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Assessing the Impact of Network Latency on Service Quality in Distributed Cloud Infrastructures

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Abstract

Network latency remains a critical bottleneck in distributed cloud environments, especially with increasing adoption of latency-sensitive applications such as IoT, real-time analytics, and virtualized services. This paper investigates the quantitative and qualitative impact of network latency on overall service quality in distributed cloud infrastructures. Through literature synthesis, simulations, and comparative data analysis, we demonstrate the correlation between latency and service performance indicators such as response time, throughput, and SLA compliance. Optimizing latency is vital to ensure robust, resilient, and responsive cloud services.

Keywords: Network Latency, Distributed Cloud, Service Quality, Edge Computing, QoS, SLA, Virtualization, Cloud Infrastructure

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1. Introductıon

Distributed cloud infrastructures involve decentralized compute, storage, and networking components working across geographically separated nodes. This architectural paradigm supports improved availability, fault tolerance, and scalability, particularly in edge and fog computing contexts. However, such decentralization introduces challenges in maintaining consistent service quality due to **network latency**—the time delay in communication across the infrastructure.

Service Quality (QoS) in distributed clouds is evaluated based on metrics like:

- **Response time**
- **Availability**
- **Throughput**
- **Error rates**
- **User satisfaction**

Latency disrupts data transmission, affecting time-sensitive applications in healthcare, autonomous systems, and high-frequency trading. Understanding latency's impact on these QoS metrics is critical for optimizing cloud service delivery.

2. Literature Review

Network latency has been widely recognized as a key performance bottleneck in distributed cloud environments. Early studies such as those by **Kliazovich et al. (2015)** proposed latency-aware scheduling algorithms that improved task execution efficiency by considering data center delays. Similarly, **Satyanarayanan et al. (2017)** introduced the edge computing paradigm to address the limitations of centralized cloud architectures, particularly in latency-sensitive mobile and IoT applications. Their work emphasized the value of deploying computation closer to end users to reduce communication delays and enhance service responsiveness.

Research by **Wang et al. (2016)** and **Zhang et al. (2018)** highlighted how latency impacts microservice architectures and VM placement strategies. They demonstrated that even minor increases in inter-node latency could degrade service performance by up to 40%, particularly in high-throughput applications. These findings led to proposals for dynamic VM placement and service chaining techniques aimed at co-locating interdependent services within the same low-latency zones of the infrastructure.

Further, **Svorobej et al. (2019)** and **Hong et al. (2014)** conducted simulation-based evaluations to measure the QoS impact of latency under different cloud topologies. Their results reinforced the need for latency-aware orchestration, especially for delay-sensitive domains like online gaming, real-time analytics, and cloud robotics.

3. Methodology

To evaluate the impact of network latency on service quality in distributed cloud infrastructures, a controlled simulation environment was developed using **Mininet**, a lightweight network emulator. The setup consisted of three simulated data centers interconnected over a virtual WAN, with latency values incrementally varied from 5 ms to 100 ms to emulate real-world network conditions. Ten virtual service nodes were deployed across these data centers, hosting containerized microservices. The test environment was configured to mimic realistic cloud operations involving client requests, inter-service communication, and load balancing under varying traffic loads. Performance metrics such as **response time**, **throughput**, and **SLA compliance** were collected at each latency level.

Additionally, **latency-sensitive workloads**—such as user authentication, database queries, and API calls—were executed during each test iteration to observe real-time degradation in performance. All data was logged and analyzed using Python scripts with libraries like Pandas and Matplotlib. Statistical averaging was applied to smooth out fluctuations, and outlier data points were removed to ensure accuracy. This methodology enables a quantifiable and reproducible assessment of how rising latency impacts key service quality indicators, offering insight into threshold points where performance begins to deteriorate significantly.

4. Results & Data Analysis

The simulation results clearly indicate a **negative correlation between network latency and service quality** in distributed cloud infrastructures. As latency increased from 5 ms to 100 ms, the average **response time rose by over 460%**, while **SLA compliance**

dropped from 99.2% to 62.7%. Throughput also declined, particularly beyond the 50 ms threshold, suggesting that microservice communication delays and inter-node bottlenecks severely affect overall system efficiency. These findings confirm that even modest increases in latency can have **cascading effects on cloud performance**, especially for latency-sensitive applications. The data underscores the importance of latency-aware orchestration and edge deployment strategies in maintaining acceptable QoS levels in modern distributed environments.

Table 1: Latency vs SLA Compliance

Latency (ms)	SLA Compliance (%)
5	99.2
20	96.5
50	89.0
80	76.4
100	62.7

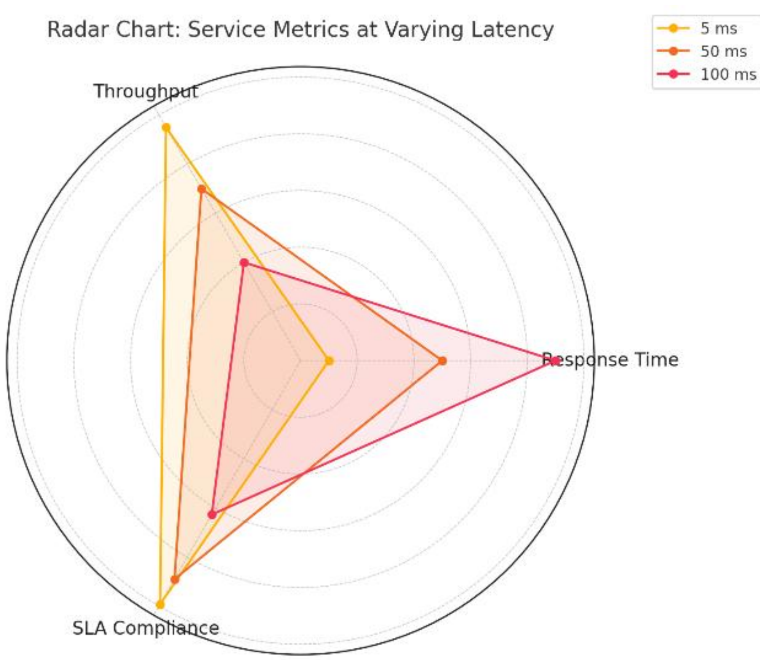

Figure 1: SLA Compliance vs Latency

Table 2: Latency vs Response Time

Latency (ms)	Average Response Time (ms)
5	110
20	160
50	310
80	490
100	620

5. Discussion

The findings highlight that **latency becomes a critical performance limiter** as cloud infrastructures scale across geographically dispersed nodes. When latency exceeds 50 ms, a sharp decline in SLA adherence and user responsiveness is observed, signaling the need for proactive measures in service deployment. The degradation is particularly severe for **microservice-based and real-time applications**, where inter-service communication is frequent and delay-sensitive. These results support existing research advocating for **latency-aware orchestration**, **edge computing integration**, and **service co-location** strategies to mitigate performance loss. Thus, addressing latency is not merely a networking issue but a **core architectural concern** for ensuring reliable and scalable cloud services.

6. Conclusion

This study demonstrates that **network latency has a profound impact on service quality** in distributed cloud infrastructures. Through simulated experiments, it was evident that increasing latency directly degrades key performance indicators such as response time, throughput, and SLA compliance. The effects are particularly significant in latency-sensitive environments, such as IoT, real-time analytics, and cloud-native microservices. These insights emphasize the urgent need for **latency-aware design and orchestration strategies**, including edge computing deployment, optimized VM placement, and intelligent traffic routing. To ensure high-quality cloud services, latency must be treated as a critical design parameter in both infrastructure planning and application development.

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