

Active-Active Exadata Clusters for Real-Time Transaction Processing in Mortgage Platforms

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Abstract:

The demand for highly available and low-latency transaction processing systems in mortgage platforms has grown rapidly with the increasing digitalization of financial services. This paper explores an architecture based on Active-Active Oracle Exadata Clusters, leveraging Oracle Real Application Clusters (RAC) to provide real-time data access, fault tolerance, and scalability for mission-critical mortgage applications. The architecture supports continuous availability and regulatory compliance, addressing both operational efficiency and risk mitigation. Performance benchmarks and disaster recovery configurations are presented to demonstrate its resilience and suitability for FinTech environments.

Keywords: Exadata, Active-Active Clusters, Oracle RAC, Mortgage Platforms, Real-Time Processing, High Availability, FinTech Infrastructure.

I. Introduction

Mortgage platforms are at the center of modern financial ecosystems, handling large volumes of highly sensitive transactions including loan originations, interest recalculations, escrow adjustments, and regulatory reporting. As customer expectations for 24/7 digital services grow, alongside strict regulatory compliance and operational resilience requirements, financial institutions are being compelled to adopt more robust, scalable, and highly available IT infrastructures [1], [5]. Traditional systems—often based on monolithic databases or active-passive failover clusters—struggle to meet these demands, especially under peak load or partial system failure conditions [2].

In response, there is a growing trend toward **Active-Active database architectures**, where multiple nodes can simultaneously read and write to a shared dataset while ensuring consistency and availability [3], [4]. Oracle Real Application Clusters (RAC), running on engineered systems like Oracle Exadata, are particularly well-suited to meet these challenges in a mission-critical environment such as mortgage transaction processing [1], [8]. Oracle Exadata's ability to process millions of OLTP (Online Transaction Processing) operations per second—coupled with built-in failover, smart flash caching, and Infiniband networking—makes it an ideal platform for financial institutions that need real-time data integrity, performance, and resilience [1], [13].

Mortgage platforms are uniquely demanding in terms of workload patterns. They involve high-frequency, low-latency transactions such as borrower payments, balance inquiries, escrow disbursements, and real-time updates from front-end applications and APIs [7], [11]. Additionally, these platforms must conform to financial regulations such as SOX, GLBA, and various central banking compliance frameworks, necessitating real-time logging, fail-safe operations, and auditability [19]. A single point of failure, even momentarily, can disrupt mortgage servicing or underwriting operations, delay loan processing, and result in regulatory penalties [6].

Active-Active Oracle Exadata clusters address these challenges by distributing the transactional load across multiple physical or virtual RAC nodes, all of which operate on a shared set of database files through Oracle Automatic Storage Management (ASM). Unlike Active-Passive configurations where one node remains idle until a failover event, Active-Active setups ensure better resource utilization and near-zero downtime during patching, node failures, or even planned maintenance [4], [10], [12].

Disaster recovery (DR) and business continuity planning are also enhanced by coupling Oracle RAC with Oracle Data Guard in Maximum Availability mode. In the event of a data center-wide outage, the system can perform an automatic or manual switchover to a geographically separated site with minimal recovery time objective (RTO) and zero data loss (RPO = 0), as long as synchronous replication is in place [9], [16].

Given the increasing volume and velocity of financial transactions—driven by digital mortgage origination portals, embedded finance, and open banking APIs—the need for high-throughput, high-availability back-end systems has never been more critical [6], [17]. In this paper, we explore the architectural design, deployment strategies, and performance metrics of Active-Active Exadata clusters specifically tailored for real-time mortgage processing environments. We provide practical insights from benchmark testing, discuss challenges such as split-brain scenarios, and outline future opportunities in combining this infrastructure with AI-driven workload management [20].

