IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, November 2024

Comprehensive Analysis of Cloud Computing Performance Factors: Investigating the Impact of Response Time, Load Balancing and Service Broker Policies on Cloud Service Efficiency Using CloudSim Simulation

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Abstract*:* *Cloud performance refers to the efficiency and effectiveness with which a cloud system operates delivering hosted services over the internet. As cloud computing continues to offer flexibility, scalability and computational power monitoring and improving cloud performance is essential. Performance optimization is influenced by factors such as load balancing and service broker policies which impact system response times and overall user experience. This paper provides an in-depth review of key publications and real-time cloud performance tools identifying critical performance factors that affect cloud efficiency. Notably, response time emerged as a fundamental metric for cloud service quality. Using CloudSim simulation we examine cloud performance evaluation criteria and experimentally assess the impact of response time dependencies on broker policies, load balancing techniques and data center distribution. This study offers a framework for understanding cloud performance evaluation and highlights strategies to enhance user experience in diverse cloud environments.*

Keywords: Cloud computing, performance evaluation, response time, load balancing, service broker policies, CloudSim simulation, data center distribution, cloud optimization, user experience

I. INTRODUCTION

Cloud computing provides a model for enabling on-demand access to a shared pool of configurable computing resources such as servers, storage and applications over a network. This technology offers flexibility and scalability to meet dynamic user demands but ensuring consistent service quality is challenging. Often, the performance experienced by cloud users may fall short of service providers targets highlighting the need for efficient management and evaluation practices. Monitoring cloud performance is essential for identifying areas for improvement as it directly impacts user satisfaction and service reliability. Effective cloud performance evaluation can help pinpoint the optimizations required for a cloud system to operate at its best.

In cloud computing, resources are provided as services by major providers like Google, Microsoft, Amazon and IBM among others. However, delivering a seamless user experience remains a complex challenge due to various factors such as implemented service policies, load balancing techniques, and the limitations of data centre infrastructure. Each of these elements plays a role in determining the efficiency of cloud services, and their collective impact shapes the overall cloud experience. Therefore, understanding and assessing these performance factors is crucial for improving cloud service delivery. This paper focuses on the significant factors influencing cloud performance exploring how aspects like response time, network bandwidth, user loads and service broker policies contribute to a cloud system's

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effectiveness. Through this research we aim to provide a comprehensive framework for evaluating and enhancing cloud performance to meet user expectations in diverse cloud environments.

