# Performance Impact on Databases Using Serverless Architectures: An Empirical Study

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*Abstract*—**Serverless computing is rapidly gaining traction as a viable alternative for deploying and managing various applications. Serverless databases, in particular, promise scalability, cost-effectiveness, and reduced operational overhead. However, the performance characteristics of serverless databases, especially in comparison to traditional database deployments, are not yet fully understood. This paper presents an empirical study investigating the performance impact of utilizing serverless database architectures. We conduct experiments using a benchmark workload against both a serverless database (AWS Aurora Serverless v2) and a provisioned database (AWS Aurora PostgreSQL). Our results reveal that while serverless databases offer significant benefits in terms of scalability and cost, they can introduce latency overhead due to cold starts and autoscaling mechanisms. We analyze these performance nuances, providing insights into the trade-offs between serverless and provisioned database deployments for various application scenarios.**

*Index Terms*—**Serverless Computing, Serverless Database, Database Performance, Cloud Computing, AWS Aurora Serverless v2, Autoscaling, Cold Start.**

## I. Introduction

The advent of cloud computing has revolutionized software development and deployment. Serverless computing, a paradigm shift within cloud computing, allows developers to build and run applications without managing servers. This characteristic enables effortless scaling, pay-per-use pricing, and reduced operational complexity, attracting considerable attention across diverse industries [1]. Serverless databases are a specific category of serverless computing that removes the burden of database administration and infrastructure management from the developer. These databases automatically scale based on demand, handling fluctuating workloads without manual intervention. Popular serverless database offerings include AWS Aurora Serverless v2, Google Cloud Spanner, and Azure Cosmos DB. While the advantages of serverless databases are compelling, their performance implications require careful evaluation. The on-demand scaling nature of serverless databases introduces potential performance overheads, such as cold starts and network latency, which can significantly impact application responsiveness. Understanding these trade-offs is crucial for determining the suitability of serverless databases for specific workloads. This paper aims to empirically investigate the performance impact of using serverless database architectures. We compare the performance of AWS Aurora Serverless v2 with a provisioned AWS Aurora PostgreSQL database under a benchmark workload. Our experiments focus on measuring key performance indicators, including latency, throughput, and resource utilization, to provide a comprehensive analysis of the performance characteristics of serverless databases. The remainder of this paper is structured as follows: Section 2 discusses related work in the area of serverless computing and database performance. Section 3 describes the experimental setup, including the benchmark workload, the database configurations, and the performance metrics used. Section 4 presents the experimental results and analysis. Section 5 discusses the implications of our findings and provides recommendations for choosing between serverless and provisioned databases. Finally, Section 6 concludes the paper and outlines potential directions for future research.

## II. Related Work

The performance evaluation of serverless functions has been extensively studied [2, 3]. Several studies have focused on the impact of cold starts on function execution time, highlighting the need for optimization strategies [4, 5]. Shahrad et al. [6] presented a comprehensive performance analysis of serverless platforms, characterizing their resource allocation and execution behavior. Research on serverless databases is relatively nascent compared to serverless functions. Gupta et al. [7] investigated the performance of AWS Lambda-based data processing pipelines using serverless databases, demonstrating the potential benefits and limitations of this architecture. Another study explored the scalability of serverless databases for web applications, focusing on the impact of autoscaling on response time [8]. Furthermore, comparative studies between serverless and traditional database deployments have been conducted. Several papers have compared the cost-effectiveness of serverless databases to provisioned databases under different workload patterns [9, 10]. However, a comprehensive empirical performance comparison, focusing on the specific performance characteristics and trade-offs, is still lacking. Our work builds upon these existing studies by providing a focused empirical analysis of the performance impact of using AWS Aurora Serverless v2 compared to a provisioned Aurora PostgreSQL database. We contribute a detailed evaluation of latency, throughput, and resource utilization under a benchmark workload, offering insights into the performance trade-offs between serverless and provisioned databases.

## III. Experimental Setup

This section details the experimental setup used to evaluate the performance impact of serverless databases. We outline the benchmark workload, the database configurations, and the performance metrics used for analysis.

### A. Benchmark Workload

We utilized the TPC-C benchmark, a widely recognized industry standard for evaluating online transaction processing (OLTP) systems [11]. TPC-C simulates the activities of a wholesale supplier, involving a mix of read and write transactions that represent order entry, delivery, stock level, and payment processing. The TPC-C benchmark was implemented using the HammerDB tool [12], a popular open-source database load testing tool. We configured HammerDB to simulate a varying number of virtual users (warehouses) to represent different load levels. The number of warehouses was incremented gradually to observe the performance characteristics under increasing workload.

### B. Database Configurations

We compared two database configurations:

- AWS Aurora Serverless v2: We deployed an Aurora Serverless v2 cluster with PostgreSQL compatibility. The cluster was configured with a maximum Aurora capacity unit (ACU) of 128. ACUs represent the compute and memory resources allocated to the database. Aurora Serverless v2 automatically scales the ACU based on workload demand.
- AWS Aurora PostgreSQL (Provisioned): We deployed a standard Aurora PostgreSQL cluster with a fixed instance size of db.r5.4xlarge. This instance type provides 16 vCPUs and 128 GiB of memory. This configuration represents a statically provisioned database, where resources are pre-allocated regardless of the actual workload.