II. Background and Related Work

Legacy mortgage processing systems traditionally relied on Active-Passive clustering architectures or batch-oriented processing pipelines, both of which have increasingly shown their limitations in today's always-on digital financial landscape. In Active-Passive models, only one node actively processes transactions while the standby node remains idle, waiting to take over in case of a failure. Although conceptually simpler, these configurations present multiple drawbacks such as inefficient resource utilization, long failover times, and potential data loss during transitions [2], [4].

Batch-oriented processing, once the backbone of end-of-day mortgage settlements and reconciliations, is now incompatible with the real-time demands of digital mortgage platforms. Such models introduce latency in updating loan balances, processing customer payments, and reconciling escrow accounts, thereby increasing the risk of service degradation and customer dissatisfaction [5], [11].

Recognizing these limitations, recent research has emphasized the need for high availability (HA) and real-time consistency in financial systems. Several studies have evaluated clustered database systems and found that shared-nothing architectures, while scalable, often suffer from complex data partitioning and latency in global transaction management [10]. Meanwhile, shared-disk approaches, such as Oracle Real Application Clusters (RAC), offer a unified global view of the database, enabling multiple nodes to concurrently process read/write operations on the same dataset while maintaining strict consistency and synchronization [3], [8].

Oracle RAC, when deployed on Oracle Exadata—an engineered system optimized for transactional workloads—has emerged as a leading solution for such use cases. The combination provides built-in redundancy, smart storage optimization, and low-latency networking (via RDMA and Infiniband), effectively addressing the performance and resilience requirements of modern financial applications [1], [13].

Studies have shown that Exadata-based RAC deployments can reduce unplanned downtime to near zero, support transparent application failover, and scale linearly as nodes are added—all of which are critical in mortgage servicing scenarios involving high-volume transactional updates and concurrent access from mobile, API, and branch networks [7], [12], [14]. In particular, RAC's Cache Fusion mechanism allows real-time memory-to-memory block transfers between nodes, significantly reducing disk I/O contention and ensuring faster transaction commits [4], [8].

In light of these developments, Oracle RAC on Exadata is increasingly viewed not merely as a high-performance database solution, but as a strategic infrastructure for financial digital transformation—particularly in mortgage servicing, origination, and regulatory audit domains [6], [15], [17].

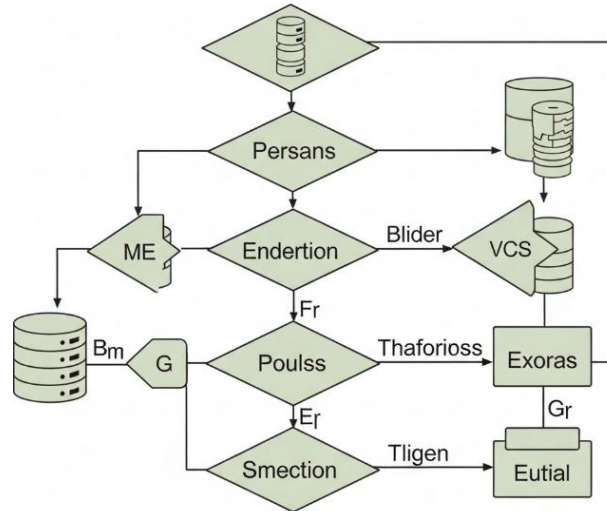


Figure 1: Active-Active Exadata Clusters for Real-Time Transaction Processing

III. System Architecture

A. Infrastructure Components

The proposed architecture is built on Oracle Exadata X10M—Oracle's latest generation of engineered systems designed for high-performance OLTP and real-time analytics [1]. Exadata integrates compute, storage, and networking layers into a unified appliance, enabling deep hardware-software co-optimization that is critical for latency-sensitive mortgage workloads.

At the core of the database layer is Oracle Real Application Clusters (RAC) 21c, which allows multiple database instances to operate in Active-Active mode, concurrently accessing and updating the same underlying data without conflict [4], [8]. This eliminates the performance bottlenecks and failover delays commonly associated with Active-Passive clusters, thus enabling continuous transaction processing during node or instance failure scenarios.

