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TimesTen

Oracle TimesTen In-Memory Database for the Financial Industry

ORACLE WHITE PAPER | MARCH 2019

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Executive Overview

Certain classes of financial applications operate with a rigid requirement for highly-available, fault-tolerant processes that can sustain operations with high-speed data streams. To compete, these systems must guarantee minimal latency during retrieval of mission-critical data, provide robustness to ensure non-stop operation and deliver scalability to handle a growing amount of data and concurrent users. This white paper illustrates how Oracle TimesTen In-Memory Database (Oracle TimesTen), which has been widely used in the financial industry for more than a decade, meets these needs and more, providing a strong data management platform for successful operations today and in the future.

Introduction

The financial services industry is going through a transformation in regulatory requirements, technology, and operational resource needs. The era of highly customized, proprietary hardware and software is no longer desirable because it breeds high infrastructure costs and extends the time from concept to inception and implementation — severely limiting the ability to compete. For many years, financial platforms were often based on home-grown software, using closed proprietary frameworks and data management solutions. While the resulting home-grown infrastructures achieved some measure of success, they often did not scale well and lacked the flexibility to cost-effectively accommodate new services and technological innovation.

The demand for high-performance computing and scalability is driving a fundamental shift in application frameworks. By using the best commercial-off-the-shelf (COTS) solutions, the financial industry is realizing dramatic price and performance benefits and the ability to deploy innovative applications faster. Especially with the growth of electronic trading (etrading) and mobile computing with “anywhere, anytime” connectivity, the reasons for choosing an in-memory database for real-time data access are increasingly clear.

To deliver products that help ensure the highest quality of service, Original Equipment Manufacturers (OEMs) and Independent Software Vendors (ISVs) require extremely fast data access and continuous data availability. In-memory database technology is a vital solution for any application that must supply data instantly and reliably.

Trading systems with high transaction volumes and a requirement for extremely fast response times are examples of applications for which in-memory database technology is particularly well suited. The financial sector has used highly-tuned in-memory technology for several years, with Oracle TimesTen being embedded in real-time systems for trading on stock exchanges such as Philadelphia Stock Exchange, Bombay Stock Exchange, Deutsche Börse, and KOSDAQ.

Whether running on enterprise servers, embedded in appliances, in the cloud, or processing constantly-changing complex data, financial applications need a platform characterized by low latency, high availability, and a scalable infrastructure that allows for rapid growth. To stay ahead of the market and plan for future growth, system developers need products that are ready now to integrate into their plans—embeddable products that help provide an agile framework. The products should be easy to use for developing, managing and deploying applications, and should provide a long-term return on investment by offering response time, reliability and scalability that supports high demand and continued growth.

Oracle TimesTen provides the necessary agility for companies developing and deploying financial applications that meet or exceed today's stringent requirements. This paper describes how Oracle TimesTen provides developers a superior alternative to building or deploying other data management solutions — and helps developers deliver greater innovation with shorter time to market.

Data Management Challenges

The challenges of pursuing business opportunities, keeping up with a growing amount of market data and complying with ever-increasing regulatory requirements have many ramifications for database technology.

Low Latency Data Access

Accurate and timely data is essential to the efficacy of modern financial networks and applications. Financial services professionals expect data to arrive correctly and services to be delivered quickly, while acceptable latency continues to shrink. Tolerance for delay is poor, particularly when investment firms are using algorithmic trading systems for which low latency provides a competitive advantage, or when fraud detection must be completed in real time to prevent a fraudulent transaction from completing. The ability to have a real-time view of Risk or the Position of the bank is paramount in today financial climate. Achieving service-level agreements (SLAs) of a few milliseconds requires that underlying database transactions complete in microseconds. Failure to achieve SLA's often results in severe financial penalties to the financial institution.

