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Review of Techniques and Algorithms of Load Balancing in Cloud Computing

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Abstract

Cloud computing has revolutionized the delivery of modern applications and services through its scalability, flexibility, and cost-effectiveness. Efficiently allocating jobs among servers or virtual machines is a significant challenge in fully harnessing the capabilities of cloud systems. This review does a comprehensive comparison and analysis of various cloud-based dynamic load balancing algorithms to identify the most effective one. A variety of load balancing algorithms, including Round Robin, ESCE, Min-Min, Max-Min, and Throttled, are covered in the discussion along with their effects on throughput, fault tolerance, scalability, and overhead. The literature review stresses the dynamic nature of the cloud computing landscape by highlighting important contributions from scholars. Additionally, the study identifies issues in cloud services, such as automated service provisioning, virtual machine migration, energy management, stored data management, and the growth of small data centers. Even though cloud computing has become widely used, these difficulties highlight the continued need for innovation in the industry. This review serves as an excellent resource for individuals engaged in the optimization, research, and development of cloud computing systems, providing insights into contemporary load balancing techniques.

Keywords: Cloud Computing, Load Balancing, Load Balancing Algorithm, Round Robin Algorithm, ESCE, Throttled Algorithm, Min-Min Algorithm, Max-Min Algorithm

1. INTRODUCTION

Cloud computing is a widely recognized technology that provides services, both private and public, such as convenient access to data, programs, and files over the internet (cloud). It offers scalable storage services for storing files online instead of relying on local storage on devices like computers or phones. It is known for providing dynamic services, including cost-effective and scalable alternatives, as well as a wide range of services to clients[1].

A distributed collection of computer resource systems and services known as "the cloud" can be easily installed and accessible via the internet, requiring less time and effort for initial setup. The cloud includes several features, such as privacy, security, and speed. You can think of cloud computing as the internet's paradigm. We can place network services in someone else's hands using cloud computing, which is an excellent method to cut costs. Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) are the categories under which these services fall[2].

In cloud computing, users only pay for the resources they utilize, as opposed to purchasing and maintaining dedicated infrastructure. Cloud providers outsource resources to their clients, offering scalability and flexibility. However, cloud computing also presents several challenges, with load balancing being a prominent issue. Load balancing plays a crucial role in distributing workloads across nodes, ensuring efficient and fair allocation of computing resources. By preventing load imbalance, it mitigates system bottlenecks and enhances user satisfaction. Load balancing is a relatively recent technique that promotes high resource utilization and improves response time[3].

A load balancer, which takes jobs from several places and transfers them to the data center, is used to properly disperse the load. It is a tool that distributes application network load among several servers and functions as a reverse replacement. Enhancing performance, maintaining stability, and scalability for accommodation are the objectives of load balancing. The backup plan is important in the event of a system crash and will lower associated expenses if there is an increase in large-scale computing[4].

The use of load balancing in cloud computing:

A. **Improved Performance: -**Load balancing ensures equitable distribution of workloads across servers, preventing overloading and enhancing performance by optimizing resource utilization and reducing response times [5].
B. **Scalability and Elasticity: -**In cloud systems, load balancing makes horizontal scaling possible. According to workload demands, it enables the dynamic addition or removal of resources, ensuring optimal resource allocation and effective utilization [6].
C. **High Availability and Fault Tolerance -**High availability is facilitated by load balancing by distributing workloads among redundant resources. Load balancing transfers traffic to other accessible resources if a server or resource fails, reducing downtime and ensuring fault tolerance [7].
D. **Cost Optimization: -**The consolidation and efficient use of resources is made possible by load balancing, which helps with cost optimization. Reduced infrastructure expenses are the result of avoiding resource over- or under-provisioning in cloud installations [8]
E. **Traffic Management: -**Load balancing is essential for controlling network traffic. It facilitates the effective distribution of incoming requests, preventing congestion and maximizing the usage of network resources [9].
F. **On-request service: -**The user can request any cloud service and evaluate it at any moment.
G. **Board Network Access: -**Numerous services are available in the cloud and can be accessed online. The Cloud services can typically be accessed on any common device or through local networks.
H. **Fast Elasticity: -**The services on this enable less frequent use of workloads that previously required many servers to run for short periods.

