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Fuzzy Logic Based Resource Provisioning in Cloud Computing

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Abstract: Cloud computing, the well-known virtualized data storage technique, being one of the most advantageous emerging technologies that attract the attention of majority of researchers in the field of Computer Science and information technology. One of the accompanying challenges is the accurate and logical provisioning of resources. The choice is between private and public cloud service providers. Organizations prefer hybrid clouds keeping their critical data on relatively secured and efficient private cloud services and remaining data on more economically viable public cloud services. This work aims to facilitate decision making process in order to determine the choice of service provider for any particular process by using rule based fuzzy logic technique by utilizing human minds and deep learning. The decision is based on parameters such as priority, age and execution time required for the process. Cloud sim and Matlab tools are used for the purpose of fulfilling the requirements of proposed technique. The simulation results are impressive in terms of security, accuracy, response time and resource utilization. The response time in fuzzy Logic rule based approach is measured in nano seconds and CPU utilization in seconds for our convenience.
Keywords: Cloud Computing, Resource Provisioning, Hybrid Cloud, Fuzzy Logic, Soft Computing.

1 Introduction

1.1 Cloud Computing

Cloud computing is one of the most promising and accepted Web based technologies in IT industry. Cloud Computing is the system of computing that contains hardware and software resources that can be delivered to the customers on the basis of resources requested[1].These resources are provided to the consumers as services on pay as you go model. The cloud consumers can arrange resources from the service providers when needed and release those resources when no longer required [2]. As per NIST organization "Cloud computing[3] is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications and services) that can rapidly be provisioned and released with minimal management effort or service provider interaction". The main advantage of cloud computing is a reduced investment cost of infrastructure and resources [4]. Cloud computing attracts enormous amount of research due to its relevance. The trend is to arrange resources from multiple providers and multi cloud [5]. Broadly, cloud computing provides three types of services which are Infrastructure as a service (IAAS) for providing hardware resources on demand to the consumers[6] and IAAS providers include Amazon, Go Grid etc[7], Platform as a service (PAAS) for providing users' complete operating environment as service on which they can deploy their applications[6] and Software as a service (SAAS) that provide ready- made applications to the cloud users[7].Cloud users need not incur cost for procuring these expensive software's. The various SAAS providers are Microsoft, Oracle etc [7].Cloud providers are broadly classified into four categories: public cloud which is open for use for anyone who is on the internet [8], private cloud that provides services to the organizations in which it is built and managed [9], hybrid cloud which is the blend of both public cloud and private cloud and community cloud that is shared by many organizations. Both private and public cloud provide complimentary benefits [10].To enjoy the benefits of both private cloud and public cloud, an organization prefer to use hybrid cloud. In cloud computing, resource provisioning is a rigorous task [11]. Resource provisioning involves activities like identification of available resources and selection of best resource-workload match while considering Quality of Service (QOS) requirements submitted by the user in terms of Service Level Agreement (SLA) provided [11]. Resource

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provisioning helps in determining the required resources and the respective amount required for the submitted workload in order to maintain QOS parameters such as security, availability, reliability and CPU utilization [12]. Resource provisioning approach is an improvement over queuing model by minimizing the delays when competition between users forces jobs to wait for resources to become available [13]. One of the main aims of resource provisioning technique is to assess how much resources are required for the submitted jobs processing while minimizing the cost from the user's point of view and maximizing the resource utilization from the service provider's point of view [14]. Resource provisioning policies contain issues which are the hot topics in today's research[15].Various cloud computing based resource provisioning mechanisms which are covered in our recent work[12] are hybrid based ,reliability Based, Queuing Model Based, rule based etc.

In our proposed work, we have presented a three dimensional fuzzy Logic rule based approach (based on three factors i.e. security, age and execution time) for a job for provisioning resources in a hybrid cloud based environment. Basically, it is a decision making model for routing the cloud computing process to an appropriate cloud.

