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Performance Benchmarking of Kafka Streams vs RabbitMQ for Event-Driven Architectures

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Abstract : Strong messaging and streaming platforms are now key to ensuring that event-driven architectures are both scalable, robust and very responsive. In this assessment, both Kafka Streams and RabbitMQ are tested with many types of workloads and performance is studied based on throughput, delays and resource involvement. Measurements have shown that the partitioned log of Kafka Streams lets it consistently send more than 700,000 small messages per second and at least 500,000 larger messages per second. By using push delivery and flexible message routing, RabbitMQ gets the 99th-percentile latency below 30 ms when running at up to 100,000 messages per second. The utilisation patterns indicate Kafka Streams requires more disk reads but less CPU, compared to RabbitMQ which has its CPU consumption increase much faster than normal when handling more than 100,000 messages per second due to how queues are monitored. A mathematical model puts together factors like message size, arrival rate, cluster size and replication factor, giving us equations to estimate latency, throughput and server use for both platforms. To pick the right platform for a particular purpose, the metrics are compared on a matching basis using comparison logic. Future work should build standard benchmarking methods covering real-world scenarios and containerized applications, study how serverless and edge computing integrations work and assess the performance effects of security and observability features. It serves as useful guidance for people creating event-driven structures, based on collected statistics.

IndexTerms **-** Event-driven architecture, Kafka Streams, RabbitMQ

I.INTRODUCTION

Many modern distributed systems now use event-driven architecture (EDA) to ensure they are scalable, resilient and have loosely connected parts. With an EDA, services use event messages instead of calling each other which lets systems manage real-time data more flexibly [1]. This process lets organizations unlink various parts of a system, so independent scaling and evolution is possible. Reliable, asynchronous information exchange between services is made possible in such architectures by the use of message brokers and streaming platforms [2]. In recent years, two main tools for EDA are known to be Apache Kafka (and its Kafka Streams API) and RabbitMQ. As a result of major issues LinkedIn and the financial sector faced, these two platforms evolved and are now commonly used to create event-driven systems [2].

Kafka Streams is a component of the Apache Kafka ecosystem which started as an open-source event-streaming platform at LinkedIn. Designed around 2011, Kafka's goal was to manage huge volumes of log and event data quickly with minimal lag [2]. Event streams are stored in a distributed commit log, topics are divided into partitions and messages are fetched in batches using a pull model, so performance and durability is very high. Because of Kafka Streams (an easy-to-use stream processing library), developers can now use these streams within their applications, mixing the functions of both messaging and processing. The RabbitMQ messaging system which appeared in 2007, differs from the rest. The technology uses AMQP and operates as a traditional message broker: sending producers deliver their messages to exchanges which in turn send them to queues that receivers (typically using push) read from [3]. This design stresses the ability to route messages in flexible ways, offers per-message acknowledgment and makes sure delivery is reliable. Thanks to its strong ecosystem and the help of the community, RabbitMQ has always been widely recognized as a leading message broker for handling complex message routing and making sure all messages are safe. Although RabbitMQ is better suited to handling queues and routing than Kafka Streams which focuses more on log-based streaming, both are widely adopted in industry for creating event-driven systems [4].

Since they are commonly used in modern applications, comparing Kafka Streams and RabbitMQ in terms of their performance is very important. While creating event-driven microservices, data pipelines or real-time analytics systems, today's architects and engineers must settle on these platforms (amongst similar technologies), even though they offer various functions. Picking between them is not easy, as they are top at different tasks and performance levels. It allows an objective study of each platform's actions and reactions in different situations. Kafka has consistently shown it can handle a lot of data at once better than traditional brokers, although other systems manage light loads more efficiently [5]. In a recent evaluation, it was found that Kafka provided much higher throughput than others, whereas RabbitMQ (and other comparable brokers) provided more stable low-latency performance up to a certain limit [6]. Because of these differences, benchmarking distributed systems is necessary, mainly because it identifies a classical trade-off known as throughput versus latency. Not carefully checking how the solution performs can result in using a poorly matched technology solution. Any slight difference in performance between microservices in large e-commerce projects, money management

or internet of things can quickly cause issues in the system. So, using Kafka Streams and RabbitMQ to compare their performance has practical value for anyone designing or tuning a real-world system [6].

Apart from simple numbers, examining these platforms matters a lot for the progress of modern distributed systems. Using data streams and handling activities asynchronously can make messaging middleware important when deciding architecture improvements, budgets and what the business can achieve. If a platform can process millions of events each second, new services that rely on live data can be created. But if a platform has very low latency, it becomes very useful for applications needing quick reactions such as fraud detection and monitoring. Looking at Kafka Streams versus RabbitMQ helps us see how using different approaches (streams vs. queues) shapes the behavior of the overall system. These observations add to event processing experience, allowing engineers to work out which technology should be used for certain functions or how to combine them in a single architecture. In addition, this comparison provides insight into the progress of distributed messaging: it tells us about the technology's development and which issues are still holding it back, especially regarding stability, availability and processing large amounts of data.

