Managing Transactions and Analytics Simultaneously in the High-Speed World of Financial Services

Executive Summary

Successful financial services organizations today must be able to simultaneously process transactional and analytic workloads at high scale, processing billions of messages per day while supporting thousands of analytic queries per second from hundreds of applications, without incident. The consequences of dropped trades – or worse, a system failure – can be severe, incurring financial losses and reputational damage to the firm.

Traditional operational databases are often too slow to accommodate the high throughput and data-access rates required. These databases insert and update records in milliseconds, rather than delivering the microsecond response times that are needed, and are not optimized to concurrently support both transactional and analytic workloads at scale.

Today, in-memory databases are being used throughout the financial services industry, primarily due to their ability to support high-performance data-insert operations and analytic workload processing. However, in-memory databases alone have proved to be less than ideal, especially at handling mixed workloads as transaction volumes increase.

This white paper describes the requirements of transaction management and analytics platforms that must operate at very high scale without performance or reliability issues, even during periods of market volatility. It describes the strengths and weaknesses of the various technologies that have been used to date, and presents a new platform, InterSystems IRIS Data Platform. This platform is optimized for multi-workload processing at scale, delivering performance equal to or greater than in-memory technologies with the persistence and reliability of a traditional operational database.

For one leading global bank, InterSystems technology improved throughput by up to 500 percent and decreased latency by 1,000 percent compared with its previous in-memory DBMS-based system, and it has operated without incident since its implementation.
Introduction

Increasing trade volumes and periods of high market volatility create significant technology challenges for financial services firms. This is especially true for sell-side firms, which can experience extremely high transaction volumes, since they partition already high volumes of incoming orders into even more child orders for execution. At the same time, they must support a high number of concurrent analytic queries to provide order status, risk management, surveillance, and other information for internal and external clients. This requirement for multi-workload processing at very high scale coupled with the highest levels of performance and reliability has historically been difficult to satisfy.

Compounding the challenge, transaction volumes grow not only incrementally and within expectations, but unexpected world events that affect markets can cause transaction volumes to spike dramatically. Recent examples include the 2008 financial crisis, the 2010 “flash crash,” and the devaluation of China’s currency in 2015.

A critical component of a sell-side firm’s technology infrastructure is its transaction management and analytics platform. The platform must be extremely reliable and highly available – able to withstand both normal transaction-volume growth as well as the extreme spikes that can occur during periods of market volatility – without incident.

A failure, or even just a slowdown of the transaction management and analytics platform can have severe consequences for a firm. For example, it can take many hours to rebuild order state and resume normal operations after a failure. In the meantime, the firm’s ability to process additional trades and provide order status and other critical information is compromised and financial losses mount. Even a slight delay or outage can cause significant financial losses and impact the firm’s reputation. One major bank recently reported a loss of $100,000 for each minute of system downtime.

High-Performance Transaction Management and Analytics Platform

A high-performance transaction management and analytics platform must record all orders originating from clients and from internal sources, ensure proper routing and execution of the orders, maintain the state integrity of the orders (for example, if an order is only partially filled), record and properly allocate all trade executions, and preserve all data, while concurrently processing analytic workloads on the trade data.
To successfully handle growth and volatility without performance or availability issues, the platform must balance transactional workloads with the concurrent analytic demands of downstream applications at scale. Financial services organizations, particularly sell-side firms, must be able to process millions of messages per second, while simultaneously supporting thousands of analytic queries from hundreds of systems that must report on the state of orders while performing other queries.

Traditional operational databases are too slow to accommodate the high throughput and data-access rates required. These databases insert and update records in milliseconds, rather than the required microsecond response times, and are not optimized to concurrently support both transactional and analytic workloads at scale.

Currently, in-memory databases are being used throughout the financial services industry, primarily due to their ability to support high-performance data-insert operations and analytic workload processing. However, in-memory databases alone are not an ideal platform for transaction management and analytics for a number of reasons:

- **Limited ability to concurrently process transactional and analytic workloads at scale.** In-memory databases are not designed to support multi-workload processing at high scale. As a result, as volumes increase, at some point both the transaction processing and the analytic queries will slow or stall.

- **Scale limitations.** Since the data in an in-memory database is stored in main memory, the working data set is limited by the available amount of memory. This creates significant risk when transaction volumes spike, compromising the ability to process new orders once the available RAM is filled. It also limits the amount of data that can be queried and analyzed in real time.