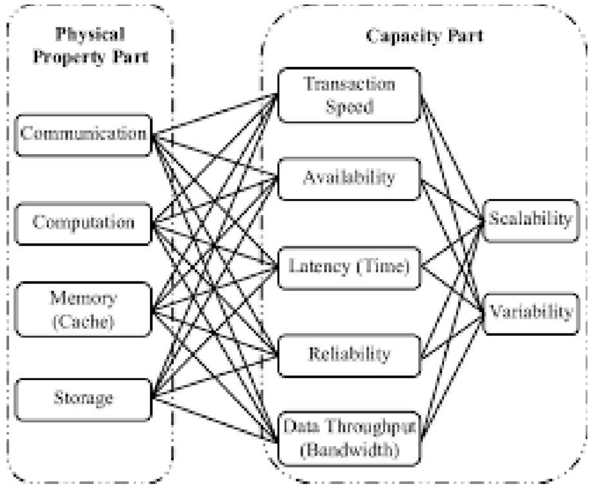

Fig 1: Performance features of Cloud services for evaluation

II. LITERATURE REVIEW

Paper Title	Abstract	Findings	Research Gap
D. Gritto and T. S. Vasughi, "Enhancing Cloud Services: Streamlining Performance Metrics and Cloudlet Scheduling," 2023 *2nd International Conference on Automation, Computing and Renewable Systems (ICACRS), Pudukkottai, India, 2023*, pp. 1841-1848, doi: 10.1109/ICACRS58579.2023.10404522	Enhancing cloud services through performance metrics optimization and resource utilization and it also evaluates cloudlet scheduling algorithms using CloudSim for performance improvement.	Identified essential performance metrics for cloud services.	A comprehensive evaluation of cloudlet scheduling algorithms on key performance metrics for optimizing cloud service quality is lacking.
Ajay Katangur, Shusmoy Chowdhury. DEThresh: Enhancing Cloud Computing Performance with Differential Evolution-Driven Datacenter Selection and Threshold-based Load Balancing Optimization, 06 February 2024, PREPRINT (Version 1) available at Research Squarehttps://doi.org/10.21203/rs.3.rs-3929293/v1	DEThresh enhances cloud performance with datacenter selection and load balancing. Superior response times and reduced costs with fewer datacenters.	Achieves cost reduction with fewer datacenters used.	Lack of effective algorithms that simultaneously optimize datacenter selection and load balancing to enhance cost-efficiency and performance in cloud computing.
K. Prabakaran and B. Sivakumar, "Efficient Data Access and Streamlined Retrieval: Enhancing Performance in Cloud-Based Systems," *2024 2nd International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT)*, Bengaluru, India, 2024, pp. 1139-1144, doi:10.1109/IDCIoT59759.2024.104678	Cloud storage simplifies data retrieval but may cause latency issues. Research focuses on improving query translation and system performance.	Improved Query Transformation Layer enhances user-friendliness and data retrieval. Addressed HiveQL complexities and user satisfaction	Difficulties in retrieving data and user satisfaction. Need for precise query translation across diverse datasets.

27		issues.	
Thilagavathy, R., Deebalakshmi, R., Jayasankari, S., Nivedita, V. (2023). Enhancing the Performance of Cloud Environment by a Novel Three-Stage Task Scheduling Policy. In: Iwendi, C., Boulouard, Z., Kryvinska, N. (eds) Proceedings of *ICACTCE'23 — The International Conference on Advances in Communication Technology and Computer Engineering. ICACTCE 2023*. Lecture Notes in Networks and Systems, vol 735. Springer, Cham. https://doi.org/10.1007/978-3-031-37164-6_1	Proposes a three-stage task scheduling model for cloud computing.Aims to reduce completion time and improve resource efficiency.	Significant reduction in task completion time achieved.Decreased energy usage observed in scheduling model.	Previous models have unsolved issues in task scheduling. Need for improved resource utilization and QoS satisfaction.
G. J. Mirobi, V. Suresh and M. K. Devi, "An Efficient Workflow Scheduling Approach for Enhancing the Performance in Cloud Environment," *2023 12th International Conference on Advanced Computing (ICoAC)*, Chennai, India, 2023, pp. 1-5, doi: 10.1109/ICoAC59537.2023.10249499	Workflow Scheduling arranges jobs and manages task execution.Proposed approach enhances performance by prioritizing consumer requests.	Proposed efficient workflow scheduling enhances system performance.Prioritizes consumer requests and optimally assigns virtual machines.	Existing algorithms ignore request and performance variations.Need for efficient scheduling for high incoming tasks.

III. REVIEW OF CLOUD PERFORMANCE OPTIMIZATION RESEARCH

Several key studies and research efforts have addressed various aspects of Cloud performance, with a particular focus on optimizing resource management, latency reduction and cost-effectiveness.

Leading Cloud service providers like Google Cloud Platform, Amazon Web Services (AWS), Microsoft Azure, Oracle Cloud and IBM Cloud offer distinct environments, architectures and performance attributes. Each platform's architecture, which includes specialized data centers and global distribution models provides critical benchmarks for evaluating cloud performance across different regions, configurations and service types. This variety of configurations allows for extensive performance evaluation across different real-world cloud environment sress the challenge of affordability and enhanced performance in cloud storage, researchers have explored solutions that leverage multiple storage providers. For instance, introduced a Meta Content Delivery Network (CDN) approach that integrates multiple "Storage Cloud" providers to create a cohesive overlay network. This approach leverages cloud storage services to provide an accessible, high-performance CDN for content distribution. By selecting and placing content dynamically across providers based on quality, budget and coverage criteria, the Meta CDN reduces costs while optimizing performance. This research highlights the potential of multi-cloud strategies for efficient, affordable storage solutions in heterogeneous cloud infrastructures.