I. **Resource Sharing: -**Cloud computing offers various models that enable users to share and dynamically allocate resources provided by service providers based on their requests. These models allow for efficient resource utilization and allocation [14].

Challenges with cloud services:

A. Interoperability
B. Lack of Experience
C. Performance Monitoring
D. Cost Management
E. High Dependence on the Internet

One of the crucial issues in cloud computing is load balancing. To increase system utilization and task response times, load balancing comprises the act of distributing varied loads among different nodes. It also helps when one node is underutilized while others are overutilized or go into idle mode. Through load balancing, each system or node operates consistently and simultaneously completes equal work. Load balancing becomes increasingly necessary as users' demand for cloud services grows. Users benefit from increased resource utilization and user happiness. To free up resources and make them available to improve response times and ensure better resource utilization, load balancing maps every task assigned to the cloud. To provide load balancing, you need numerous servers or resources to meet user needs. Load balancing still works even if one or more components are unable to offer service. To free up resources and make them available to improve response times and ensure better resource utilization, load balancing maps every task assigned to the cloud. To provide load balancing, you need numerous servers or resources that can meet user needs. Even if one or more components don't work properly [10].

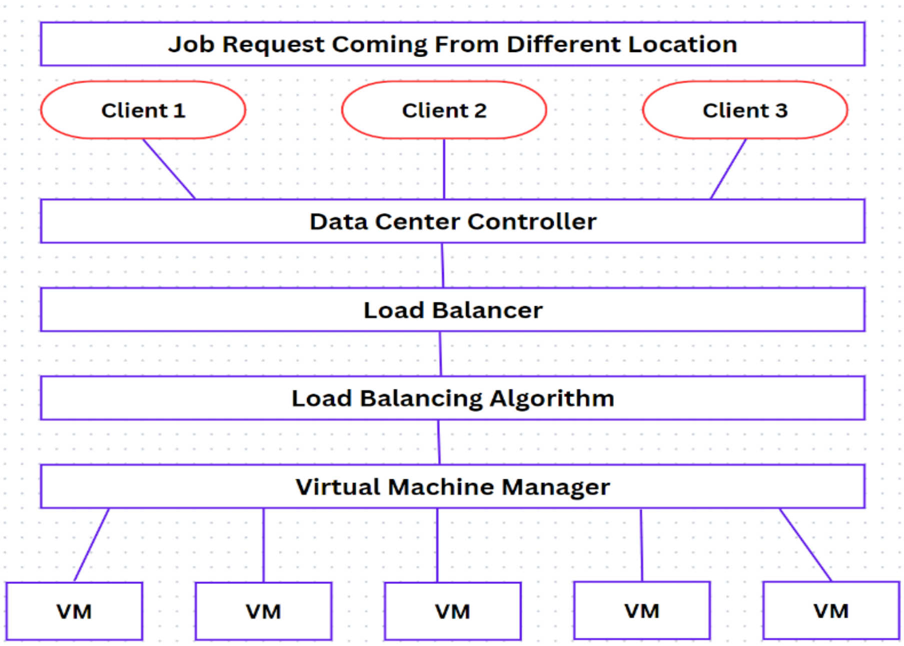

Figure 1. Load Balancing in Cloud Computing

2. LITERATURE SURVEY

Table 1: Discusses load balancing strategies

S.No.	Authors	Main Focus	Key Contributions
1.	Shafiq et.al.[1]	Load balancing methods in cloud computing	Thorough analysis of load balancing methods in static, dynamic, and cloud systems. Quantitative assessment, graphical representation, and identification of areas for additional research.
2.	Dhumal et.al.[2]	Importance of cloud computing and load scheduling algorithms	Focuses on load scheduling algorithms in cloud computing, proposes an improvement to the Shortest Job First (SJF) algorithm, and evaluates the performance of various algorithms using a cloud simulator.
3.	Tyagi et.al.[3]	Importance of load balancing in cloud computing	Highlights the importance of load balancing for effective resource utilization in cloud computing. Calls for the development of more effective load balancing algorithms.
4.	Tasneem et.al.[4]	Challenges faced by Cloud Computing	Addresses challenges faced by Cloud Computing, including data security, resource utilization optimization, performance management, cost management, and Cloud migration.
5.	Khare et.al.[10]	Load balancing for effective resource utilization and user satisfaction	Reviews various load balancing techniques in cloud computing to ensure effective resource utilization and user satisfaction.
6.	Alsaih et.al.[11]	Transparent exchange of information, computations, and services in cloud	Introduces a new paradigm for load balancing in cloud. Highlights challenges in load balancing techniques and emphasizes resource-efficient use for maximizing earnings.