1.2 Fuzzy Logic

Fuzzy Logic was developed by Dr. Lotfi Zadeh in 1960's. The classical logical systems do not represent the imprecise meaning in natural language but Fuzzy Logic helps in taking decisions in uncertainty and imprecision[16].Fuzzy Logic is a tool which provides a way of decision making where input information is vague, ambiguous and inaccurate or missing[17]. Fuzzy Logic is a four step process. In every problem, Fuzzy Logic follows a sequence of four steps which are shown in Fig 1:

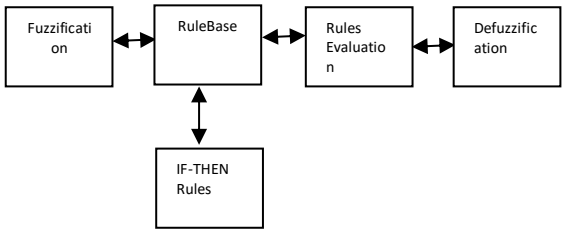

Fig. 1: FUZZY LOGIC PROCESS[17]

The above process is explained as follows:

Fuzzification defines membership functions for the linguistic terms for fuzzy variables [18].Membership is a curve that defines the degree to which an element belongs to universal set. Larger values denote higher degree of membership to set [19]. Next comes the rule base. The rules along with their weights are defined in the rule base. On the basis of input to the model, the rules according to their strengths will be fired. Defuzzification is the process of obtaining crisp output. Output must be crisp, if we want to take any action as fuzzy output can't be applied in the practical problem .There are many ways to compute defuzzified output. Some of them are maximum membership principle, centroid method, weighted average method, min-max method.

2 Literature Review

An on demand resource provisioning [20] is presented in multiple clouds for provisioning resources to the cloud users on demand. For critical applications, resources are provisioned from private cloud otherwise resources are provisioned from public cloud, virtual cloud or private cloud, if available. Proposed approach is implemented on Cloud Sim v2.1.1.The results have shown that proposed approach helps in increasing resource utilization and proves to be cost-effective. Another failure free resource provisioning [21] for hybrid cloud infrastructure has been presented. Here, the researchers propose hybrid cloud resource provisioning along with the failure recovery policies. The researcher emphasize on redirecting the longer resource request in terms of time and size to public cloud. The proposed policy is implemented on cloud Sim. Results reveal that the proposed policy is able to improve QOS by improving 32% in case of deadline violation rate and 57% in case of slowdown. A dynamic resource provisioning [22] in cloud based on queuing model has also been proposed. The research aims at dynamic allocation of resources to the requests by applying Banker's algorithm to handle the condition of deadlock. The interactive applications of the proposed system are simulated on Hadoop, a cloud computing simulator. The results show that the proposed system provides better response time in serving requests. A rule based approach [23] for effective resource provisioning in hybrid cloud environment has been proposed where the researchers have taken public cloud along with the private cloud for resource provisioning. The researcher divides applications on the basis of criticality and security and assigns the priorities to the applications that mean high priority requests for critical applications and low priority requests for non-critical applications. High priority requests always go to private cloud and low priority requests go to public cloud or private cloud, if available. The above approach is simulated on Cloud Sim 3.0. The results show that private cloud utilization is found to be 70.59% with rule based approach as compared to 64% with non-rule based approach. Another resource management [24] in a hybrid cloud infrastructure has been proposed. The researchers give the priority to the user's requests on the basis of VMs requested. In this way, this model promotes scalability. Cloud Sim 3.0 is used for simulation and integrated with Eclipse (indigo) in Windows 7.The proposed research work helps in decreasing overall expenditure of the company. An application based

brokering algorithm [25] for optimal resource provisioning in multiple heterogeneous clouds has been presented. Users' request is sent to multiple clouds. Selecting the services from multiple service providers is a challenging task. To reduce this complexity and to reduce cost, the broker allocates the resources from multiple service providers on the basis of resources request constraints specified by the user and the required level of SMI attributes (a method to measure cloud service). Here, algorithm for deployment is implemented. Efficiency of the algorithm is checked by numerical studies and sensitivity analysis. A cost-effective service provisioning [26] for hybrid cloud applications has been proposed consisting of multiple private clouds and multiple public clouds. The researchers first use the private cloud for fulfilling resource requests then the public clouds are utilized. As the price of public cloud changes with time, this policy adjusts accordingly. Other features of this policy include adding or removing cloud providers for maintaining cost-effectiveness. Because multiple clouds are used, this policy also focuses on load balancing problem. A dynamic resource provisioning mechanism [27] has been proposed with two concepts i.e. autonomic computing and reinforcement learning. The reinforcement learning algorithm is used to learn about the action which is to be taken for example; is it the case of underutilization and overutilization or not? The above step to be taken is put into action in last stage like scaling up of VMs or scaling down of VMs etc. Results show that proposed policy reduces total cost by 50% and improves resource utilization by 12% while comparing proposed technique with cost-aware LRM, cost-aware (ARMA) and DRPM.

