

AN EFFICIENT APPROACH FOR LOAD BALANCING IN CLOUD COMPUTING

A Dissertation submitted in partial fulfillment of the requirement for the

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CERTIFICATE

This is to certify that the thesis entitled “**An Efficient Approach for Load Balancing in Cloud Computing**” submitted by **SANTOSH ANAND SHAH(2K14/ISY/24)** to the Delhi Technological University, for the award of the degree of Master of Technology is a bona-fide record of research work carried out by him under my supervision. The contents of this thesis, in full or in part, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

The advent of cloud computing in recent years has sparked an interest from different organizations, institutions and users to take advantage of services and applications. Because of serving a very attractive package of services, cloud technology has grasped a huge attention from academia, IT industry and government organizations. Cloud computing promises scalability and on-demand availability of resources. As the number of users on the internet goes on increasing, it becomes difficult to handle the millions of user requests on it. Many a times it happens during the peak-hours that the traffic on the network increases abruptly. In such situations it is commonly observed that the System performance degrades. Though having many good features such issues restrict a user to use the services. Users may not find it that much reliable.

Therefore, one of the important issues which need a major consideration of the researchers is load balancing in cloud computing systems. A number of load balancing algorithm are proposed by various researchers, to solve this problem. Two kinds of load balancing algorithms are there one is static and other is dynamic. A cloud computing system is supposed to handle the request dynamically rather than doing it by a static approach which is supposed to be the less efficient approach. Also there are number of parameters like resource utilization, throughput, scalability, flexibility, response time, which are used to validate any load balancing algorithm. Any load balancing developer is supposed to maintain a good of trade-off between these parameters.

In this thesis a hybrid approach for load balancing in cloud computing is proposed. This algorithm aims at distributing the equal load on each server in the cloud network using the dynamic spread policy. This also improves the resource utilization. With the hybrid approach a situation in which only few resources are loaded heavily while others are just sitting idle will never arise. The hybrid algorithm is also compared with the existing load balancing techniques.

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CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Cloud computing has significantly improved its existing technologies in context of the services they provide. In previous years, Grid as well as Distributed computing was unable to provide the flexibility as compared to cloud computing. Various attractive features have resulted in the increment of the popularity of cloud computing. The model which cloud computing follows is pay-as-you-go and provides on demand provisioning of resources. The raising standards have increased the demand of cloud computing in the field of business where infrastructure setup is high. Using this technology of cloud, one can easily have the run time environments, services and infrastructure. Users from different domains can make best of the benefits of cloud computing as per their needs. The main entity is the cloud provider which enables users to use different services as per their needs. They provide the customers with many resources like network, storage capacity which can be joined with any registration process where any authenticated user can request and work with the services of cloud.

Among the various different tasks of provider of cloud services, the crucial one is to assign nodes for requests of user. This mentioned task need to be efficient. In order to perform this, total processing time should be less [1] as possible whereas in parallel various other issues of network delays and heterogeneity need to be managed. Cloud computing is very much popular in the area of Information and Communication Technology (ICT). To cope up with speedy growth in cloud requests, service providers is required to build more capabilities in components which is performed by increasing the number or power or both. Such situation can turn into a large network consisting of cloud users, nodes, tasks and virtual machines. As the network size becomes large, workload also need to be managed to

increase overall performance. This area of load balancing aims at high detection rate and best distribution of workload in network.

Major issue which earns more attention from cloud developers is the load balancing task. Various parameters are tested for algorithms of load balancing for better quality service. In turn, this parameter is analyzed to judge the concerned algorithm.

1.2 CHALLENGES AND MOTIVATION

Cloud Computing is earning more attention from users as it is scalable, elastic, easy accessible and last but not the least delivery of services. These features contribute in making it marketable. This model may lead to set a new world to cloud computing where every user can run its services as per requirements, not knowing how the internal process is working. The overall workload of the entire procedure of cloud computing is directly proportional to the number of users accessing the services. It's a challenging task to manage the resources like memory, CPU, secondary storage. It's a prerequisite of any cloud service to provide load balancing in an effective manner.

In any scenario it may happen, that the traffic may rise in exponential manner, e.g. in the occasion of New Year, people may wish each other by sending messages which may create traffic in websites. In this critical condition, they may raise the charges of sending messages. Similar traffic may be obtained while results of Board exams are declared. Another major challenge to be faced is the federation of cloud. A cloud may comprise of private, public, community or hybrid cloud. Any communication between these may result in addition of responsibilities of service provider. Also, the requirement of Internet is the prior need to provide any cloud services. Therefore any bottlenecks in network that occur frequently may result in a major issue and then resources need to be effectively used.

1.3 OBJECTIVES AND CONTRIBUTIONS

This study of thesis relates to LB challenges in cloud computing environment. The purpose of this thesis is to generate an efficient mechanism for load balancing, which may be a benefit for both the service providers as well as cloud users. Proper distribution of the load among the existing nodes in network will be the best way to

utilize the resources and to process the requests of user. This task of load balancing can be performed by scheduling of tasks into VM and then from virtual machine to nodes existing in system. An effective algorithm for LB will get high rate of fault tolerance.

The Major contribution deals with:

- A technique for load balancing with high concern on improvement of performance parameters like response time, resource utilization and throughput.
- A Comparative study and analysis of existing major load balancing algorithms. Various contributors like peak hour usage and distribution of services are studied and analyzed for algorithms.

CHAPTER 2

CLOUD COMPUTING

2.1 INTRODUCTION

Previous years have resulted into the approach to process information in larger scope, in more effective manner. With the advancement in the area of cloud computing, trauma of storing, retrieving and processing big data through internet is not seen now. The idea of computation which is now network oriented in early 1990s led to the development of Grid computing and from 2015 , the computation entered a new field of Cloud computing. From many previous years, researchers are focusing on bringing utilities to be given as service to their users. User may want to acquire software, hardware or any platform based on usage through an internet. It can be said that cloud computing is simply a path to provide utility espoused by IT agents like IBM, Amazon, Google, HP etc. The technology dealing in cloud has a tremendous rise which is displayed in the figure 2.1. The technology spread in the entire globe in a very short interval of time.

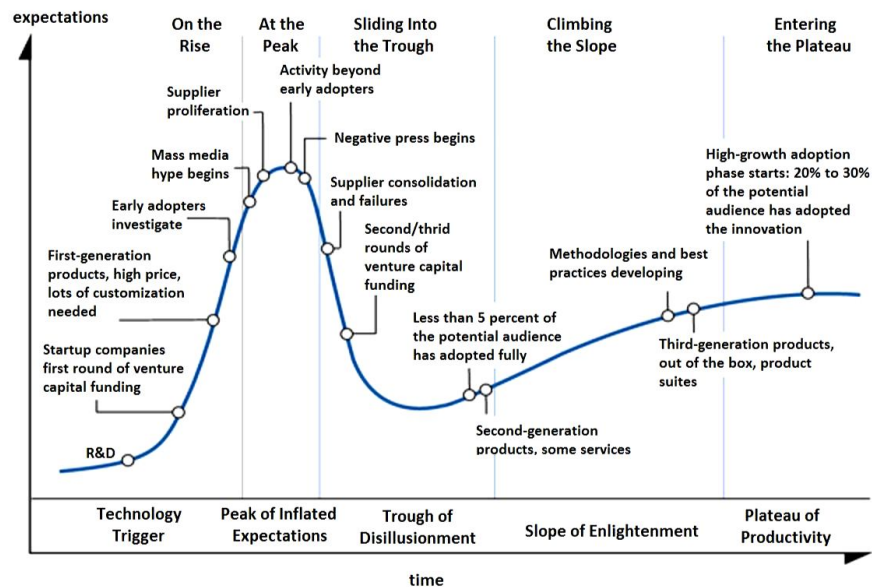


Figure2.1: Hype cycle for cloud computing

2.1.1 CLOUD COMPUTING DEFINITIONS

The word Cloud is one of the most famous and popular words since 2007 in the IT industry. Different researchers gave a different definitions for cloud computing. In relation to this, Joe Weinmn gave a term “Cloudonomics”, which states it from economical view, shown below:

1. **C**ommon Infrastructure: It states that a pool of resources should be provided to users.
2. **L**ocation-independence: It states that a user can work using any resource and it does not depend on its location.
3. **O**nline connectivity: It states that a user needs to use any services only through a connection which is consistent.
4. **U**tility Pricing: It declares that the payment should be done as per use and benefits should be provided in accordance with their demands.
5. **O**n-**D**emand Resources: It informs that scalable and elastic resources should be managed and then provided.

2.1.2 CLOUD COMPONENTS

The components of the cloud work as an integrated unit which comprises of data centers, servers and clients as shown below:

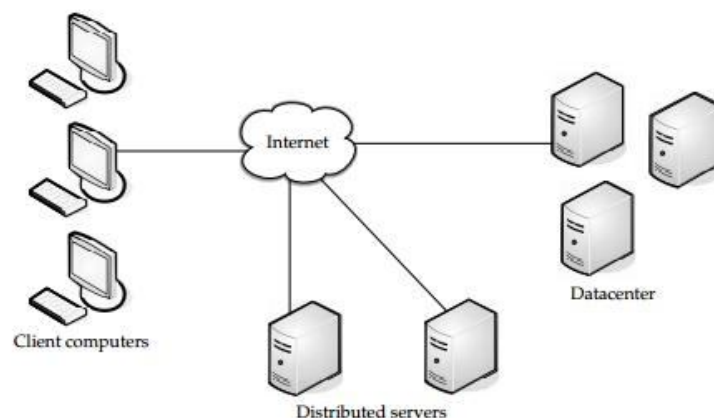


Figure 2.2: Cloud Components

Clients

It includes the computers we generally use in our life. It may consist of desktop computer, mobile phone, PDA. These clients should be able to gain access to use the cloud interface through internet.