7.	Afzal et.al.[13]	Load unbalancing problem in cloud computing	Comprehensive review of load balancing techniques, highlighting their advantages, limitations, and addressing critical challenges. Proposes insights for the development of efficient algorithms.
8.	Alruwaili	Rapid development of cloud computing	Addresses load balancing challenges in cloud computing. Proposes a novel load balancing algorithm

	et.al.[14]		to enhance application performance and adapt to evolving infrastructure and resource requirements.
9.	Bala ji et.al. [15]	Cloud as a new paradigm for offering services on demand	Examines challenges with current load balancing methods in the cloud and calls for the creation of more effective algorithms.
10.	Goswami et.al.[16]	Overview of load balancing strategies in various cloud settings	Discusses load balancing strategies to achieve effective resource allocation and SLA adherence in different cloud settings.
11.	Jaiswal et.al.[17]	Load balancing algorithms in IoT contexts	Analyzes various load balancing algorithms for cloud computing in the context of the Internet of Things (IoT).
12.	Mishra et.al.[18]	Task scheduling in cloud environments	Addresses the challenging task of scheduling user requests in cloud environments. Presents a taxonomy of load balancing algorithms and evaluates heuristic-based algorithms through simulation.
13.	Shameem et.al.[19]	Growing paradigm of cloud computing	Focuses on the transparent distribution of data, calculations, and services in the growing paradigm of cloud computing. Evaluates and compares various load balancing strategies.
14.	Sansanwal et.al.[20]	Evolution of cloud computing and load balancing challenges	Discusses the evolution of cloud computing and the challenges of load balancing. Introduces a novel algorithm, IG-GWO, to address load balancing challenges.
15.	Tabassum et.al.[21]	Importance of availability in cloud computing systems	Emphasizes the importance of availability in cloud computing systems. Examines load balancing in the context of system availability using a Hospital Database Management solution as a case study.
16.	Kumar et.al. [22]	Overview of research on optimal load balancing in server environments	Provides a comprehensive overview of research on optimal load balancing in server environments. Highlights the significance of scalability, agility, and availability in cloud load balancing.
17.	Nagamani et.al.[23]	Security issues in radio, television, and wireless ad hoc networks	Discusses security issues in radio, television, and wireless ad hoc networks. Proposes a cross-layer authentication system to counteract privacy assaults.

18.	Venkata et.al.[24]	Significance of load balancing in Cloud Computing	Discusses the significance of load balancing in Cloud Computing for optimizing resource utilization and improving user experience.
19.	Samunnisa et.al.[25]	Significance of load balancing in cloud computing systems	Emphasizes the importance of load balancing in cloud computing systems for minimizing task overload and ensuring reliable and valuable service delivery.
20.	Kaur et.al.[26]	Effective task scheduling in cloud computing	Discusses the importance of effective task scheduling in cloud computing for satisfying user needs, improving resource utilization, and boosting overall performance.