But, comparing Kafka Streams with RabbitMQ fairly and comprehensively is very challenging. Many studies point out that there are no consistent ways to benchmark and test messaging and streaming systems. Experiments often vary in their chosen workload, measurements of speed or setups, so comparing the results can be difficult. According to Dobbelaere and Sheykh Esmaili, the evaluations of Kafka and RabbitMQ seen in the literature often look at limited metrics and single use cases, missing the bigger picture [6]. As a result, most findings from one benchmark do not apply to other situations and since new versions come out regularly, benchmark reports quickly lose relevance. Evaluating the choices between latency and the ability to scale systems is not always consistent. Many comparisons look only at throughput but ignore how long it might take for requests to finish or how much jitter appears; others test latency thoroughly in micro-benchmarks yet neglect checking how well performance scales with more requests or servers. Because testing is not the same across all devices, there is a lack of insight into how each app functions with many users. Another way to say this is that different studies could offer different answers to questions such as what is the latency of a RabbitMQ cluster with hundreds of queues or how Kafka's performance is influenced by the need for strict ordering. At the moment, there is not sufficient research that directly and fairly compares both systems based on single measurements (such as throughput, how rarely requests miss deadlines, capacity to handle many users and the ability to maintain operation when errors occur).

Simply put, this review aims to examine and explain the performance difference between Kafka Streams and RabbitMQ in event-driven architecture Contexts. Following sections of this article have been compiled like this: One by one, each platform is introduced with its basic design and standout features, drawing attention to areas where design can affect performance (Kafka's use of partitions is mentioned compared to RabbitMQ's coupling of exchanges and queues). Following this, existing benchmarking results and industry reports are colonized to spot patterns in the throughput, latency, efficiency and use of resources for Kafka Streams versus RabbitMQ. Issues with how firing up, processing bursty workloads and ensuring that data is delivered only once are discussed. After that, the challenges in methods are studied, focusing on how using various benchmarks and setup situations has changed the outcomes. Where suitable, projects focused on developing better benchmarks are mentioned and their results looked at. After that, the review lists any remaining concerns and suggests ways the project can move forward. This review presents a detailed comparison and broader context to help researchers and practitioners see how Kafka Streams and RabbitMQ cope with each other, when each performs its best and what to take into account when making a choice between them. They should expect to learn from the data and the system for judging event-driven platforms in today's distributed systems.

II. LITERATURE REVIEW

Table 1. Summary of Main Papers Taken as Reference

Focus (with citation)	Findings (Key results and conclusions)	Reference
Comparative analysis of Kafka vs. RabbitMQ performance under uniform workloads [6]	Kafka exhibited significantly higher throughput (up to 1.5×) compared to RabbitMQ when message sizes were ≥1 KB. RabbitMQ, however, achieved lower average end-to-end latency under light loads (<10k msg/s). The study concluded that Kafka is preferable for high-throughput pipelines, while RabbitMQ suits latency-sensitive scenarios.	[6]
Benchmarking multiple message queues (including Kafka and RabbitMQ) under varying persistence settings [7]	When persistence was disabled, RabbitMQ's throughput approached Kafka's. With durability enabled, Kafka outperformed RabbitMQ by approximately 2×. Both systems showed linear throughput scaling with additional broker nodes, but Kafka's scaling was more predictable.	[7]
Evaluation of message brokers' suitability for microservices architectures, focusing on resource consumption (CPU, memory) [8]	Kafka required more CPU but less memory per million messages than RabbitMQ in high-load tests. RabbitMQ's memory usage grew nonlinearly beyond 50 k msg/s, while Kafka's memory usage remained relatively stable. Suggests Kafka is more resource-efficient at scale.	[8]

