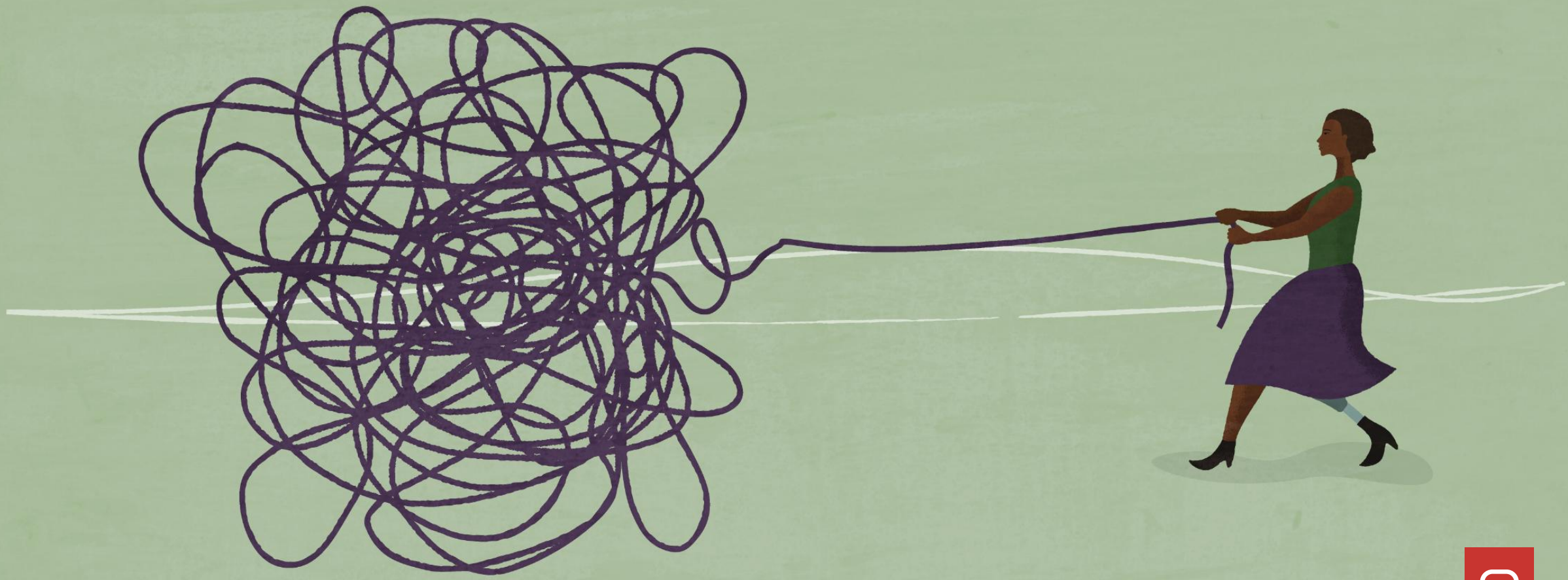
ORACLE

Oracle Maximum Availability Architecture (MAA)

Blueprints for reduced planned and unplanned downtime for the On-Premises, Exadata-based or Cloud-based Oracle AI Database

August 2026

Why is Availability so important?



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Impact of downtime

$350K
average cost of downtime per hour

87 hours
average amount of downtime per year

$10M
average cost of unplanned data center outage or disaster

91%
percentage of companies that have experienced an unplanned data center outage in the last 24 months

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Key terminology

High availability
A system type with redundant components and enabling software that provides consistent and uninterrupted service, even in the event of hardware or software failures.

Disaster Recovery
A method of protecting computer systems from failure, in which standby equipment automatically takes over when the main system fails.

Recovery Time Objective (RTO)
Time to resume application service after failure. The shorter the Recovery Time Objective (RTO) the quicker you get back to business.

Recovery Point Objective (RPO)
Tolerance for data loss (sec's, hours, days); impacted by frequency of backups and replication approaches.

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Protect systems during planned and unplanned downtime

Downtime type	Typical causes	Examples
Planned	System changes Data changes	• Server changes • Database changes • Data changes • Application changes
Unplanned	Server failures Data failures	• Computer failure • Storage failure • Human error • Data corruption • Lost writes • Hang or slow down • Site failure

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MAA & Chaos Engineering – Breaking things to ensure your peace of mind

Chaos Engineering *is the art form of experimenting (i.e. proactively breaking things) on a system in order to build confidence in a system's resilience to withstand turbulent events in production*

In today's digital age, this may include but is not limited to:

- Network, server & storage failures
- Human errors & data corruption
- Data corruption
- Power failures or site failure (i.e. *Godzilla attack or hurricane*)
- Application, database & server software updates
- Data reorganization or changes
- Application changes and optimizations

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Oracle Solutions for High Availability and Disaster Recovery

Maximum Availability Architecture

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Oracle Maximum Availability Architecture (MAA)

Ultra-resilient availability tiers for all applications

Built on decades of engineering expertise

Reference architectures

26ai

Production site

24/7

Replication

26ai

Replicated site

HA features, configuration & operational practices

Deployment choices

Generic Systems

Engineered Systems

Multicloud

BaseDB, ExaDB

Autonomous AI DB

Zero Downtime Migration (ZDM)

High performance

- Resource Management
- Database In-Memory
- True Cache

Continuous availability

- Application Continuity
- Online Redefinition
- Edition-based Redefinition

Data protection

- Flashback
- RMAN
- ZDLRA+ ZRCV

Active replication

- Active Data Guard
- Full Stack DR
- GoldenGate

Scale out & Lifecycle

- RAC
- Globally Distributed AI Database
- FPP
- Real Application Testing

Next-Gen MAA Reference Architectures

High availability tiers for the Oracle AI Database, uniquely engineered for resilience

Bronze:
- Local HA RTO - Mins to 1 Hour
- Regional DR RTO - Hrs to Days
- RPO < 15 min

Dev, test, prod

Single Instance, Backup & Restore

Silver:
- Local HA RTO - Secs to Mins
- Regional DR RTO - Hrs to Days
- RPO < 15 min

Prod/departmental

Bronze +

High Availability with RAC or Data Guard

Gold:
- Local HA RTO < 60 secs
- Regional DR RTO < 5 min
- RPO – Zero or near-zero

Business-critical

Silver with RAC +

DB replication with Active Data Guard with automatic failover

Platinum:
- Local HA RTO < 10 secs
- Regional DR RTO < 30 secs
- RPO – Zero or near-zero

Mission-critical

Gold +

Active Data Guard with Oracle AI Database 26ai on Exadata, or GoldenGate with Oracle Database 19c on Exadata

Diamond (NEW):
- Local HA RTO < 3 secs
- Regional DR RTO < 3 secs
- RPO – Zero or near-zero

Extreme availability

Globally Distributed Database with Raft Replication

or GoldenGate 26ai replicas, *each running*:

Oracle AI Database 26ai
+ RAC on Exadata
+ (Active) Data Guard

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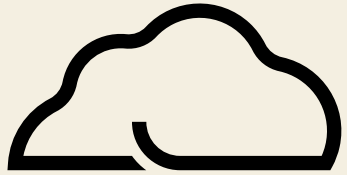
MAA, has you covered, no matter where your apps reside

On-premises, on commodity hardware, or on engineered systems like Exadata



In Oracle Cloud Infrastructure, using services such as the Autonomous AI Database or Exadata Database Cloud

In hybrid and multicloud environments; e.g. Oracle AI Database@Azure, Oracle AI Database@Google Cloud, or Oracle AI Database@AWS

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Examples and benefits of MAA everywhere and anywhere….

Generic Systems:

- MAA Reference architectures (bronze through platinum)
- MAA configuration and operational best practices for all tiers
- MAA database compliance and health checks (i.e. Orachk)

Engineered Systems:

- Fully integrated end-to-end MAA best practices including DB, OS, network, storage
- Designed for lowest brownout, best performance, QoS, and highest data protection, agility, and availability
- Specialized hardware designed for the highest availability, resiliency and performance
- Fully MAA compliant OOTB with Exachk for full stack compliance and health checks

Exadata Database Cloud in OCI or Multicloud

- Cloud automation deploys and manages the database architecture
- MAA operational and configuration best practices are automated and built-in
- Collaboration with Azure, Google, AWS providing MAA in multicloud
- Multi-cloud MAA evaluations

Autonomous AI Database in OCI
or Multicloud

- Fully managed MAA-compliant architecture and configuration
- Simplified deployment, operations, and Oracle-managed maintenance

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Oracle AI Database MAA Availability Recent Features

New In 26ai

Rolling Patching for Complex Changes

Globally Distributed DB with RAFT

Single Server Rolling Database Maintenance

DBMS_ROLLING with Application Continuity

FPP Local Mode

Exadata Fleet Update

In-Database Firewall

Data Guard Redo Decryption for Hybrid DR Configurations

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Oracle AI Database 26ai MAA Scalability Recent Features

New In 26ai

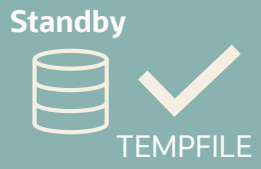
RAC Smart Connection Load Balancing

True Cache

Real-time Query for PDB Standby

Clusterware Resiliency

Ordered Sequences with Oracle RAC



Automatic tempfile creation on the standby database

Oracle RAC Fast Start Reconfiguration

RDMA-based Exadata RAC Scaling

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Thousands of Oracle customers making use of MAA

Maximum Availability Architecture

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Thousands of critical deployments use MAA, on-premises and cloud

76% of Fortune Global 100 run Exadata | **53%** run Exadata Cloud

Superior architecture for ALL workloads

- **Petabyte warehouses**
- **Super critical systems**
  - Financial trading
  - Process manufacturing
  - E-commerce
- **Packaged applications**
  - SAP, Oracle, Siebel, PSFT, …
- **Database consolidation**

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Diving into the MAA tiers

Maximum Availability Architecture

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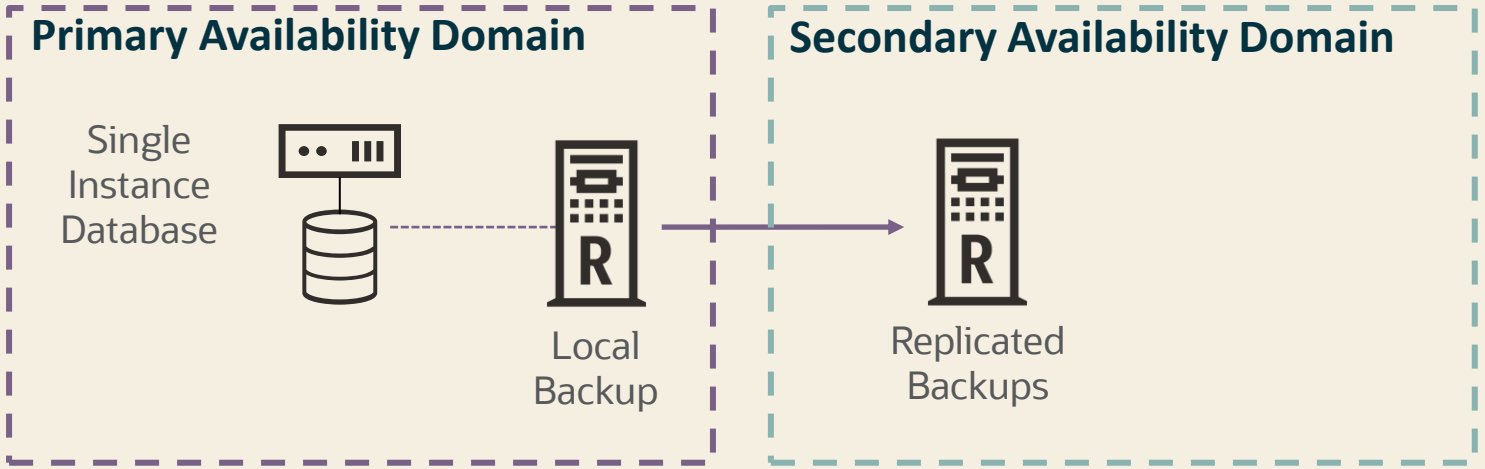
BRONZE

Dev, Test, Prod - Single Instance or Multitenant Database with Backups

- Single Instance with Clusterware Restart
- Advanced backup/restore with RMAN
  - Optional ZDLRA with incremental forever and near zero RPO
- Storage redundancy and validation with ASM
- Multitenant Database/Resource Management with PDB features
- Online Maintenance
- Some corruption protection
- Flashback technologies



Outage Matrix

Unplanned Outage	RTO / RPO Service Level Objectives (f1)
Recoverable node or instance failure	Minutes to hour
Disasters: corruptions and site failures	Hours to days. RPO since last backup or near zero with ZDLRA
Planned Maintenance	
Software/hardware updates	Minutes to hour (f1)
Major database upgrade	Minutes to hour

f1 : RPO=0 unless explicitly specified

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Oracle Clusterware for Automatic Restart

1. Oracle Clusterware is available for all Oracle AI Databases
2. Enables HA capabilities and resource management:
   - Automatic Restart of database instances, listeners, and other resources
   - Fleet patching
   - Service management, including restarting service after failure
   - Automatic Storage Management (ASM) for HA, data protection and ease of use

