. In its nature, there may be a failure of cloud services. During the process of the selection algorithm, the selected provider by the proposed algorithm cannot be completely successful, but the success rate of the cloud service selection is considered as a performance measure for evaluation purposes. The successful selection rate is defined as the ratio between the number of successful selections and the total number of selections as shown below in Equation 6.

Table 1 Average response time of the proposed architecture for SLA members

Number of Users (SLA Members)	Differentiated Module (ms)	WTQS (ms)
400	0.32	0.28
3000	0.37	0.32
6000	0.54	0.4

Table 2 Average response time of the proposed architecture for Non-SLA members

Number of Users(SLA Members)	Differentiated Module (ms)	WTQS(ms)
600	0.9	0.82
2000	0.84	0.73
4000	1.1	0.96

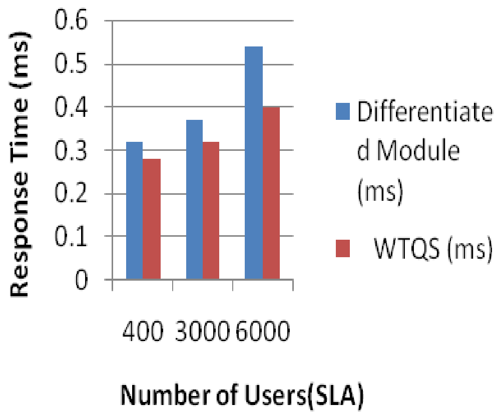

Figure 4 Average response time of the proposed architecture for SLA members

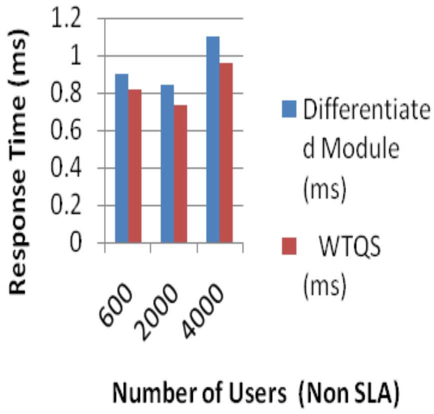

Figure 5 Average response time of the Proposed architecture for Non SLA members

$$\text{Successful Selection Rate (SSR)} = N_{suc} / N_{TOT} \tag{6}$$

In other words, N_{suc} denotes the exchanges of messages between user and provider. In the experiment, the value of N_{suc} is decided based on the average rate of throughput. N_{TOT} refers to the number of cloud selections attempted. If the probability value is greater than 0.5, then the SSR is efficient. In the experiment, there are four cloud selections and 25 messages were exchanged between user and provider.

The number of providers that matched the specific service request in the federated cloud is inversely proportional to the average response time. In other words, the number of providers in the federated cloud increases the average response time decreases. Hence, it is concluded that the selection rate of cloud provider for the service is effective and efficient by the ranking algorithm.

5. CONCLUSION

Cloud computing has become an important technology for outsourcing various resource needs of organizations. The pproposed Federated Cloud mechanism helps to resolve the difficulties of selecting the optimal cloud provider for the service. The issue of starvation is resolved by introducing a scheduling algorithm called WTQS. The shortlisted providers are ranked based on fuzzy sets and this depends on the availability of the top ranked provider being assigned for the tasks. The performance of the proposed Federation Cloud mechanism was compared and it was found to be better than the existing Federated Cloud Architecture.

6. REFERENCES

Aljawarneh, S., 2011. Cloud Security Engineering. *International Journal of Cloud Applications and Computing*, Volume 1(2), pp. 64–70

Brennan, M., Palaniswami, M., Kamen, P., 2001. Do Existing Measures of Poincare Plot Geometry Reflect Nonlinear Features of Heart Rate Variability. *IEEE Transactions on Biomedical Engineering*, Volume 48(11), pp.1342–1347

Buyya, R., Garg, S., Calheiros, R., 2011. SLA-oriented Resource Provisioning for Cloud Computing: Challenges, Architecture, and Solutions. *2011 International Conference on Cloud and Service Computing (CSC)*, pp. 1–10

Buyya, R., Ranjan, R., Calheiros, R., 2009. Modeling and Simulation of Scalable Cloud Computing Environments and the CloudSim Toolkit: Challenges and Opportunities. In: *Proceedings of the 7th High Performance Computing & Simulation*, pp. 1–11

Buyya, R., Ranjan, R., Calheiros, R.N., 2010. InterCloud: Utility-oriented Federation of Cloud Computing Environments for Scaling of Application Services. In: *Proceedings of the 10th International Conference on Algorithms and Architectures for Parallel Processing*, pp. 13–31

Buyya, R., Yeo, C., Venugopal, S., Broberg, J., Brandic, I., 2009. Cloud Computing and Emerging IT Platforms: Vision, Hype, and Reality for Delivering Computing as the 5th Utility. *Future Generation Computer Systems*, pp.599–616

Csmic.org., 2016. Available online at: http://csmic.org, Accessed on 5 April 2016

Czarnul, P., 2013. An Evaluation Engine for Dynamic Ranking of Cloud Providers. *Informatica: An International Journal of Computing and Informatics*, pp. 124–125 and pp. 123–130

Ganghishetti, P., Wankar, R., Almuttairi, R., Rao, C., 2011. Rough Set based Quality of Service Design for Service Provisioning in Clouds. *Rough Sets and Knowledge Technology*, pp. 268–273

Garg, S., Versteeg, S., Buyya, R., 2011. SMICloud: A Framework for Comparing and Ranking Cloud Services. *2011 Fourth IEEE International Conference on Utility and Cloud Computing*, pp. 210–218

Grewal, R., Pateriya, P., 2013. A Rule-based Approach for Effective Resource Provisioning in Hybrid Cloud Environment. *Advances in Intelligent Systems and Computing*, pp. 41–57

Jrad, F., Tao, J., Streit, A., 2012. SLA based Service Brokering in Inter Cloud Environments. *2nd International Conference on Cloud Computing and Services Science*, pp. 76–81

Lu, K., Yahyapour, R., Wieder, P., Yaqub, E., Abdullah, M., Schloer, B., Kotsokalis, C., 2016. Fault-tolerant Service Level Agreement Lifecycle Management in Clouds using Actor System. *Future Generation Computer Systems*, Volume 54, pp. 247–259

Princy, B., Sahil, V., 2014. SLA Aware Cost based Service Ranking in Cloud Computing. *International Journal of Application on Innovation in Engineering and Management*, pp. 257–268

Qu, C., Buyya, R., 2014. A Cloud Trust Evaluation System using Hierarchical Fuzzy Inference System for Service Selection. *2014 IEEE 28th International Conference on Advanced Information Networking and Applications*, pp. 850–857

Rajarajeswari, C., Aramudhan, M., 2014. Ranking Model for SLA Resource Provisioning Management. *International Journal of Cloud Applications and Computing*, Volume 4(3), pp. 68–80

Villegas, D., Bobroff, N., Rodero, I., Delgado, J., Liu, Y., Devarakonda, A., Fong, L., Masoud Sadjadi, S., Parashar, M., 2012. Cloud Federation in a Layered Service Model. *Journal of Computer and System Sciences*, Volume 78(5), pp. 1330–1344

Wu, L., Garg, S., Versteeg, S., Buyya, R., 2014. SLA-based Resource Provisioning for Hosted Software-as-a-Service Applications in Cloud Computing Environments. *IEEE Transactions on Services Computing*, pp. 465–485