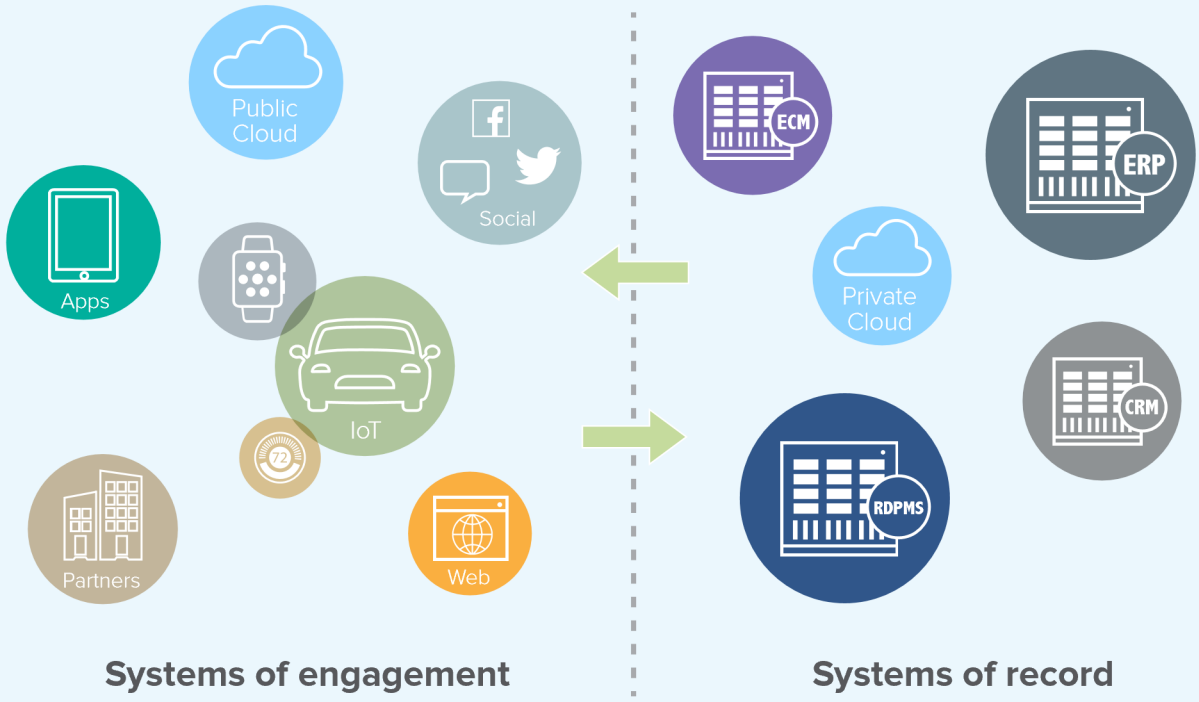
Building Enterprise-Grade Database Architecture for Mission-Critical, Real-Time Applications

A new generation of applications –

Systems of engagement

For more than a half-century, database technologies have evolved to enable a range of applications that automate repetitious transactional business processes inherent in Enterprise Resource Planning, Customer Relationship Management, and other systems. In enterprises of every size, these types of applications serve as systems of record, representing the authoritative data source for a given piece of information.

But it's no secret that a new generation of applications is emerging, spawned in large part by the convergence of big data, mobile computing, social media, and the Cloud. These applications are enabling businesses to deliver products and services that only a few years ago could never have been imagined. Business author and strategist Geoffrey Moore draws a clear line of distinction between the business systems that were built throughout the latter half of the 20th century, and the new dynamic and highly interactive consumer-oriented systems that are now proliferating at a rapid pace.



In describing this new generation of applications, Moore has coined the term "systems of engagement," which he notes often overlay and build upon the older, established systems of record. Many of these newer systems evolve from traditional applications over a period of time as businesses undergo digital transformation. In contrast to systems of record, systems of engagement connect customers, employees, suppliers, and business partners in real time. They are also mobile, location-aware, ubiquitous, and increasingly embedded in the daily routines of the modern workforce.