Data Centers

It acts as the most core element of the entire cloud process. It may comprise of many nodes in a room. Configuration of data centers is performed by service providers and they rely on service and deployment model.

Distributed Servers

It seems to the user as the server is working together, but in reality they are unaware of the actual location. The use of distributed servers results in increment of fault tolerance rate.

2.2 CLOUD COMPUTING ARCHITECTURE

Cloud computing supports any IT service which can be consumed as a utility and delivered through a network, most likely the Internet. Such characterizations have quite different aspects: infrastructure, development platforms, application and services. It is possible to organize all concrete realizations of cloud computing into a layered view covering the entire stack from hardware appliances to software systems. Figure 2.3 shows the layered architecture of cloud computing.

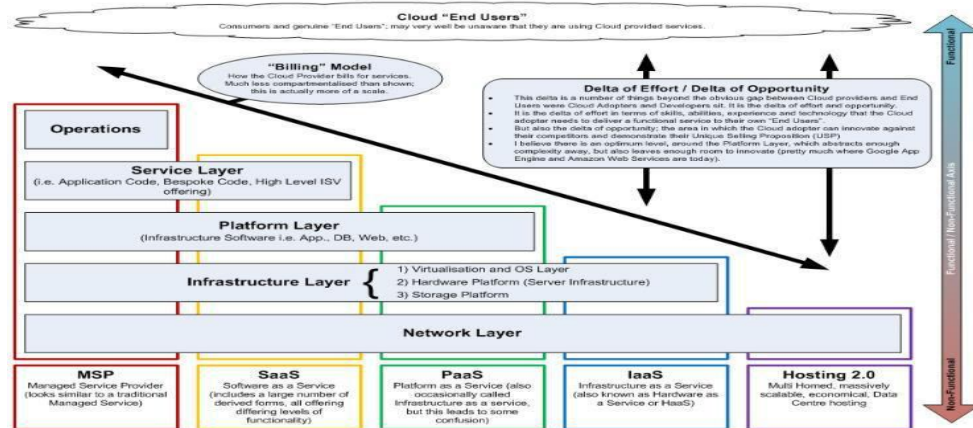


Figure 2.3: Cloud Computing Architecture.

2.3 CLOUD SERVICE MODELS

Once a cloud is developed and ready to be used by its consumers, it has to be decided that how to use the services offered by the cloud. The most common way in which it can be used is by categorizing all the services according to the commonly used business model. In cloud computing there are basically three delivery mechanisms through which a service can be delivered to the cloud users: software, platform and infrastructure. There are number of services offered by the cloud, but the primary service models which are deployed over the cloud are discussed below [5]:

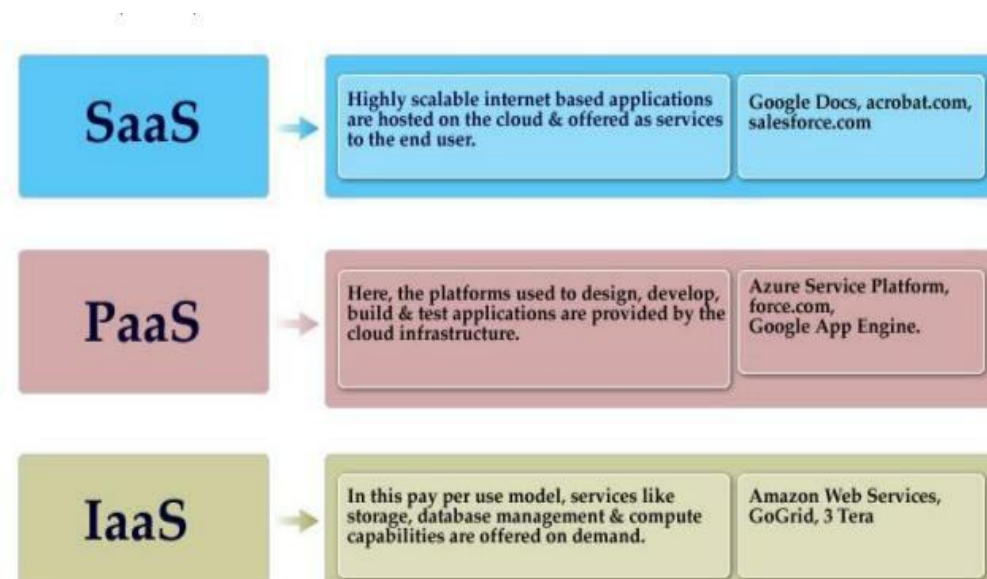


Figure2.4: Cloud Models

2.4 CLOUD DEPLOYMENT MODELS

Deployment models define the type of access to the cloud, i.e., how the cloud is located? Cloud can have any of the four types of access: Public, Private, Hybrid and Community. There are number of cloud consumers who want infrastructure of different sizes and each of these infrastructures requires different kind of management. Also different user groups want different types of infrastructures based on the nature and services offered by the cloud.

2.4.1 PUBLIC CLOUD

The Public Cloud allows systems and services to be easily accessible to the general public. Public cloud may be less secure because of its openness, e.g., e-mail. Public cloud can be managed, operated and owned by a government, academic, or business organization. Examples are: Amazon's Elastic Compute Cloud (EC2), Google's AppEngine, IBM's Blue Cloud, Sun Cloud and Windows Azure Services Platform.

2.4.2 PRIVATE CLOUD

The Private Cloud allows systems and services to be accessible within an organization. It offers increased security because of its private nature. An organization can request to a third party or it may develop its own private cloud infrastructure. An organization can serve many other users of it by its own private cloud for e.g., Google is serving its users by providing them services like Gmail, Drive, GoogleApp engine and many more. Depending upon the deployment of the cloud, there are two types of private cloud:

- ON-PREMISE PRIVATE CLOUD
- EXTERNALLY HOSTED PRIVATE CLOUD

2.4.3 HYBRID CLOUD

The Hybrid Cloud is mixture of public and private cloud. However, the critical activities are performed using private cloud while the non-critical activities are performed using public cloud. Hybrid cloud as the name suggests is a combination of two or more different types of cloud. It may be a combination of a private cloud, a public cloud or a community cloud. Cloud infrastructures of these clouds are entirely different. A cloud service provider needs to manage between the clouds to provide a required service to its users.

2.4.4 COMMUNITY CLOUD

The Community Cloud allows systems and services to be accessible by group of organizations. The concept of community cloud is similar to grid computing. There are certain specific communities of users from different organizations.

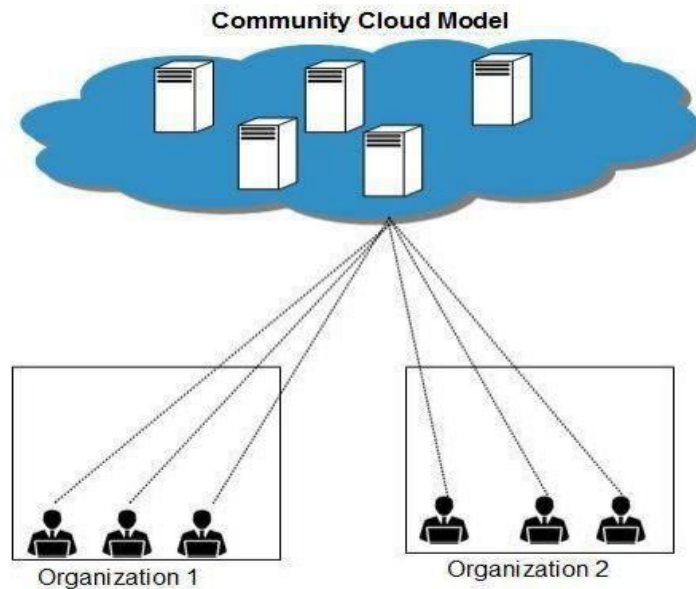


Figure2.12: Community Cloud

2.5 CLOUD COMPUTING VIRTUALIZATION

Virtualization is a technique, which allows sharing single physical instance of an application or resource among multiple organizations or tenants (customers). It does so by assigning a logical name to a physical resource and providing a pointer to that physical resource when demanded. Creating a virtual machine over existing operating system and hardware is referred as Hardware Virtualization. Virtual Machines provide an environment that is logically separated from the underlying hardware. The machine on which the virtual machine is created is known as host machine and virtual machine is referred as a guest machine. This virtual machine is managed by a software or firmware, which is known as hypervisor. Hypervisor is a firmware or low-level program that acts as a Virtual Machine Manager. There are two types of hypervisor. Here are the three types of hardware virtualization:

2.5.1 Full Virtualization

In Full Virtualization, the underlying hardware is completely simulated. Guest software does not require any modification to run.

2.5.2 Emulation Virtualization

In Emulation, the virtual machine simulates the hardware and hence become independent of it. In this, the guest operating system does not require modification.

2.5.3 Para-Virtualization

In Para virtualization, the hardware is not simulated. The guest software runs their own isolated domains.