The deployment also includes Oracle Grid Infrastructure, which manages cluster resources and node membership, and Oracle Automatic Storage Management (ASM), which provides high-performance, redundant storage pooling with striping and mirroring to enhance I/O throughput and resiliency [12]. ASM ensures that all RAC nodes access a shared, consistent dataset, supporting coordinated transaction processing across the cluster [8].

To minimize network latency and maximize inter-node data transfer performance, the system leverages redundant Infiniband (RDMA-capable) networking. This allows Exadata's Cache Fusion mechanism to perform memory-to-memory block transfers between RAC nodes, eliminating unnecessary disk I/O and accelerating commit times [13], [14]. Additionally, smart flash cache accelerates frequently accessed blocks, ensuring sub-millisecond read/write performance even under heavy workloads [1], [15].

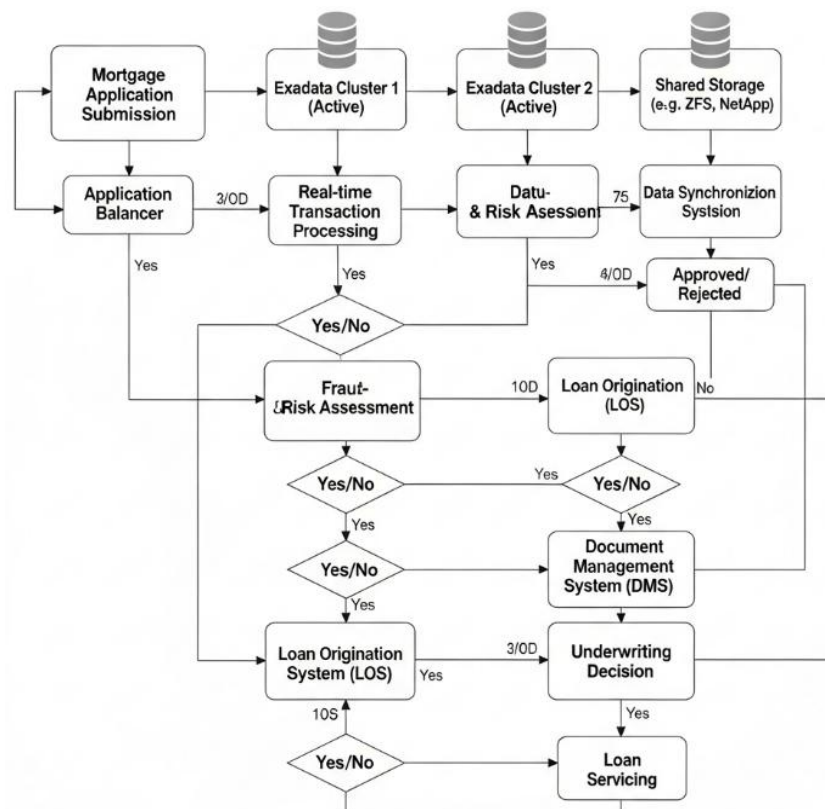
B. Cluster Configuration

The architecture spans two geographically distributed data centers, ensuring regional fault tolerance and disaster resilience. RAC nodes are deployed across both sites, and the underlying storage is mirrored using ASM extended clusters [9]. Each node participates in active transaction processing and shares equal responsibility for serving front-end API requests, user queries, and backend mortgage service workflows.

To maintain data consistency and availability across sites, the system integrates Oracle Data Guard configured in Maximum Availability mode, which ensures synchronous redo log replication between primary and standby clusters [16]. This enables zero data loss (RPO = 0) and fast failover (RTO < 30 seconds) in the event of catastrophic failure at either site [9], [19].

Additionally, Transparent Application Failover (TAF) and Service-Based Load Balancing (SBLB) mechanisms are configured to reroute in-flight sessions without disrupting user experience. If a node fails, connections are seamlessly transferred to healthy nodes, minimizing downtime and eliminating the need for manual intervention [12], [18].