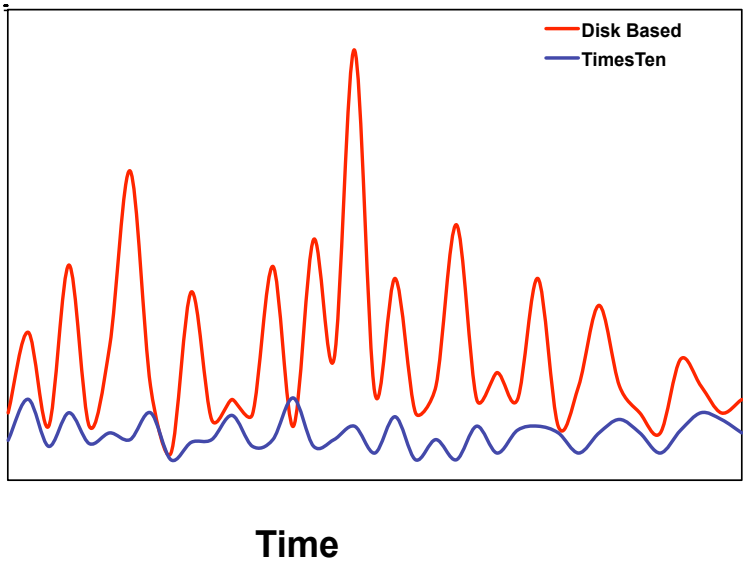

Figure 1. Disk databases cannot match the predictable response times from using Oracle TimesTen

High Availability (HA)

The data access requirements of financial systems are not limited to high performance with low and predictable latency. They also include maximun availability for a financial world that operates around the clock and cannot tolerate service outages. They also include zero data loss for financial transactions that

cannot tolerate any inaccuracies. Solutions that track market data, manage risk and perform real-time analyses need to ensure that despite a hardware failure or other outage, applications will be available and services will continue without interruption. Executing an order, for example, must be accurate, always available when markets are open and the data must be accessible for settlement.

Scalability

The operative words that best describe the situation in the financial industry are growth and volume. Markets grow, new products are added, trading volumes trend upwards, regulation gets tighter and the volume of data continues to increase dramatically. While there may be short-term slowdowns or contractions, the long-term trend is upwards. Spikes in load can occur at different times of the day with surges in trading activity in global markets that span multiple time zones. Neither performance nor reliability can be allowed to deteriorate as load varies. Any solution must be able to scale seamlessly, handling both transient peaks and long-term sustained growth.

Support for Industry Standards

Having identified a window of opportunity, a system development organization needs to build and ship applications quickly, often integrating them into existing infrastructure. Compliance with *de jure* or *de facto* standards makes recruitment easier, minimizes learning curves and enables software developers to use existing skill sets. Integration with existing applications and tools is simpler, shortening time to market.

Ease of Embedding

While Oracle TimesTen is often incorporated into internally developed and deployed applications, it is also easily embeddable for external distribution in COTS software. Using fully-embedded commercial database software in products enables OEMs and ISVs to offer complete solutions, deliver direct services and act as a single point of contact. Because solutions are deployed in many locations (often largely unattended), installation, normal operation, updating and recovery from error conditions all must happen without administrator intervention or an onsite presence.

Addressing the Challenges

Oracle TimesTen In-Memory Database (Oracle TimesTen) is a memory-optimized SQL database that provides applications with extremely fast response time and very high throughput as required by transaction processing applications and real-time analytics for purposes such as trading, detecting fraud, mitigating risk and managing portfolios. Deployed in the application tier, Oracle TimesTen databases reside entirely in physical memory with persistence to disk storage for recoverability. Applications access the in-memory database using standard SQL interfaces. High availability is provided through real-time transactional replication.

Oracle TimesTen can be deployed as either a stand-alone in-memory relational database with full persistence and recoverability, or as a database cache for Oracle Database and Oracle Exadata Database Machine. In either case, Oracle TimesTen is integrated with the Oracle infrastructure software stack including Oracle Clusterware, Oracle Enterprise Manager, and Oracle SQL Developer. When acting as an

in-memory database cache, Oracle TimesTen improves transaction response time by caching performance-critical subsets of data from Oracle Database in the application tier.