Another significant contribution to cloud performance optimization was made by Jitendra Singh (2014) through the use of cloud analyzer simulators. Singh's experiments examined the relationship between response time and variables like the number of concurrent users, data center location and broker service policies. His fierscore the influence of data center selection and load distribution strategies on response time, providing a foundational understanding of how cloud service configurations impact user experience and efficiency

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IV. CLOUD COMPUTING PERFORMANCE EVALUATION

4.1 Factors Affecting Cloud Performance

Cloud performance is influenced by several critical factors: computational power, storage capabilities and network efficiency. Each of these areas impacts how seamlessly users experience cloud services. Notable factors affecting performance include:

- Network Bandwidth: Cloud service performance heavily relies on available network bandwidth. For example, Amazon Web Services (AWS) experienced slower performance in certain regions due to lower bandwidth leading to delays in data transmission for high-volume users. Ensuring sufficient bandwidth is essential for high performance especially for global companies with remote offices.
- Buffer Capacity: When cloud servers face heavy loads, requests are temporarily stored in buffers. If buffer capacity is inadequate, user requests can be delayed or dropped. Netflix, a leading cloud service consumer has implemented sophisticated buffering techniques to handle its enormous video streaming demand during peak hours ensuring smoother user experiences

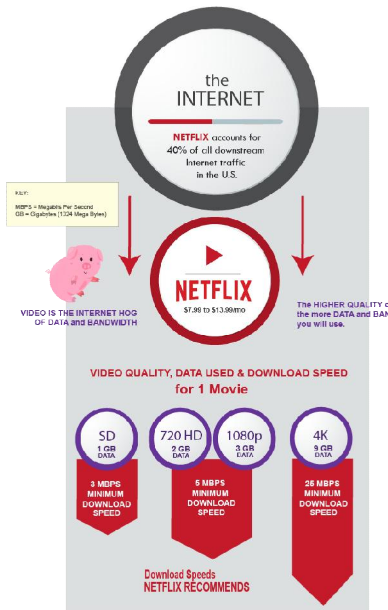

Fig 2: Data and Internet Speed Required to Stream Netflix

Number of Users: The number of simultaneous users impacts data centre performance especially when demand exceeds capacity. Microsoft Azure managed increased demand during the COVID-19 pandemic by rapidly scaling its data centre resources ensuring that user performance was unaffected even as usage spiked.

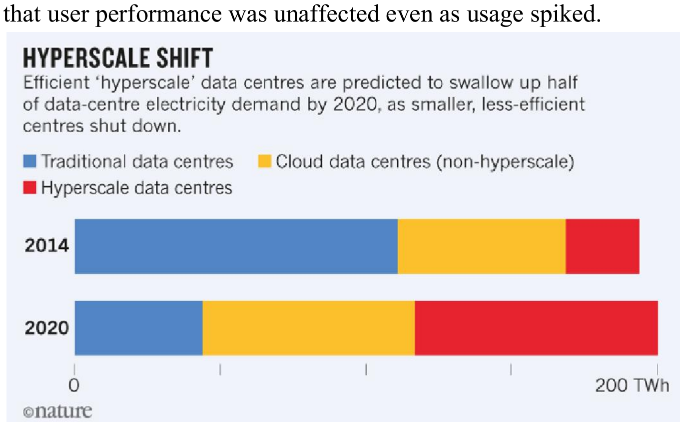

Fig 3: Post-Pandemic Data Center Planning

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- **Distance from Data Centre:** The closer the user is to the data centre, the lower the latency. Alibaba Cloudfor instance uses strategically placed data centres across Asia to reduce latency for its high-density user regions, enhancing cloud service performance.