- Trade off: additional software maintenance for Grid Infrastructure

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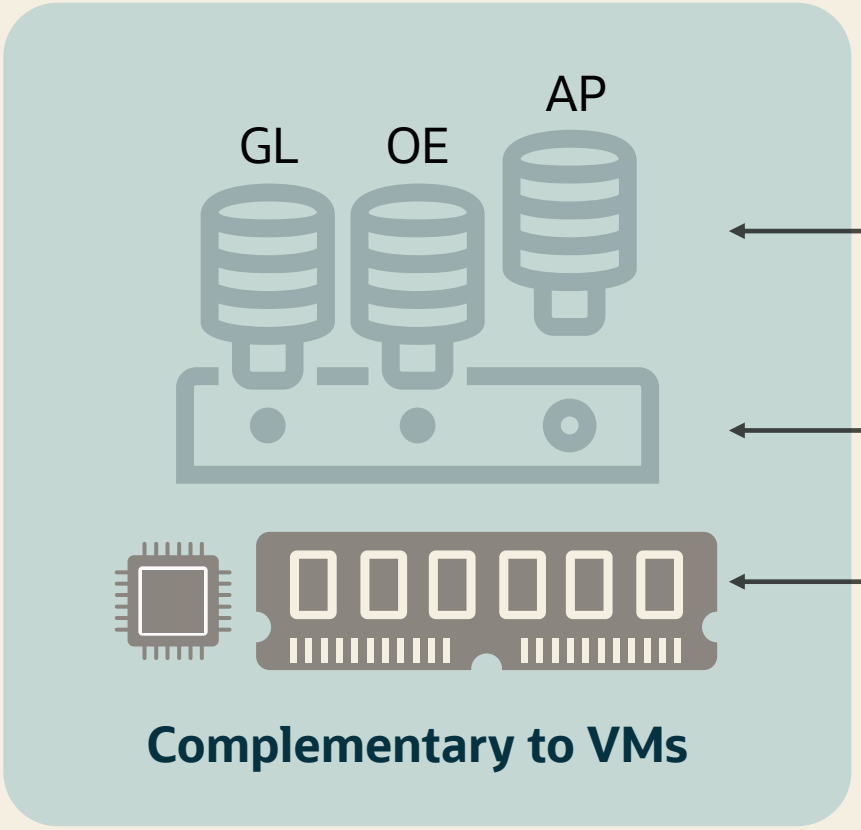
Advantages of Multitenant Architecture

Isolation and agility with economies of scale



Self-contained PDB for each application
- Applications run unchanged
- Rapid provisioning (via clones)
- Portability (via pluggability)

Common operations performed at CDB level
- Manage many as one (upgrade, HA, backup)
- Granular control when appropriate

Shared memory and background processes
- More applications per server

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Oracle Multitenant Features

Rapid cloning and provisioning

- Local clones and remote clones
- Snapshot clones
- Refreshable PDBs

Manage many as one

- Database consolidation
- Improve productivity
- Maintain granular control

Improve agility for development teams

- Pre-configured service level agreement
- Compatibility
- Interface

Enhance security

- Separation of duties
- Data security
- Resource isolation

Integration with Oracle RAC

- High availability
- Scalability
- Flexibility

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Pluggable Database Backup, Restore and Recovery

- Backup and restore pluggable database …
- Create Restore Point ‘before_event’ for pluggable database…
  - Normal or Guaranteed Restore Point
  - Clean Restore Point

- Flashback Pluggable Database
- Complete ZDLRA support

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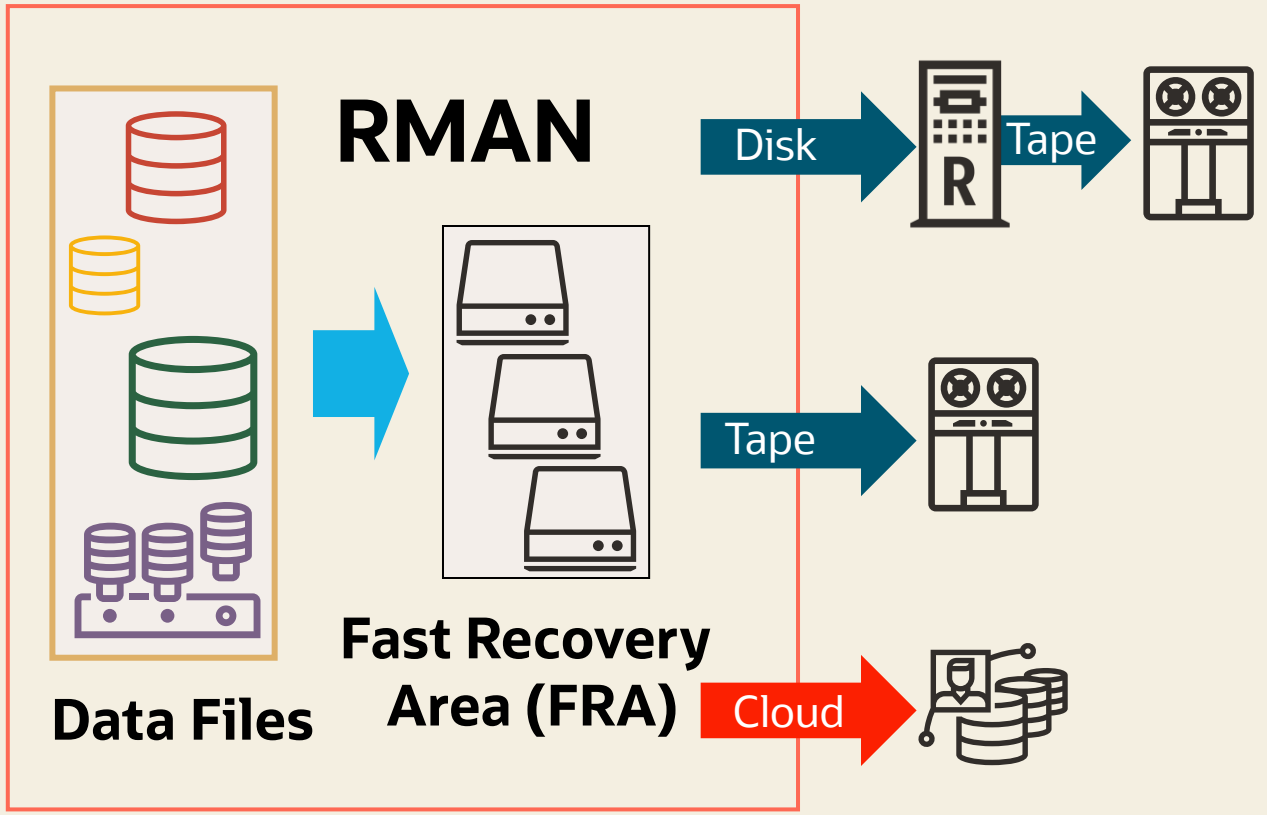
Oracle Recovery Manager - RMAN

Database Integrated Backup and Recovery

- Unique knowledge of database file formats and recovery procedures
  - Oracle block validation
  - Online block-level recovery
  - Native encryption, compression
  - Table/partition-level recovery
  - Oracle Multitenant support
- Tape and cloud backups
- Unified Management



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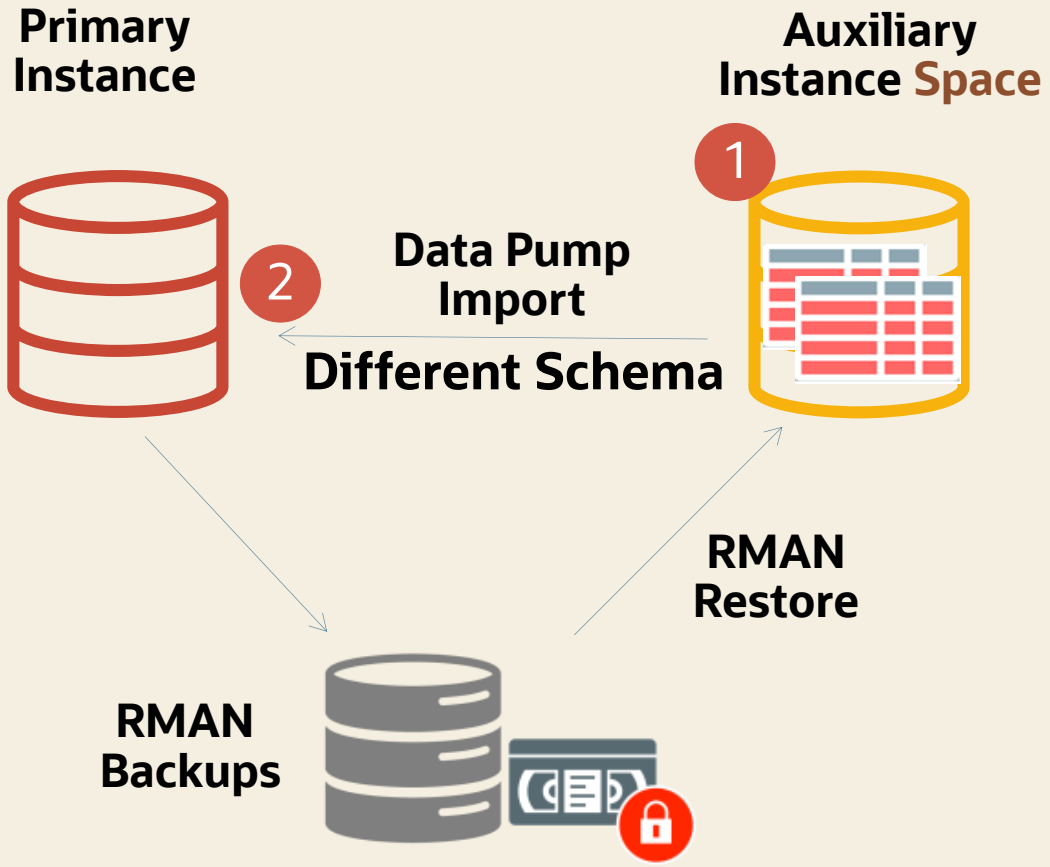
RMAN Enhancements for Table Recovery



1) Check Auxiliary Instance Disk Space
   - Automated Table Recovery requires disk space for SYSTEM, SYSAUX, UNDO and User Tablespace(s)
   - Pre-check for space in the Auxiliary Instance disk space to avoid failures in the middle of the process
2) Recovery Across Schema
   - Enables Table level recovery under different schema
   - Provide **OLD: NEW Schema(s)** under REMAP TABLE

```
RECOVER TABLE hr.department, sales.product
UNTIL SCN 1234 AUXILIARY DESTINATION
'/tmp/' REMAP TABLE
hr.department:dev.testdepartment,
sales.product:mkt.newproduct;
```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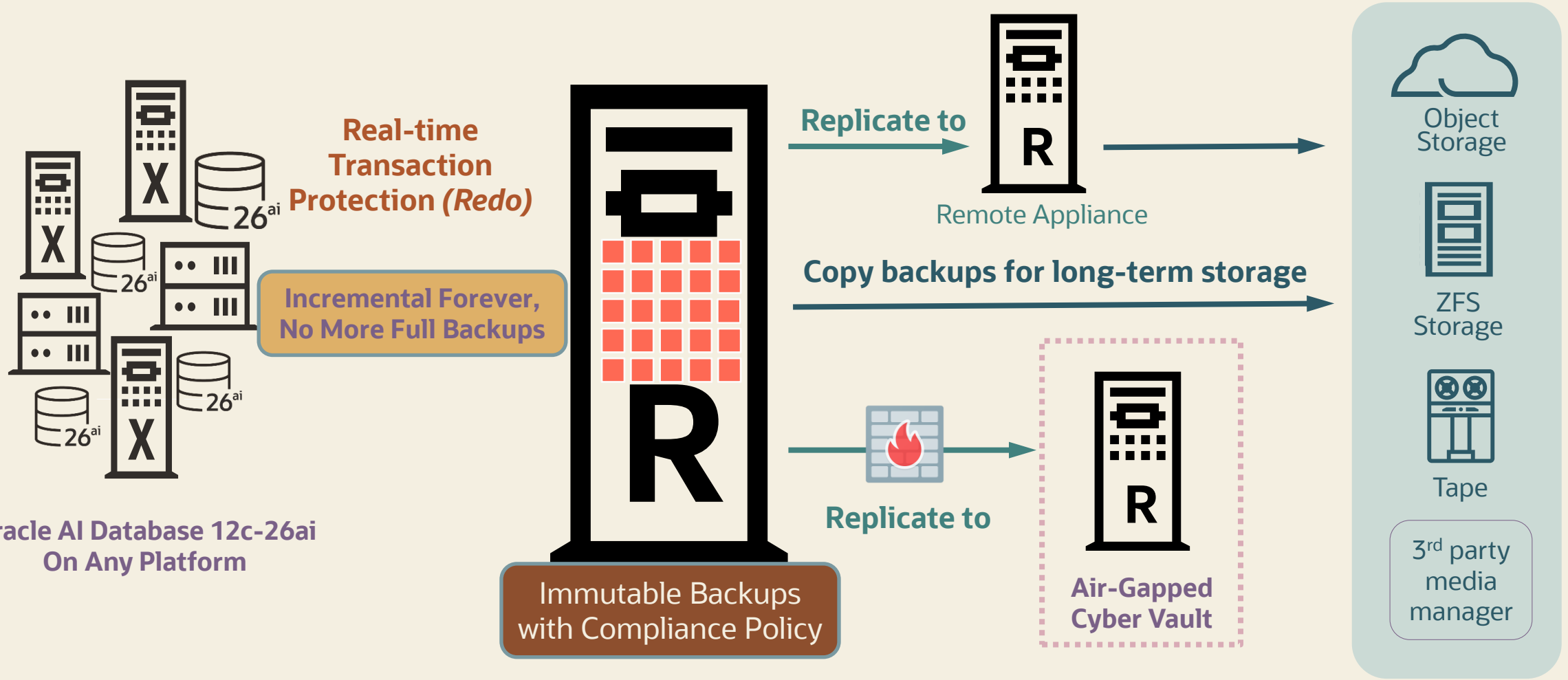
Recovery Appliance Recommended

Continuous data protection and multi-tiered backup addressing compliance requirements



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Database and Exadata Health Checks

Assessment Report

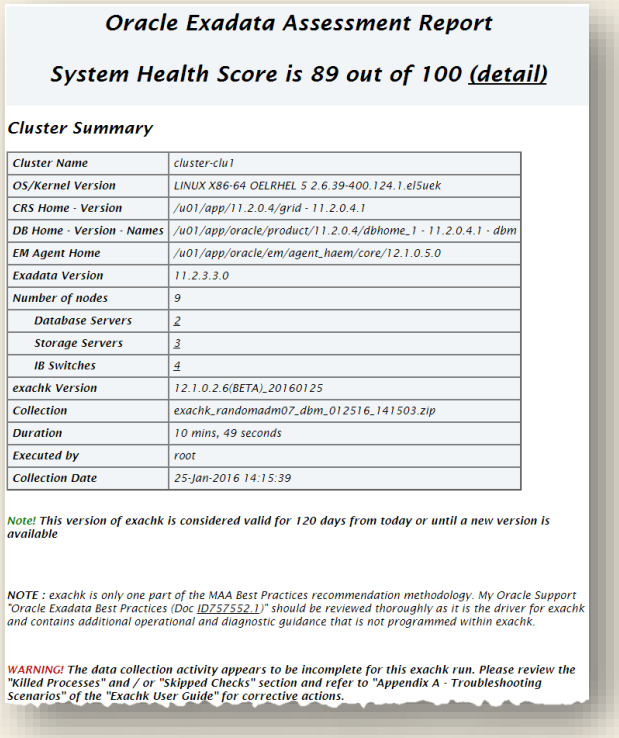
- Health Score, Summary, Findings

Findings & Recommendations

- How to Solve the problem?