2.6 CLOUD COMPUTING OPERATIONS

Today, cloud computing operations have become very popular and widely employed by many of the organizations just because it allows performing all business operations over the Internet. These operations can be performed using a web application or mobile based applications. The operations are:

- Always employ right tools and resources to perform any function in the cloud. Things should be done at right time and at right cost.
- Selecting an appropriate resource is mandatory for operation management.
- The process should be standardized and automated to avoid repetitive tasks.
- Using efficient process will eliminate the waste and redundancy.
- One should maintain the quality of service to avoid re-work later.

2.7 CLOUD COMPUTING BENEFITS

Enterprises would need to align their applications, so as to exploit the architecture models that Cloud Computing offers. Some of the typical gains are mentioned below:

- **Reduction in Cost**

So many numbers of reasons to attribute Cloud technology with low costs. The billing model is pay as per usage; cloud infrastructure is not purchased due to its low maintenance. Starting expense and revenant expenses are too less than conventional computing.

- **Heightened Storage**

With the massive Infrastructure that is offered by Cloud providers today, storage & maintenance of large volumes of data is a reality. Sudden workload spikes are also managed effectively & efficiently, since the cloud can scale dynamically.

- **Flexibility**

This is an extremely important characteristic. With enterprises having to adapt, even more rapidly, to changing business conditions, speed to deliver is critical. Cloud computing stresses on getting applications to market very quickly, by using the most appropriate building blocks necessary for deployment.

2.8 CLOUD COMPUTING CHALLENGES

Despite its growing influence, concerns regarding cloud computing still remain. In our opinion, the benefits outweigh the drawbacks and the model is worth exploring. Few challenges are:

- **Protection of Data**

Securing data is a vital element that warrants scrutiny. Enterprise firms are not eager to buy an assurance of business data protection from vendors. They may feel fear of losing data to competition and confidentiality of consumers.

- **Recovery of Data and Availability**

Most of the business applications have Service level agreements that are stringently followed. Operational teams have a crucial role in execution of service level agreements and runtime governance of applications.. If the mentioned services are not fulfilled by a cloud provider, the damage & impact could be severe.

- **Capabilities Management**

Although being multiple cloud service providers, the whole management of cloud platform and infrastructure is still there in its infancy. Features like 'Auto-scaling' for example, are a crucial requirement for many enterprises. There is huge potential to improve on the scalability and load balancing features provided today.

- **Regulatory and Compliance Restrictions**

In many countries, Government regulations do not allow customer's personal information and other sensitive information to be physically located outside the state or country. In order to meet such requirements, cloud providers need to setup a data center or a storage site exclusively within the country to comply with regulations.

CHAPTER 3

LOAD BALANCING

3.1 INTRODUCTION

As the user load increases on cloud, the existing processing performance degrades automatically which leads to delay in serving users. There might be a case in which some nodes are overloaded with requests and some are under loaded at the same time. We need to implement load balancer to improve our load sharing between network nodes which use load balancer algorithms to improve load balancing among network nodes. A wide range of load balancing algorithms are defined to implement load balancers. Implementation of correct load balancer was important for network performance only in older distributed systems. Now load balancing includes low power consumption with respect to processing as network nodes are usually power hungry blade servers. Energy consumption is crucial in any cloud role out and load sharing helps in cost reduction. Usually cloud implementer defines a specific policy for load balancing to improve system performance and it is a field of extensive research.

3.2 LOAD BALANCING DEFINED

A network or cloud consists of various servers, network devices and storage units. Workload on resources increased abruptly as number of user's increase and resource management become difficult in the network which leads to poor performance and increased resource consumption.

System throughput and resource utilization can be improved by using load balancer which can improve system response time and performance effectively. A good load balancer's job is to equally distribute workload among all nodes present in the cloud. Ineffective utilization can be explained with example of social networking providers which has hundred millions of users or search engine provider which

handles millions of queries per minutes and it is difficult to serve so many requests from a centralized system. It can lead to bad throughput or delay increasing response time. It can solved by using geographically distributed systems, which leads to a scenario where a system in a particular geographical system is overloaded with requests at a particular time for example a new product launch or multiple request for viral video but other adjacent systems are underutilized . A good load balancer can forward request to underutilized nodes which can normalized system response without increasing processing capabilities of system. Various schemes or mechanisms are used by cloud developers to tackle low throughput and data replication for fault tolerance.

3.3 GOALS OF LOAD BALANCING

Various IT and Engineering organizations have own networking systems and use customized policies for load balancing in their network. They use global policy for cloud requirement and specify technical goals for load balancers which compliment business-goals.

3.3.1 TECHNICAL GOALS

All technical specs, problems and targets are covered in technical requirements and address all problems and functionalities regarding network.

Important technical requirement are listed below:

- Performance improvement of system
- Redundancy in case of system failure
- Ensure stable throughput and normalize work load among all nodes
- Scalable for future modifications, easy interfacing to with other systems and extensible
- Maximum service availability
- Response time to serve content or response to user

3.3.2 BUSINESS GOALS

Technical specs are driven by business logic of an organization and have business policies dedicated to improve user experience and minimize cost which can make it a market leader in its niche and move faster or develop more features and provide different solutions to clients or end user than its competitors to dominate market or capture more market share.

- Minimize operational cost.
- Conform to industry standard and compliances and acquire certain patents or certificates from responsible agencies.
- Prepare service level agreements and licensing agreements for clients.
- Check all legal issues and government policies.
- Business model for every geographical and political situation with other parameters like maximum usage hours of a day.

3.4 LOAD BALANCING IN CLOUD COMPUTING ENVIRONMENT

Response Time is the measurement for a cloud performance and load balancer should minimize it without underutilization of resources and increasing operational cost. Enhancing resource management needs an effective load balancing technique with a task scheduler with optimized mechanism to avoid any kind of resource blocking in the system. Cloud developer, service provider and user are main concerned entities in any cloud system.

A cloud network consists of various nodes which consist of processing units and storage units. Every node has many virtual machines to serve requests and a task is assigned to any of the virtual machine or resource. Resource is released after completing a task and can be allocated again to any other request according to some allocation policy. CloudSim can effectively simulate load balancing or scheduling in cloud environment.

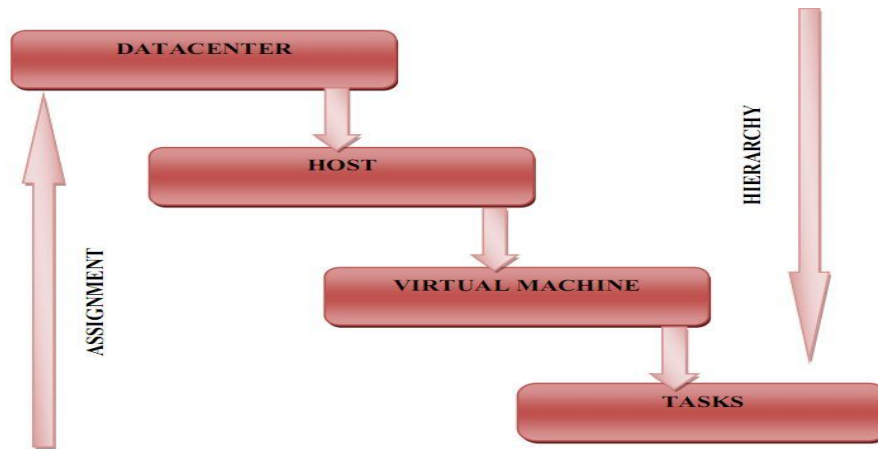


Figure 3.1: Hierarchy and assignment of cloud components

Task scheduling and resource provisioning are main mechanism which is responsible for proper load balancing in cloud. Resource provisioning defines resource mapping with tasks or any other network entity. Resource provisioning can be enabled on two different levels:

- **Host level**
- **Virtual Machine**

3.4.1 AT HOST LEVEL: ALLOCATING THE HOST TO VM

There is many to one relation between physical server and virtual machines as many VM's can be hosted by a single physical server more than one virtual machine can be allocated to user as per allocation policy defined for that particular user.

3.4.2 AT VM LEVEL: ALLOCATING VM TO USER TASKS

User tasks are mapped to virtual machines .VM's and user tasks has many to many relation means a user task can be handled by various virtual machines or various tasks can be handled by a single instance of virtual machine .Virtual Machines can be mapped to users dynamically or statically to user which is also defined by allocation policy.

Various load balancing algorithms are executed as per the provisioning policy in the cloud environment. The user tasks are provisioned for virtual machines by the virtual machine manager.