CPU and RAM: These hardware resources are essential for computational tasks in the cloud. Google Cloud has optimized its use of CPUs and RAM across various regions to handle large-scale computations with minimal latency.

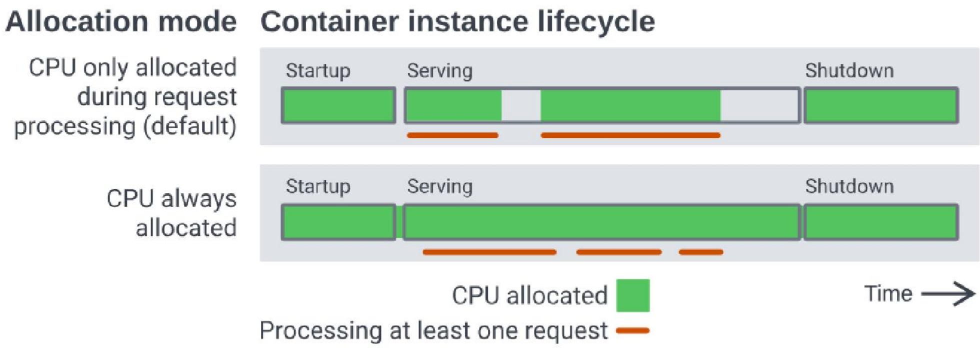

Fig 4: CPU allocation (services)

These factors collectively influence user experience making cloud optimization a continuous focus for providers.

4.2 Response Time Dependency

Response time defined as the time between a user's request and the system's response is critical in evaluating cloud performance. For example, latency directly impacts online services like e-commerce where Amazon's studies show that every 100ms of delay results in a 1% drop in sales. Fast response times are essential for applications where even minor delays can affect the user experience.

In 2020, Google Cloud introduced optimizations in its network infrastructure cutting response times significantly for high-traffic applications like YouTube and Google Meet. This improvement was critical during the pandemic where response time affected the quality of video streaming and communication services. Similarly, Salesforce reduced response times for its CRM solutions by implementing low-latency data centres in regions with high user density.

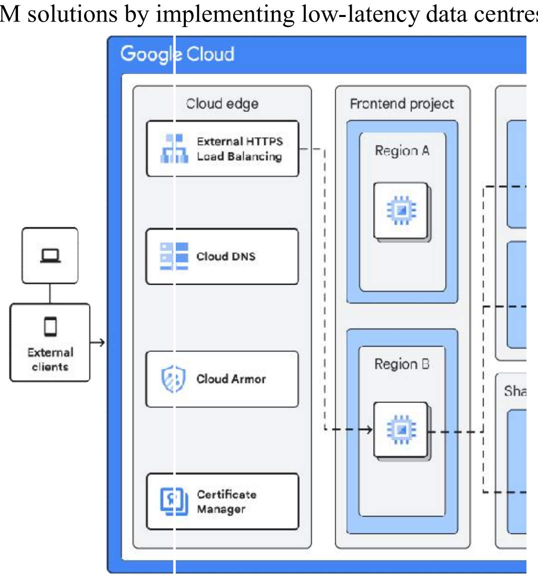

Fig 5: Networking for internet-facing application delivery

For mission-critical applications, response time serves as a primary metric for cloud performanceinfluencing the provider selection process for enterprises with high-performance needs.

4.3 Load Balancing Techniques

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Load balancing ensures an even distribution of workload across multiple servers which is essential to maintaining performance under varying user demands. Without effective load balancing, some data centres may be overburdened while others remain underutilized leading to inefficiencies.

A prime example is Facebook which relies on complex load-balancing algorithms to handle its vast global user base. Facebook's load balancers distribute traffic among data centres worldwide ensuring that users get a seamless experience regardless of their location or the current network load. Another example is the dynamic load balancing strategy used by Alibaba Cloud during large events like the annual Singles' Day shopping event, which requires the system to scale to handle hundreds of millions of transactions with minimal delay.