MAA Score Card

- MAA architectural readiness and configuration practices



Oracle Exadata Assessment Report

System Health Score is 89 out of 100 (detail)

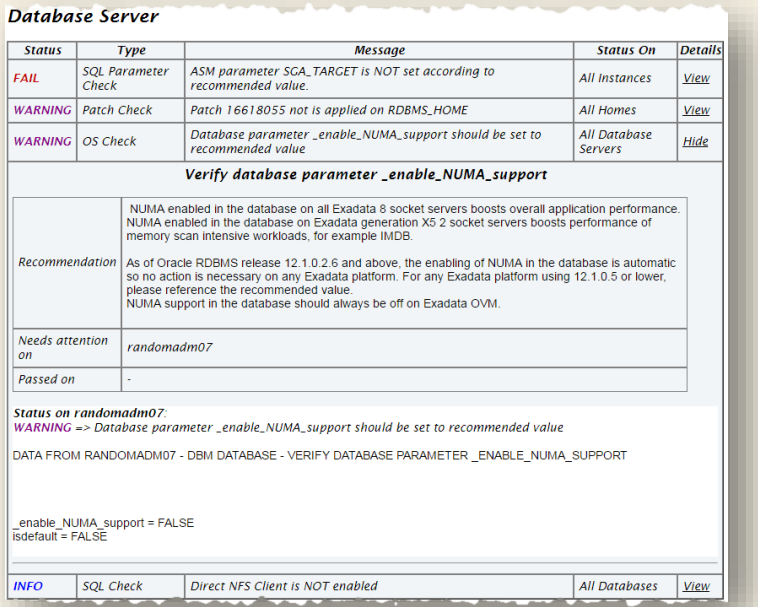
Cluster Summary

Cluster Name	cluster-clu1
OS/Kernel Version	LINUX X86-64 OELRHEL 5 2.6.39-400.124.1.el5uek
CRS Home - Version	/u01/app/11.2.0.4/grid - 11.2.0.4.1
DB Home - Version - Names	/u01/app/oracle/product/11.2.0.4/dbhome_1 - 11.2.0.4.1 - dbm
EM Agent Home	/u01/app/oracle/em/agent_haem/core/12.1.0.5.0
Exadata Version	11.2.3.3.0
Number of nodes	9
Database Servers	2
Storage Servers	3
IB Switches	4
exachk Version	12.1.0.2.6(BETA)_20160125
Collection	exachk_randomadm07_dbm_012516_141503.zip
Duration	10 mins, 49 seconds
Executed by	root
Collection Date	25-Jan-2016 14:15:39

Note! This version of exachk is considered valid for 120 days from today or until a new version is available

NOTE : exachk is only one part of the MAA Best Practices recommendation methodology. My Oracle Support "Oracle Exadata Best Practices (Doc ID757552.1)" should be reviewed thoroughly as it is the driver for exachk and contains additional operational and diagnostic guidance that is not programmed within exachk.

WARNING! The data collection activity appears to be incomplete for this exachk run. Please review the "Killed Processes" and / or "Skipped Checks" section and refer to "Appendix A - Troubleshooting Scenarios" of the "Exachk User Guide" for corrective actions.



Database Server

Status	Type	Message	Status On	Details
FAIL	SQL Parameter Check	ASM parameter SGA_TARGET is NOT set according to recommended value.	All Instances	View
WARNING	Patch Check	Patch 16618055 not is applied on RDBMS_HOME	All Homes	View
WARNING	OS Check	Database parameter _enable_NUMA_support should be set to recommended value	All Database Servers	Hide

Verify database parameter _enable_NUMA_support

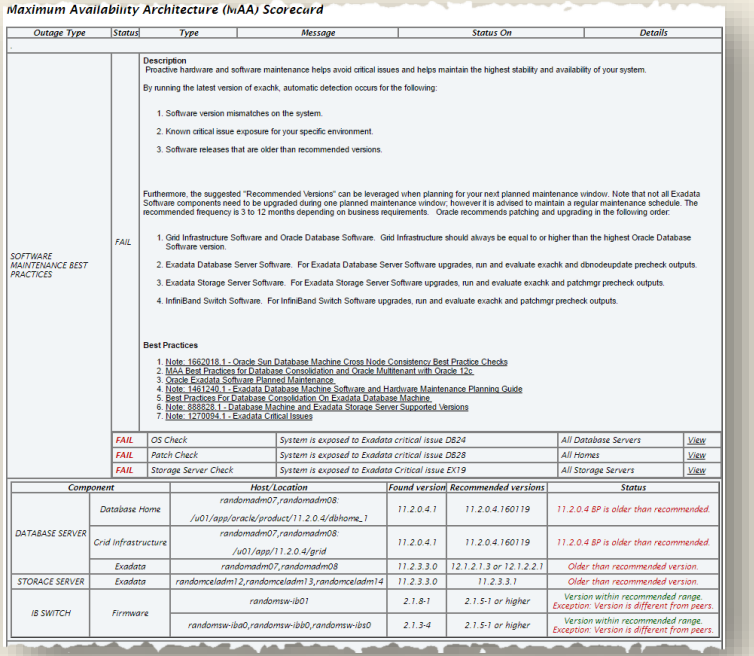
Recommendation	NUMA enabled in the database on all Exadata 8 socket servers boosts overall application performance. NUMA enabled in the database on Exadata generation X5 2 socket servers boosts performance of memory scan intensive workloads, for example IMDB. As of Oracle RDBMS release 12.1.0.2.6 and above, the enabling of NUMA in the database is automatic so no action is necessary on any Exadata platform. For any Exadata platform using 12.1.0.5 or lower, please reference the recommended value. NUMA support in the database should always be off on Exadata OVM.
Needs attention on	randomadm07
Passed on	-

Status on randomadm07:
WARNING => Database parameter _enable_NUMA_support should be set to recommended value

DATA FROM RANDOMADM07 - DBM DATABASE - VERIFY DATABASE PARAMETER _ENABLE_NUMA_SUPPORT

_enable_NUMA_support = FALSE
isdefault = FALSE

INFO	SQL Check	Direct NFS Client is NOT enabled	All Databases	View



Maximum Availability Architecture (MAA) Scorecard

Outage Type	Status	Type	Message	Status On	Details
SOFTWARE MAINTENANCE BEST PRACTICES	FAIL	Description Proactive hardware and software maintenance helps avoid critical issues and helps maintain the highest stability and availability of your system. By running the latest version of exachk, automatic detection occurs for the following: 1. Software version mismatches on the system. 2. Known critical issue exposure for your specific environment. 3. Software releases that are older than recommended versions. Furthermore, the suggested "Recommended Versions" can be leveraged when planning for your next planned maintenance window. Note that not all Exadata Software components need to be upgraded during one planned maintenance window; however it is advised to maintain a regular maintenance schedule. The recommended frequency is 3 to 12 months depending on business requirements. Oracle recommends patching and upgrading in the following order: 1. Grid Infrastructure Software and Oracle Database Software. Grid Infrastructure should always be equal to or higher than the highest Oracle Database Software version. 2. Exadata Database Server Software. For Exadata Database Server Software upgrades, run and evaluate exachk and dbnodeupdate precheck outputs. 3. Exadata Storage Server Software. For Exadata Storage Server Software upgrades, run and evaluate exachk and patchmgr precheck outputs. 4. InfiniBand Switch Software. For InfiniBand Switch Software upgrades, run and evaluate exachk and patchmgr precheck outputs. Best Practices 1. Note: 1662018.1 - Oracle Sun Database Machine Cross Node Consistency Best Practice Checks 2. MAA Best Practices for Database Consolidation and Oracle Multitenant with Oracle 12c 3. Oracle Exadata Software Planned Maintenance 4. Note: 1461240.1 - Exadata Database Machine Software and Hardware Maintenance Planning Guide 5. Best Practices For Database Consolidation On Exadata Database Machine 6. Note: 888828.1 - Database Machine and Exadata Storage Server Supported Versions 7. Note: 1270094.1 - Exadata Critical Issues		
	FAIL	OS Check	System is exposed to Exadata critical issue DB24	All Database Servers	View
	FAIL	Patch Check	System is exposed to Exadata critical issue DB28	All Homes	View
	FAIL	Storage Server Check	System is exposed to Exadata Critical issue EX19	All Storage Servers	View

Component		Host/Location	Found version	Recommended versions	Status
DATABASE SERVER	Database Home	randomadm07,randomadm08: /u01/app/oracle/product/11.2.0.4/dbhome_1	11.2.0.4.1	11.2.0.4.160119	11.2.0.4 BP is older than recommended.
	Grid Infrastructure	randomadm07,randomadm08: /u01/app/11.2.0.4/grid	11.2.0.4.1	11.2.0.4.160119	11.2.0.4 BP is older than recommended.
	Exadata	randomadm07,randomadm08	11.2.3.3.0	12.1.2.1.3 or 12.1.2.2.1	Older than recommended version.
STORAGE SERVER	Exadata	randomceladm12,randomceladm13,randomceladm14	11.2.3.3.0	11.2.3.3.1	Older than recommended version.
IB SWITCH	Firmware	randomsw-ib01	2.1.8-1	2.1.5-1 or higher	Version within recommended range. Exception: Version is different from peers.
		randomsw-iba0,randomsw-ibb0,randomsw-ibs0	2.1.3-4	2.1.5-1 or higher	Version within recommended range. Exception: Version is different from peers.

Note: Automated Orachk/Exachk Healthcheck MOS 107954.1 updated frequently

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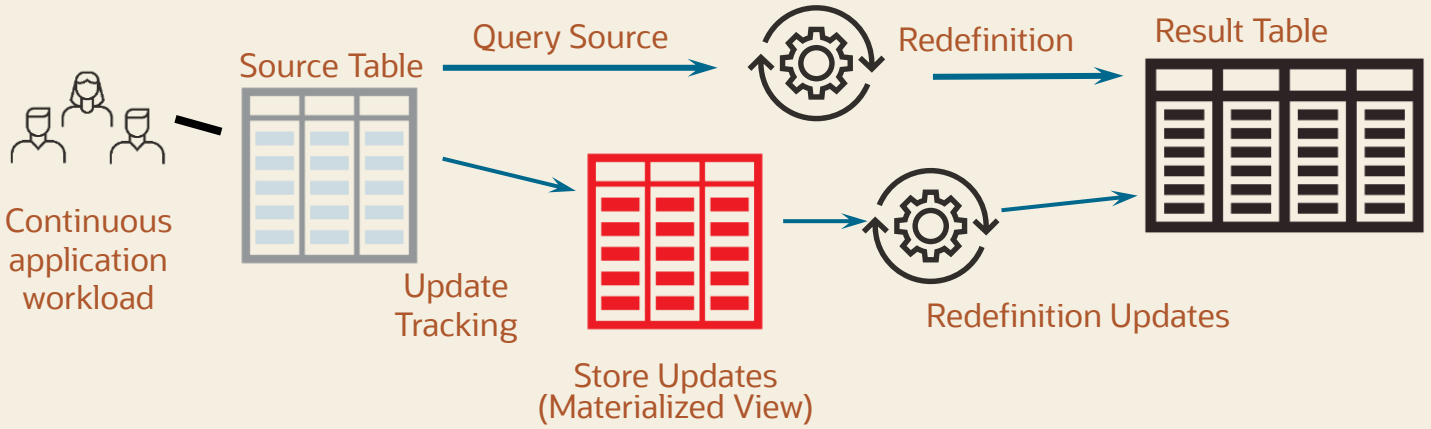
Online Operations

Redefine your data structures without taking tables offline

- Online Redefinition: reorganize and redefine tables online
  - Examples:
    - add/drop/rename/reorder columns
    - change physical storage structures
- Updates / queries not interrupted
- Resumes at point of any failure
- Ability to enable fast rollback to prior definition if needed
- Ability to monitor progress throughout redefinition operation