3. LOAD BALANCING

A technique for streamlining VM resources in a cloud computing context is load balancing. In the cloud environment, load balancing is one of the key methods used to ensure that the workload is distributed equally and dynamically and that resources are used effectively. [1]

Load balancing is a critical concern in cloud computing. It involves the even distribution of dynamic workloads across all nodes within the cloud infrastructure, thereby preventing scenarios where certain nodes are overloaded while others remain idle or underutilized. Load balancing enhances user satisfaction and maximizes resource utilization, resulting in improved overall system performance and resource efficiency. By ensuring equitable distribution, it mitigates the risk of bottlenecks caused by load imbalances. Additionally, load balancing facilitates service continuity by implementing failover mechanisms, provisioning and deprovisioning application instances seamlessly in the event of component failures [11].

Classification of load balancing:

The two main types of load balancing are static and dynamic load balancing.

A. **Static algorithm: -**The system's design or implementation largely defines this strategy. Static load balancing techniques evenly distribute traffic among all of the servers.
B. **Dynamic algorithm: -** This method solely evaluated the system's current condition while measuring the effectiveness of load balancing. Processes are rearranged across processors while a dynamic algorithm is running; this approach is better suited for globally distributed systems like cloud computing. The primary drawback of dynamic algorithms is the run-time overhead resulting from the communication lags connected with the task rearrangement itself as well as the transfer of load information among processors and decision-making for the diversity of processes. Depending on whether responsibility for the task of global dynamic scheduling should actually lie in a single processor (centralised) or whether the work required in drawing conclusions should be physically distributed among processors, dynamic load balancing methods can be either central or distributed.
   There are two types of dynamic load balancing algorithms, which are centralised (non-distributed) approach and distributed approach. It is characterised as follows:

- **Centralized approach: -** In a centralised model, the sole node is in charge of the system's operation and dissemination. Additionally, not all nodes are accountable for this.
- **Distributed approach:** - In a distributed approach, each node independently constructs its own load vector by gathering load data from other nodes. Local load vectors are utilized to draw conclusions in close proximity. The distributed approach is particularly suitable for widely distributed systems, such as cloud computing [10].

Objectives of load balancing algorithms:

A. **Cost effectiveness: -** Load balancing assists in improving system performance while reducing costs.
B. **Scalability and flexibility: -** The size of the system for which load balancing methods are used may alter over time. Therefore, the algorithm must handle these kinds of circumstances. Algorithms must therefore be adaptable and scalable.
C. **Priority: -** The resources or tasks need to be prioritised. Thus, higher priority tasks have a better likelihood of being completed [3].

Algorithms for load balancing:

A. **Round Robin Algorithm: -** The Round Robin algorithm utilizes a time slice mechanism where time is divided into several slices. Each node is allocated a specific time quantum within which it performs its processes [12]. Resources are allocated to clients based on this time quantum. The Round Robin algorithm follows a round-robin technique of assigning jobs, which does not consider the load on different machines. As a result, some nodes may experience heavy loads while others have no requests.
   The time quantum plays a crucial role in the Round Robin scheduling process. If the time quantum is too large, the Round Robin algorithm behaves similarly to the First-Come, First-Served (FCFS) scheduling algorithm. On the other hand, if the time quantum is too small, the Round Robin algorithm becomes a Processor Sharing algorithm, resulting in a high number of context switches.
B. **Equally Spread Current Execution Algorithm (ESCE): -**In the spread spectrum method, the load balancer aims to distribute an equal load among all connected virtual machines (VMs) in the data center. The load balancer maintains an index table that tracks the number of requests allocated to each VM. When a new VM needs to be allocated, the load balancer checks the index table to identify the least loaded VM. If multiple VMs are equally minimally loaded, the load balancer selects the first VM from the list and assigns it to handle the client/node request. The load balancer also returns the VM ID to the respective data center controller. The data center then routes the request to the identified VM and updates the index table by incrementing the share count for that VM. Once the assigned task is completed by the VM, a notification is sent back to the data center and reported by the load balancer. The ESCE algorithm's function is depicted in **Figure 2**.