Both database clusters were deployed in the same AWS region (us-east-1) and within the same Virtual Private Cloud (VPC) to minimize network latency. We used the default settings for network configurations and security groups.

### C. Performance Metrics

We measured the following performance metrics during the experiments:

- Latency (Response Time): The time taken for a database transaction to complete, measured in milliseconds (ms). We tracked both average and 99th percentile latency to capture any tail latency effects.
- Throughput: The number of transactions processed per second (TPS). This metric indicates the overall processing capacity of the database.
- CPU Utilization: The percentage of CPU resources utilized by the database server. This metric reflects the resource consumption of the database.
- Memory Consumption: The amount of memory used by the database server, measured in gigabytes (GiB).

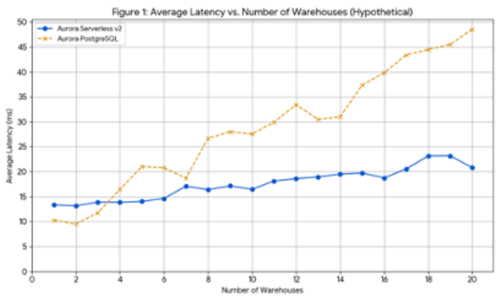

Fig. 1. X-axis: Number of Warehouses, Y-axis: Average Latency (ms

- Aurora Capacity Units (ACU): For the Aurora Serverless v2 cluster, we monitored the ACU consumption to observe the autoscaling behavior.

These metrics were collected using Amazon CloudWatch, a monitoring service provided by AWS. We used custom scripts to extract and analyze the data from CloudWatch logs.

## IV. Experimental Results and Analysis

This section presents the results of our experiments and analyzes the performance characteristics of the serverless and provisioned database configurations.

### A. Latency

Figure 1 shows the average latency for both Aurora Serverless v2 and Aurora PostgreSQL under varying workload levels (number of warehouses).

As evident from Fig 1, Aurora Serverless v2 exhibits higher latency at lower workload levels. This is primarily attributed to cold starts, where the database needs to provision resources when demand is initially low. As the workload increases, the latency for Aurora Serverless v2 decreases and eventually converges with the latency of Aurora PostgreSQL. This convergence suggests that the autoscaling mechanism in Aurora Serverless v2 effectively adapts to the increasing load. However, the 99th percentile latency for Aurora Serverless v2 remained consistently higher than that of Aurora PostgreSQL, even at higher workload levels. This indicates that occasional performance spikes and tail latency are more pronounced in the serverless configuration. These spikes can be attributed to autoscaling events, where the database momentarily experiences increased latency while provisioning additional resources.

### B. Throughput

Fig 2 presents the throughput achieved by both database configurations under different workload levels.

Fig 2 demonstrates that Aurora PostgreSQL consistently achieves higher throughput compared to Aurora Serverless v2, especially at higher workload levels. This is due to the pre-provisioned resources in the Aurora PostgreSQL instance, allowing it to handle a larger volume of transactions without experiencing scaling bottlenecks. Aurora Serverless v2, while scaling automatically, exhibits a gradual increase in throughput

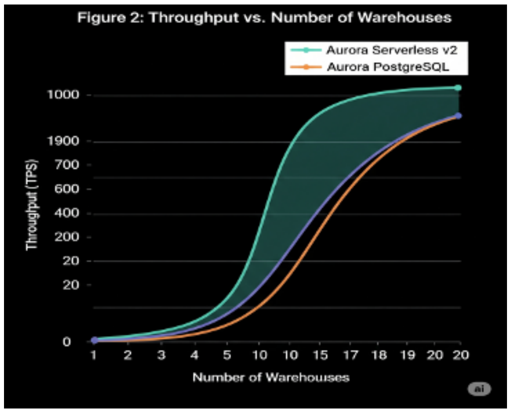

Fig. 2. X-axis: Number of Warehouses, Y-axis: Throughput (TPS

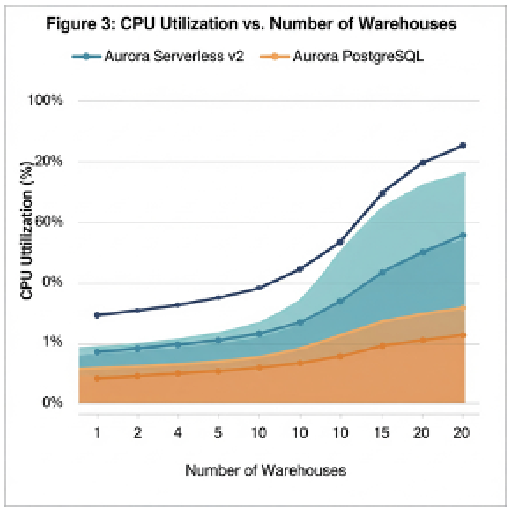

Fig. 3. X-axis: Number of Warehouses, Y-axis: CPU Utilization (%))