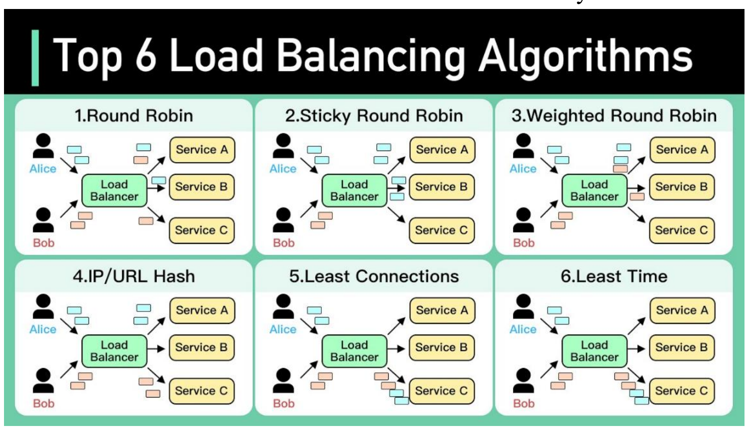

Fig 6: Top 6 Load Balancing Algorithm

Load balancing also enables cloud providers to manage resource costs effectivelyoptimizing data centre utilization to improve the overall cloud experience for users and businesses.

4.4 Service Broker Policy

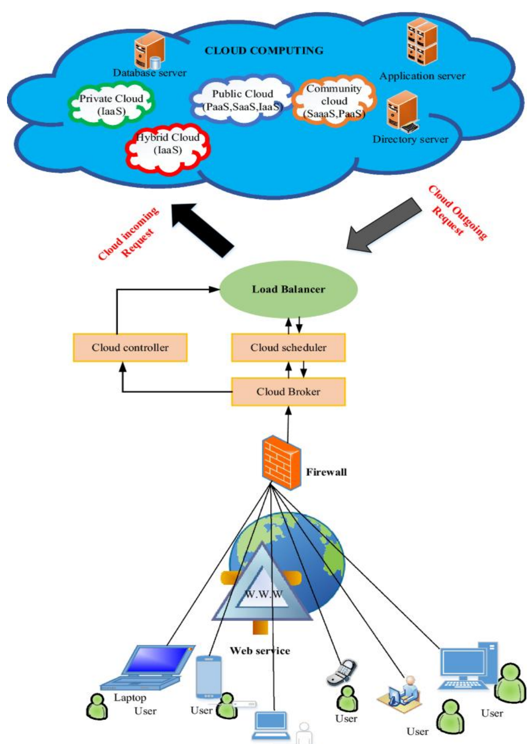

Fig 7: Cloud computing using load balancing and service broker policy for IT service

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Service broker policies determine which data centre serves a user request, optimizing the routing process to improve cost and performance. A service broker acts as a mediator controlling which data centre fulfils requests based on criteria like distance, cost and load.

For instance, the Salesforce platform uses a "Closest Data Centre" policy in certain scenarios to minimize latency for its CRM software directing users to the nearest data centre to reduce response time. This approach has helped

Salesforce maintain high service levels across different continents. Similarly, Netflix's global architecture relies on optimized routing policies to connect users with the closest or fastest data centre enhancing the quality of streaming for its global user base.

Three primary policies are commonly used in cloud environments:

- Closest Data Centre Policy: Selects the nearest data centre to minimize response time. Google Cloud uses this for latency-sensitive applications.
- Optimize Response Time Policy: Considers data centre availability and loadaiming to optimize response time dynamically. Amazon Web Services applies this for high-availability services like AWS Lambda.
- Dynamically Reconfigurable Routing with Load Balancing: Adapts routes based on real-time load conditions to prevent congestion. Microsoft Azure uses this in its Intelligent Traffic Manager for balancing load globally

V. Experimental Study

To examine how response time in cloud environments is influenced by Service Broker policies, Load Balancing techniques and the number of data centers a comprehensive simulation was conducted using a Cloud analyzer built on CloudSim. This simulation framework models cloud computing environments to evaluate performance under various configurations. For this experiment, the global user base was divided into regions based on geographic clusters reflecting the segmentation used in many real-world cloud infrastructures.