In the above literature, various cloud based resource provisioning mechanisms have been summarized. In the proposed work, a soft computing tool namely fuzzy logic is taken. In the following sections, we are briefing some of the applications of fuzzy logic in cloud computing. An efficient load balancing scheme [28] in cloud computing using fuzzy logic has been presented where a new load balancing algorithm is presented with two input variables for fuzzification i.e. assigned load and processor speed. After fuzzification and on the basis of 12 rules defined in fuzzy inference system, defuzzified value in the form of crisp value is obtained which is considered as the balanced load. This algorithm is compared with the existing round robin load balancer. The results obtained show that fuzzy logic based load balancing algorithm helps in load balancing by decreasing processing time as well as improving overall response time. A job scheduling [29] using fuzzy neural network algorithm in cloud environment has been presented where Fuzzy logic converts the input parameters like bandwidth, memory, time into linguistic variables. The genetic algorithm in neural network is used for mapping the system resources with the jobs then the linguistic variables are converted to the crisp values using fuzzy logic. The algorithm is compared with traditional Berger model and the result shows that the proposed technique result in reduction in bandwidth utilization and completion time thereby enhancing performance. A hybrid job scheduling algorithm [30] for Cloud computing environment has been proposed using two artificial intelligence tools i.e. genetic algorithm and fuzzy logic. The researchers have modified the genetic algorithm with fuzzy logic .The researchers take the concept that resources should be allocated on the basis of job's length. This helps to avoid the wastage of the resources .Also this approach considers the load balancing. This approach helps in reducing execution time and execution cost thereby, enhancing performance. A fuzzy-based firefly algorithm [31] for dynamic load balancing in cloud computing environment has been proposed. The researchers propose a new version of dynamic load balancing technique .The researchers take the fire fly algorithm along with the fuzzy logic. Firstly, the cloud is partitioned into heavy and least loaded nodes. With this algorithm, the best suited node for the current load is selected and firefly algorithm helps this load to get attracted towards that partition. The fuzzy logic handles the situation of uncertainty. The proposed algorithm is compared with the genetic algorithm approach. The result shows that the algorithm consumes less execution time, incurs less cost, can handle much heavier load, and balances a good amount of arrived load as compared to genetic algorithm. A fuzzy based improved multi queue job scheduling [32] for cloud computing has been proposed. The researchers take the concept of load balancing by maintaining the multiple queues by dividing the jobs in ascending order according to their burst time. The load is balanced among multiple nodes and fuzzy logic is used for load migration. The results show that by using fuzzy logic, the waiting time and response time is reduced as compared to existing technique, thereby enhancing performance. A fuzzy logic based algorithm of resource scheduling [33] for improving the reliability of cloud computing has been proposed. For fuzzification, three input parameters are taken i.e. cost, trust and length. The defuzzified output is the priority allocated to the resource in which these resources will be scheduled. The results are compared with the various existing algorithms like FIFO, Max-Min, Min-Min and the result shows that there is improvement in waiting time, turn-around time thereby improving the accuracy and performance by using this algorithm. A fuzzy logic based risk assessment approach[34] for evaluating and prioritizing risks in cloud computing environment has been proposed and prove that fuzzy logic is more beneficial in risk assessment and management process. The model is based on fuzzy logic to deal with insufficient and incomplete information. For fuzzification, the two fuzzy input variables are taken i.e. impact of risk and probability of risk. The membership functions and the rule base are defined. The defuzzified crisp value is obtained which is the crisp risk rate and the calculated crisp risk rate is compared with the expected risk rate to show the accuracy of the proposed technique.