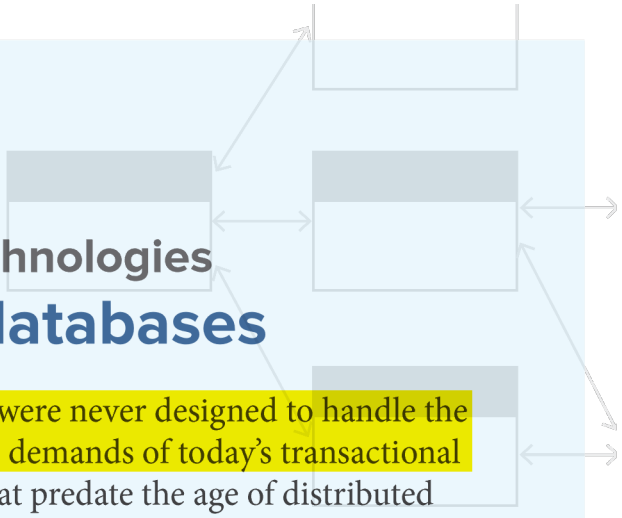
The need for speed and enormous scale that characterize systems of engagement has exposed gaps in legacy database technologies that pose significant challenges for deployment teams tasked with ensuring that all system components integrate efficiently and reliably.

For example, system availability must be compromised to ensure data consistency among nodes in clusters and, when cache is added to speed performance, data consistency between cache and persistent storage is compromised. The issue is compounded when it becomes necessary to establish separate databases for reads and writes in order to improve performance. The incremental patchwork approach typically taken to address legacy database performance and scalability limitations inherently creates an ever-expanding web of complexity.

New challenges –

Always on at the speed of now

Essential to all these mission-critical, real-time applications is the need to deliver instantaneous responses and 24/7 availability; anything less can damage a firm's brand and result in lost customers. As every application developer, architect, and CTO knows, successful implementations can be both challenging and unpredictable, especially when an application needs to scale. Thousands of users can quickly morph into millions of users. Transaction volumes can grow from thousands to millions or even billions – every second. Data volumes are now typically measured in hundreds of terabytes, and acceptable speed is now measured in milliseconds. As workloads increase and become more dynamic, more stress is added to the existing system architecture. Application infrastructures must be able to scale accordingly, without affecting performance, user experience, or system reliability.



Shortcomings of conventional technologies

Limitations of relational databases

Relational database management systems (RDBMS) were never designed to handle the volume, velocity, and variety of data, or the real-time demands of today's transactional applications. Designed for computer architectures that predate the age of distributed computing and commodity, cloud-based server farms, relational databases typically run on a single server. While a server in a RDBMS can be scaled up by adding CPU, IOPs and memory, eventually, an upper limit is inevitably reached and budgets exceeded.

To address these issues, relational database vendors created more complex "primary/secondary" architectures, in which the "primary" is the single server, and the "secondary" are additional servers that can handle parallel processing and replicated data – i.e., data that is "shared" to ease the workload on the primary server. While these architectural enhancements can help, they rarely suffice to handle the workloads associated with real-time enterprise applications. Significant application complexity is required to deal with eventual consistency when reading from secondary sources of data.

Deployment teams often work around these issues in an incremental progression that to a great extent undo many of the virtues of relational database technology. The most common first step to improve query performance is to denormalize the data, effectively reversing prior work. When denormalization is no longer sufficient to maintain acceptable performance, a memory caching layer is typically placed in front of the database. Later, when the limits of RAM are reached, deployment teams often find it necessary to create and maintain separate databases for reads and writes. In desperation, they even remove joins and multi-statement transactions. Collectively, these steps result in breaking the model and original promise of relational database technology.

Emergence of NoSQL

Due to the shortcomings of relational databases, NoSQL databases are rapidly emerging as the preferred alternative for enabling systems of engagement and real-time applications. Indeed, NoSQL databases provide significant advantages:

Scalability – A NoSQL database can scale horizontally, enabling applications to run in parallel on a cloud-based cluster comprising dozens, hundreds, or even thousands of commodity servers. NoSQL databases can also scale up to exploit new hardware like SSDs (solid-state drives) and transactional memory.

Flexibility – A schema-less NoSQL database can process and store structured, unstructured and semi-structured data, and enable flexible and rapid development of applications and use cases such as right-time decisioning, recommendations, profile management, bidding, and risk profiling.