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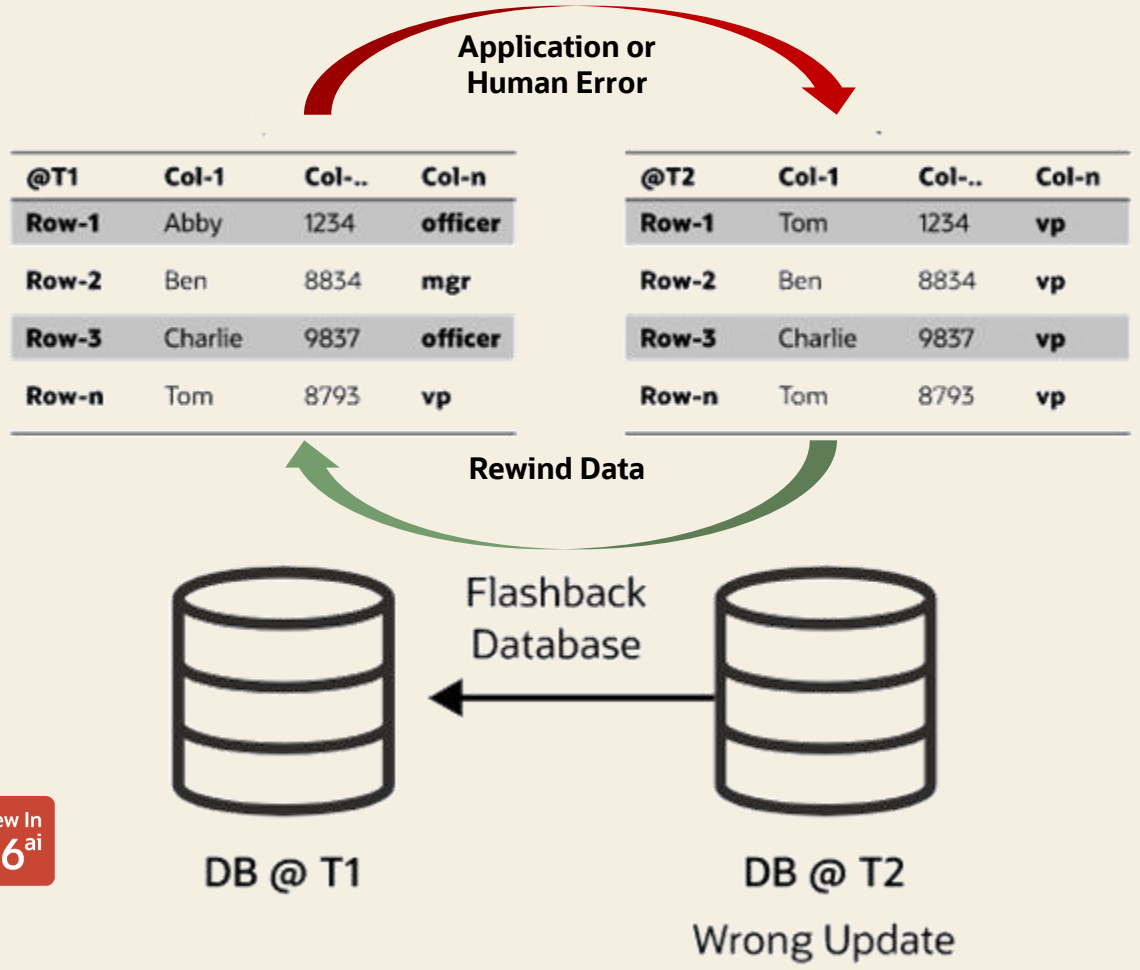
Flashback Technologies

Rewind Button for Oracle AI Databases

- Fast point-in-time recovery (PITR) without expensive restore operation
- Error investigation
  - View data as of previous point in time
- Error correction
  - Back-out a transaction
  - Incorrect table updates
  - Rewind the entire database
- *New in Oracle AI Database 26ai:*
  - Flashback Time Travel operates at the transactional level tracking and archiving transactional changes to tables

New In 26ai



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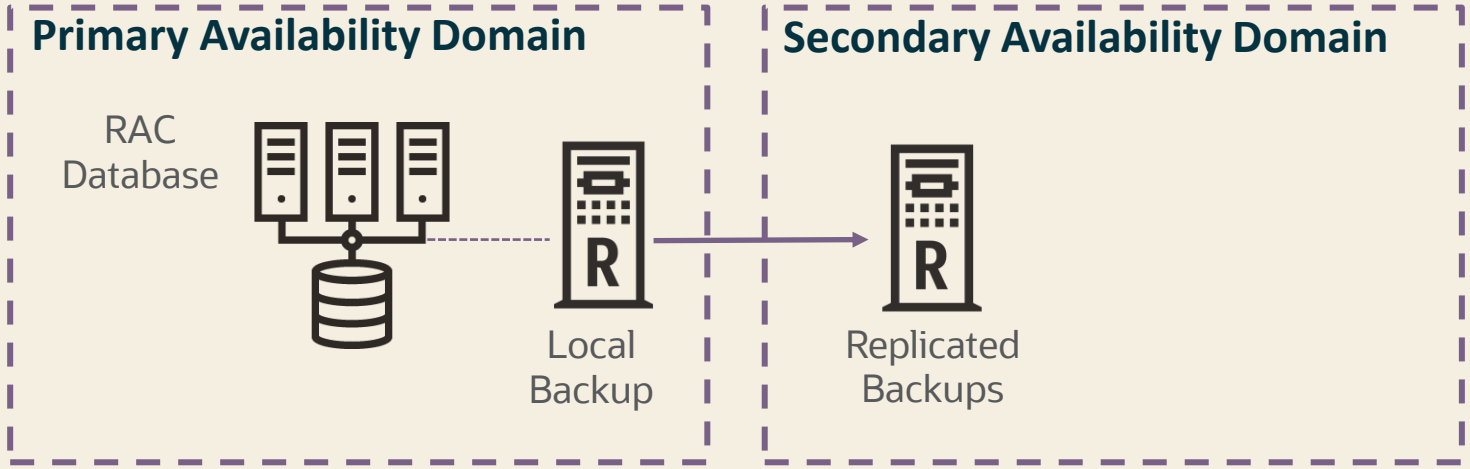
SILVER (Option 1)

Prod/Departmental

Bronze +

- Real Application Clustering (RAC)
- Application Continuity
- Globally Distributed Database (Optional)
  - Provides fault isolation, scalability, and geographical distribution

Client connectivity best practices:
https://docs.oracle.com/en/database/oracle/oracle-database/26/haovw/continuous-availability-applications.html



Outage Matrix

Unplanned Outage	RTO/RPO Service Level Objectives(f1)
Recoverable node or instance failure	**<30 seconds (f2)**; single-digit minutes on non-Exadata
Disasters: corruptions and site failures	Hours to days. RPO since last backup or near zero with ZDLRA
Planned Maintenance	
Software/Hardware updates	**Zero** (f1)
Major database upgrade	Minutes to hour

f1: RPO=0 unless explicitly specified
f2: Fast sub-30 seconds role transition is on Exadata; near-zero with Application Continuity enabled.

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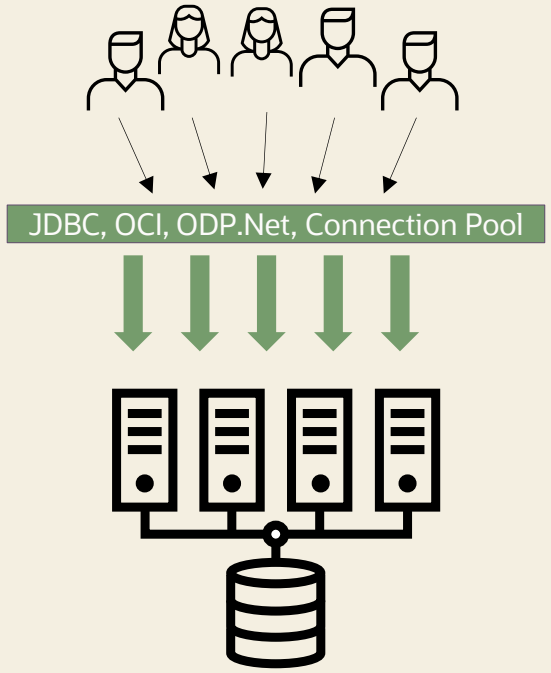
Oracle RAC (Real Application Clusters)

Active-active instances provide unmatched scalability, performance and availability



- Unique scale-everything, highly available database architecture with concurrent active active instances
- Scales OLTP, OLAP, and Hybrid Workloads and minimizes downtime with rolling patching
- Applications supported on single instance runs without any changes on Oracle RAC
- Applications scale by simply adding nodes to the cluster without incurring downtime

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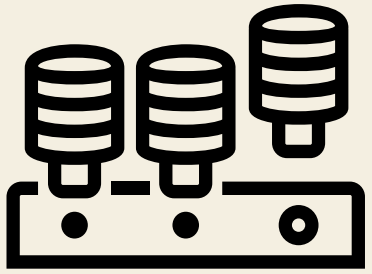
Oracle RAC 26ai Improvements

New In 26ai

Parallel operations result in consistent performance



2X faster Pluggable Database Open

Parallel Distributed Lock Manager operations during PDB open

8X faster to create 10k services

14X faster to create, **23X** faster to delete individual services with 10k services

10X Faster start of work on instance crash or restart

Buddy Instance, Parallel operations on dirty buffers list and other features

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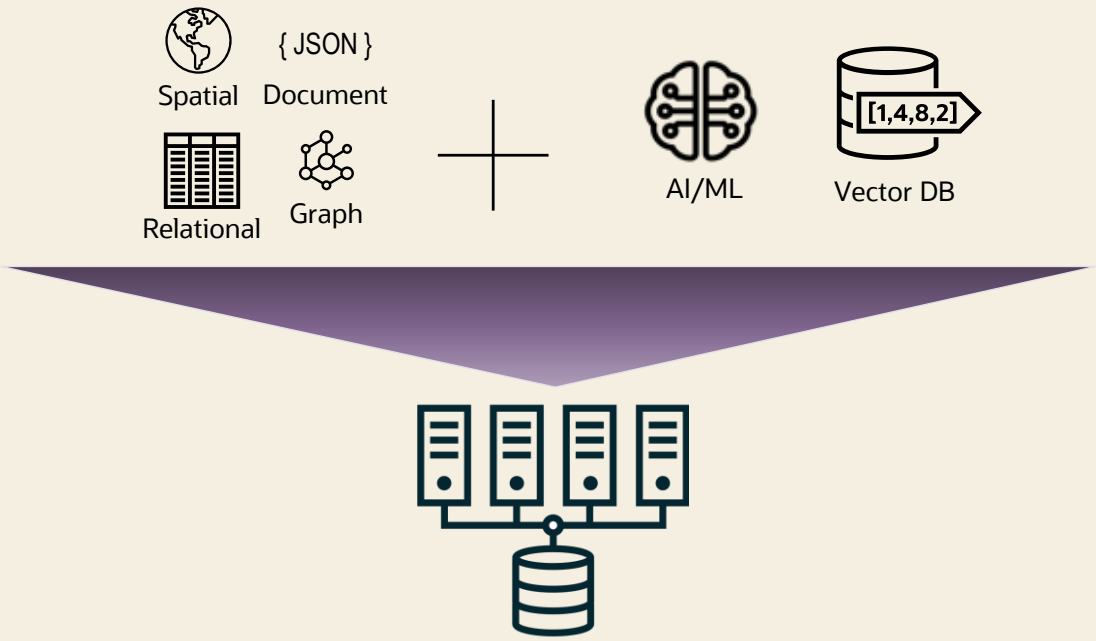
Distribute Vector AI and OLTP workloads on Oracle RAC Instances

Realtime insights without interrupting or slowing business operations

New In 26ai

Integrate AI Vector Search with Business Data



Best of both: Isolate ongoing Business operations on one set of instances while running RAG workloads on another

- Integrate AI Vector search on business-critical data with simple-to-use SQL that can benefit from both inter-node and intra-node parallel operations.
- Active-Active Oracle RAC
  - Protects against outages due to hardware failures
  - Scales performance as workloads can run concurrently on different Oracle RAC instances
- Even better performance, scalability and high availability on Engineered Systems such as Exadata

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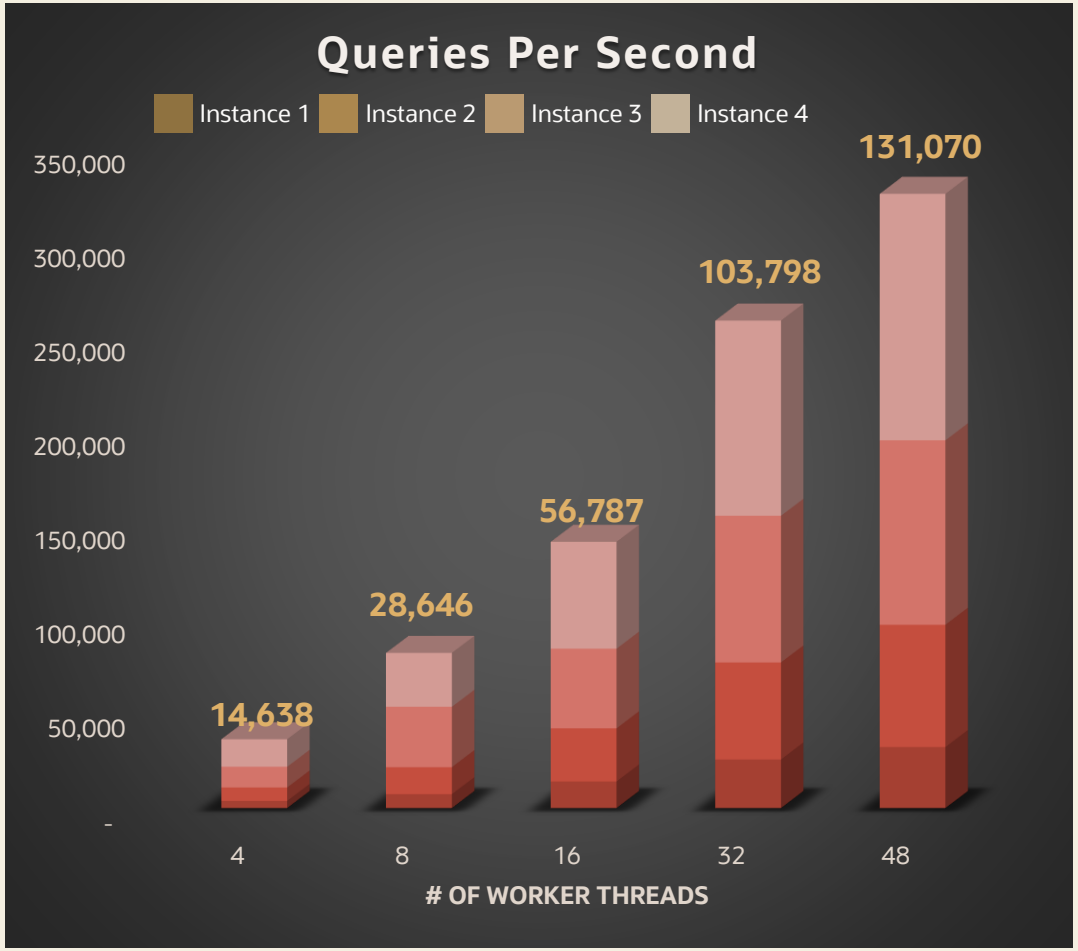
Performance of sample AI Vector Search workload on Oracle RAC

Data Set: GloVe-25 | ~1.2 million rows (VECTOR(25, FLOAT32)