- **High costs.** Since servers have hard memory limits, scaling in-memory databases beyond these limits requires purchasing and procuring additional nodes – to sustain normal operations plus headroom for unexpected volatility, increasing costs.

- **System downtime.** Since the data is stored in memory, if the database server fails, the data that is resident in memory on that server is lost. Some in-memory database systems offer persistence through mirror databases, replication, and other approaches. These techniques can affect ingest performance and cost, and add maintenance complexity. For databases where the data is stored in files and transaction logs, the recovery effort involves rebuilding the database using the logs, checkpoint files, and other backup data. This is a time-consuming effort, during which time the bank’s ability to process orders is compromised, resulting in revenue losses and other penalties to the business.
InterSystems IRIS Data Platform for High-Performance Transaction Management with Analytics

InterSystems IRIS Data Platform is a hybrid processing (HTAP) database platform that delivers the performance of an in-memory database with the persistence and reliability of a traditional operational database. Unlike any other database, it is optimized to accommodate both very high transactional workloads and a high volume of analytic queries on the transactional data concurrently, without incident or performance degradation, even during periods of extreme market volatility.

At the core of InterSystems IRIS Data Platform is a comprehensive, multi-model DBMS that delivers fast transactional and analytic performance without sacrificing scalability, reliability or security. It handles relational, object-oriented, document, key-value, and hierarchical data objects in a common, persistent storage tier.

It offers a unique set of features that make it highly attractive for mission-critical high performance transaction management and analytics applications, including:

- High performance for transactional workloads with built-in persistence
- High performance for analytic workloads
- Consistent high performance for concurrent transactional and analytic workloads at scale
- Lower total cost of ownership

For one leading global bank, InterSystems data platform has improved throughput by 3 – 5x and performance by 10x. It has reduced operating costs by 75% compared with its previous in-memory DBMS-based system, and has operated without incident since its implementation.
High performance for transactional workloads with built-in persistence

InterSystems IRIS Data Platform includes a high-performance database that provides transactional performance equal to or greater than in-memory databases along with built-in persistence at scale. It is the permanent data store, and it is always current. Data is not lost when a machine is turned off, eliminating the need for any database recovery or re-building efforts.

Its superior ingest performance results in part from its multidimensional data engine that allows efficient and compact storage of data in a rich-data structure. By using an efficient, multi-dimensional data model with sparse storage techniques instead of two-dimensional tables, data access and updates are accomplished faster, using fewer resources and less disk capacity. In addition to traditional TCP/IP access APIs, it provides in-memory, in-process APIs, further increasing ingest performance.

The resulting ingest performance is typically three to 10 times faster than in-memory databases. One InterSystems customer is processing 40 billion transactions per day on one two-socket Intel Xeon machine at an average insertion rate of 455,000 objects per second.¹

High performance for analytic workloads

InterSystems IRIS provides a wide range of analytic capabilities, including full SQL support, enabling financial organizations to use their existing SQL-based applications with few or no changes. Since the database stores data in efficient multidimensional structures, SQL applications achieve better performance than with traditional relational databases. It provides native support for other data paradigms, including objects, documents, key-value data, and unstructured data.

Its high performance for analytic workloads also derives from its unique approach to real-time indexing – transactional bitmap indexing – which significantly increases the performance of complex queries on the live, transactional data. Most databases use traditional indexes that maintain a list of IDs for values in rows or objects. In contrast, bitmap indexes contain a separate bitmap for each possible value of a column or property. The advantage of bitmap indexes is that complex queries can be processed by performing Boolean operations without searching through the entire database, increasing response times for queries that search large volumes of data by 100 times or more. However, with traditional bitmap indexing, updating the index can be slow. Such indexes can also require a significant amount of storage, which has limited their use with databases, especially if they need to analyze real-time transactional data.

¹In this example, the database is inserting new data objects of 2 kB average size.

The unique transactional bitmap indexing in InterSystems IRIS leverages multidimensional data structures to eliminate these two problems. Consequently, updating the bitmaps is fast, often faster even than traditional indexes, and advanced compression techniques significantly reduce storage requirements. The result is ultra-fast bitmaps that can search very large data sets and enable analytic queries to incorporate “live” data with high performance at scale.