Availability – NoSQL databases feature a distributed architecture that ensures there is no single point of failure. If one or more servers go down, the other nodes in the system can continue operations without data loss, and without impacting availability of the data.

Time to market – A NoSQL database enables developers to avoid shoehorning data into a fixed schema and to quickly roll new applications and updates into production. In spite of these advantages, many organizations running NoSQL still encounter performance and reliability problems as their application workloads grow. The standard approach to dealing with this is to deploy wider clusters that get increasingly expensive and difficult to manage. Organizations that use relational databases often add in-memory databases in a dedicated caching layer. This presents another set of challenges

Challenges of adding a caching layer

A caching layer, which works by storing frequently accessed data in memory, helps to overcome the performance and scalability limitations of operational databases. This approach accelerates transactional response times through immediately accessible in-memory stored data, and improves scalability via distributed caching to help databases scale horizontally. Caching is a sound strategy when data is relatively static. But in systems of engagement where data is highly dynamic, caching usually becomes a major liability.

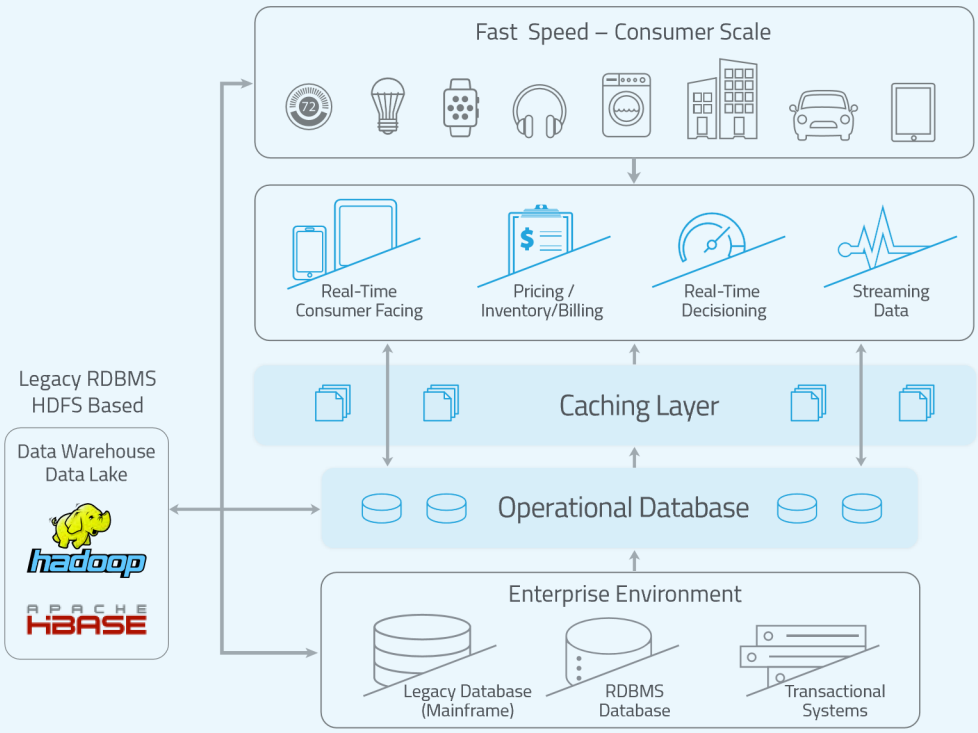


Figure 1. *Old data architecture featuring a caching layer*

When a caching layer is deployed with a dynamic operational database, a number of significant challenges are introduced, namely:

Instability under duress – Caching strategies routinely fail for use cases with heavy write loads, especially those that exceed available DRAM. Cache invalidations or misses means a round trip to the operation databases, adding load and latency to the overall response time.

Complexity – Adding more caching layers increases complexity, which in turn slows development cycles while increasing development and maintenance costs. More complex systems are harder to reason about, causing elongated break-fix cycles when problems do occur.

Data loss – In-memory data is not saved in case of a server crash or power loss, hence the potential for data loss between writes to persistent disk storage. This leads to more architectural complexity, since reliable queues or message busses have to be employed to ensure the data will be preserved to the system of record.