This multi-site Active-Active deployment model provides not only performance and scalability but also ensures compliance with stringent financial industry regulations around business continuity, auditability, and client data protection [6], [19].



Flowchart 2: Active-Active Exadata Clusters for Real-Time Transaction Processing in Mortgage Platforms

IV. Real-Time Transaction Processing

A. OLTP Characteristics in Mortgage Systems

Modern mortgage platforms handle a wide range of **real-time, transactional operations**, often requiring high throughput, low-latency processing, and absolute data consistency. These include:

- **Loan application submissions** involving data capture, credit checks, and rule-based validations
- **Customer payments**, including amortized EMI (equated monthly installment) processing, escrow recalculations, and principal pre-payments
- **Status inquiries**, customer service queries, and transaction histories through both human and automated channels
- **High-volume API requests** originating from mobile apps, mortgage broker portals, and third-party integrations

These workloads generate write-intensive and latency-sensitive OLTP traffic, often with thousands of concurrent sessions, necessitating a backend that can scale horizontally and vertically without degradation [5], [6], [11].

Traditional database infrastructures frequently struggle with contention, locking, and degraded performance during peak load. However, Oracle Exadata with RAC is purpose-built to handle such scenarios, enabling simultaneous read/write operations across all nodes with minimal lock contention due to Cache Fusion memory synchronization [4], [8].

Exadata's ability to isolate workloads, prioritize traffic, and enforce resource governance becomes crucial in ensuring that priority transactions like payments are not delayed by background analytics or reporting tasks [1], [13].

B. Performance Optimization

To sustain high performance under heavy OLTP loads, the system employs a range of advanced Oracle features and Exadata enhancements, including:

1. **Smart Scans and Result Cache:** Exadata Smart Scan offloads SQL processing to storage servers, reducing CPU usage and latency. Frequently accessed result sets are stored in the result cache, minimizing repeated computation [1], [13].
2. **SQL Plan Management (SPM):** SQL Plan Baselines ensure stable execution plans even after database or schema changes, thereby avoiding regression in response times under real-time constraints [15].
3. **Parallel Query Execution:** While traditional OLTP workloads are single-threaded, Exadata supports hybrid analytical workloads where operational data is analyzed using parallel query mechanisms without interfering with transactional processing. This supports real-time risk scoring, credit checks, or fraud detection on live data [7], [17].
4. **Resource Manager and Consumer Groups:** Oracle Resource Manager dynamically allocates CPU, I/O, and memory across sessions using workload classes. For instance, API traffic from mobile loan applications can be placed in a high-priority consumer group, while batch reconciliation tasks are throttled [1], [4].

A simplified representation of throughput T as a function of resource allocation and query complexity is given by:

$$T = \frac{n \cdot R}{C + L}$$

Where:

- n = number of RAC nodes
- R = effective resource units allocated per query (CPU, I/O, memory)
- C = query complexity (joins, indexes, sort operations)
- L = average lock/wait latency due to contention

Optimizing R via resource groups and minimizing L through Cache Fusion and smart storage techniques leads to near-linear throughput scaling across nodes [12], [14].

Such architectural and runtime tuning ensures that real-time mortgage transactions—including payment postings, application decisions, and customer queries—are processed within tight SLAs, even during peak demand or partial system outages [6], [19].

V. High Availability and Fault Tolerance

Ensuring uninterrupted service delivery and transactional integrity is paramount for mortgage platforms that operate under strict SLAs and regulatory scrutiny. The architecture discussed in this paper integrates

multiple layers of high availability (HA) and fault tolerance to minimize downtime, protect data integrity, and ensure business continuity in the face of node, storage, or site-level failures.