In the approach taken by the researchers for allocating resources to the appropriate cloud, we have identified some problems.

Priority conflict situation is there meaning thereby; no

attention is given to the situation, when requests of same priority will arrive. Next, the existing approach is uni-dimensional, that is, only security is taken for defining the priority to the process. Security is not only the parameter on which priority allocation is based. Our aim is to address the problems discussed above and also improve the existing approach in terms of response time, security and accuracy. After analyzing various successful applications of fuzzy logic in various areas, we also have applied fuzzy logic as a tool in cloud computing for reprioritizing the cloud computing based requests for resources.

3 Design of the Model

The main aim of our work is to design fuzzy logic based decision making system that will route the cloud computing based processes to the appropriate cloud for provisioning resources. Fuzzy logic is a soft computing technique that mimics the intelligence of a human brain. In resource provisioning, the decision requires closeness to human behavior. To achieve this, we add a fuzzy inference system (FIS) to the existing system because the literature has proved that in real life applications, fuzzy logic always work in terms of enhancing accuracy. While designing model, we take 3 fuzzy variables along with their linguistic terms as inputs:

1. Priorities on the basis of security and importance [Very Low (VL), Low (L), Medium (M), High (H), Very High (VH)]
2. Age [Very Low (VL), Low (L), Medium (M), High (H), Very High (VH)]
3. Execution time [Very Low (VL), Low (L), Medium (M), High (H), Very High (VH)]

On the basis of above inputs, data in the form of clubbed priority is collected from the IT experts. The membership functions for the above three variables have been defined. On the basis of suggestions of experts, FIS is built that gives a defuzzified output in the form of crisp value that is compared with a pre-defined threshold value. If the allocated priority is less than threshold value, process is allocated to public cloud otherwise; process is allocated to a private cloud. The results with the fuzzy logic are more accurate as compared to other techniques that enforce single rule but fuzzy logic enforces multiple rules at the same time. Fuzzy logic is used in numerous real life applications like DSS for dental treatment [18], anti-lock braking system [35] etc. Various applications of fuzzy logic are reviewed in our review paper [36]. The proposed algorithm concentrates on enhancing accuracy of the system which is a good improvement over the existing approach. Priority conflict is highly improbable with the help of FIS as not only security factor of a process is considered, other two factors like age and execution time are also considered. The methodology of our approach in pictorial form is shown in Fig: 2.

The fuzzy logic part is designed and implemented in MATLAB [37] in our previous paper [38] and explained as follows

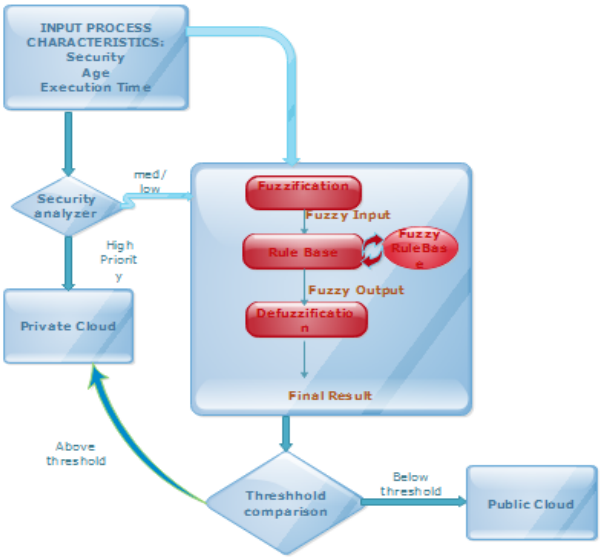

Fig. 2: Fuzzy Logic based model.