Delayed consistency – Writes lag behind real-time events, resulting in "eventual consistency" where stale data is used by the application – an unacceptable norm.

Server sprawl – With limited DRAM capacity per node, additional servers must be continuously added as workloads increase. DRAM, which is significantly more expensive than disk drives and SSDs, introduces additional power consumption and cooling issues and can be a major contributor to runaway system costs.

High operating expense – Personnel hours are wasted on activities that need to be performed manually, such as cluster management, scaling, and data replication. In addition, as clusters grow, annual server maintenance expenses increase.

Long warm-up cycles – Warming up a cache can take days, which adversely impacts system availability, performance, and data consistency; it can even result in data loss.

Limited data access – Because cache storage capacity is limited by physical and economic factors, only a subset of data can be made available for real-time access. The lack of access to the entirety of the data set can greatly restrict the functional capabilities needed by the business, and can potentially compromise data availability.

A better way –

In-memory speed without a caching layer

What if you could achieve in-memory speed without the added complexity, cost, and drawbacks of a caching layer? Now you can.

Industry's first SSD-optimized NoSQL database architecture

Aerospike has pioneered a modernized architecture that combines the persistence and caching layers into one. This combination provides a cost-effective, simplified solution that delivers speed at scale for mission-critical applications. Aerospike's innovative new approach is made possible in large part by a hybrid RAM/SSD storage architecture that lets you achieve RAM-like performance at a lower cost by leveraging flash memory (SSDs). This new architecture delivers predictable performance while using up to ten times (10x) fewer servers than most other databases, as illustrated in the next page (Figure 2.).

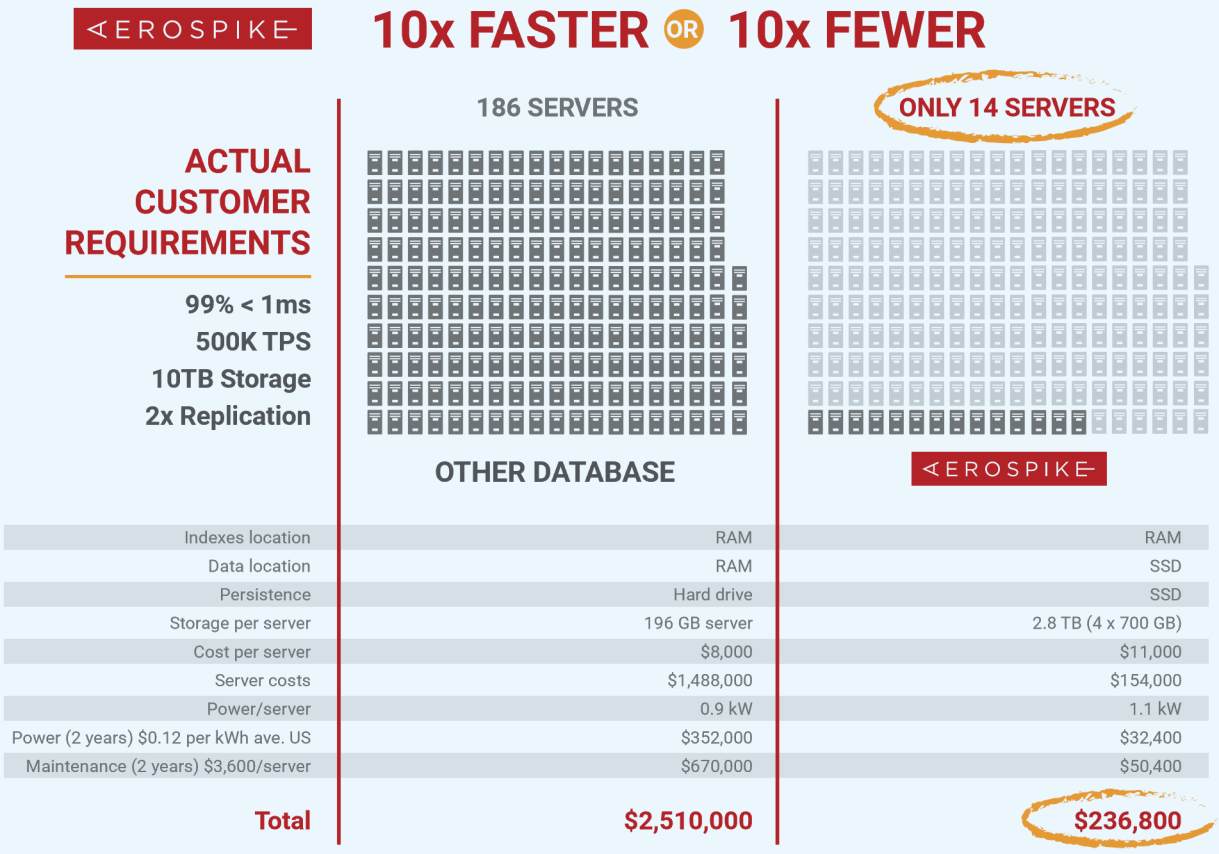
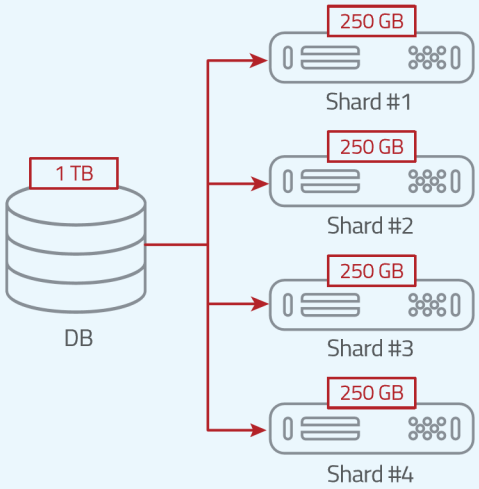