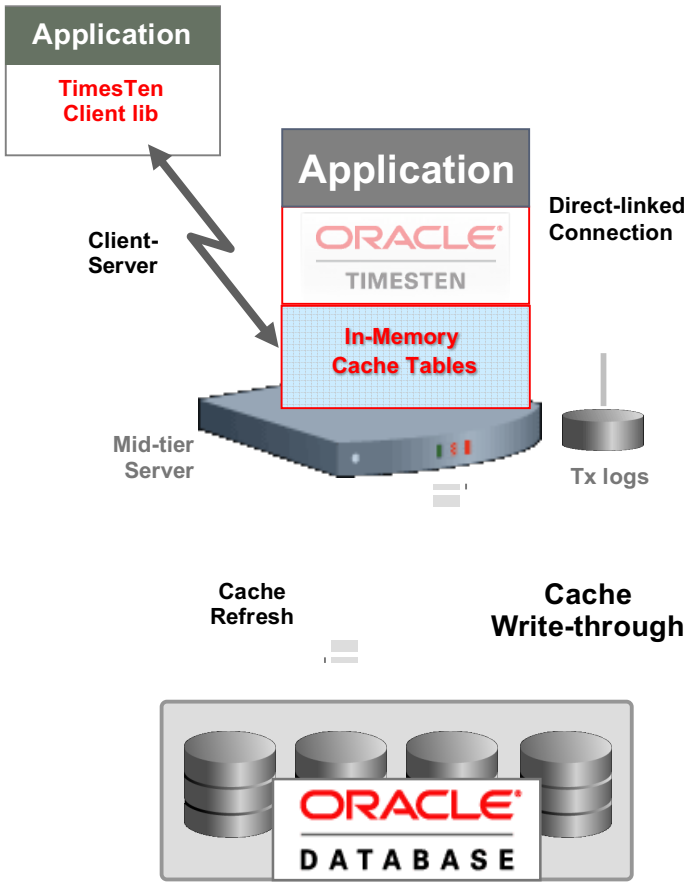

Figure 2. Oracle TimesTen cache tables improve query execution times for Oracle Database 11g

Microsecond Response Times

Oracle TimesTen delivers real-time performance by managing data entirely in main memory. Oracle TimesTen optimizes data structures, algorithms and access paths accordingly. Because data is entirely in random-access memory (RAM) at runtime, Oracle TimesTen does not incur the overhead of managing a disk buffer pool or waiting for disk I/O operations. These factors enable database operations to execute with maximum efficiency, achieving dramatic gains in responsiveness and throughput, even compared to a fully cached disk-based SQL DBMS. In addition, when applications link directly with Oracle TimesTen and run in the same process as the database, recommended for optimal performance, both inter-process communication and networking overhead are also eliminated.

Real-time data management has two performance dimensions – response time and throughput. With Oracle TimesTen, a transaction that reads a database record can be completed in 2.5 microseconds (measured on Intel Xeon 2.93 GHz processor running Oracle Solaris), while writing a record takes just 10 microseconds. Consequently, throughput is measured in tens to hundreds of thousands of transactions per second, running on commodity hardware or enterprise servers, such as Oracle Sun Fire Servers and Oracle Sun SPARC Servers.

Extreme low latency and predictable microsecond response times enable Oracle TimesTen to provide real-time access to data for highly time-sensitive operations such as processing transactions, messages and data streams, whether for trading systems, risk management, fraud detection or other applications.

Durability

There's a natural reaction when hearing about in-memory database technology. It is obvious to most that it will be faster than other approaches, just as RAM is clearly faster than disk. But what happens to all that data when a server goes down?

Oracle TimesTen operates with a safety net. As a relational database it's fully ACID compliant. In the event of a server outage, the database is recoverable from disk or from an in-memory database replica on an alternate server. Oracle TimesTen applications can use both solutions to guard against partial or incomplete transactions, to prevent data loss, and to ensure data integrity. Customers have chosen either or both safety nets, depending on need.