3.1 Fuzzification

In our work, we have three input fuzzy variables and one output fuzzy variable whose membership functions are defined as follows:

3.1.1 Security and Importance

While defining security, we take triangular membership function.

$$\mu_L(x) = \begin{cases} 0 & if x \le .02684 \\ \dfrac{x - .02684}{.2765 - .02684} & if x \in (.02684, .2765) \\ \dfrac{.5261 - x}{.5261 - .2765} & \text{if } x \in (.2765, .5261) \\ 0 & \text{if } x \ge .5261 \end{cases}$$

3.1.2 Age

While defining age, we take Gaussian membership function developed by a well-known scientist Carl Friedrich Gauss. Gaussian membership function has smooth boundaries [39].

$$\mu_l(x) = [exp - (x - .25)^2 / 2 * .1062^2]$$

$$\mu_H(x) = [exp - (x - .75)^2 / 2 * .1062^2]$$

3.1.3 Execution Time

Here, we have used triangular function.

$$\mu_M(x) = \begin{cases} 0 & if x \le .2499 \\ \frac{x-.2499}{.5-.2499} & if x \in (.02499, .5) \\ \frac{.7501 - x}{.7501 - .5} & \text{if } x \in (.5, .7501) \\ 0 & \text{if } x \ge .7501 \end{cases}$$

3.1.4 Allocated Priority

The allocated priority is the clubbed priority (on the basis of above three factors i.e., Security, age, execution time) allocated to each process. For this, we use triangular function.

$$\mu_H(x) = \begin{cases} 0 & if x \le .4999 \\ \frac{x-.4999}{.75-.4999} & if x \in (.4999, .75) \\ \frac{1 - x}{1 - .75} & \text{if } x \in (.75, 1) \\ 0 & \text{if } x \ge 1 \end{cases}$$

3.2 Defining Rule Base

On the basis of IT experts' responses, a rule base in fuzzy logic is designed. In our work, we use Mamdani approach for defining rule base in the following way:

R_1: if x is $A_1$and y is B_1 then z is C_1
R_2: if x is A_2 and y is B_2 then z is C_2
57 rules have been defined in the Rule Base.

3.3 Defuzzification

In our work, we use centroid method of defuzzification. Following formula is used as centroid method

$$z_0 = \frac{\int \mu_i(x) x \, dx}{\int \mu_i(x) \, dx}$$

Where z_0 is the defuzzified output, μ_i is a membership function and x is an output variable.
A simple graphical user interface is designed for taking inputs in the form of security, age and execution time and giving outputs in the form of allocated priority.

4 Implementation and Testing

The expert responses and our system responses are checked for consistency by applying Mann Whitney test [40] to check the accuracy of our system and are shown in Fig: 3-9.

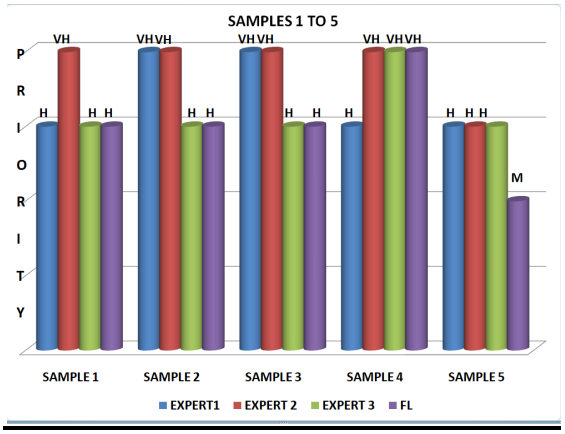

Fig. 3: System and Expert Responses.

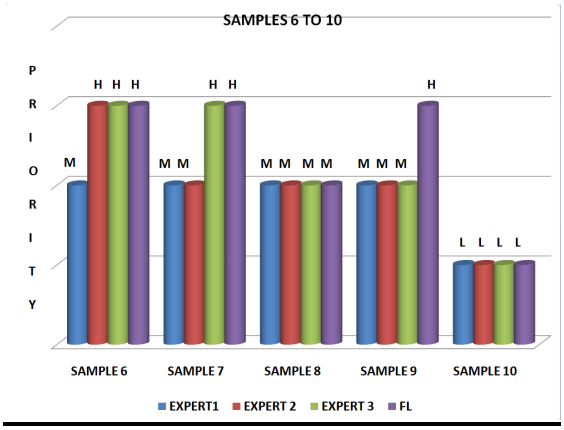

Fig. 4: System and Expert Responses.