Figure 2. *Example comparing Aerospike to other databases, based on a typically priced 10 TB system (with 2x replication) handling a total of 500K transactions per second (TPS).*

How it works



Automatic database sharding is a key capability in the Aerospike architecture that dramatically improves performance by distributing the database and the workload across multiple servers. Sharding occurs on the fly, in real time, with no manual intervention, and removes application-level sharding built into the code.

Aerospike takes advantage of memory in a way that has never been done before. Rather than using conventional file systems on top of the O/S block and file caches, Aerospike utilizes DRAM for the index and stores the data on SSDs treated as a raw block device. Aerospike's proprietary log structured file system is built to exploit the properties of flash devices while eliminating issues associated with wear leveling, yielding superior and consistent performance and throughput. And unlike other NoSQL solutions, Aerospike is able to drive dozens of SSD devices per server before it becomes CPU-bound. Its parallelism is powerful, both within a node and across nodes; the best performance is achieved by scaling up on one node and scaling out across nodes using DRAM and Flash. Access is optimized for the way in which Flash works – with small block reads and large block writes – and parallelized across multiple SSDs for better throughput.

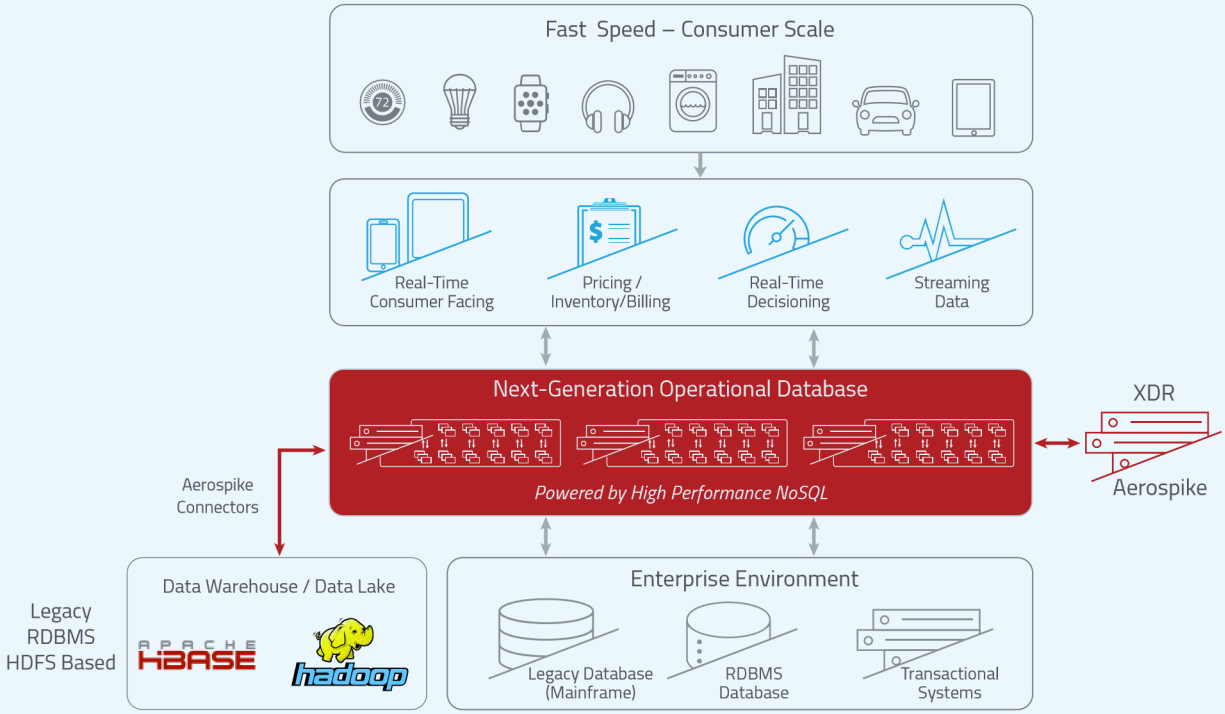


Figure 3. *Aerospike's architecture*

Aerospike achieves additional gains in performance and efficiency by working closely with leading SSD device manufacturers – including Intel, Samsung, and Micron – throughout the product development process. These partners are able to tune the firmware on their drives to ensure optimal performance with Aerospike as they release new products.

Patented algorithms are a key aspect of Aerospike's distributed "shared-nothing" architecture designed to reliably store data with automatic failover and provide replication at the server level to handle failures. By integrating these mechanisms with transaction processing, the system is highly resistant to common failures and is, to a great extent, self-managing.

Exploiting cost and durability breakthroughs in Flash memory technology