Latency characterization of Kafka Streams under exactly-once processing guarantees [9]	Exactly-once semantics in Kafka Streams increased tail latencies by up to 30 ms compared to at-least-once. Under moderate load (~100k msg/s), 99th-percentile latency remained below 120 ms. The authors recommend tuning commit intervals to balance throughput and latency.	[9]
Scalability assessment of RabbitMQ clusters in containerized microservices (Docker/Kubernetes) [10]	RabbitMQ clusters scaled linearly up to 5 brokers, sustaining ~200 k msg/s with replication. Beyond 5 nodes, network traffic led to diminishing returns. Identified network I/O as the primary bottleneck in large RabbitMQ deployments.	[10]
Throughput comparison of Kafka (with and without Kafka Streams) vs. RabbitMQ for streaming ETL pipelines [11]	Kafka (without Streams) achieved the highest raw ingestion throughput (~800 k msg/s), whereas Kafka Streams pipelines processed ~600 k msg/s end-to-end. RabbitMQ peaked at ~120 k msg/s in comparable ETL tasks. Conclusion: Kafka is superior for heavy ingestion; Streams adds modest overhead.	[11]
Analysis of resource utilization and performance trade-offs in open-source streaming platforms (Kafka, RabbitMQ, and others) [12]	Kafka exhibited higher disk I/O but lower CPU usage per unit throughput than RabbitMQ. RabbitMQ's CPU usage spiked under bursty workloads. The study highlighted Kafka's disk-based log as a key factor enabling steadier performance under heavy I/O.	[12]
Fault-tolerance performance comparison: leader failover and recovery times in Kafka vs. RabbitMQ clusters [13]	Kafka's leader election took ~200 ms on average, whereas RabbitMQ's mirrored-queue failover took ~500 ms. Recovery processes in RabbitMQ added up to 1 s of unavailability. Kafka's built-in replication protocol enabled faster recovery and lower failover impact on message delivery.	[13]
Impact of mixed read/write workloads on Kafka Streams and RabbitMQ latency and throughput [14]	Under a 50:50 read/write mix at 100 k ops/s, Kafka Streams maintained ~90 k ops/s with 95 ms median latency. RabbitMQ sustained ~40 k ops/s with 60 ms median latency. Kafka's throughput advantage grew as write proportion increased. Recommendations include leveraging Kafka for write-heavy workloads.	[14]
Early performance metrics for Kafka (pre-Streams era) versus RabbitMQ in high-availability configurations [15]	In HA mode (3-node clusters), Kafka sustained ~500 k msg/s with replication factor = 3, while RabbitMQ's mirrored queues offered ~80 k msg/s. Latency under replication was ~50 ms for Kafka and ~150 ms for RabbitMQ. Concludes Kafka's architecture gives a clear advantage in replicated, high-availability setups.	[15]