- Oracle RAC scales the GloVe-25 workload linearly across all the instances
  - The GloVe-25 dataset contains pre-trained, 25-dimensional word vectors generated using the GloVe (Global Vectors for Word Representation) algorithm
  - Each entry maps a single English word to a compact numerical representation based on semantic similarity
  - ~99% of the query elapsed time was CPU time

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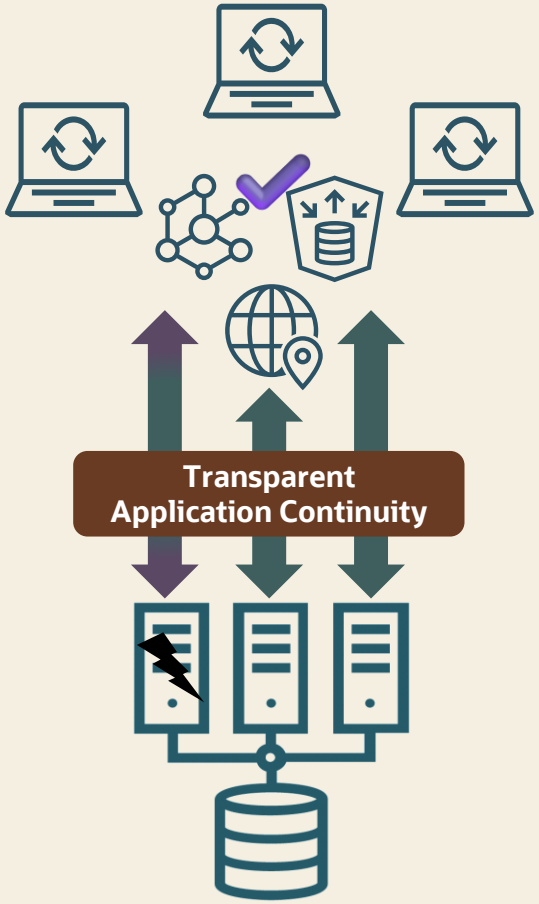
Transparent Application Continuity (TAC)

Keeps applications online during outages without requiring any custom error handling

- Hide downtime from end-users
  - TAC rebuilds the session state and replays in-flight transactions as part of automated session failover
- Eliminate errors unless unrecoverable
  - For both planned maintenance and unplanned outages
- Fast Application Notification (FAN) and session draining
  - FAN notifies clients of database status changes - helps break applications out of TCP timeouts
  - Draining causes sessions to complete their work on a given instance to prepare the node or the database for maintenance - no application changes required
- Best used with an Oracle (compatible) connection pool
- Oracle AI Database 26ai provides Application Continuity through DBMS_ROLLING operations.

New In 26ai



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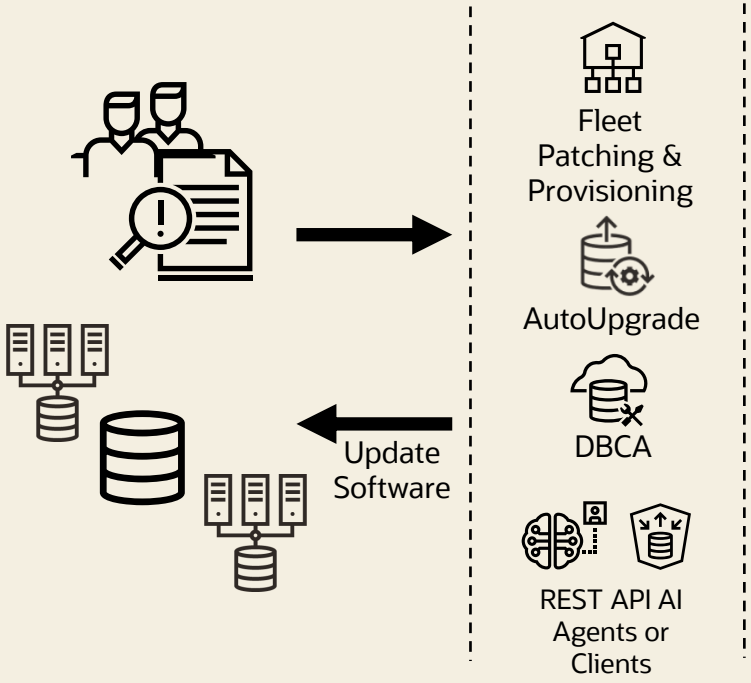
Oracle Update Advisor

How does it work?

Integrated with DBCA, FPP, and AutoUpgrade

Customer runs getStatus / getRecommendation via update tool (optional w/ policy)



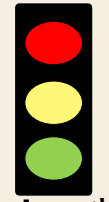
Update tool (DBCA – FPP - AutoUpgrade) or REST API (Custom CLI, Agent)

- Gathers inventory details
- Submits request to Oracle Update Advisor

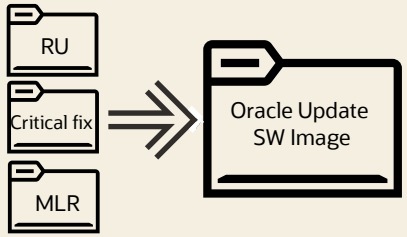
Get response from

Oracle Update Advisor

Oracle Update Advisor provides



- Software Status*
  - Why Status != GREEN
- Software Recommendation*
  - Retain existing fixes in the current software
  - Include additional fixes
  - Adjusted per policy
- Software Image
  - Matching recommendation



*FPP and DBCA only; AutoUpgrade software recommendations coming soon

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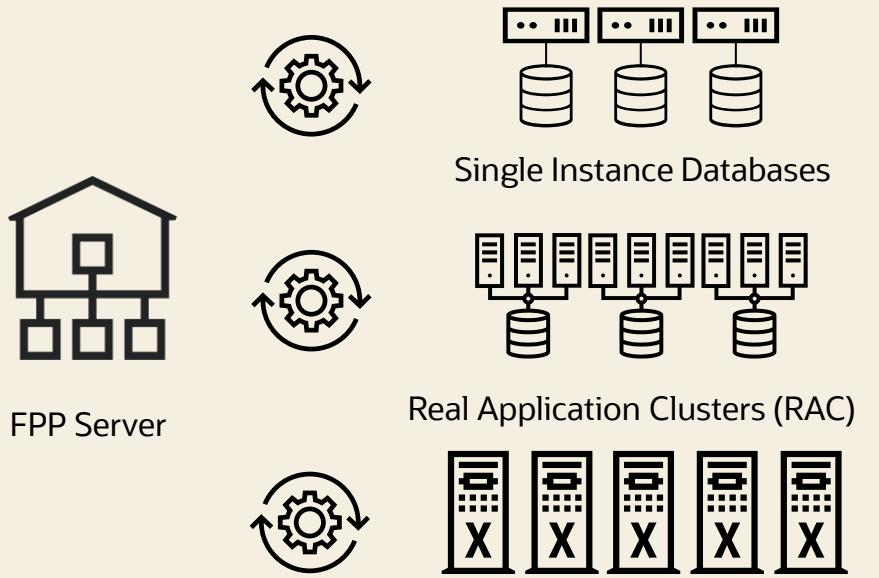
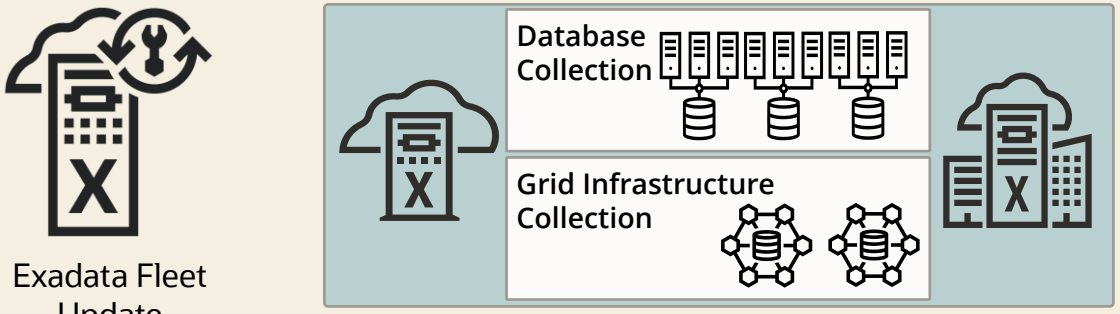
Fleetwide maintenance on-premises and for ExaDB in OCI



Fleet Patching & Provisioning:

- Gold image-based drift detection
- Integrated job scheduling
- User actions for extensibility
- Comprehensive Exadata Patching
- Full-stack Exadata patching



Exadata Fleet Update:

- Group multiple Oracle AI Databases and Oracle Grid Infrastructures into collections
- Rolling and non-rolling, session draining, scheduling of pre-check, staging, and patch operations
- Less complexity with out-of-place patching mechanism
- Available for ExaDB-D and ExaDB-C@C deployments

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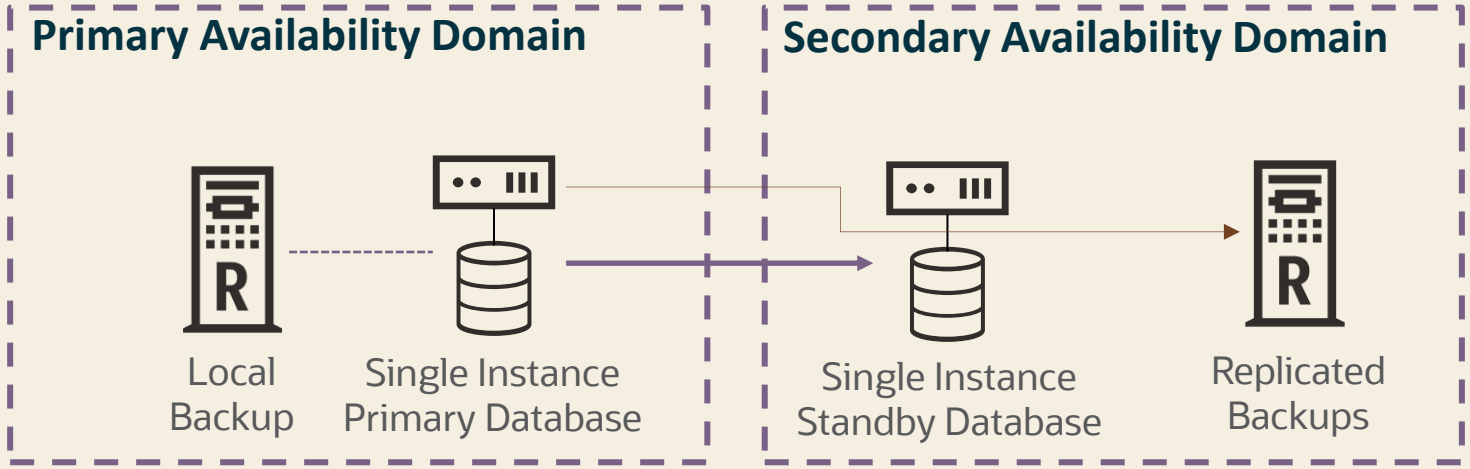
SILVER (Option 2)

Prod/Departmental

Bronze +

- Local Standby Database using Data Guard
  - Protects from local failures but minimal benefits for planned maintenance
- Globally Distributed Database (Optional)
  - Provides fault isolation, scalability, and geographical distribution

Client connectivity best practices:
https://docs.oracle.com/en/database/oracle/oracle-database/23/haovw/continuous-availability-applications.html



Outage Matrix

Unplanned Outage	RTO/RPO Service Level Objectives(f1)
Recoverable local failure	< 1 min
Disasters: corruptions and site failures	Hours to days. RPO since last backup or near zero with ZDLRA
Planned Maintenance	
Software/Hardware updates	Minutes to hour (f1)
Major database upgrade	Minutes to hour

f1: To achieve minimal downtime or lowest impact, apply application client best practices; Batch jobs should be deferred outside planned maintenance window.

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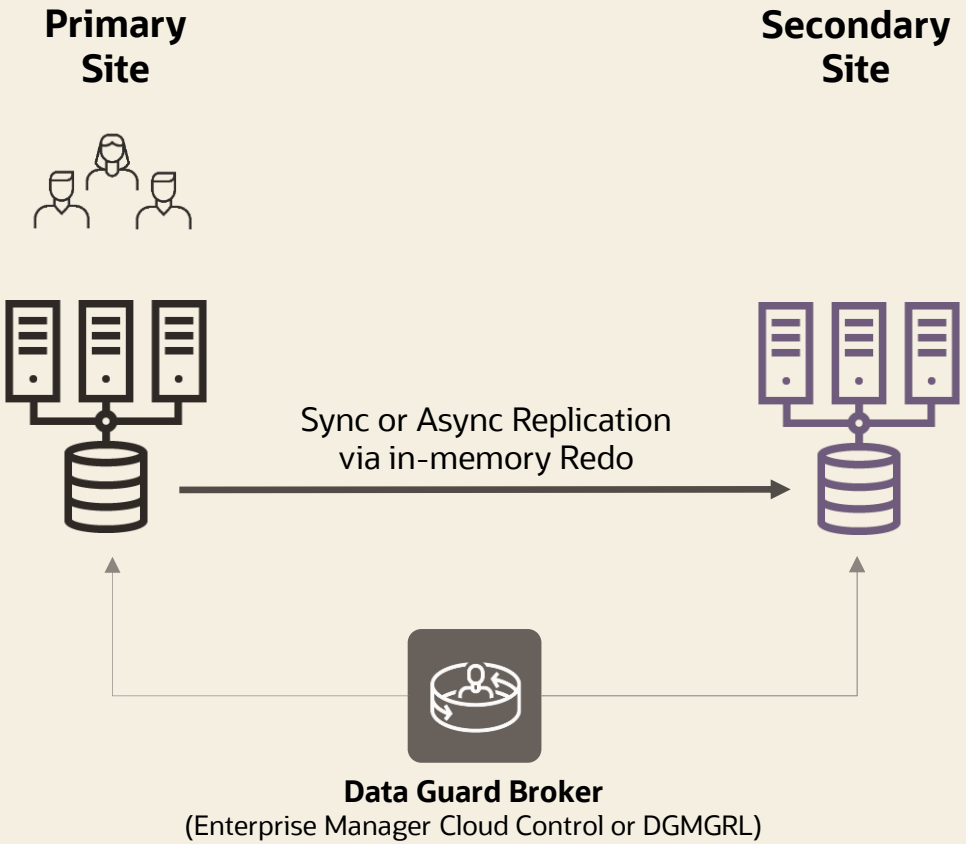
Oracle Data Guard