Flash storage has historically been cost-prohibitive, and for many, that perception remains. However, in recent years, prices have fallen dramatically. Today, the cost of flash storage is approximately one-tenth that of RAM, as illustrated in this detailed analysis of the economics of Flash vs. RAM.

There have also been issues in the past with the reliability and durability of flash memory technology. This also has changed dramatically, as noted in a rigorous endurance test conducted recently by THE TECH REPORT. The report's author, Geoff Gasior, summarizes the state of modern SSD technology succinctly:

> *"You won't believe how much data can be written to modern SSDs. No, seriously. Our ongoing SSD Endurance Experiment has demonstrated that some consumer-grade drives can withstand over a petabyte of writes before burning out."*

The advances in consumer-grade devices noted by Gasior are even greater – by an order of magnitude – for enterprise devices.

Enterprise-Grade NoSQL has arrived

Thanks to the development of a SSD-optimized NoSQL architecture, combined with many other industry-leading innovations pioneered by Aerospike, enterprise-grade NoSQL is no longer an aspiration or a theoretical concept. Aerospike's massively scalable, high-performance NoSQL database is being used in production today, where it powers some of the world's most demanding real-time applications. Indeed, Aerospike's technology provides a demonstrated competitive advantage for market-leading enterprises across a broad spectrum of industries.

Financial services – Position system of record and risk

The use of Aerospike by a leading financial services firm provides both a quantitative and qualitative illustration of the competitive advantage enabled by this pioneering technology. The financial services company's business mandate – to seamlessly service more than 10 million customers and process more than 250 million transactions daily, while positioning itself to eventually process 1 billion transactions per day – was at risk. Its conventional RDBMS infrastructure and caching capabilities were not consistently able to deliver the performance, scalability, and flexibility needed to meet these requirements. To address the challenge, the firm implemented the following setup: an intraday system of engagement created and managed in Aerospike, while the historical system of record (and a few core applications) are managed separately in the pre-existing mainframe RDBMS.