Finally, InterSystems IRIS provides the ability to perform sophisticated analytic queries on very large data sets, including performing joins that can access data distributed on disparate nodes or shards, with extremely high performance and without making multiple copies of the data. This capability allows organizations to access more order data with their analytic queries. Some organizations are even importing historical data sets from data lakes in Hadoop and other data repositories to be analyzed with the current transaction data. The result is that organizations can include much more data in their analytics to support downstream applications and ad hoc analytic queries to gain new and more accurate insights from the data, with near real-time performance.
Consistent high-performance for concurrent transactional and analytic workloads at scale

InterSystems IRIS provides the highest levels of performance for both transactional and analytic workloads concurrently, at high scale, without compromising performance for either type of workload. Since rising order volumes increase both the transactional and analytic workloads on the system, a data platform must scale to handle such workloads without experiencing performance or availability issues, especially during periods of market volatility. InterSystems IRIS comprises several features to support these demands.

Enterprise Cache Protocol. To achieve this superior multi-workload performance and scalability, InterSystems has developed a unique technology, Enterprise Cache Protocol (ECP).

A key benefit of ECP is that resources can be scaled independently based on workload type (i.e. transaction processing or analytic queries) and load. ECP optimally coordinates the flow of data across a multi-server environment from ingestion to consumption. It enables full SQL access to all of the data in the environment without replicating or broadcasting data.

ECP enables the servers in a distributed system to function as both as application servers and data servers, and to dynamically access remote databases as if they were local databases. Primary ownership of the data only needs to be held by a small percentage of the servers in the system. If analytic requirements increase, more application servers can be added instantly. If disk throughput becomes a bottleneck, more data servers can be added and the database becomes logically partitioned.

Each node in the distributed system can operate on data that resides in its own disk system or on data transferred to it from another data server by ECP. When a client makes a request for data, the application server will attempt to satisfy the request from its local cache. If the data is not local, it will request it from the remote data server, and the data is then cached on the local application server where it becomes available to all applications running on that server. ECP automatically manages cache consistency and coherency across the network.

Using ECP is transparent, and requires no application changes or specialized techniques. Applications simply treat the entire database as if it were local.

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**Figure 2: Most databases can be tuned either for inserts and updates, or for processing queries. Enterprise Cache Protocol is a unique technology that optimizes processing for both kinds of workloads in a single environment.**
Sophisticated memory management techniques. InterSystems IRIS uses sophisticated memory management techniques to ensure high performance and availability. Most in-memory databases rely on the operating system for memory management and thus can exhaust memory resources during periods of high workloads. InterSystems IRIS requests a continuous chunk of memory from the operating system at startup, and then intelligently manages and optimizes the memory, independently of the OS. It is possible (and expected) that during periods of high workloads, the allocated memory may be completely consumed. If that occurs, it dynamically releases the least recently used data, freeing memory, and continues operating seamlessly. If some required data is not available in memory, it simply retrieves it from disk.

Cache optimization. Unlike most other databases, which maintain a separate cache for each process running on a machine, InterSystems IRIS maintains a single cache for each machine, and allows processes running in their own memory address space to access the data. Since multiple clients are able share a single cache, only one copy of the data needs to be maintained for each machine, resulting in reduced storage requirements, reduced network I/O, and superior scalability. For example, in an InterSystems IRIS-based system of 250 machines, each with eight cores, only 250 caches need to communicate with one another to maintain cache coherence. In contrast, systems that require a separate cache for each core would need to coordinate among 2,000 caches.

The performance and scalability benefits of InterSystems IRIS are dramatic, enabling organizations to efficiently process transactional and analytic workloads concurrently, without compromising either type, using a single platform, with the highest levels of performance and reliability, even when transaction volumes spike.

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<thead>
<tr>
<th>Feature</th>
<th>InterSystems</th>
<th>In Memory DBMS</th>
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<tbody>
<tr>
<td>Optimized for concurrent transactional and analytic workloads</td>
<td><img src="#" alt="Green" /></td>
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<td>Ability to handle increasing workloads not limited by RAM</td>
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<td>Low cost to scale</td>
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<td>Automatic built-in persistence</td>
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Figure 3: Comparing InterSystems IRIS with in-memory databases

Lower total cost of ownership

InterSystems IRIS provides a single, consistent architecture for working with multiple data types and for processing transactional and analytic workloads, eliminating the need to learn or integrate multiple technologies and approaches. It also provides a highly intuitive application development and maintenance environment, speeding implementations, simplifying application maintenance, and enabling firms to accomplish more with fewer resources, while lowering development and maintenance costs.