While Oracle TimesTen uses RAM to store the database at run time, the entire database and the transaction logs are made persistent on disk as log files and checkpoint files. Oracle TimesTen supports standard transaction semantics as expected in conventional disk-based SQL database systems. The logging and checkpointing mechanisms are highly flexible, allowing the application developer to tune them as needed. For an extra measure of performance, some users of Oracle TimesTen have used solid-state disks for logging.

For the utmost in durability, fully synchronous logging to disk or replication to memory on another system ensures there is no single point of failure, while asynchronous mechanisms provide a high degree of durability with much higher performance.

Data Replication

Replication has become a defining characteristic of modern system architectures when scalability, performance and high availability are important design constraints. Replication is a key ingredient in a recipe for high availability, eliminating single points of failure and enabling fast recovery from server outages.

Replication enables organizations to mirror databases and maintain highly-available systems. Recently Ericsson has reported that Oracle TimesTen replication enabled Ericsson to configure an architecture that had an uptime of "five and a half nines" (99.9995% uptime), including scheduled downtime for upgrades.

The Oracle TimesTen transaction-log based replication scheme enables high efficiency and low overhead real-time transactional data replication between Oracle TimesTen databases. Asynchronous replication

provides maximum performance, and the application is completely decoupled from the receipt process of the replicated elements on the subscriber. For applications where no transaction loss is of the highest importance on fail over, synchronous replication provides the guarantee of no transaction loss if failover to a standby database is required.

The flexible deployment architecture supports a range of configuration options over local-area and wide-area networks (LAN and WAN) for active-standby, active-active and N-way replication. The standby database is always available for reads; more read capacity can be provided by configuring additional read-only subscribers.

Oracle TimesTen replication is therefore the capability at the heart of addressing several of the challenges outlined in the previous section:

- High availability as well as support for online upgrades without downtime.
- Integration with Oracle Clusterware for automated failover and recovery.
- Geographic redundancy and locality of data by enabling WAN-based as well as LAN-based replication.
- Scaling through seamless addition of both read-only and read-write capacity.

Standard Interfaces

Applications access the Oracle TimesTen database using interfaces such as JDBC ™, Open Database Connectivity (ODBC), Oracle Call Interface (OCI), Pro*C/C++ and .NET programming APIs. ODBC and JDBC are native Oracle TimesTen interfaces that operate directly with the database engine. ODBC and JDBC processing does not require additional libraries that implement a proprietary interface and introduce an additional layer of processing. Oracle TimesTen supports PL/SQL, implements database connectivity that is fully-complaint with the ODBC and JDBC specifications, and is tuned for maximum performance in the Oracle TimesTen environment.

Oracle TimesTen also supports Oracle Call Interface (OCI) and the Pro*C/C++ pre-compiler thus enabling OCI applications to run against Oracle TimesTen applications. Furthermore, applications that need access Oracle TimesTen from the .NET framework can do so using the Oracle ODP.NET data provider.

Using standards-based APIs and Oracle Database compatible APIs simplifies programming when Oracle TimesTen is configured to operate as a cache for a disk-resident SQL platform, such as Oracle Database 11g. The use of other caching mechanisms can require that developers learn one set of APIs for the SQL database and another set of APIs for a caching scheme. Oracle TimesTen alleviates the problem and does not incur the costs of having to learn and work with disparate APIs for caching and SQL processing.

Track Record of Success

For more than a decade, Oracle TimesTen has been a part of mission-critical infrastructure in different industries, including various parts of the financial industry. Oracle TimesTen has been in use inside systems for trade order management, market data distribution, risk management and real-time analytics.

One can examine the Oracle TimesTen track record and see successful deployments in a variety of scenarios and a mix of applications, but with a common requirement for low latency and high-throughput.