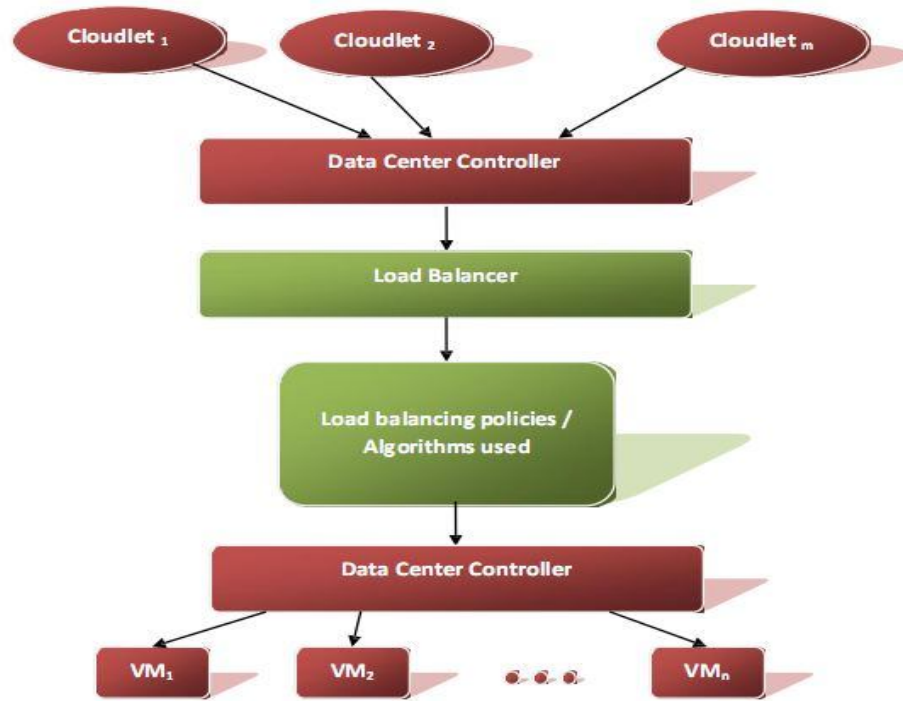


Figure 3.2: Execution of load balancing algorithm

3.5 TYPES OF LOAD BALANCING ALGORITHMS

Various load balancing algorithms have been developed and are in use since the area of distributed computing. Load balancing is based on many factors like system configuration and system topology, and old techniques still can be used in cloud computing for improved resource utilization.

3.5.1 STATIC LOAD BALANCING TECHNIQUES

Static techniques are easy to define and predefined resource mapping with tasks. It is feasible for small and fixed request handling networks. Static or deterministic techniques make a system less scalable and cannot handle changes in the nature of tasks. It requires more manual effort in mapping more users to system resources.

- **Round Robin**

It handles clients request in a circular manner and every task get lock on virtual machine till it get completed and serves user tasks on FIFO basis.

- **CLBDM(Central Load Balancing Decision Model)**

It is an improvement over round robin and also finds out time duration of session established between client and node. Time Duration can be defined as execution time taken by task till completion on given virtual machine or resource.

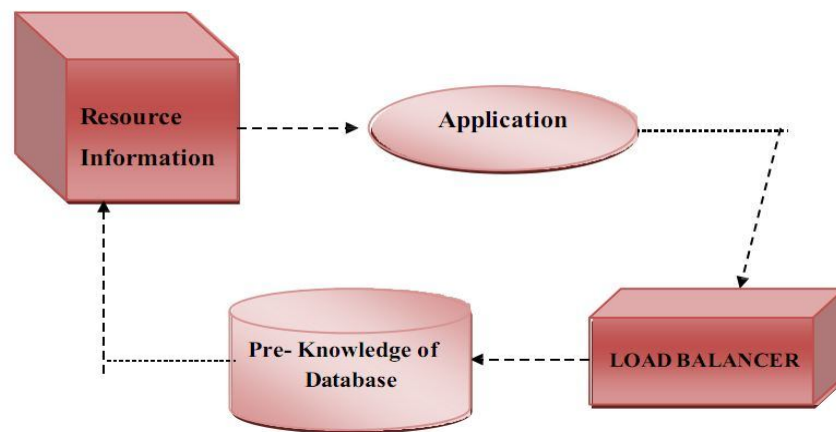


Figure.3.3: Static Load Balancer

3.5.2 DYNAMIC LOAD BALANCING TECHNIQUES

Dynamic techniques can also be classified in centralized or distributed topology. All decisions for system resource provisioning or scheduling is controlled by a master and assigned to a slave means slaves merely serves request forwarded by master to them and cannot take their own decisions whereas in distributed system control is disturbed in network and more than one node can handle provisioning or scheduling of resources.

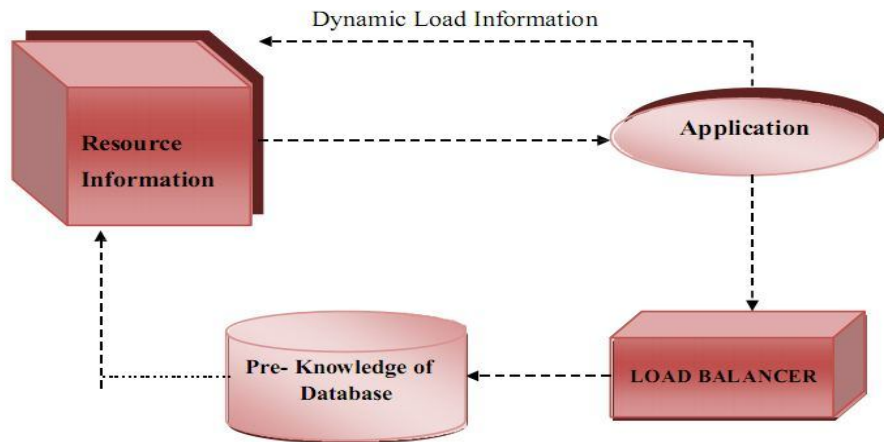


Figure.3.4: Dynamic Load Balancer

Commonly used dynamic policies are:

- **ESCE Policy**

It equally spreads execution load to all available resources and maintain record of all resources and number of task assigned to every resource or virtual machine when any new task is received to load balancer it searches for most underutilized resource or virtual machine.

- **Throttled policy**

Under this policy, each resource is assigned with only one task at a time and any other job can be assigned only after completion of previous task assigned to it. Load balancer or job manager maintains all resource lists.

When a new user task is received job manager check list and if any free resource is not found, it keeps task in waiting queue and poll on list to check virtual machine status.

3.6 LOAD BALANCING ISSUES

There are many open issues while taking care of load balancing in a cloud environment. Every load balancing has its own strength and weakness for example some algorithms are suited for real time systems and stress on achieving minimum

RTT, or any other algorithms is designed to achieve max resource utilization or max throughput. Some major challenges which are considered while designing a load balancing algorithm are:

3.6.1 NODES GEOGRAPHICAL DISTRIBUTION

Overall system performance is drastically effected by geographical location of nodes as it reduces number of network hops in serving any client and very significant for enterprise with large user base for example all social networking or search providers. A well geographically distributes system results in more fault tolerable and efficient system with significantly reduced response time as compared to no distributed system.

3.6.2 ALGORITHM COMPLEXITY

Load balancing algorithm complexity can also affect system performance. For example complex algorithm can increase throughput and resource utilization of a system but can increase response time due to more processing whereas a simple algorithm can reduce response time but gives poor results in fault tolerance. So an algorithm should be decided bases on system requirements.

3.6.3 STATIC VS DYNAMIC LOAD BALANCING

Static policies are simple, less complex and easy to implement defined earlier and hard coded in system and can lead to sudden failure of the system over an unhandled change in system. Dynamic algorithms are improvement over static algorithms nut are more complex and system driven in nature. Dynamic algorithms can handle changes in system or failure of any node make system more robust and fault tolerable leading to more stabilize system operation and throughput.

3.6.4 TRAFFIC ALAYSIS OVER DIFFERENT GEOGRAPHICAL LOCATIONS

All business regions across the globe have their own time zone, own working hours and peak hours in any resource utilization, therefore load balancer should be able to

handle peak hour traffic using resources of that particular location and in case of sudden burst of request.

3.6.5 REPLICATION AND STORAGE IN CLOUD

Data is the most important for every organization and it should be handled carefully and replicated to handle failure of main storage unit. Geographical replication of data is used to minimize response time to serve any task.

3.7 PERFORMANCE METRICS FOR LBA EVALUATION

3.7.1 THROUGHPUT

Throughput of an algorithm is used to estimate number of tasks that has been executed successfully.

3.7.2 OVERHEAD

It can be defined as extra cost associated with implementation of any algorithm for example system maintenance or migration time. System Implementer should try to keep it as low as possible.

3.7.3 FAULT TOLERANCE

It measures load balancer's capability of uniform load sharing among nodes in case of any sudden node failure. Node failure in peak hours can affect whole system performance.

3.7.4 MIGRATION TIME

It is the time taken by load balancer to shift any job or task from one node to other node usually in case of node failure.

3.7.5 RESPONSE TIME

Time taken by system in between a task is submitted and response generated. Load balancer should try to keep it is minimum.

3.7.6 RESOURCE UTILIZATION

Uniform load sharing and optimal resource utilization. A load balancer should avoid any node from over loading as well as underutilization, avoid wastes processing cycles.

3.7.7 SCALABILITY

Load balancer should be able to incorporate changes in system infrastructure. Algorithm should be able to handle changes in node or system topology without any or minimal manual efforts.

3.8 SUMMARY

In this chapter, we studied various aspects, features and requirements of load balancing from the point its utilization in cloud network. Various technical and business requirements has been covered in this chapter which effects load balancing algorithm design decisions in cloud network implementation. Widely used load balancing policies and techniques categories were also discussed in this chapter taking in account all pro and cons of every category. It covered all current implementation standards and parameters defined to check cloud network performance.

CHAPTER 4

RELATED WORK

Cloud computing is the current advancement in the technology field concerned to IT industry. This chapter deals with related contributions in the area of load balancing related to cloud computing.