Its highly efficient use of system resources reduces the amount of infrastructure needed, especially compared with in-memory databases, significantly lowering infrastructure costs. Using InterSystems technology, one financial services firm is experiencing a 75 percent reduction in operating costs while increasing throughput, performance, and reliability, compared with its previous in-memory DBMS-based system.
Hybrid Transaction/Analytical Processing (HTAP) Databases

Traditionally, online transaction processing (OLTP) and online analytical processing (OLAP) workloads have been handled independently, by separate databases. However, operating separate databases creates complexity and latency because data must be moved from the OLTP environment to the OLAP environment for analysis. This has led to the development of a new kind of database. In 2014, Gartner coined the term hybrid transaction/analytical processing, or HTAP, for this new kind of database, which can process both OLTP and OLAP workloads in a single environment without having to copy the transactional data for analysis.

HTAP databases are being used in multiple industries for their ability to uncover new insights, create new revenue opportunities, and improve situational awareness and overall business agility for organizations.

However, not all HTAP databases are alike. While in-memory technology is a critical component, HTAP databases that rely exclusively or too heavily on in-memory architectures experience some of the same challenges associated with in-memory databases. These include the inability to tune for both transactional and analytic workloads concurrently at high scale, excessive costs to scale, and hard scalability limits that are governed by the amount of available memory.

These limitations can affect an organization’s ability to reliably handle transactions during periods of peak loads without performance or availability issues. In financial services in particular, this could mean not being able to process all orders during periods of market volatility.

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2 Hybrid Transaction/Analytical Processing Will Foster Opportunities for Dramatic Business Innovation, January 2014, Massimo Pezzini, Donald Feinberg, Nigel Rayner, Roxane Edjlali, Gartner.
Customer Examples

High-Performance Transaction Management with Analytics

A leading global sell-side investment bank with 50,000 employees and more than $1 trillion in assets under management had conflicting requirements for its transaction management and analytics platform: to reliably handle increasing trade order volumes while lowering infrastructure costs.

The globally distributed system had to accommodate billions of daily orders, with sufficient headroom to handle unexpected spikes during periods of market volatility. At the same time, the system had to service analytic queries from 250 applications across the organization.

The bank had previously used an in-memory DBMS-based transaction management system, but had experienced serious performance and availability issues during periods of peak loads. The bank migrated the application to InterSystems technology, resulting in 3-5x increase in throughput, 10x increase in performance, and a 75% percent reduction in operational costs. In addition, the bank is now able to include more order data in analytic queries, compared with its previous in-memory based system.

With the InterSystems-based implementation, there is no single point of failure. Each functional component is linearly scalable, and it has successfully handled all trading days – with no performance or reliability issues.

Big-Data Analytics on Historical and Real-Time Transactional Data

A different sell-side investment bank with more than 35,000 employees and more than $800 billion in assets under management had requirements to analyze its transactional data and respond to end-user queries in milliseconds. The bank had imported 70 years’ worth of historical data into a data lake in Hadoop, but it was not able to meet all of its requirements using the analysis capabilities in Hadoop alone:

- While the Apache Hive data warehouse infrastructure was able to support simple SQL queries, it was unable to perform the necessary SQL queries to correlate data (e.g., via joins) to identify new relationships and insights.
- Many of the queries exceeded the bank’s strict performance service-level agreement of 200 milliseconds.
- The bank was experiencing unacceptable latencies incorporating the current transactional data into the analyses.

The bank implemented InterSystems technology to complement its data lake in Hadoop. As a result, it is now able to perform complex SQL queries faster, including inner, outer, cross, and cross-network joins. Traditional SQL queries now execute five times faster on average, and all queries execute in less than 200 milliseconds. In addition, more data, including the real-time transactional data, can be included in the analytics to deliver new and more accurate insights.

Conclusion

InterSystems IRIS is an ideal platform for high-performance transaction management and analytics applications that must support both transaction processing and analytic queries concurrently, at very high scale, with the highest levels of reliability, and a low total cost of ownership.

For more than 35 years, InterSystems has been the engine behind the world’s most important applications. In financial services, healthcare, government, and wherever lives and livelihoods are at stake, millions of people worldwide depend on the power, scale, integration, and performance of InterSystems’ technology.

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