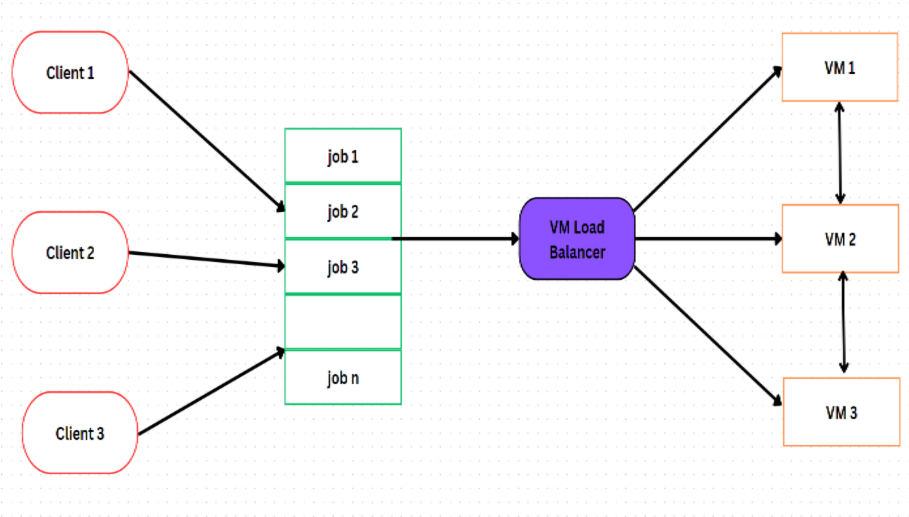

Figure2. ESCE Algorithm

C. **Min-Min Algorithm: -** These algorithms begin with a set of tasks that are initially not assigned to any of the nodes. For all of the accessible nodes, the least completion time is first taken into account. The job with the shortest anticipated completion time is then chosen and assigned to the node with the shortest execution time. The task has now been eliminated from the task list. This procedure is repeated until all task kinds are assigned to the same nodes. As a result, the algorithm improves if the smaller work is larger than the smaller task.

D. **Max-Min Algorithm: -** The max-min algorithm in question is identical to the min-min algorithm. The Max-Min method begins with a list of all the jobs that have been submitted but are not yet allocated to any nodes. The shortest completion time for each sort of work that is accessible is determined at the beginning. The resource with the shortest response time is then assigned the process with the longest execution duration.

This method replaces the Min-Min algorithm, which prioritizes short processes over long ones.

E. **Throttled Algorithm: -** This kind of algorithm operates by identifying the best virtual machine to assign a specific task to. The load balancer maintains an index table of virtual machines and their statuses using this type of method. The customer first requests that the data centre locate a suitable virtual machine to carry out a specific task. The customer submits a request to the data centre for the distribution of virtual machines. After that, the data centre asks the load balancer to distribute the virtual machines. Until the first accessible VM is located or the index table has been thoroughly searched, the load balancer searches the index table from above.

The VM Id is sent to the Data Centre if the VM starts. The Data Centre will then link the demand to the VM identified by the Id. The data centre then recognizes the load balancer for the most recent allocation and carefully examines the index table.

If a VM is unavailable while handling a client request, the load balancer sends a value of -1 to the data centre. The Data Centre then queues the request for the subsequent virtual machine accessibility. When the VM has finished processing the request, it notifies the data centre of the results and recognizes the load balancer for VM de-allocation. The allocation for VM is then decreased by 1 by the load balancer, which notifies the allocation table.