- **Basic in-memory redo replication (included with DB EE)**
  - License primary and secondary sites
- **Active-passive**
  - Standby is used only for failovers
- **Automatic failover to Standby site**
- **Zero / near-zero data loss**
- **Continuous data validation**
- **Simple migrations and upgrades**

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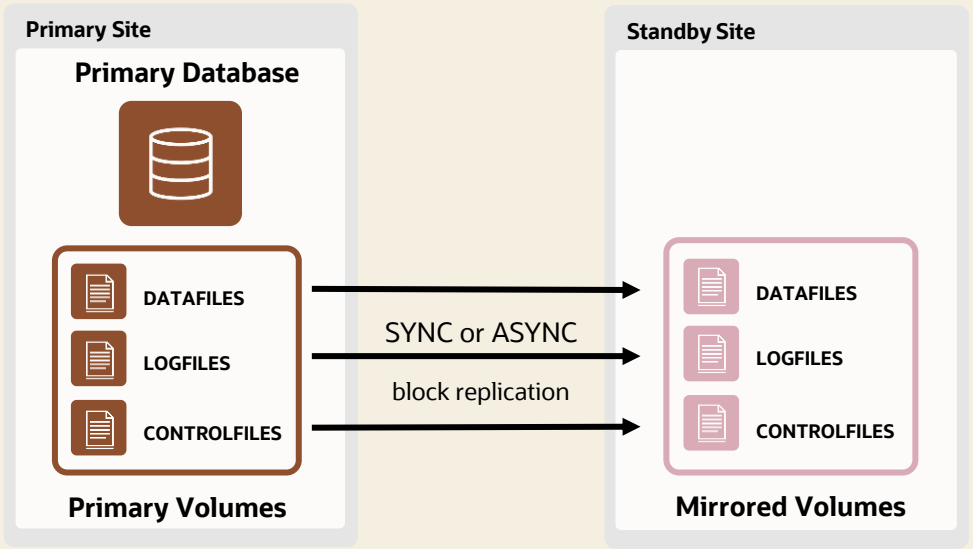
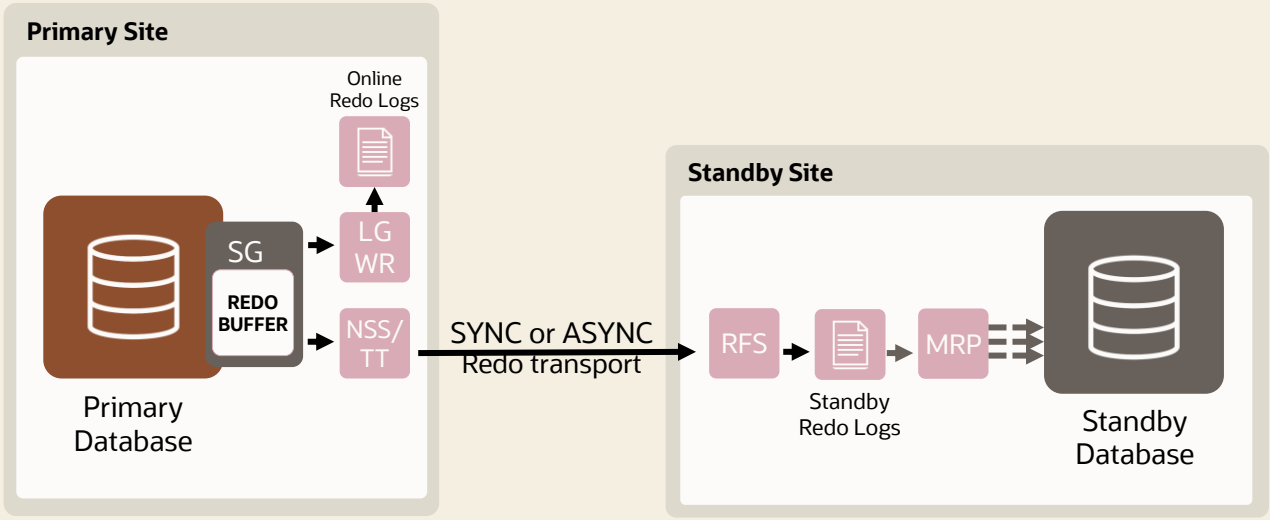
Data Guard is Optimized for the Database

Better than storage mirroring or 3rd party solutions





Traditional replication

- Corruptions are replicated
- Unusable destination
- 7x network volume
- 27x network I/O
- Standby needs warm-up

Data Guard replication

- **Validation end to end**
- **Ransomware Protection**
- Only the essential information is replicated
- Efficient and performant
- **Implicit Integrity**

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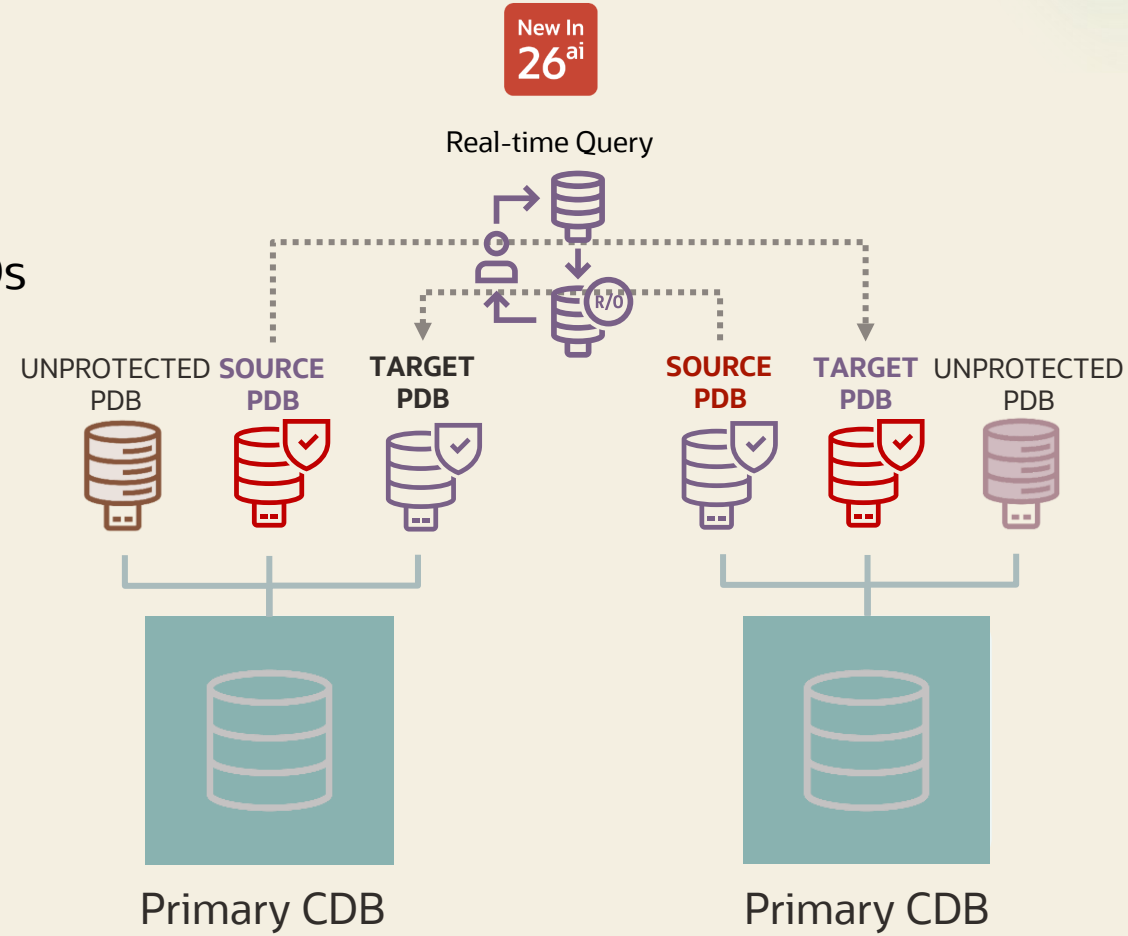
Data Guard per Pluggable Database

- Two Container Databases (CDB) actively running workload
  - Both open read-write with different database IDs
- Disaster Protection at the PDB level
  - No need to fail over a full Container Database
  - Role transition on a single PDB with Data Guard Broker
  - Automatic gap fetching from the source
  - ASYNC support
- Real-Time Query for DGPDB configurations now available in Oracle AI Database 26ai



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GOLD

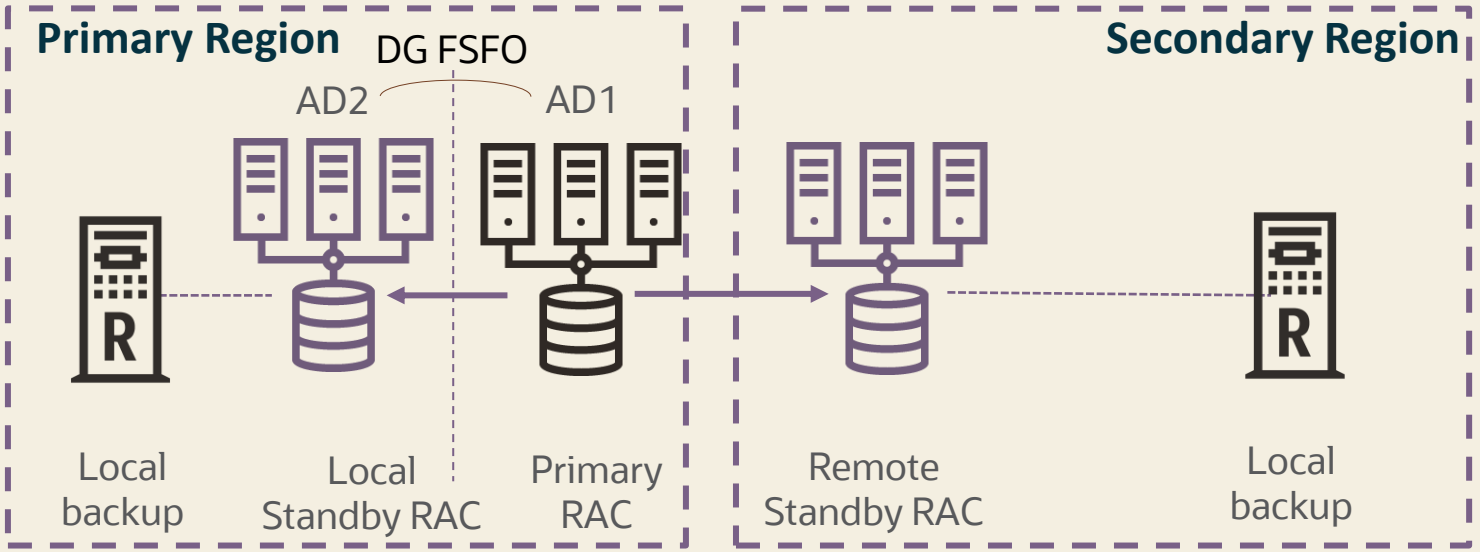
Business Critical

Silver (Option 1 with RAC) +

- Active Data Guard
  - Comprehensive Data Protection

MAA Architecture:

- At least one standby is required across AD or region.
- Primary in one data center(or AD) replicated to a Standby in another data center
- Data Guard Fast-Start Failover (FSFO)
- Local backups on both primary and standby



Outage Matrix

Unplanned Outage	**RTO/RPO Service Level Objectives** (f1)
Recoverable node or instance failure	< 30 seconds (f2)
Disasters: corruptions and site failures	**Seconds to 2 minutes. RPO zero or seconds**
Planned Maintenance	
Software/Hardware updates	Zero (f2)
Major database upgrade	**< 30 seconds**

f1: RPO=0 unless explicitly specified

f2: To achieve zero downtime or lowest impact, apply application checklist best practices; Batch jobs should be deferred outside planned maintenance window.

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Oracle Data Protection

Gold – Comprehensive Data Protection

	Capability	Physical Block Corruption	Logical Block Corruption
Manual	Dbverify, Analyze	Physical block checks	Logical checks for intra-block and inter-object consistency
Manual	RMAN, ASM	Physical block checks	Intra-block logical checks
Runtime	Active Data Guard	• Continuous physical block checking at standby • Strong isolation to prevent single point of failure • Automatic repair of physical corruptions • Automatic database failover (option for lost writes)	• **Detect lost write corruption, auto shutdown and failover** • **Intra-block logical checks at standby**
Runtime	Database	In-memory block and redo checksum	In-memory intra-block checks, shadow lost write protection
Runtime	ASM	Automatic corruption detection and repair using extent pairs	
Runtime	Exadata	HARD checks on write, automatic disk scrub and repair	HARD checks on write