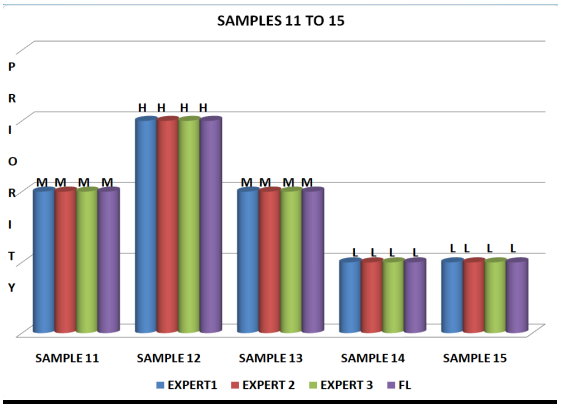

Fig. 5: System and Expert Responses.

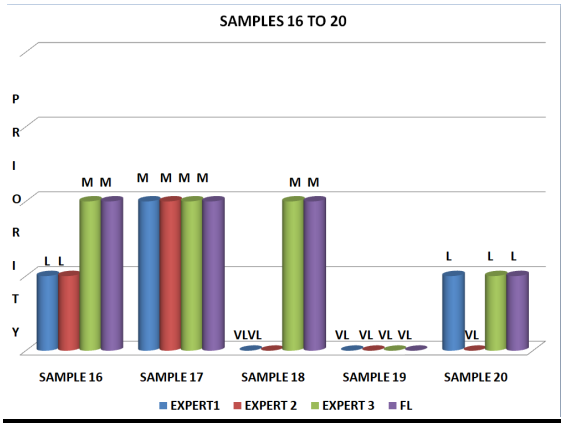

Fig. 6: System and Expert Responses.

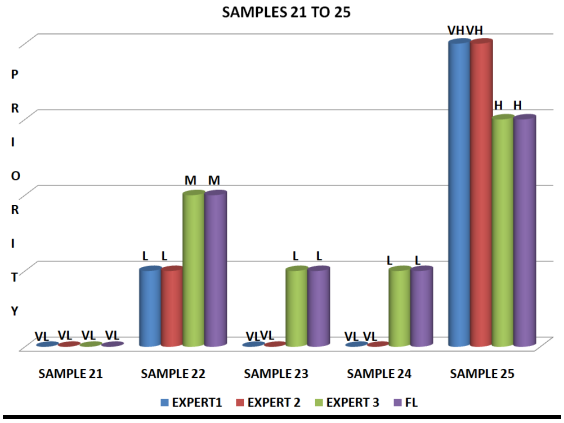

Fig. 7: System and Expert Responses.

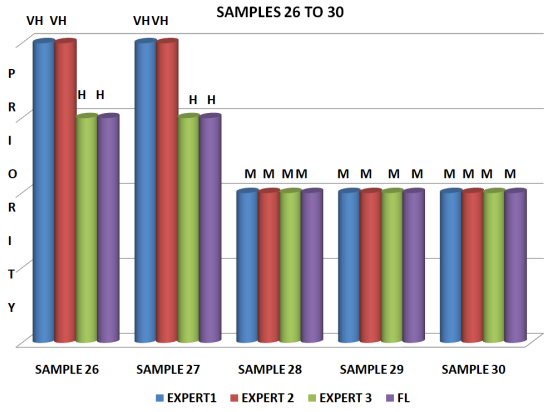

Fig. 8: System and Expert Responses.

5 Simulation and Results

For simulation and modeling of above results, we have used Cloud Sim3.0.The following parameters metrics are taken:

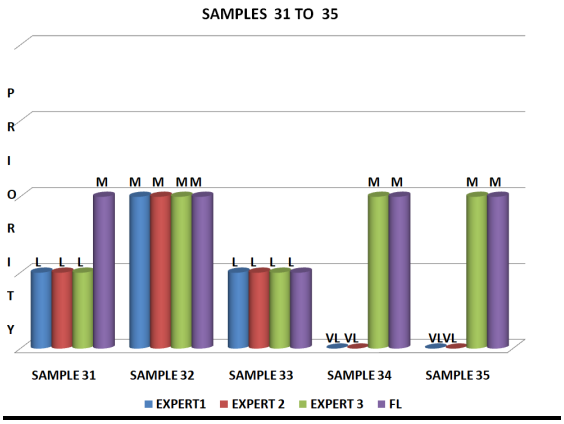

Fig. 9: System and Expert Responses.