Portfolio and Risk Management

Financial institutions often want the twin goals of aggressive trading activity and minimal risk. Today's portfolio managers and risk managers are among the class of users who require powerful computing systems. This type of user requires a platform that can process high-volume data streams, such as market data, concurrently with activity such as online transaction processing (OLTP) and real-time analytics.

Oracle TimesTen has been a tool of choice for use in systems that serve the diverse needs of those managing portfolios, including users in corporate and investment banking divisions. One current project involves developing a portal for a global user base, with sales and CRM application modules for corporations and investment banks. To ensure scalability and maximize availability, Oracle TimesTen is used to augment Oracle Database 11g.

Financial institutions have increasingly had to focus on risk management. This is partly due to regulatory issues, such as Sarbanes-Oxley requirements in the US and Basel II,III and MiFID in European Union (EU). Regulatory compliance, as well as sound business practice, spurred many financial services and banking companies to turn to technology for mitigating risk.

For example, a global bank implemented a cross-product risk engine operating in a distributed processing architecture. The application determines and reports Current Credit Exposure (CCE), Projected Future Exposure (PFE) and Expected Positive Exposure (EPE) by using Monte-Carlo methods to simulate risk factors and basic financial variables. Another example is a system that uses Oracle TimesTen to mitigate risk exposure for a wagering system in Asia. Because it supports fixed-odds betting on football, wagers on horse racing, plus a lottery, it has a sub-second window to aggregate and correlate high volumes of data while monitoring betting activity.

For applications that assess risk, real-time performance is often critical. Oracle TimesTen has been proven to deliver such performance for risk management applications. One such deployment was a system that monitored electronic payments in Europe, requiring real-time responsiveness to service more than 50 million customers.

Problems that surfaced during the financial crisis have caused the financial services industry to pursue better solutions for expansion of business and risk analytics. Although there are some stellar examples of risk management systems, a recent survey showed the respondents felt their investment firm's analytics tools fell short of the mark. An *InformationWeek* Financial Services survey [1] of 223 financial industry professionals explored whether organizations were ready to meet current and future demand for business analytics. The response indicated that most financial firms do not have systems in place that can handle continued growth in data volumes and the stringent latency requirements for complex analytics. 47% of respondents at buy-side investment firms said they were overwhelmed by data volumes, while 41.5% at sell-side firms held the same opinion. Those who felt their firm's systems had adequate capacity were in the minority. Only 37.5% of respondents at buy-side firms and 34% at sell-side firms believed their firm's infrastructure would be capable of keeping up with future requirements with latency shrinking and data

volumes increasing. To create new analytics software 14% of the buy-side firms said they'd use only internal resources while the rest would use third-party software or consultants, or a combination of internal and external resources. 29% of respondents from sell-side said they'd use only internal resources.

The report concludes

"Financial institutions currently lack sufficient computing power to perform a variety of business analytics essential to increasing efficiency, managing risk, complying with regulations and achieving competitive advantage, according to the survey results."

The survey responses are a clear indication there will be growth in the real-time risk analytics market. The investment firms and the ISVs who can open more doors to business opportunities with investment firms will be those that leverage low-latency, high-performance platforms as a competitive edge. Bringing such systems to market is more easily done by using Oracle TimesTen to provide the database infrastructure for a product.

Fraud Detection

Applications that approve, process, and monitor payments or other exchange of funds are another type of software for which real-time performance has become a requirement. Oracle TimesTen has been integrated into system architectures that also include messaging, authentication and authorization components to provide real-time capabilities to thwart fraud in electronic payments systems.

Fraud detection applications are found in diverse industries, such as when money moves electronically or when large amounts change hands in a short period of time. Banks, for example, use fraud detection software to monitor debit card transactions. Credit card companies use software to monitor transactions and to alert cardholders. In one fraud detection application using Oracle TimesTen, three types of fraud were checked before each row was inserted into the database. Each transaction finished within 17 microseconds and the system sustained more than 100,000 row insertions per second. Running concurrently with the detection and insertion logic was summary reporting from the same data set.