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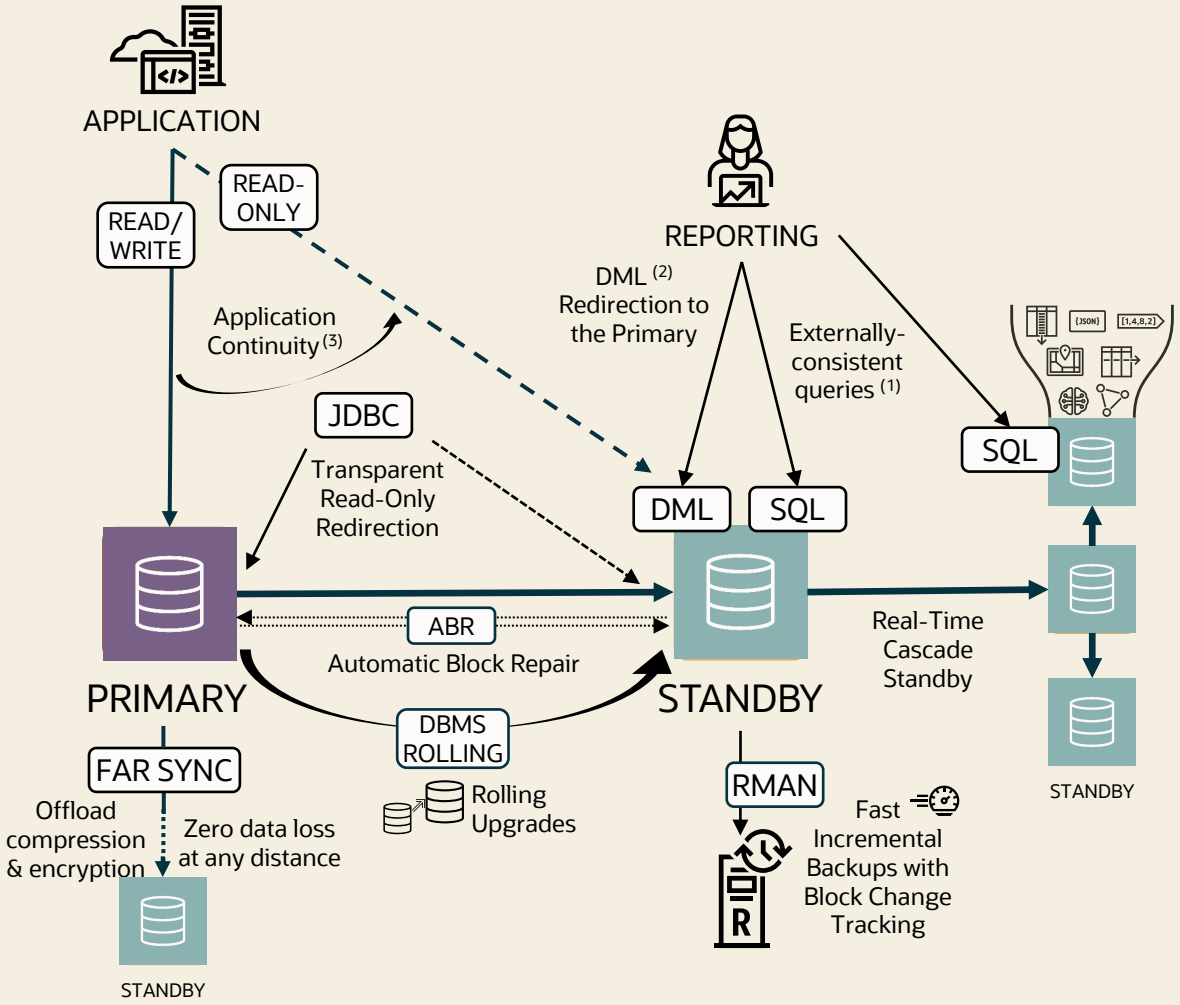
Oracle Active Data Guard



Offload & scale

Don't leave your standby infrastructure idle:

- **Offload** queries, reports, and backups
- **Linearly scale** the application's read-only activity
- **Increase** read/write **throughput** by freeing important resources
- Transparently load balance across replicas

Enhanced protection

- All your transactions are **protected regardless of the distance**
- Block corruptions are **fixed** on the fly **without application errors**
- Cascaded standbys protect your transactions without delay
- Backups are **incredibly fast**, also on the standby database

Higher availability

- Major **upgrades are transparent** or require minimal downtime
- **Mask failovers** to the application **without additional coding**

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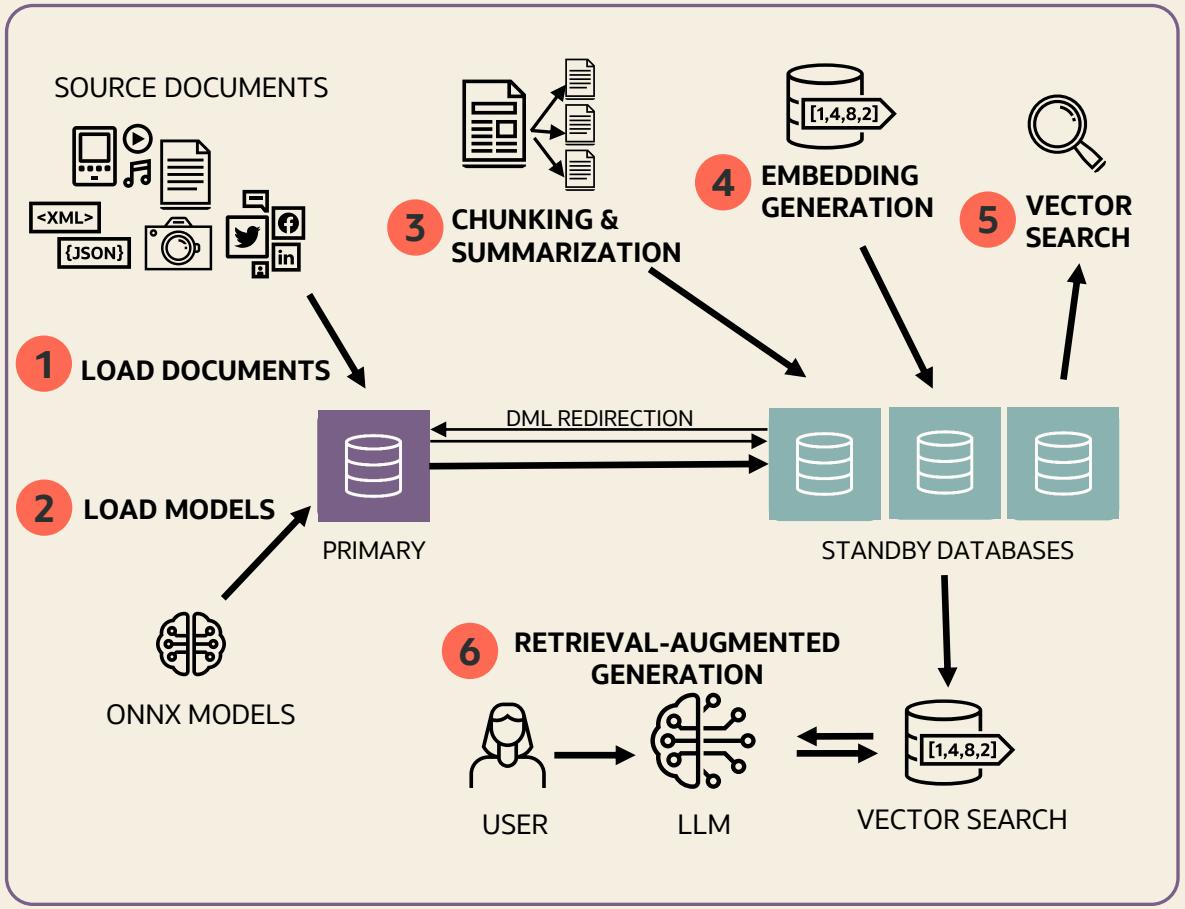
New In 26ai

Offload Inferencing and AI Vector Search to Oracle Active Data Guard

Leverage the standby for AI workloads, keeping the primary free for mission-critical transactions



- Offload CPU-intensive workloads
  - Inferencing
  - Chunking and summarization
  - AI Vector Search
- Embeddings are created on the standby database
- Vectors are inserted via DML Redirection
- Standby resources are fully utilized

Primary database performance is unaffected

https://blogs.oracle.com/maa/onnx-on-active-data-guard

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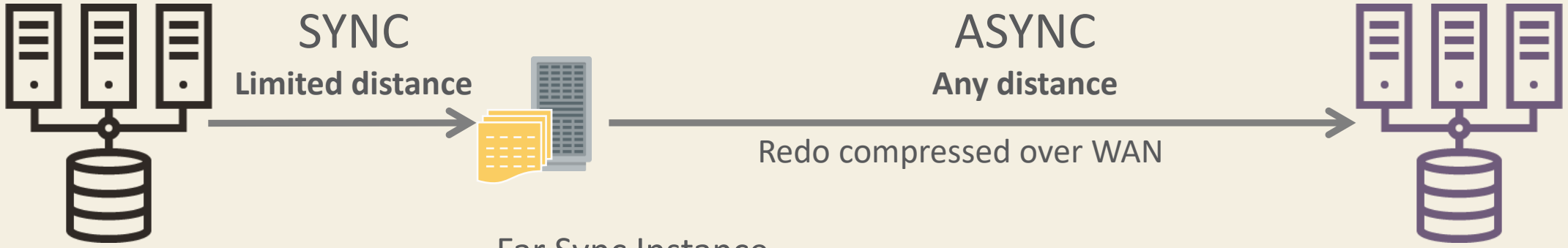
Active Data Guard Far Sync

Zero Data Loss Protection at Any Distance



Primary Database
- Production copy

Far Sync Instance
- Oracle control file and log files
- No database files
- No media recovery
- Offload transport compression and/or encryption

Active Standby Database
- Zero data loss failover target
- Database open read-only
- Continuous Oracle validation
- Manual or automatic failover

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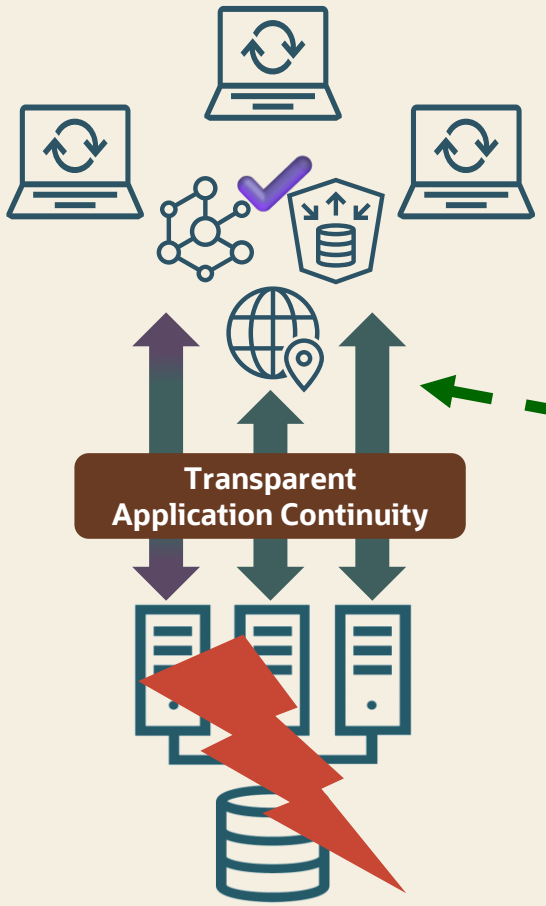
Unplanned Outages, Application Continuity expanded to the Standby



Primary RAC Database

Active Data Guard Standby

Outage or Interruption at Database:

- Database Request interrupted by an Outage or timeout
- Session reconnects to the RAC Cluster (or Standby) and
- Database Request replays automatically
- Result from Database Request returned to the user
- Oracle AI Database 26ai provides Application Continuity through DBMS_ROLLING operations. New In 26ai

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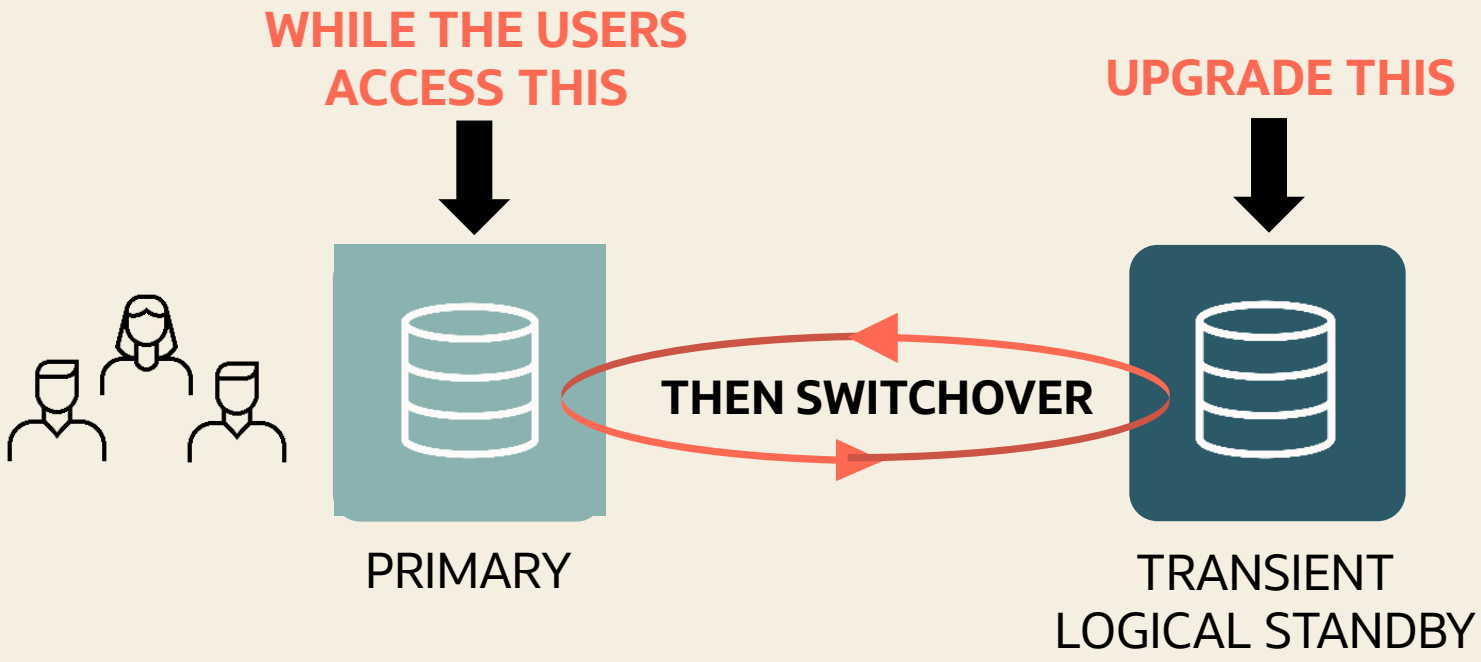
Active Data Guard Rolling Maintenance and Upgrades

Using DBMS_ROLLING package



- Use a transient logical standby database to upgrade with very little downtime.
- The only downtime is as little as it takes to perform a switchover.
- Oracle AI Database 26ai provides Application Continuity Support New In 26ai

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Different Ways to Configure Oracle Data Guard