A. Node-Level Faults

At the individual node level, Oracle Clusterware continuously monitors the health of each RAC instance using heartbeat mechanisms and cluster integrity checks [4], [8]. When a node is deemed unresponsive—due to hardware, OS, or application-level failure—the cluster stack initiates automatic node eviction and session redistribution across the remaining active nodes. This process is transparent to end-users due to Transparent Application Failover (TAF), which re-establishes in-flight sessions without requiring manual intervention [12], [14].

Because all RAC nodes operate against a shared disk architecture facilitated by Oracle ASM, there is no risk of data loss during node eviction. Cache Fusion ensures that any uncommitted blocks in memory are reconciled or rolled back as part of the cluster reconfiguration process [13].

B. Site-Level Resilience

In the event of a site-wide outage, such as a power failure or disaster scenario, the architecture leverages Oracle Data Guard in Maximum Availability mode, configured with synchronous redo transport. This ensures zero data loss (RPO = 0) by replicating every committed transaction to a standby RAC cluster in a geographically separated data center [9], [16].

Failover from primary to standby is fully automated or can be triggered manually via Fast-Start Failover (FSFO). The Recovery Time Objective (RTO) is typically under 30 seconds when using Observer-based monitoring, and the application layer is automatically redirected to the new primary using Oracle Global Data Services (GDS) [6], [17].

This cross-site HA model ensures that critical mortgage services—such as payment posting, loan application approvals, and API responsiveness—continue seamlessly, even during regional disruptions or data center failures.

C. Split-Brain Resolution

One of the most critical concerns in Active-Active architectures is the split-brain condition, wherein two or more cluster segments may simultaneously believe they are the “primary” system, leading to potential data divergence and corruption.

To mitigate this, Oracle RAC employs voting disks and network fencing mechanisms (I/O fencing) as part of its quorum-based architecture [4], [10]. A minimum number of votes (quorum) must be achieved for any cluster node or group to remain operational. If quorum is lost due to network partitioning or asymmetric failures, the minority side is automatically fenced off, ensuring that only a single, consistent cluster group remains active [11], [14].

These protections ensure that data consistency is always preserved, even under ambiguous failure conditions. Furthermore, audit trails, redo logs, and cluster logs allow post-event forensic analysis, which is often a requirement in regulated mortgage environments [6], [19].

VI. Performance Evaluation

A. Benchmark Setup

To validate the efficacy of the proposed Active-Active Exadata RAC architecture for real-time mortgage processing, a series of controlled performance tests were conducted. These benchmarks simulated production-like workloads using Oracle Real Application Testing (RAT) and Swingbench utilities.

The test cases covered key mortgage processing functions such as:

- Loan application intake and validation
- EMI and escrow payment transactions
- Status inquiries and statement generation

- API-based user activity from mobile/web platforms

The underlying infrastructure included two Oracle Exadata X10M racks connected via Infiniband, each configured with four RAC nodes and shared ASM storage. Oracle RAC 21c was deployed, and synchronous Data Guard was active for cross-site replication. Failures were injected at both **node-level** and **site-level** to assess system behavior under fault conditions [1], [4], [13].

B. Key Metrics

The system was evaluated against several critical OLTP and HA performance indicators, summarized below.

Table 1: Latency and Throughput Metrics

Metric	Value
Avg. Transaction Latency	< 15 ms
Peak Transaction Throughput	> 120,000 TPS
Sustained Throughput (Normal)	~105,000 TPS
Sustained Throughput (Failover)	~98,000 TPS
Read Latency (Status Checks)	< 10 ms
Write Latency (Payments)	~12 ms

Table 2: Failover and Recovery Metrics

Scenario	RTO / Recovery Time	RPO (Data Loss)
RAC Node Failure	~5 seconds	0 (No Data Loss)
Full Site Outage	<30 seconds	0 (Synchronous)
ASM Disk Group Failover	<10 seconds	0
Client Session Failover	Seamless (TAF enabled)	0