In [16] A.Khiyaita provided a review of load balancing techniques. Classification of these algorithms is done on the basis of system topology and load. Multiple examples in the concerned paper elaborated their implementations in classical systems. Key technologies specific to cloud computing was specified. Authors also mentioned challenges faced during the implementation phase. Nidhi [17] also discussed techniques aiming to reduce the overhead, response time and the performance. It also analyzed parameters governing performance specific to techniques. Shu-Ching [18] combined the functionalities of LBMM i.e., Load Balance Min-Min and OLB i.e. Opportunistic Load Balancing in order to propose scheduling algorithm and then it gave an improvement to existing algorithm Min-Min algorithm. OLB kept every node busy not concerning the workload in particular node. OLB assigned tasks in random manner to all the available nodes whereas MCT algorithm assigned tasks to only that node which expected minimum completion time to other nodes.

Another very important and effective algorithm came into existence by Che-Lun Hung, Yu-Chen Hu and Hsiao-his Wang in [19] which was LB3M. [20] Gave the concept to get any resource of cloud by incorporating Co-operative Scheduling of power aware. It was considered as a good replacement to the challenges concerned to load balancing keeping into concern energy efficiency. It incorporated both centralized as well as distributed approach making the best use of inherent efficiency related to centralized one and energy efficiency as well as fault tolerant behavior of distributed method. In [21], percentage of node utilization in PALB is calculated and this percent decided the count of computed nodes that are kept

operated when another one gets shut down completely. The technique consists of three sub areas: Balancing area gave the method to instantiate the virtual machines based on utilization percentage. Another area which is Upscale gave the method to power on the nodes. Area of Downscale was used to shut down the nodes that are idle. It gave the promise to decrease the consumption of power and also managing the resource availability in parallel.

Raul Calvo [22] proposed method to manage image collection of large amount in real world techniques. This paper creates a service and provides its use for analysis of images. Various operations on data are stated to work in distributed area for different sub-images. Now these sub-images are stored and their processing is done separately by multiple agents. It deals with the execution of method in large images in parallel way. Resource scaling and consuming power are the factors to be dealt with any load balancing method. [23] Improvements that can be measured are obtained in cloud environment Load balancing techniques should be such that to obtain measurable improvements in resource utilization and availability of cloud computing environment [23].

In [24] Alexandru Iosup studied the services of cloud and analyzed for scientific computing. They experimented on workloads of real scientific world of MTC requests of user. MTC stands for many task computing. They deal with applications that are loosely coupled which complete tasks as per the scientific goals. In [25] Srinivas proposed the algorithm for load balancing adding fuzzy logic to its computation. It made the use of speed of processor and incorporated assigned load onto overall load in cloud environment as in [26]. Here authors proposed a new logic to dynamic balancing of load in cloud environment with parameters- disk space, status of virtual machine and then stated it as FAMLB i.e. Fuzzy Active Monitoring Load Balancer. Milan E Sokile focussed his work in elaboration of load balancing techniques. They include static, shortest queue, round robin methods in client environment. The result of experimental analysis is that it states that in dynamic environment diffusive load balancing is better and efficient as compared to static load balancing. [28] Gave a difference between strategies that exists among various methods and algorithms. The efficiency in load balancing leads to benefits in cloud computing.

Parallel processing [29] can be seen in a network processor. It comprises of many on-chip processors which is used to perform operations of packet level. It assures high throughput by providing fine load balancing to the available processors. It may also have a disadvantage of high rate of out of order packets. ORR which stands for Ordered Round Robin is done for scheduling packets. The heterogeneous processor which give loads need to be handled accurately.

The processed loads from the processors are ordered perfectly. Analysis of the derived expressions and the throughput in terms of batch size, count odd processors scheduled and scheduling time. Jaspreet Kaur elaborated active virtual machine algorithm in order to get free and appropriate virtual machine in lesser time. She performed simulation to do a comparative study of round robin and to spread execution policies concerned to load balancing for lesser time and cost.

Algorithm in [31] added capacity related to dynamic balancing method of cloud. Experiments performed by Zhang Bo clearly demonstrated that it achieved better degree of load balancing and took lesser time in loading tasks. Soumya Ray [32] explored many algorithms like central queuing algorithm and many more. The analysis was carried between MIPS vs. HOST and MIPS vs. VM. The experiment demonstrated that the response time can be improved in terms of number of VMs in Datacenter. In order to handle the random selection based load distribution problem, dynamic load balancing algorithm can be implemented as the future course of work to evaluate various parameters. In [33], the authors have proposed an algorithm for load distribution of workloads among nodes of a cloud, by the use of Ant Colony Optimization (ACO). This algorithm uses the concept of ant colony optimization.

Shridhar G.Domanal and G.Ram Mohana Reddy [34] have proposed a local optimized load balancing approach for distributing incoming job request uniformly among the servers or virtual machines. Performance of proposed algorithm is analyzed using CloudAnalyst [14] simulator; further comparison is done with other existing Round Robin and Throttled algorithms. In [35], the authors have analyzed various policies utilized with different algorithm for load balancing using a tool called cloud analyst, mostly different variants of Round Robin algorithm for load balancing has been analyzed. Dynamic Round Robin algorithm is an improvement over static Round Robin algorithm [36], this paper analyzed, and the Dynamic Round Robin algorithm with varying parameters of host bandwidth, cloudlet length,

VM image size and VM bandwidth. Results have been analyzed based upon the simulation carried in CloudSim simulator. In [37], the authors Ching-Chi Lin, Pangfeng Liu, Jan-Jan Wu, have proposed a new Dynamic Round Robin (DRR) algorithm for energy-aware virtual machine scheduling and consolidation.

CHAPTER 5

PROPOSED METHODOLOGY

5.1 INTRODUCTION

As discussed earlier, selection of right technique for load balancing is one of the critical moves for developers. We are having a wide list of techniques suggested by researchers which are used for the load balancing. They are all having their respective pros and cons. There are several network oriented computing systems in which their respective applications need the computational process in parallel fashion with large quantity load while few applications only require short and quick response. For example, scientific research based activities require a very huge computational requirement for a setup while a particular simple user login job requires fast and easy evaluated processing over network. A particular range of LB techniques emphasize on effective resource utilization, some on having low execution time and few are emphasizing on setting a monitoring trade-off in between these parameters. There are two types of situations comes under LB either it would be high load or would be load below average. So after consideration of these parameters a customized LB is selected. With the respective hybrid methodology our main aim is to balancing the total workload in the network architecture among different nodes either it would be server or a local host. Several metrics are discussed earlier in the chapter 3 to maintain equilibrium between theses parameters for achieving the better results. Before discussing the hybrid LBA let's take a look on the steps which are needed to perform a suitable LBA:

- Starting from the very first step, user requests comes into the load balancer as an input and then load balancer checks that load is high or low.
- In next step, information is exchanged related to input parameters by load balancer among the different nodes in the datacenter.

- After that, information is exchanged related to total load by load balancer between different VMs which are deployed over the targeted nodes in DC.

An effective LBA can boost the performance of a cloud network. It provides the better resource utilization with increased throughput of the system. For better understanding the hybrid LBA we have to cover few terminologies which are below mentioned in description.

5.2 DESCRIPTION

These are the basic recommended terminologies which are used in our hybrid LBA.

- **Datacenter (DC):** DC comprises a set of hosts either they are servers or local nodes. As per the budget and requirements of the particular organization which wants to establish a cloud infrastructure, they can also facilitate number of DCs.
- **Host:** A host is having the full server characteristics with their respective processing cores. They reside in the DC. These processing cores will further allocate to respective VMs. It depends upon the requirements that how many hosts are needed to deployed in the DC.
- **Virtual Machine (VM):** Virtual machine is the processing unit in the cloud environment. VMs are the instances which are propagated by user on the basis of his budget and requirements. These machines are allocated for the different tasks based on the configuration of cloud infrastructure.
- **Virtual Machine Capacity:** VMs are processing units for a particular cloud infrastructure. In technical terms the VMs are having the processing power to execute the task based on its processing capacity. VM capacity is commonly depends upon the certain factors. These factors are CPU utilization, memory, input-output capacity, number of cores in CPUs, CPU's clock speed, communication bandwidth between VMs and many more hardware related factors.
- **Datacenter controller (DCC):** It is a communication repository between the cloud users and the respective cloud load balancer. It is responsible for load assigning to load balancer and recipient for the requests from cloud users.

For assignment of load to VMs we require an allocation policy for VMs. The hybrid LBA is described step-wise below as:

5.3 Proposed Hybrid Algorithm: Load Balancer

Input:

1. Virtual machines $\langle VM1, VM2, VM3, \dots, VMn \rangle$
2. Hosts $\langle H1, H2, H3, \dots, Hm \rangle$
3. Cloudlet $\langle T1, T2, T3, \dots, Tk \rangle$.

Where 'n' , 'm' and k are the number of virtual machines , hosts and Cloudlets(task) respectively.

Output: All Cloudlets (Tasks) $\langle T1, T2, T3, \dots, Tk \rangle$ are allocated to some virtual machines $\langle VM1, VM2, VM3, \dots, VMn \rangle$ and all Virtual Machines are allocated to some hosts $\langle H1, H2, H3, \dots, Hm \rangle$.

Step.1: Hybrid Load Balancer maintains:

1. An index table of virtual machines,
2. An index table of cloudlets(Tasks),
3. A value for each host(i.e. PES_h = 2) and virtual machine(processing power).