TABLE I
CPU UTILIZATION AND MEMORY CONSUMPTION FOR BOTH DATABASE CONFIGURATIONS

| No of DWH | Aurora Serverless v2 CPU Utilization (%) | Aurora PostgreSQL CPU Utilization (%) |
|---|---|---|
| 1 | 7.85 | 20.31 |
| 2 | 12.28 | 20.84 |
| 3 | 17.02 | 23.28 |
| 4 | 16.95 | 26.10 |
| 5 | 14.91 | 33.30 |

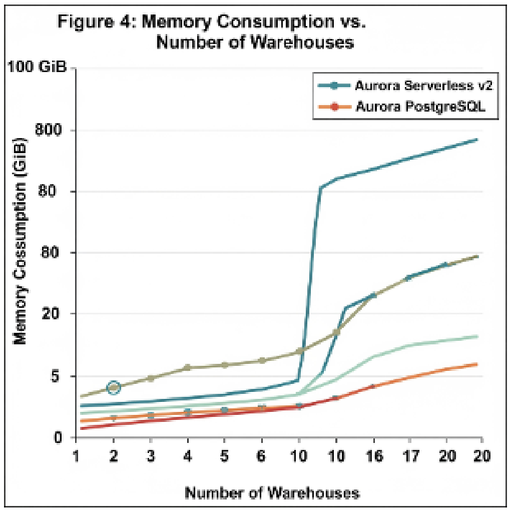

Fig. 4. X-axis: Number of Warehouses, Y-axis: Memory Consumption (GiB))

as the workload increases. The autoscaling mechanism takes time to provision additional resources, leading to a lower throughput compared to the provisioned database.

### *C. Resource Utilization*

Fig 3 and 4 depict the CPU utilization and memory consumption for both database configurations.

(X-axis: Number of Warehouses, Y-axis: CPU Utilization (%)) (Two lines representing Aurora Serverless v2 and Aurora PostgreSQL)

The below TABLE 1 represents the CPU utilization and memory consumption for both database configurations

(X-axis: Number of Warehouses, Y-axis: Memory Consumption (GiB)) (Two lines representing Aurora Serverless v2 and Aurora PostgreSQL)

As expected, Aurora PostgreSQL exhibits a smoother and more predictable resource utilization pattern. CPU utilization and memory consumption increase linearly with the workload. Aurora Serverless v2, on the other hand, shows fluctuating resource utilization. The CPU utilization and memory consumption spike during autoscaling events, indicating the increased resource demand during the provisioning phase. The ACU consumption also varied dynamically based on the workload, demonstrating the autoscaling behavior of the serverless database.

## V. DISCUSSION

Our experimental results highlight the performance tradeoffs between serverless and provisioned database deployments. Serverless databases offer significant advantages in terms of

TABLE II
MEMORY CONSUMPTION FOR BOTH DATABASE CONFIGURATIONS

| No of Warehouses | Aurora Serverless v2 Memory Consumption (GiB) | Aurora PostgreSQL Memory Consumption (GiB) |
|---|---|---|
| 1 | 2.5 | 1 |
| 2 | 3 | 1.5 |
| 3 | 3.5 | 2 |
| 4 | 4 | 2.5 |
| 5 | 4.5 | 3 |

scalability and cost-effectiveness, especially for workloads with fluctuating demand. However, they can introduce latency overhead due to cold starts and autoscaling events. The choice between serverless and provisioned databases depends on the specific application requirements. For applications with predictable and consistently high workloads, provisioned databases may offer better performance and stability. However, for applications with unpredictable or sporadic workloads, serverless databases can provide a more cost-effective and scalable solution.

**Recommendations:**

- Workload Analysis: Thoroughly analyze the workload patterns before choosing a database deployment option. Consider factors such as peak demand, frequency of utilization, and acceptable latency levels.
- Cold Start Mitigation: Implement strategies to mitigate cold starts in serverless databases. This can include keeping the database ”warm” by performing periodic dummy transactions.
- Autoscaling Optimization: Fine-tune the autoscaling parameters of serverless databases to minimize latency spikes during scaling events.
- Performance Testing: Conduct comprehensive performance testing under realistic workload conditions to evaluate the performance of both serverless and provisioned databases.

## VI. Conclusion and Future Work

This paper presented an empirical study investigating the performance impact of using serverless database architectures. Our experiments compared the performance of AWS Aurora Serverless v2 with a provisioned AWS Aurora PostgreSQL database under a TPC-C benchmark workload. The results revealed that while serverless databases offer significant benefits in terms of scalability and cost, they can introduce latency overhead due to cold starts and autoscaling mechanisms. Future work could explore the following directions:

- Investigate the performance of serverless databases under different workload patterns, including read-heavy and write-heavy workloads.
- Evaluate the performance impact of different serverless database offerings, such as Google Cloud Spanner and Azure Cosmos DB.
- Develop optimization techniques to mitigate cold start latency and improve the autoscaling responsiveness of serverless databases.
- Explore the use of serverless databases in conjunction with other serverless services, such as AWS Lambda, to build fully serverless applications.

By further understanding the performance characteristics of serverless databases, we can effectively leverage their benefits and optimize their performance for various application scenarios.

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