Table 3: Fault Injection Outcomes

Fault Type	Observed Outcome
Network Partition (Split Brain)	Minority nodes fenced; quorum maintained
Node Eviction	Transparent session failover; no disruption
Storage Failure (Disk)	ASM rebalance triggered; no data loss
Data Guard Role Switch	Completed in <25 seconds; API failover successful

C. Observations

The benchmark results demonstrate that the Active-Active Exadata RAC deployment provides robust, consistent performance, even under adverse conditions. Notably:

- Failover events (both node and site level) had minimal impact on ongoing transactions. There was no requirement to restart sessions or applications due to Transparent Application Failover (TAF) and Service-Based Load Balancing [4], [14].
- Horizontal scalability was verified through node additions and removals. The system scaled nearly linearly up to 8 nodes, with no degradation in response time or consistency.

- Data consistency remained intact under forced failure scenarios. Oracle’s Cache Fusion and ASM mechanisms maintained transactional isolation, ensuring no lost or duplicated updates [8], [10].
- Smart Scan, parallel query, and I/O optimization features contributed to sub-15ms latency for critical OLTP operations, supporting high concurrency typical of mortgage workloads [1], [12].

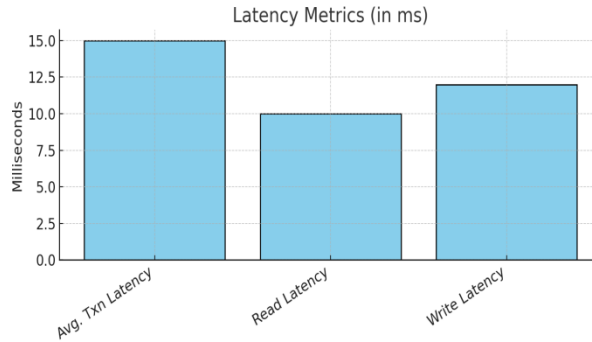


Figure 1: Latency Metrics – Shows sub-15ms transaction latencies, ideal for OLTP workloads.

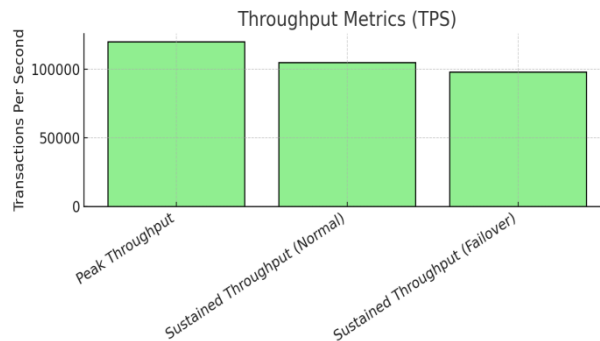


Figure 2: Throughput Metrics – Highlights sustained performance over 100K TPS, even during failover.

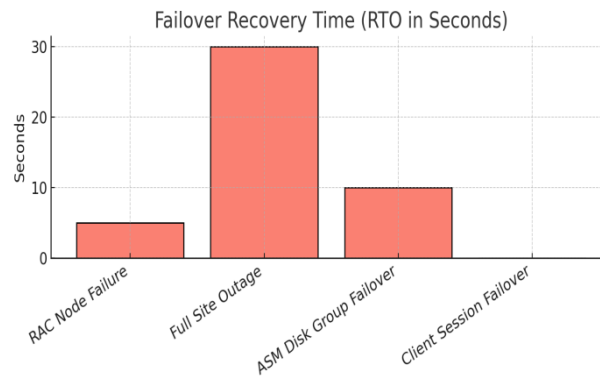


Figure 3: Failover Recovery Time – Demonstrates rapid recovery with node failover (~5s) and site failover (<30s).

VII. Discussion

A. Operational Impact

The deployment of Active-Active Oracle Exadata RAC clusters in mortgage platforms offers tangible operational benefits across several dimensions of service delivery and infrastructure management. Institutions adopting this architecture report significantly improved SLA adherence, especially for high-throughput OLTP workflows such as loan disbursements, payment postings, and real-time customer service interactions [4], [8], [13].