Initially all hosts and virtual machines are available therefore the processing power of each one is set to a highest number, that can be processed by them.

Host_Allocation():

Step.2: Data Center Controller receives new request.

Step.3: Data Center Controller queries the Hybrid Load Balancer for the assignment of current virtual machine to appropriate host.

Step.4: Hybrid Load Balancer starts looking for the availability of host, by checking the status of each host, initially starting from H1.

4.1: if host is available

4.1 a) Hybrid Load Balancer checks for the number of processing elements in that host, saves the host id and updates the PES accordingly.

4.1 b) Continue from Step.4 for the next host, until all the hosts are traversed one by one.

4.2: else

4.2 a) Continue from Step.4 for the next host, until all the hosts are traversed one by one.

Step.5: Now there are two cases:

Case 1: if a host is available with maximum pes value

- a). The Hybrid Load Balancer returns the host id to the Data Center Controller.
- b). Data Center Controller allocates the virtual machine to the host using dynamic spread way identified by that id.
- c). Data Center Controller notifies the Hybrid Load Balancer for new resource allocation.
- d). Hybrid Load Balancer updates the allocation table and PES accordingly of the corresponding host.

Case 2: if all the hosts are busy and no one have the available processing elements.

- a). The Hybrid Load Balancer returns null.
- b). Data Center Controller sends virtual machine request to the waiting queue for fast processing.

VM_Allocation():

Step.2: Data Center Controller receives new request.

Step.3: Data Center Controller queries the Hybrid Load Balancer for the assignment of current cloudlet to appropriate virtual machine.

Step.4: Hybrid Load Balancer starts looking for the availability of virtual machine, by checking the status of each virtual machine, initially starting from VM1.

4.1: if virtual machine is available

4.1 a) Hybrid Load Balancer checks the processing power of virtual machine, saves the VM id with its processing power.

4.1 b) Continue from Step.4 for the next virtual machine, until all the vms are traversed one by one.

4.2: else

4.2 a) Continue from Step.4 for the next vm, until all the vms are traversed one by one.

Step.5: Now there are two cases:

Case 1: if a virtual machine is available with maximum processing power

- a). The Hybrid Load Balancer returns the VM_id to the Data Center Controller.
- b). Data Center Controller allocates the virtual machine to the current cloudlet(task) using dynamic spread way identified by that id.
- c). Data Center Controller notifies the Hybrid Load Balancer for new resource allocation.
- d). Hybrid Load Balancer updates the allocation table and processing power accordingly of the corresponding vm.

Case 2: if all the VMs are busy and no one have the available processing elements.

- a). The Hybrid Load Balancer returns null.
- b). Data Center Controller sends cloudlet request to the waiting queue for fast processing.

Step.6: When the processing of virtual machines got finished they are destroyed and the status of the corresponding host is changed to available again.

Step.7: If there are more Cloudlet or virtual machine request comes, Data Center Controller repeats step 4 until all the cloudlets get resources.

Step.8: exit.

5.4 PROCESS OF OPERATION

The hybrid LBA demonstration is explained by the help of the example. In this given example, we take one DC, four Hosts, eight VMs, sorted task time array, and number of PES associated with each host for better explanation of hybrid LBA. We have two tables, commonly named as Index table and VM table. Initially all the VMs are available for each host for their PES task allocation. We select the host which has maximum PES in the Index table and move to next Host with largest number of PES after done the previous Host. We have inputs which are as follows:

Host Table:

S.No	Host Id	PES
1	H1	3
2	H2	2

Table 5.1: Index table for Hybrid LBA

VM Table:

VM ₁	VM ₂	VM ₃	VM ₄
-----------------	-----------------	-----------------	-----------------

Table 5.2: VM table with processing power

Cloudlet Table:

Array of requested tasks in terms of execution time associated with each Host.

T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈
----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------

Table 5.3: Task table for hybrid LBA

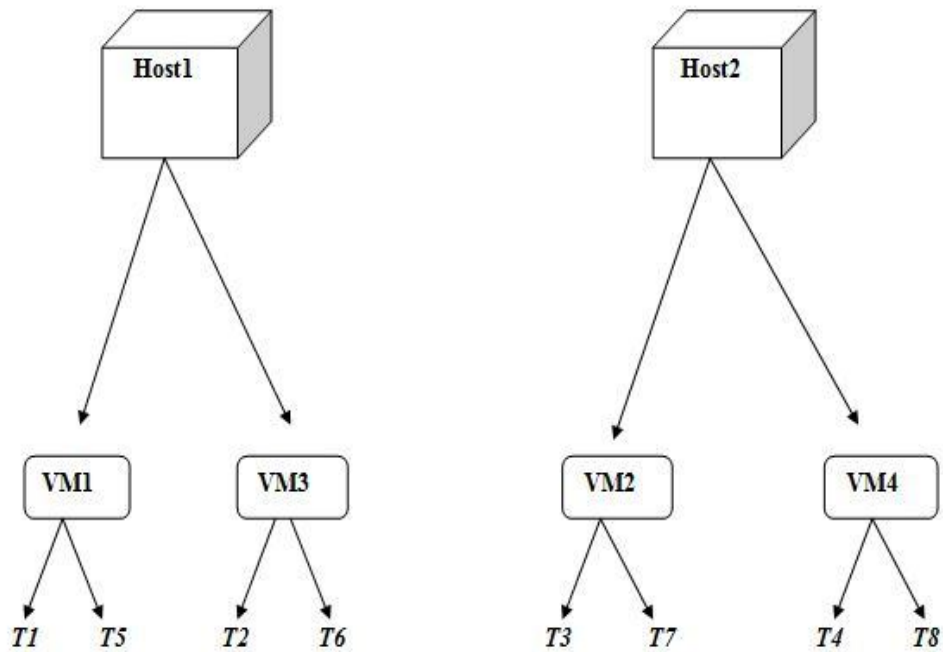


Figure 5.2: Resource allocation by hybrid LBA

The figure 4.2 describes the VM allocation for all the Hosts by hybrid LBA. The hybrid LBA efficiently distributes VMs on the network nodes in the datacenter. Since this LBA is works on the Host level so information related to Hosts, VMs, and the PES as inputs provided to LBA. A hybrid LBr initially focuses on VMs, Hosts available in the DC. From above example explanation it is clear that hybrid LBA is achieving its goal for balancing the load (task) in homogeneous manner. It uniquely allocates VMs to all the requested tasks efficiently. The hybrid LBA is fully static and focused to the static load balancing in the cloud environment describe with the output results in next chapter.

CHAPTER 6

EXPERIMENTAL SETUP AND RESULTS

As discussed in previous chapters, there are lots of LBAs proposed by many research scholars, everyone have their pros and cons. Selection of an effective LBA for a cloud system is one of the crucial tasks for the developers. With the proposed work it was tried to maintain an appropriate trade-off between different performance parameter so as to achieve the better results. In chapter 3 we have discussed about the various metrics which are used to judge the performance of any LBA which have been done. With the proposed LBA our main aim is to balance the overall workload among different nodes (server or host) in the network.

6.1 USED TECHNOLOGIES

In this section we present a brief description of the technologies which are used in our proposed LBA. These intersecting technologies are discussed below:

6.1.1 JAVA

Java is an object oriented programming language which operates by the help of objects. It supports the object oriented features which are commonly used in the present scenario. These features help developers to deploy and develop many applications and services in cloud computing environment. In cloud computing a platform is provided through which a user can interact with the cloud services and further using as per the needs. This platform must be accessible from any device whether it is a mobile, a laptop, a tablet, or any other device. Java's ability to be run on any platform makes this possible.

Java's byte code made it more secure and portable for use. Many computational tasks performed in cloud network require smooth and quick networking services.

6.1.2 CLOUDSIM

CloudSim [13] works as a simulator which simulates the cloud environment in your surroundings under CloudSim toolkit. We can visualize the cloud infrastructure by the help of CloudSim. We used **CloudSim3.0** to implement our proposed LBA. For simulating demonstration of the cloud computing scenarios we follow this simulator. It implements certain scenarios as per the user requirement to test the policy or work of the particular entity in a well established manner with the effectiveness of suitable environment. For simulating demonstration of the cloud computing scenarios we follow this simulator. With the help of CloudSim we model the cloud components. These cloud components includes different datacenters, virtual machines (VMs), and various resource provisioning policies. CloudSim toolkit also offers federation of clouds i.e., internetworking of different types of clouds. Figure 6.1 shows the layered architecture of CloudSim.