[1] Peggy Bresnick Kendler, *InformationWeek* Financial Services Survey, "The State of Business Analytics in Financial Services", July 2010

Oracle TimesTen enables fraud detection systems to deliver high performance even when operating with very large databases. The US Postal Service uses Oracle TimesTen to run a real-time fraud detection application using a 1.7 terabyte in-memory database. With transactions executing at RAM speed, it is capable of processing 4 billion transactions in less than six hours.

Trading Systems

Trading systems have received much attention in recent years, with competitive pressures putting a premium on high-speed trading performance while maintaining reliability and quality of service.

The software used in trading today includes Execution Management Systems (EMS) and Order Management Systems (OMS). A defining characteristic of the current generation of systems is they must deliver torrents of data that's needed by traders and fund managers. Another feature of modern systems is the use of specialized platforms for high-performance trading activity and compute-intensive analytics.

Algorithmic trading systems require low latency and they are continually pushing the performance envelope. When SLAs and the time to process a trade are measured in milliseconds, I/O execution times must be measured in microseconds. Because Oracle TimesTen can execute a read in 2.5 microseconds or a write in 10 microseconds, it's the premier data store for low-latency trading systems. It offers the flexibility of integration with high-performance messaging and event processing software such as Portware, TIBCO Rendezvous, Oracle Enterprise Messaging Service and Oracle CEP.

Some order management software developed years ago has not been engineered to meet today's requirements, such as integration with high-performance trading requirements. As a result, Independent Software Vendors (ISVs) are reassessing their current solutions to ensure they can deliver rapid innovation, scalability, and reliability.

Oracle TimesTen has served ISVs well, such as when it was used by execution management software that provides algorithmic strategies, global electronic trading capabilities, and pre- and post-trade analytics for trading equities and equity derivatives.

One trading application was able to reduce response time and improve predictability, thus meeting SLAs that were not possible with disk-based technology alone. After deployment of Oracle TimesTen, the SLA requirement to process a transaction within 80 milliseconds was met and an average trade time of five milliseconds was achieved. Another real-time trading application built over an Oracle TimesTen database infrastructure, JPMorgan Cheops, was capable of storing several days of trading data in RAM.

Using Oracle TimesTen for real-time data management enabled the NYFIX Millennium trading system to lower transaction response times to less than 3 milliseconds. For the Bombay Stock Exchange (BSE), Wipro Infotech developed the BSE online surveillance system (BOSS-i) using Oracle TimesTen at its core. BOSS-i includes real-time analytics and an engine for rapidly generating alerts. The system monitors positions in both the cash and derivative markets.

Data availability and response time are crucial to effective operation of high-performance trading systems. The availability of up to date information ensures timely trading decisions, whether made by humans or algorithmic trading systems. High availability of cached trading data ensures consistent, reliable, real-time performance.

Case Study: Trading Application

Oracle TimesTen is embedded in the Koscom Millennium Trading System (MTS). MTS provides a powerful order processing system for dozens of professional traders. It ties into STOCK-Net, which has links to service the Stock Market Division, Futures Market Division, Options Market Division and KOSDAQ Market Division. STOCK-Net also has links to the Koscom site backup center, to brokers, to market data sources, and the SignKorea certificate authority.

The Koscom MTS databases include Order, Contract, Trader, Balance, History, Fix Message, Fix Reporting and Profit and Loss data.

Earlier versions of Koscom MTS were first built to use C-ISAM files and later to use Sybase on-disk SQL databases. The C-ISAM solution made it difficult to replicate data and recover it after failures. Order processing performance was less than 50 orders per second. Replacing C-ISAM with a Sybase server that used shared external disk lowered performance to 15 orders per second and made it impossible to do real-time data replication. The solution to the performance problem at Koscom was replacing on-disk databases with Oracle TimesTen in-memory databases. The performance window has now improved to 150-300 orders per second and Koscom is able to do real-time replication to mirror the databases. Moreover there has been a significant reduction in system failures. The architecture based on C-ISAM failed on average once per month. With the Sybase server that was reduced by half (0.5 cases per month). But deploying Oracle TimesTen has reduced the failure rate to 0.5 cases per year over a period of ten years.