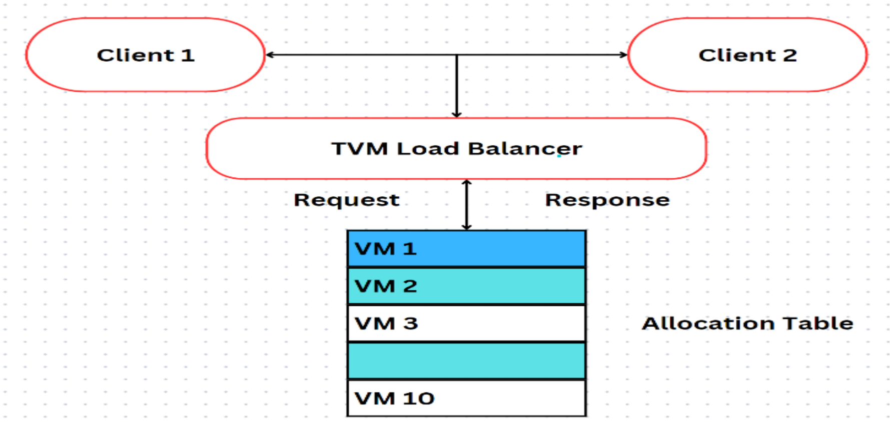

Figure 3. Throttled Algorithm

F. **Ant Colony Optimization Algorithm: -**These algorithms exhibit behaviors resembling that of actual ants. It is primarily based on ants' ability to find the best route from their shell to the source. When a demand is initiated in the Ant Colony Optimization process, the ant begins to move. Ants start at the root node and move to adjacent nodes, checking each one to see if it is overloaded or underloaded as they go. Ants alert the pheromone table, which stores the information about each node's operation when they move towards the network.

G. **Honeybee Foraging Behaviour: -** An algorithm for self-organization of this kind is one that takes inspiration from nature. Using local server operations, Honeybee achieves overall load balancing. With the system range expanding, the system's performance improves. The primary disadvantage is that throughput will not rise as the system's size grows. This particular type of algorithm is suitable when a variety of service types are needed [10].

Table 2. Comparison of several load balancing techniques based on Metric Enrolment

Parameters Algorithm	Throughput	Fault Tolerance	Response Time	Overhead	Resource Utilization	Scalability	Performance
Round Robin	Yes	No	Yes	Yes	Yes	Yes	Yes
ESCE	No	No	No	No	Yes	Yes	No
Min	Yes	No	Yes	Yes	Yes	No	Yes
Max	Yes	No	Yes	Yes	Yes	No	Yes
ALO	Yes	No	No	Yes	Yes	No	No
Honey Bee	Yes	No	No	No	Yes	No	No
Throttled	No	Yes	Yes	No	Yes	Yes	Yes

4. LOAD BALANCING CHALLENGES IN THE CLOUD COMPUTING

Although cloud computing has been widely adopted. Research in cloud computing is still in its early stages, and some scientific challenges remain unsolved by the scientific community, particularly load-balancing challenges.

Table 3: Challenges and Key questions

S.No.	Challenges	Key Question
1	Automated Service Provisioning	How can we utilize or release cloud resources automatically (elasticity) while maintaining performance comparable to conventional systems and optimizing resource utilization?
2	Virtual Machines Migration	How can virtual machines be moved between physical machines to decompress overloaded ones and distribute the load across a data centre or group of data centres, preventing bottlenecks in cloud computing systems?
3	Energy Management	How can energy be conserved in cloud computing, considering the benefits of economies of scale and the global economy? How to utilize a portion of the data centre while maintaining respectable performance?
4	Stored Data Management	How can data be efficiently distributed to the cloud to ensure maximum storage capacity and quick access, addressing the challenges of increasing data storage needs for businesses outsourcing their data storage?
5	Emergence of Small Data Centres	How can small data centres be leveraged to provide more advantageous, cost-effective, and energy-efficient solutions for cloud computing? How to address load balancing issues on a global scale for optimal resource allocation?

5. CONCLUSION

In this study, we examined various load balancing techniques used in cloud computing. Although the industry has generally adopted cloud computing, there are numerous sorts of current problems, including server consolidation, energy management, load balancing, virtual machine migration, etc. The key problem with all of these is load balancing, which is required to evenly distribute the additional dynamic local workload over all cloud nodes in order to increase customer satisfaction and resource consumption rates. Various dynamic and static load balancing algorithms for cloud computing, including Max-Min, Ant Colony Optimisation Algorithm, round robin, Honeybee, Min-Min, Throttled Algorithm, etc., have been examined and compared in this paper while taking into account features like overhead, fault tolerance, throughput, scalability, etc.

Author Contributions

The submitted version of the article was approved by all authors and all authors contributed to it.

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Conflict of Interest

The authors declare no conflict of interest.

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