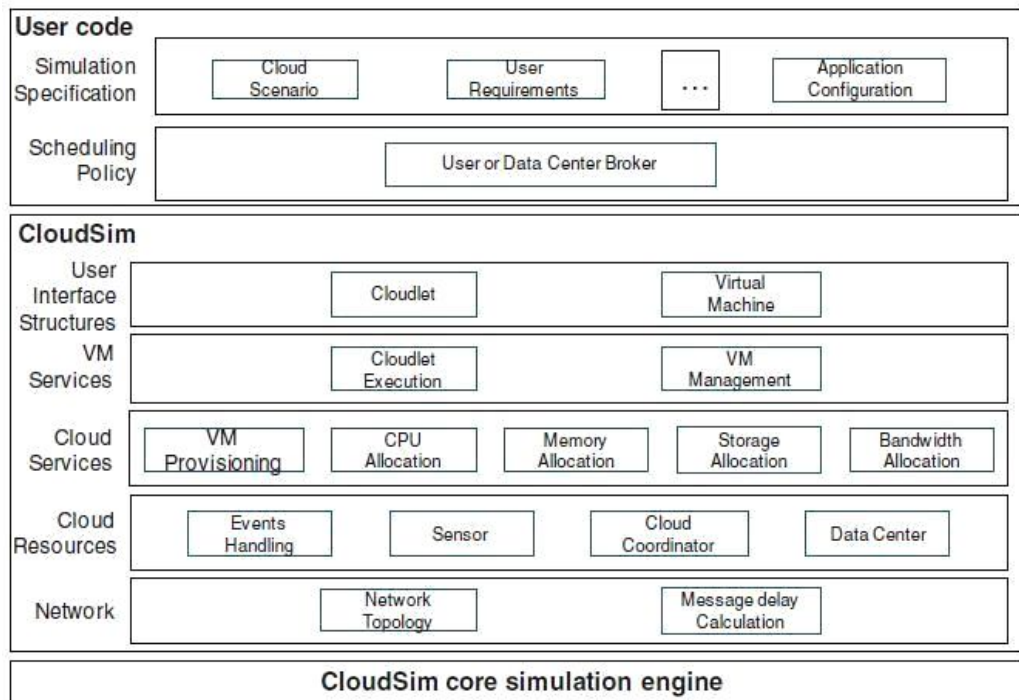


Figure 6.1: Layered architecture of CloudSim

6.1.3 CLOUDANALYST

A CloudAnalyst provides more user-friendly environment for the researchers. In CloudAnalyst a detailed report is generated for each piece of experiment.

CloudAnalyst [14] is a GUI based simulator for modeling and analysis of large scaled applications. It is built on top of CloudSim toolkit, by extending CloudSim functionality with the introduction of concepts that model Internet and Internet Application behaviors. For the comparison of various load balancing policies and datacenter broker policies CloudAnalyst is used in this thesis. Figure.6.2 shows basic component upon which CloudAnalyst [14] has been build.

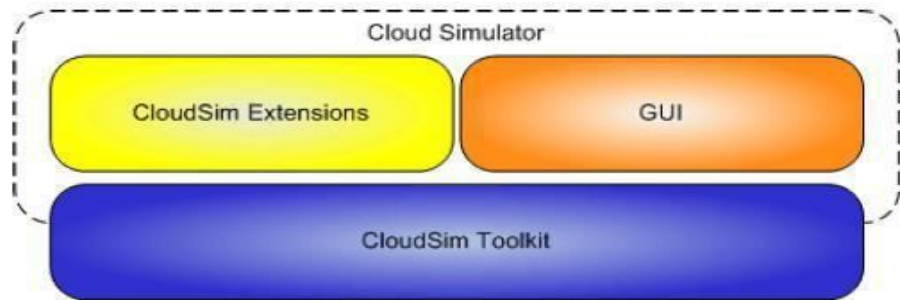


Figure 6.2: CloudAnalyst component

6.2 IMPLEMENTATION DETAILS

The implementation of our LBA is done by the help of the above technologies. The simulation work has been categorized in two sections. The first one is done using the CloudAnalyst. The second category of simulation is done using CloudSim toolkit. In this simulation of the proposed algorithm is carried out and further comparison is done with the traditional approach of load balancing. The algorithm is written in **Java** and is run on **Eclipse IDE** using CloudSim toolkit.

The program is implemented according to the flow of execution in CloudSim. Figure 6.3 shows the flow of execution of a program in CloudSim.

The CloudSim package is written in Java and it is used with the help eclipse IDE for implementation of proposed LBA. These CloudSim functional steps are shown in the output of the proposed LBA. As a functional advancement of CloudSim it is very easy to simulate the cloud environment with the all features of cloud infrastructure.



Figure 6.3: Flow of program execution in CloudSim

6.3 EXPERIMENTAL RESULTS

The results are produced by proposed LBA simulated in two categories. At first, simulation is done for the existing load balancing algorithms namely Round Robin, Throttled and Equal spread current execution algorithm in combination with the service broker policies like closest datacenter and the Optimized response time policy using the CloudAnalyst. Secondly, the proposed algorithm was simulated using CloudSim toolkit and then the results are compared with the traditional approach of load balancing. A

graphical analysis is done in order to have clear understanding of both the approaches. Let us discuss these results in detail.

6.3.1 SIMULATION RESULTS OF EXISTING LBA

The overall response time in each case can be analyzed graphically through Figure 6.4. The maximum and average response time in each case is shown separately for each case. Generally, the average response time is considered for evaluating the performance of the overall system.

It can be clearly observed from the below graphical result that ESCE load balancing policy is best suited for our application. It gives the minimum response time compared to others. And for service broker policy, it can be concluded that Closest Datacenter policy gives the maximum profit to cloud service provider by giving the lowest cost for virtual machines and data transfer.

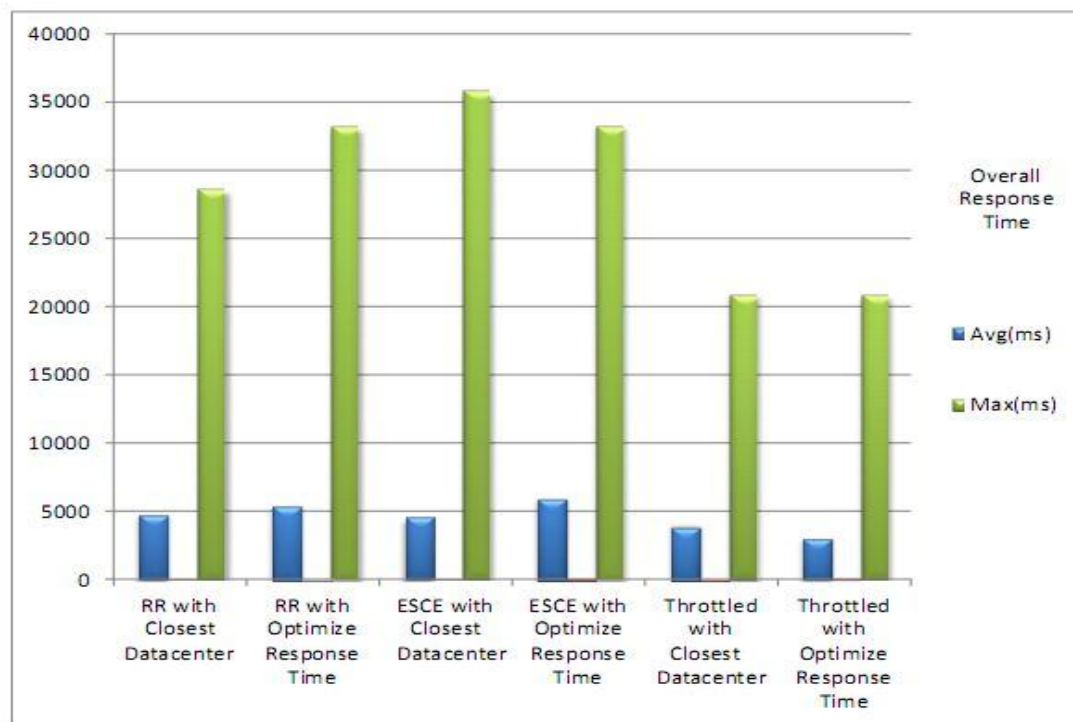


Figure 6.4: Overall Response Time for global cloud usage.

6.3.2 SIMULATION RESULTS OF PROPOSED LBA

The simulation results of the proposed LBA have been done in this section. Certain assumptions have been made regarding the experiment setup required for the verification and validation of the proposed LBA. A set of four virtual machines, two hosts and eight cloudlets configured for the experiment purpose in CloudSim. Each VM has the same configuration with equal VM capacity with the Threshold value set by the cloud service provider.

However, a proposed algorithm can be tested for a large number of scenarios, but in this thesis, for the sake of simplicity and understanding a general scenario in a cloud computing environment has been assumed. In this scenario, one datacenter is created, eight cloudlets and four VMs are created which are to be deployed on any of the two hosts created in the datacenter based upon the LBA. Each host is having different number of processing cores i.e. PES.

Here, different numbers of processing cores are assumed in order to judge the proposed algorithm more precisely in a heterogeneous environment. Here host H1 is having three PES, similarly H2 two. Also each host is same configured, each parameter like memory, bandwidth, secondary storage, number of processing cores are assigned. According to the proposed approach the virtual machines are deployed on the host with maximum number of the processing element available. It has been clearly visible in the output that the host allocation is done with the same rule of traditional approach. It is also assumed that all the virtual machine required any number of processing elements from any of the host for performing its operation.

Since, the proposed LBA is operated at both level in which hosts are allocated to the virtual machines and cloudlets are allocated to virtual machines, so assumptions are made in accordance with this. Although the main code is written in such a way that a user can take any number of datacenters, hosts, virtual machines and cloudlets. Also different configurations can be set for the each component. Allocation for the host can be clearly seen in the below output. According to proposed LBA cloudlets and VMs are well managed to hold the PES requests till its capacity.

Whenever a VM hold the Various PESs of one of the host and its current load is low as compare to its VM threshold capacity, than it will also take other PES request of another host till its capacity limit exits to process the particular task. If the sum of the next PES request task time and current load of that VM exceeds the time limit beyond the capacity of VM than that PES request is allotted to another available VM. The proposed LBA provides the more continuous distribution of load assignment of VMs to various Hosts.