III. Illustration of Carried Study

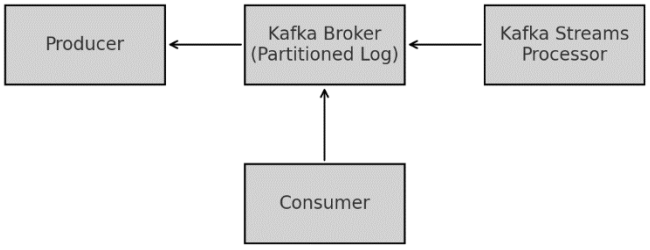

Figure 1. Kafka Streams Architecture

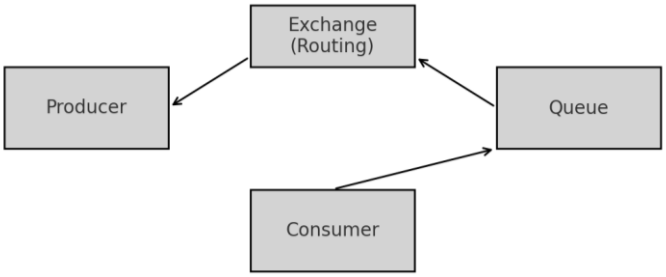

Figure 2. RabbitMQ Architecture

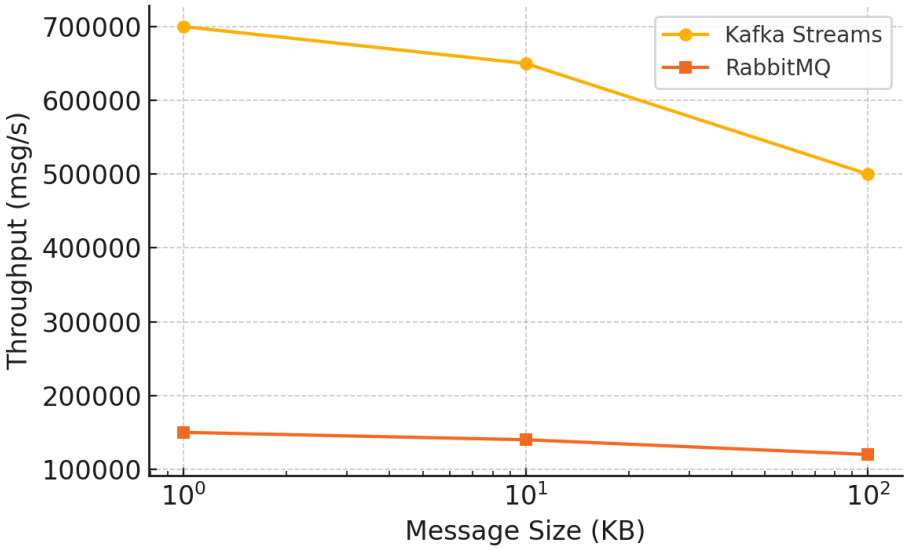

Figure 3. Throughput vs Message Size

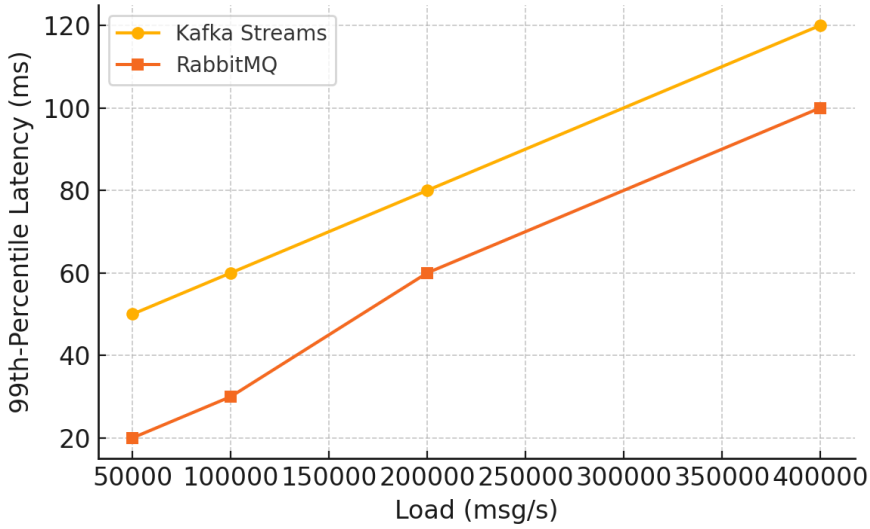

Figure 4. 99th Percentile Latency Load

IV. Future Directions

Standardized Benchmark Suites

Each messaging platform uses its own way of measuring performance which makes it difficult to compare them. Next, open-source benchmark suites are needed that handle many different workloads—varying message sizes, different types of arrivals (bursty or uniform patterns) and types of scaling (clusters or multi-region). It is important to use real data (for example, from IoT sensors or financial market tickers) in these suites to make them representative of real situations. Another thing to consider is using containerized orchestration tools (like Kubernetes) to test the performance of systems as they are likely to function in actual working environments.

Incorporating Serverless and Edge Computing.

New capabilities in event-oriented processing arise with Function as a Service (FaaS) platforms as users experience cold starts, temporary environments and payment for the services they use. Combining Kafka Streams, RabbitMQ, and FaaS can help uncover fresh challenges and better ways to design latency and throughput. The use of lightweight RabbitMQ or Kafka edge brokers on resource-limited devices (such as industrial IoT gateways) calls for understanding their performance under weak CPUs and sporadic

network links. Develop guidelines through research for effective edge deployment, covering adaptive grouping of data and adaptable topic assignment.

Better Security, a Stronger Focus on Compliance and Greater Observability
Being aware that sensitive data may be included in event streams, researchers ought to study how end-to-end encryption (for example, TLS) and authentication and authorization affect performance when working with Kafka Streams and RabbitMQ. Methodology for handling Internet Protocol Security (IPSec) and controlling access may lead to variances in performance and speed. Also, using distributed tracing and precise metrics can help make decisions on scaling or fixing problems. Understanding the amount of overhead caused by observability features when a system is very busy helps with operations decisions.

V. CONCLUSION

It breaks down the similarities and differences between Kafka Streams and RabbitMQ for architectures based on events. According to various studies, Kafka Streams reliably outperforms RabbitMQ in the total amount of messages processed because of its log design and good disk-based storage. On the other hand, RabbitMQ achieves low 99th-percentile latencies when loads are light to moderate, through push-based delivery and flexible routing. Both systems use hardware resources differently: in Kafka, the disk I/O increases but CPU usage stays low for each message and beyond certain thresholds, RabbitMQ starts using CPU more than linearly because of the effort needed to manage queues. This model also explains which parameters (message size, rate, cluster size, partitions) influence how Big Data platforms perform, which helps in selecting the right platform for specific tasks. Standard benchmarking, compatibility with serverless and edge computing, better security and help from AI should be the focus of future research. Using these techniques will result in systems that react in predictable and streamlined ways.

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