5.1 CPU Utilization

This section concerns with details of experiments with respect to utilization of resources on both private as well as public cloud. The utilization rate is calculated as the percentage of CPU being used in a given time interval. Performance of the system in terms of some vital parameters such asT_r, φ, μ which are explained below:

Percentage of Server Utilization, $\mu = \frac{T_r}{T_r+\varphi} \times 100$

Where total response time,$T_r = \sum_{i=1}^{n} T_i$,T_i= Time taken by i_{th} individual request and **φ** = time taken by the fuzzy logic based decision making process. The calculation of server utilization is based upon a total of 35 requests taken as samples and executed using CloudSim 3.0 environment [41].

φ= 0.00075947 * 35 = .02658145 sec

T_r= 0.289142801 sec

$$\mu = \frac{0.289142801}{0.289142801 + .02658145} \times 100 = 91.58\%$$

The CPU Utilization of the proposed and existing approach is shown in Fig: 10

5.2 Security

In our work, the processes that are highly sensitive and needs security are directed to private cloud as private cloud is more secure than public cloud.

5.3 Accuracy

We have shown the results of our FIS along with the experts' results in Table I. The consistency of experts' results and system results is obtained using Mann-Whitney test.

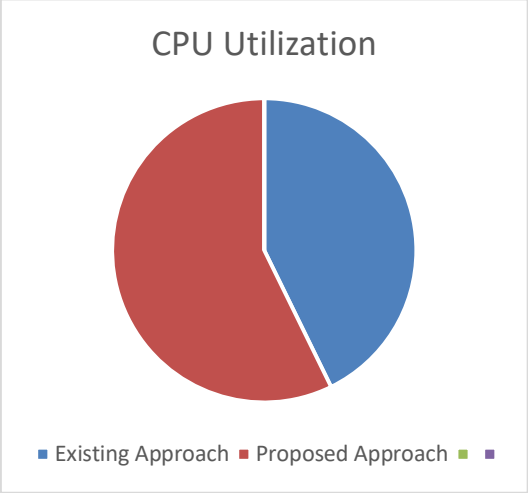

Fig. 10: CPU Utilization.

5.4 Response Time

The response Time (in terms of nano seconds) of the three cases is shown in Table 1 and also in pictorial form in Fig: 11.

Table1:

When the processes are send to Public Cloud	889523.4363839998
When the processes are send to Private Cloud	296507.81401800003
When the processes are send to Fuzzy Logic based System	289142.8009020001

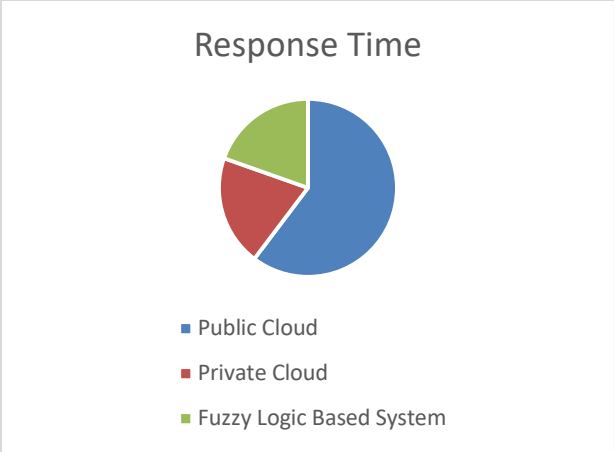

Fig.11: Response Time.

6 Conclusions and Future Scope

Our paper is based on comparing three approaches i.e. when the entire processes are directed towards Public cloud, when the entire processes are directed towards Private cloud and when the entire processes are directed towards hybrid cloud where fuzzy inference system will decide the appropriate cloud where to direct the processes. The proposed approach using Fuzzy Logic helps in improving CPU utilization, decreasing response time, improving accuracy while promoting security. In another work, we have taken artificial neural network approach for cloud based resource provisioning and found that Fuzzy Logic works well in this field. In future, we will address the security aspect in cloud based resource provisioning more extensively.

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