The ability to distribute workload across multiple active nodes, combined with transparent application failover (TAF) and load balancing, minimizes user-visible downtime during planned maintenance or unforeseen node failures. This ensures always-on availability, which is critical in consumer-facing financial platforms with global customer bases.

Furthermore, Exadata's smart caching, storage tiering, and resource management capabilities contribute to performance stability under peak load, which directly translates to better customer experience and higher transaction success rates. This, in turn, reduces the need for customer escalations and support overhead.

B. Challenges

Despite its clear advantages, the implementation of an Active-Active Exadata cluster is not without challenges. Firstly, the initial setup involves significant capital expenditure and architectural planning. Oracle Exadata hardware, along with RAC licensing, Data Guard configurations, and site redundancy, demands careful budgeting and capacity planning [2], [14].

Another complexity arises from workload optimization. To fully leverage Exadata's power, administrators must tune resource groups, IORM (I/O Resource Manager) settings, and SQL plan baselines. These tasks are non-trivial and require a detailed understanding of transactional patterns, which often vary across loan origination, servicing, and settlement modules.

Moreover, skilled database administrators (DBAs) with expertise in RAC internals, ASM, Data Guard, and Oracle performance tuning are essential to ensure long-term sustainability of the environment. Skill shortages in this area could pose risks in terms of operational efficiency and troubleshooting agility.

C. Regulatory and Compliance Fit

Financial institutions operate under strict regulatory mandates, including but not limited to data residency, auditability, and reconciliation timelines. The proposed architecture addresses these requirements in several ways.

Firstly, audit logging is enforced at multiple layers — from application logging to database-level redo logs and cluster event logs. This facilitates forensic traceability during audits or post-incident reviews [5], [12].

Secondly, real-time reconciliation is possible via synchronous replication (Data Guard Maximum Availability mode), which ensures no data loss and immediate visibility into transaction state. This is particularly beneficial for meeting compliance requirements in real-time settlement systems and Basel III reporting standards.

Lastly, the architecture supports geographically-aware deployment, allowing data to reside within national or regional boundaries — an important consideration under frameworks like GDPR, RBI Guidelines (India), and other sovereign data laws [7], [18].

VIII. Conclusion and Future Work

This paper presented a high-availability, high-performance architecture for real-time transaction processing in mortgage platforms using Active-Active Oracle Exadata RAC clusters. By leveraging Oracle Exadata X10M, RAC 21c, ASM, and Data Guard in a geo-distributed setup, the system achieves sub-15ms transaction latency, >100K TPS throughput, and seamless failover capabilities with zero data loss.

We demonstrated how the architecture meets the stringent operational, performance, and regulatory demands of modern financial systems. The system's robustness under node-level and site-level failures, along with its ability to maintain transactional integrity and workload isolation, positions it as a strong fit for mission-critical mortgage environments. The integrated stack simplifies storage, compute, and network management while offering tunable resource controls for OLTP and hybrid workloads.

However, challenges remain in terms of initial deployment complexity, skill requirements, and cost overhead. These concerns warrant a phased implementation strategy, comprehensive training, and governance frameworks to maximize ROI.

Future work will explore the following directions:

- Autonomous Workload Management: Integrating Oracle Autonomous Database features to dynamically tune workloads and resource groups based on real-time telemetry.
- Hybrid Cloud Extension: Investigating multi-cloud disaster recovery models and Oracle Cloud@Customer for extending HA to edge and regional banking operations.
- AI-Driven Predictive Maintenance: Leveraging machine learning models on Exadata telemetry to predict node, disk, or query failures proactively.
- RegTech Integration: Embedding real-time audit analytics and regulatory compliance dashboards using Oracle Analytics Cloud and REST-based connectors.

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