OUTPUT:

The output for the above stated scenario by proposed LBA is shown as:

Starting dynamic load Spread...

Initialising...

Starting CloudSim version 3.0

Datacenter_0 is starting...

Broker is starting...

Entities started.

0.0: Broker: Cloud Resource List received with 1 resource(s)

0.0: Broker: Trying to Create VM #1 in Datacenter_0

0.0: Broker: Trying to Create VM #2 in Datacenter_0

0.0: Broker: Trying to Create VM #3 in Datacenter_0

0.0: Broker: Trying to Create VM #4 in Datacenter_0

0.1: Broker: VM #1 has been created in Datacenter #2, Host #1

0.1: Broker: VM #2 has been created in Datacenter #2, Host #2

0.1: Broker: VM #3 has been created in Datacenter #2, Host #1

0.1: Broker: VM #4 has been created in Datacenter #2, Host #2

0.1: Broker: Sending cloudlet 1 to VM #1

0.1: Broker: Sending cloudlet 2 to VM #2
0.1: Broker: Sending cloudlet 3 to VM #3
0.1: Broker: Sending cloudlet 4 to VM #4
0.1: Broker: Sending cloudlet 5 to VM #1
0.1: Broker: Sending cloudlet 6 to VM #2
0.1: Broker: Sending cloudlet 7 to VM #3
0.1: Broker: Sending cloudlet 8 to VM #4
80.1: Broker: Cloudlet 1 received
80.1: Broker: Cloudlet 5 received
80.1: Broker: Cloudlet 3 received
80.1: Broker: Cloudlet 7 received
80.1: Broker: Cloudlet 2 received
80.1: Broker: Cloudlet 6 received
80.1: Broker: Cloudlet 4 received
80.1: Broker: Cloudlet 8 received
80.1: Broker: All Cloudlets executed. Finishing...
80.1: Broker: Destroying VM #1
80.1: Broker: Destroying VM #2
80.1: Broker: Destroying VM #3
80.1: Broker: Destroying VM #4
Broker is shutting down...
Simulation: No more future events
CloudInformationService: Notify all CloudSim entities for shutting down.
Datacenter_0 is shutting down...

Broker is shutting down...

Simulation completed.

Simulation completed.

===== OUTPUT =====

Cloudlet ID	STATUS	Data center ID	VM ID	Time	Start Time	Finish Time
1	SUCCESS	2	1	80	0.1	80.1
5	SUCCESS	2	1	80	0.1	80.1
3	SUCCESS	2	3	80	0.1	80.1
7	SUCCESS	2	3	80	0.1	80.1
2	SUCCESS	2	2	80	0.1	80.1
6	SUCCESS	2	2	80	0.1	80.1
4	SUCCESS	2	4	80	0.1	80.1
8	SUCCESS	2	4	80	0.1	80.1

Load Balancing finished!

In case of the proposed algorithm it is clearly visible from the output that each Host is allocated to a given VM as per the proposed methodology, which is comparatively **more distributed** in nature.

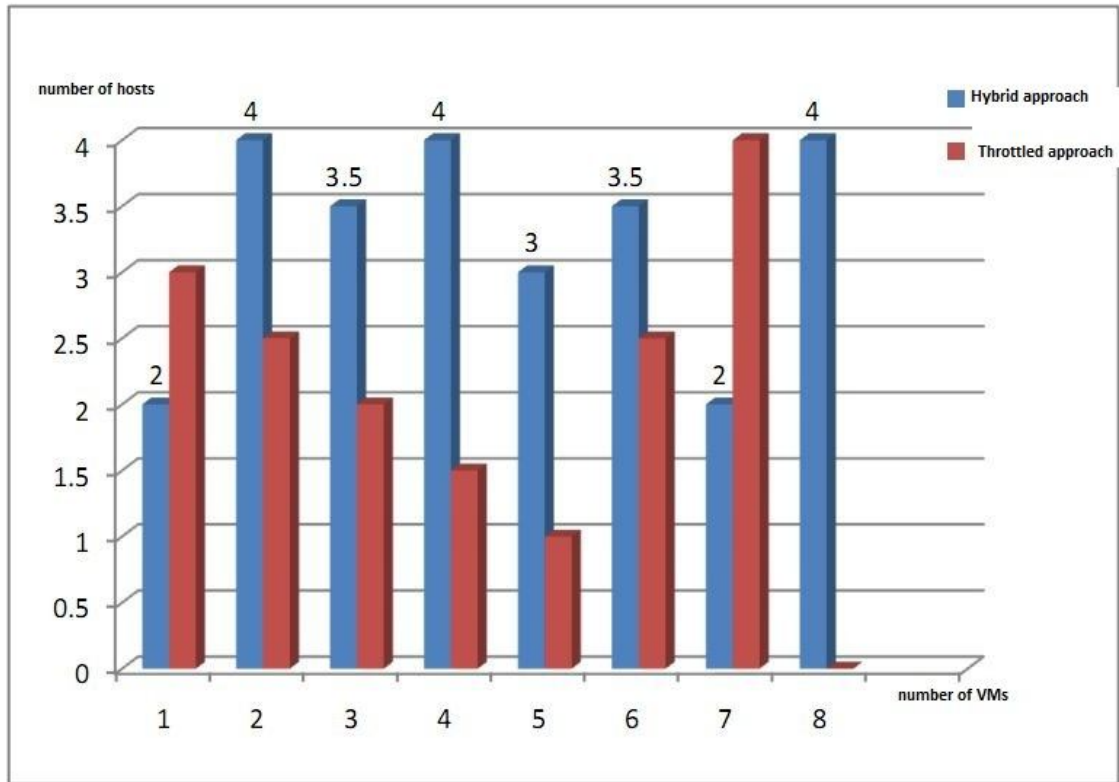


Figure 6.5: Comparison between proposed Hybrid approach and Throttled approach.

The order of Host allocation is clearly visible in the above output. A level of distribution of Hosts among the virtual machines is more in case of the Hybrid load balancing algorithm. Similarly a number of experiments can be done to compare the proposed methodology with number of other related methodologies in any kind of scenario.

A more distributive curve will be obtained in case of the proposed methodology. A graphical analysis is done in order to clearly view the difference between the proposed methodology and the existing methodology. Figure 6.5 shows this graphical analysis. X-axis shows the number of VMs and the Y-axis shows the number of hosts. In the graph it is clearly shown that the proposed methodology is more distributive i.e., the virtual machines are more distributed over the host in case of the proposed methodology.

CHAPTER 7

CONCLUSION AND FUTURE WORK

This chapter concludes the work presented in this thesis and also the future aspects of the proposed load balancing algorithm. Many other researchers can extend the work upon this research area and particularly on this proposed load balancing methodology. These all aspects are discussed here.

7.1 CONCLUSION

The basic purpose to apply this proposed algorithm is to achieve dynamic linking at the time of virtual machine allocation to the Hosts and cloudlet allocation to virtual machines. Instead of taking single host for a particular virtual machine it takes the host's PES in dynamic spread way till its capacity exist. It makes cloud architecture more flexible when the number of inputs comes in bulk for the cloud service usage. We have done this at host and virtual machine level. The basic aim is to derive this algorithm is that when a PES has less amount of CPU execution time and virtual machine has high configuration efficiency in terms of processing speed, memory and capacity then why we cannot take the whole utilization of a virtual machine to another PES cores. In this algorithm it is the main consideration with the virtual machine capacity.

Load balancing in cloud computing can be done by provisioning the resources in the cloud computing network or by scheduling the user tasks in an efficient manner. As per the research work associated with this dissertation, resource provisioning in cloud computing is chosen as it can be more effective in distributing the overall workload to

various resources in a cloud computing network. In cloud network the resource provisioning is done at two levels: VM level and host level. We have done on both levels, i.e. resource provisioning at host level in which the hosts i.e. the physical servers are allocated to various virtual machines which are instantiated by the users as per their specification and task allocation to virtual machine. Load balancing is one of the key challenge in the area of cloud computing, which is gaining a larger attention among all the researchers and developers over the globe. Therefore, this issue has been picked and analyzed thoroughly from different perspectives.

There are number of factors like throughput, complexity, scalability, flexibility, response time, etc which are together responsible for judging the right load balancing algorithm for a system. A developer must design a load balancing policy satisfying all these parameters which in turn increases the overall efficiency of the system. In this thesis we analyzed each of these parameters in detail. Different load balancing algorithms are compared based on these parameters. Various service broker policies are also analyzed in combination with the different load balancing algorithms. These service broker policies can play an important role in dealing the heavy real-time traffic over the network. Overall it is very crucial for any system to perform the all the related operations in a short period of time with higher efficiency. In cloud computing systems the same is expected.

7.2 FUTURE WORK

In future we can do number of modifications to have better results. Let us discuss some points which can be implemented in future:

- The hybrid approach can be further modified by setting an appropriate threshold to achieve power saving while making the overall system energy efficient.
- The Hybrid algorithm can be integrated with the hypervisor layer i.e. intermediate level at which virtual part can be separated from physical level. This will make the cloud system more efficient and the overall response time can be reduced further as we will understand the whole architecture.

- Also this work can be deployed in some real-time platforms to handle the real-time traffics in the network and then evaluating the performance of the system.

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