Aerospike enabled

better performance, better reliability, and material cost savings for this company with:

Speed at scale – Processing speed increased by a factor of 5x (from 200K TPS to more than 1 million TPS) with sub-millisecond latency. At the same time, the system accommodates a 4x larger object store (from 120 million objects to 480 million objects).

Predictable performance – A 3.5x increase in server capacity (from 4 TB to 14 TB) combined with linear scalability ensure that performance is not compromised during peak loads.

High availability – The company uses Aerospike's extensive partitioning, replication, rebalancing, and fault tolerance capabilities to ensure mission-critical uptime and consistency.

Lower total cost of ownership – The deployment of Aerospike resulted in 90% fewer servers being utilized, yielding a 90% reduction in Total Cost of Ownership (TCO).

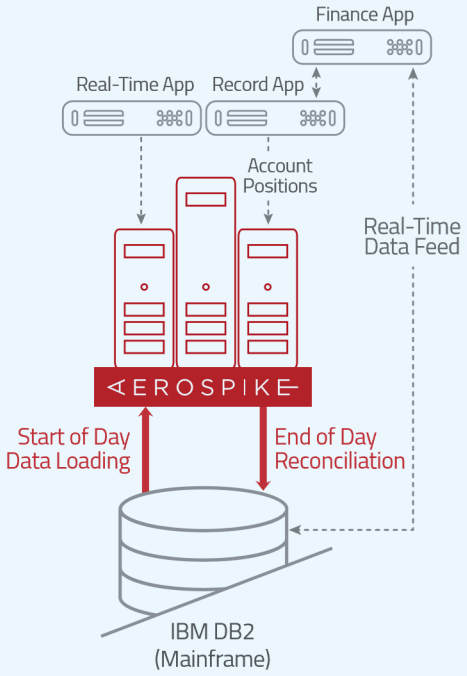


Figure 4. *Illustration of a real-world implementation of Aerospike in a financial services company*

More sample use cases

Customers are increasingly turning to Aerospike to meet their scalability and performances challenges – at a fraction of the cost of other solutions. In addition to being the intraday system of record for one of Fortune's Top 50 Most Admired Companies for 2016, Aerospike is powering real-time, mission-critical applications across virtually every industry for a broad and expanding set of use cases.

Advertising technology (AdTech)

Aerospike has become the de facto database standard among AdTech companies and providers of right-time offers and recommendation engines, including BlueKai, Nielsen, AppNexus, InMobi and Rubicon Project. These organizations provide online exchanges that connect advertisers and publishers, facilitating the purchase of display inventory in real time through auctions that take place in the milliseconds before a web page loads. Through these auctions, publishers can maximize the price for their inventory, while advertisers purchase individual and relevant impressions at prices that reflect each impression's value to the campaign. This level of precision represents a unique challenge due to both the exponential growth in data, and the need to execute on that data in near real time. All this data must be stored and analyzed in such a way as to be accessible for decision-making within milliseconds.

To tackle these requirements, AdTech companies build their applications on top of Aerospike because it was developed explicitly for speed and scale, and can consistently and cost-effectively meet the requirements of today's most demanding AdTech applications. Aerospike's ability to scale horizontally and to replicate data across data centers in a way that ensures consistency and high availability is equally important to companies in the AdTech space.

e-Commerce

Online shoppers expect the right product at the right price and at the right time. While this may sound like a simple concept, the applications supporting these goals are extremely complex. An online retailer's inventory, pricing, and marketing management system must deliver right-time updates and associated recalculations within milliseconds to serve millions of dynamically generated pages per second. As an e-commerce business scales, conventional database solutions fall short in their ability to process inventory updates, price adjustments, and personalized recommendations in real time.

Because e-commerce workloads are subject to wide fluctuations associated with seasonality and promotions, Aerospike's predictable performance, linear scalability, and high availability are particularly important to companies in this vertical. Online retailers need to be confident that the customer experience will not be compromised by slow response times or inaccurate price and availability information during peak transaction periods.