Customer Service Interaction

In contrast with machine-to-machine communications, applications involving human interaction can seem positively pedestrian. Response time requirements are typically in the range of 1-2 seconds, rather than milliseconds – up to 1,000 times slower. So at first glance it seems somewhat surprising that in-memory database technology is appropriate here. And yet, there are significant benefits to be had from accelerating this class of application.

First, both customers and staff appreciate and expect predictable response times. As we have seen, sometimes loads can spike during peak periods and this does slow response time. So a perfectly acceptable 1-2 second delay becomes a 10-second delay. Multiply this by the larger-than-usual number of interactions, and that's a recipe for poor customer service that nobody wants.

But it's not just about avoiding negatives; there are positive possibilities as well. Customers accessing websites for self-service applications or similar, will notice and appreciate a much faster response time. This can make web portals an attractive way for them to interact with financial service providers, both reducing costs and increasing the potential to offer them more advanced services (with the attendant possibility of incremental revenue). In-memory technology is already used on many retail websites to provide personalization and improve the overall experience; the opportunity to differentiate other kinds of online presence is not yet widely taken. China Finance Online use Oracle TimesTen to provide information from the Shanghai and Shenzhen stock exchanges providing faster access to their paying subscribers.

Because financial institutions compete on customer service, the quality of user experience with a customer service center is important. Cardholders, shareholders and other financial services customers become frustrated when there's a long delay in accessing their account information, their trading history, purchase history, payment history or other profile information. Accessing this data quickly does more than speed up the transaction. It enables customer service representative to get complete information, identify up-sell and cross-sell opportunities, and generate incremental revenue.

Grids and Private Clouds

The financial sector has been among the largest adopters of grid computing to keep up with demand for sophisticated analytics applications. But in the fast-paced financial services industry more is always better. A recent survey [1] of financial services professionals reported that 58.5% of buy-side investment firms and 54.7% of sell-side firms plan to invest in cloud computing in 2012.

Today, cloud computing is in the spotlight, particularly as a vehicle for data center consolidation and reducing IT infrastructure costs. ISVs that market enterprise applications are likely to find many IT shops will increasingly have an interest in running those applications in a private or public cloud.

Organizations are evaluating the feasibility and cost benefits of data center consolidation and moving on-premise applications to the cloud. There are a variety of cloud service providers (public cloud) but organizations are also looking to run office suites, ERP suites, CRM and other enterprise applications in a private cloud. Some organizations are also looking to the cloud, with distributed databases, as a disaster recovery solution.

Financial services professionals have expressed a desire for more powerful analytics platforms. One alternative to buying more servers for a corporate data center to meet those needs is to scale out by adopting a private or public cloud computing model.

The transition to cloud computing provides a window of opportunity the financial sector and for ISVs who adapt present and future applications to run in virtualized and cloud computing environments. ISVs whose products have been constrained to a limited set of servers in a corporate data center might deliver new capabilities and noteworthy performance increases by using in-memory databases in an elastic cloud environment.

Conclusion

Advances in software products for the financial industry are made possible by adoption of a platform that enables developers to focus on quality, reliability and differentiating features by relieving them of worries about data management issues.

For applications operating with market data, other high-speed data streams or demanding transaction processing requirements, the financial industry is a challenging environment. Requirements for low latency, high-performance, and reliability are not easily met, particularly during times of peak load. Oracle TimesTen has a successful track record. It's proven in the financial sector and other industries and is an essential component of solutions used by financial services professionals and hundreds of millions of consumers worldwide. Industry leaders today rely upon Oracle TimesTen to deliver low latency, data integrity and reliability in their most demanding systems today, with scalability built-in to handle the growth they expect and plan for.

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