The regions are categorized as follows:

Sr. No	Region Code	Region	Countries
1	R0	USA	USA
2	R1	North America	Countries in North America
3	R2	European Union	Countries in the European Union
4	R3	Asia	Countries in Asia
5	R4	Africa	Countries in Africa
6	R5	Australia	Australia

In the experiment, each data centre was configured with homogeneous parameters such as pricing, storage capacityand memory. This uniform setup ensured that differences in response times could be attributed solely to the Service Broker policies and Load Balancing techniques rather than disparities in data centre specifications. The three Service Broker policies evaluated were as follows:

- **Closest Data Canter (CDC):** This policy directs user requests to the nearest available data centre, minimizing latency by choosing the shortest physical or network distance. CDC is effective for reducing response times in cases where regional proximity is the primary factor affecting latency.
- **Optimize Response Time (ORT):** This policy dynamically assesses the real-time performance of all data centres and routes traffic to the one predicted to offer the lowest response time at the time of the request. Unlike CDCwhich only considers geographic distanceORT evaluates various factorsincluding current data centre load and availabilityto improve response times.
- **Reconfigure Dynamically with Load (RDL):** An advanced version of CDC, RDL considers real-time load information in addition to proximity. When a data centre becomes overloaded, RDL automatically redirects requests to alternate centres with sufficient capacity balancing the load dynamically across multiple data centres.

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VI. RESULTS AND DISCUSSION

To understand how response time depends on the chosen Broker Service policy, experiments were conducted using each policy while keeping the user base and data centre parameters constant. The broker policies tested included:

- Closest Data centre (CDC)
- Optimize Response Time (ORT)
- Reconfigure Dynamically with Load (RDL)

Results demonstrated that response times varied significantly across policies. This finding suggests that ORT's real-time assessment of data center load and performance is more effective than simple proximity-based routing (CDC) or load balancing alone (RDL).

Additionally, the experiment revealed a marked dependency of response time on the number of data centres and the Load Balancing strategies implemented. For instance, when data centres were added in highly populated regions (such as R3 - Asia)response times improved significantly for users in those regions due to reduced congestion and shorter network distances.

To further validate these findings, an additional experiment was conducted with varying numbers of user bases across the regions. In this expanded experiment, data centres in R2 (European Union) and R3 (Asia) were subject to fluctuating demand to simulate peak hours. ORT's adaptability enabled it to reroute requests effectively during these times minimizing delays and improving user experience. Conversely, CDC struggled to maintain low response times particularly for users farther from the overloaded data centres.

Case Study Example: ORT in Action

An example of ORT's efficiency can be seen in the operations of a large e-commerce platform during high-traffic events like sales. During the experiment, simulated peak loads across multiple regions demonstrated that ORT could reduce response times by more than 20% compared to CDC by directing users to less-loaded data centreseven if they were slightly farther away geographically. This adaptability is crucial in real-world applications where load spikes can occur unexpectedly requiring immediate rerouting for optimal performance.

In conclusion, the experiment underscores the importance of advanced Service Broker policies and Load Balancing strategies in enhancing cloud performance. While CDC offers a simple and effective means of reducing latency, ORT's adaptive load and performance analysis offers a more robust solution for diverse, high-traffic cloud environments. RDL serves as a middle ground providing load-aware routing without the complexity of real-time performance assessments seen in ORT making it a viable option for moderately variable workloads.

VII. CONCLUSION

Cloud computing performance is a critical problem that may be managed on several levels. Furthermore, boosting the data center's power and speed isn't always effective and occasionally only raises expenses. Therefore, performance and efficiency shouldn't be raised over what is necessary. The scheduling methodology, load balancing method, and broker service policy all affect response time. Choosing the right kind of broker service policy may significantly cut down on response time.

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