Online gaming and betting

With the massive adoption of mobile devices, gamers can play games and place bets online anytime and anywhere. Online gaming is one of the most challenging categories of database applications. Databases must scale to be able to support millions of simultaneous players, millions of objects, and terabytes of data. Betting and gaming applications must capture and process statistics in real time about many different game variables for each player, both before and during an event. In betting and Fantasy Sports, the odds constantly change; players are looking for opportunities to place micro-bets and micro-trades during games, settle those transactions, and reuse the gains for new opportunities. For intra-game play, pricing adjustments need to be made on the fly as the actual game event (e.g., Monday Night Football, World Cup Soccer) is unfolding. This highly dynamic environment demands consistent, extreme speed in order to continuously recalculate odds and process in-game bets and settlements while guaranteeing instant response times and preventing fraud.

Conventional databases are ill-suited to store, read, write, and analyze such massive volumes of data in real time. Moreover, maintaining high availability and data consistency reliably across multiple regions and data centers is a constant challenge. The speed and scalability of Aerospike's distributed hybrid storage architecture, combined with battle-tested high availability in production deployments, are helping Curse, DraftKings and many other large gaming companies provide a superior gaming experience for their customers.

Payments & fraud

Fraud detection, protection, and intervention are top priorities for digital payment providers. The ability to meet service-level agreements (SLAs) for fraud prevention and assure in real time that legitimate purchases are not denied – and fraudulent transactions not approved – are critical to growing revenues, maintaining customer satisfaction, and minimizing customer churn in this industry. Keeping digital payments fast and accurate while mitigating risk is not easy. Payment providers have developed complex, rules-based fraud algorithms, linked to comprehensive customer profiles that access massive volumes of diverse, real-time data.

The volume of concurrent transactions, coupled with the fact that a single credit card purchase can generate hundreds of reads and writes, imposes extreme loads that traditional database technologies are ill-suited to handle. Leading digital payment providers use Aerospike in production today for fraud prevention – a mission-critical application – due to Aerospike's ability to process millions of reads and writes every second, and its capacity to handle terabytes of data and billions of objects with predictable throughput and low latency. Notably, a leading payment processing gateway reduced its total query response time from approximately 750 milliseconds (at 200 DB queries per transaction) to 75 milliseconds, a fraction of the SLA. This tenfold improvement in throughput effectively allowed them to improve fraud detection by assessing more rules to detect deeper patterns of behavior.

Telecommunications (Telco)

Telco carriers today are increasingly supplementing traditional voice and text services with data services that encompass streaming video and music, gaming, web navigation, and email. They are driving revenue growth and reducing customer churn by allowing customers to opt into a range of personalized and relevant services. Data usage pricing is often segmented by service. For example, a carrier might allow free, unlimited data streaming from Spotify while YouTube streaming is charged to a customer's data plan. Carriers therefore need the ability to record how each data packet is used in order to accurately bill their customers. With exploding data volumes, a bigger subscriber base, and more personalized and granular services, carriers are now facing serious scale issues. As a result, their ability to provide real-time usage information, billing enforcement, and customer self-service is impeded. Operators have been trying to cope either by massively overspending on homegrown databases or MySQL Cluster, or by using previous-generation, in-RAM memory systems like Oracle TimesTen. Unfortunately, these databases are no longer able to meet the necessary requirements for the current environment, where both speed and scale are table stakes for success.

Aerospike is helping telecommunications companies migrate away from these legacy systems. Aerospike's SSD-optimized architecture allows these companies to eliminate their dedicated in-memory cache databases, simplify their deployment environments, and reduce their hardware requirements, while still ensuring predictable high performance as data volumes grow.

Three steps to modernizing your database architecture

To start your journey of modernizing your database architecture, it is recommended that you take the following three steps:

1. Sign up for Aerospike's Solution Overview webinar

Aerospike regularly holds Solution Overview webinars. In these live webinars, its Senior Engineers dive into the key benefits of Aerospike's high-availability architecture and present leading use cases on scaling high-performance systems. They also answer live questions, provide tips and share best practices. Sign up for an upcoming session here.

2. Find out how much you can save with the TCO Calculator

Aerospike's customers typically experience a tenfold performance improvement or a tenfold reduction in costs compared to most other databases. Use the interactive Total Cost of Ownership (TCO) Calculator to see how much you can save with Aerospike.

3. Contact us

Aerospike is happy to engage with you directly to discuss your particular situation and answer your questions. Please visit the Contact Us page to provide your contact details and a short message describing what you need, and Aerospike will be in touch with you shortly.

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