For easy integration with DevOps and configuration pipelines

dgmgrl

```
DGMGRL> create configuration mydb
> as primary database is mydb
> connect identifier is 'clu-scan:1521/mydb’
```

```
SQL> DG create configuration mydb as primary database is
mydb connect identifier is 'clu-scan:1521/mydb'
```

PL/SQL

```
DECLARE
  severity BINARY_INTEGER;
  retcode  BINARY_INTEGER;
BEGIN
  retcode := DBMS_DG.CREATE_CONFIGURATION (
    config_name         => 'mydb'
    primary_ci          => 'clu-scan:1521/mydb'
    severity            => severity
  );
END;
```

```
POST /database/dataguard/configuration/
{
 "primary_connection_identifier":"clu-scan:1521/mydb",
 "primary_database": "mydb_site1"
}
```


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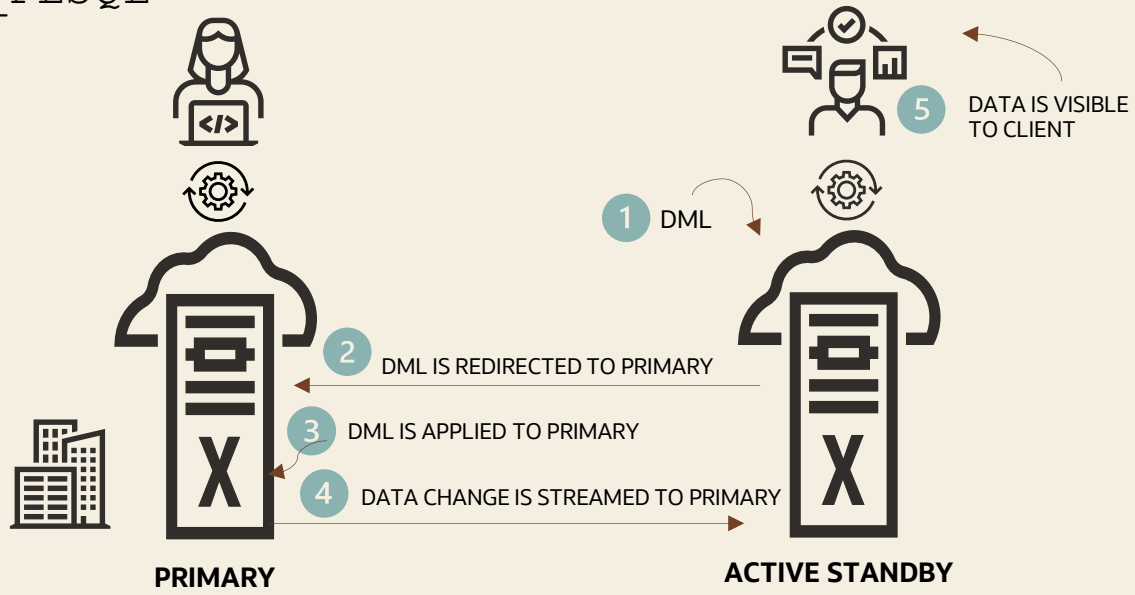
Extend Footprint of Active Data Guard Applications

Support for DML Re-direction

- DML Re-direction is automatically performed from an Active Data Guard standby to the primary (ACID uncompromised)
- New parameter `ADG_REDIRECT_DML` controls DML Redirection
- New `ADG_REDIRECT_DML and ADG_REDIRECT_PLSQL`

- "Read-Mostly, Occasional Updates" applications supported for Oracle AI Database 19c and above



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Tunable Automatic Outage Resolution

Data Guard maintains internal mechanisms that detect and correct issues with its redo transport and gap resolution processes

- In case of network or disk I/O problems, these mechanisms prevent those processes from hanging and causing unnecessarily *long gaps (or is it hangs?)*

Use the following parameters to influence the outage resolution:

- DATA_GUARD_MAX_IO_TIME
  - Sets the maximum number of seconds that can elapse before a process is considered hung while performing reads, writes, and status operations.
- DATA_GUARD_MAX_LONGIO_TIME
  - Sets the maximum number of seconds as above, but for operations such as open and close

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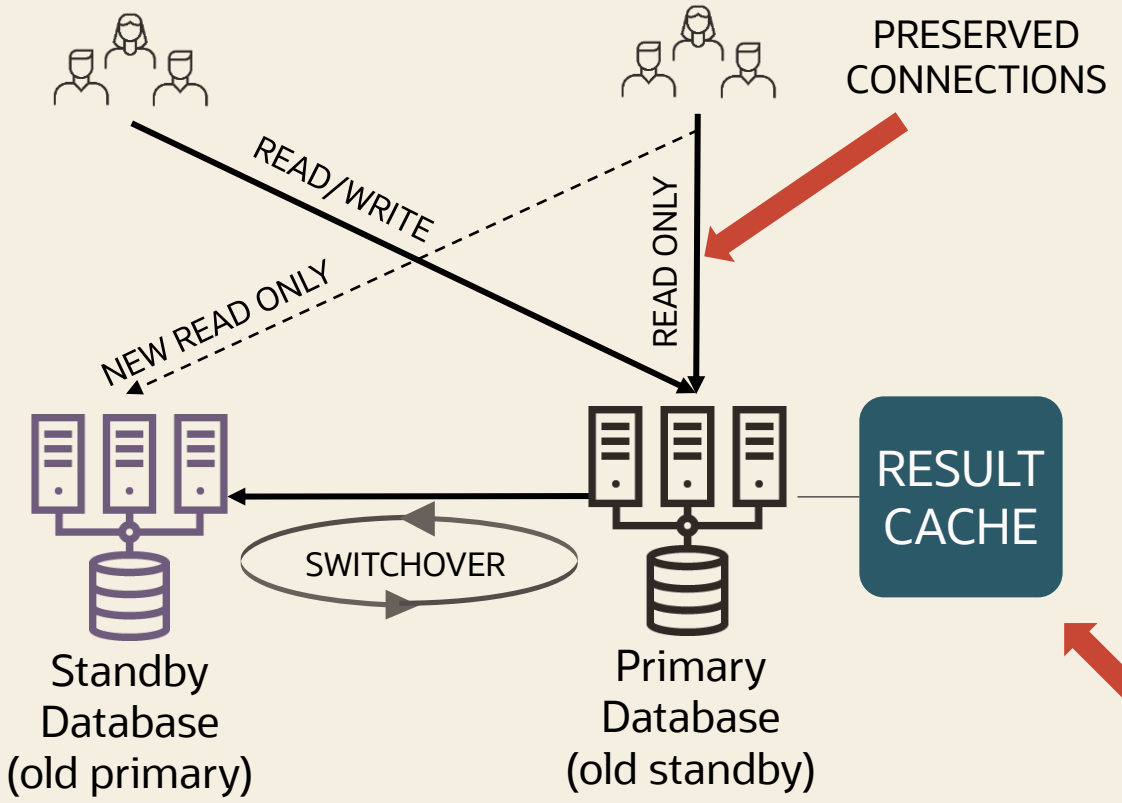
Standby Result Cache Preservation

Keep the Result Cache warm after a role transition



- Real-Time Query supports the Result Cache for queries run on the standby database (tables only)
- Result Cache improves query performance for recurring queries and reduces resource usage (CPU, I/O)
- In **21c and above**, after a role transition (switchover or failover), the Result Cache is preserved
  - Query performance not impacted
  - No cache warm-up required

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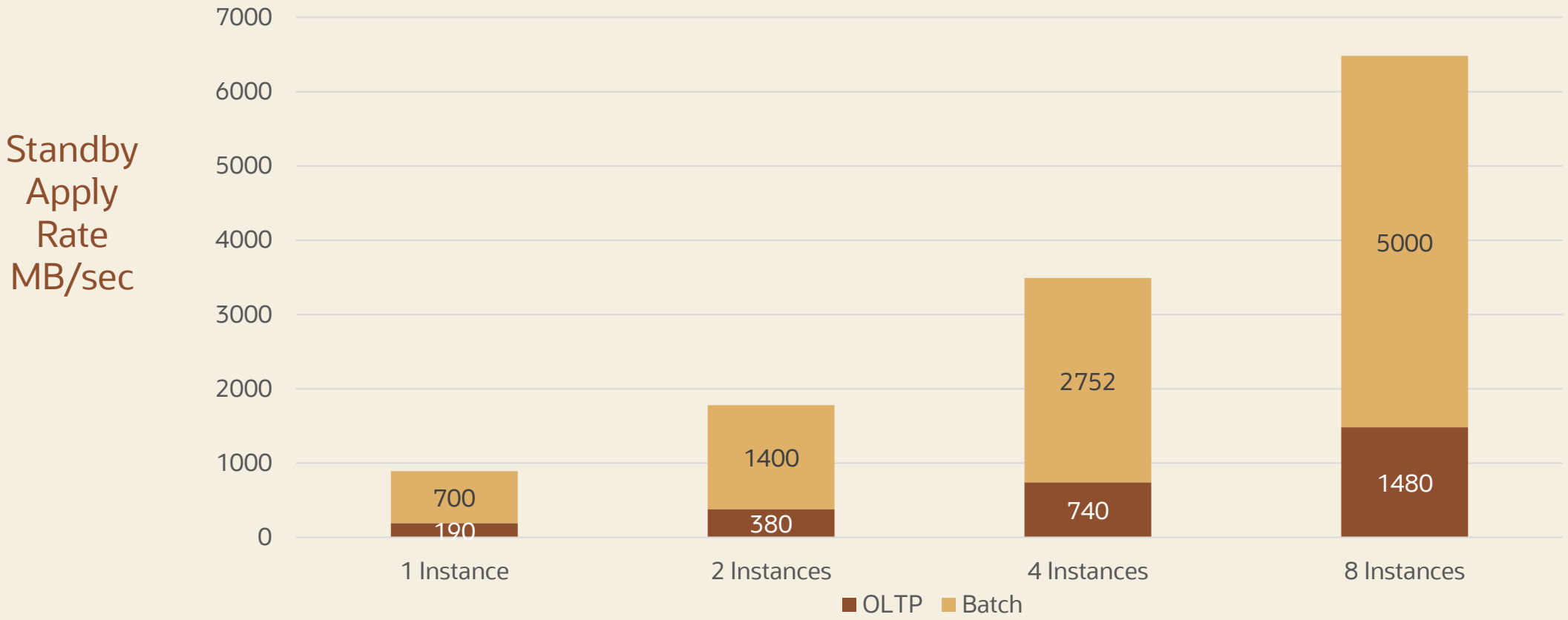
Multi-Instance Redo Apply Performance

Lower Latency Active Data Guard Standby Databases

- Utilizes all RAC nodes on the Standby database to parallelize recovery
- OLTP workloads on Exadata show great scalability



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PLATINUM

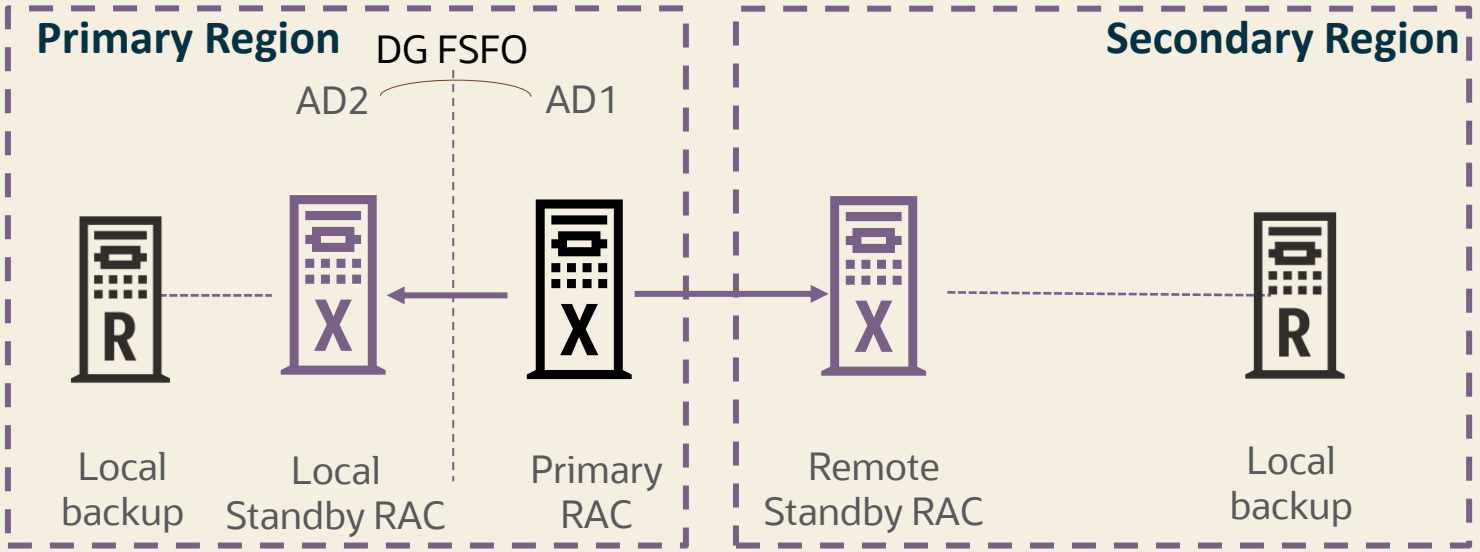
Mission Critical (Option 1)

Gold +

- Oracle AI Database 26ai
- Exadata
- Active Data Guard
  - Comprehensive Data Protection
- Edition-based Redefinition (Optional)

MAA Architecture:

- At least one standby is required across AD or region.
- Primary in one data center(or AD) replicated to a Standby in another data center
- Data Guard Fast-Start Failover (FSFO)
- Local backups on both primary and standby



Outage Matrix

Unplanned Outage	RTO/RPO Service Level Objectives (f1)
Recoverable node or instance failure	**< 10 secs (f2)**
Disasters: corruptions and site failures	**< 30 secs. RPO zero or seconds**
Planned Maintenance	
Software/Hardware updates	Zero (f2)
Major database upgrade	**Less than 30 seconds**

f1: RPO=0 unless explicitly specified

f2: To achieve zero downtime or lowest impact, apply application checklist best practices; Batch jobs should be deferred outside planned maintenance window.

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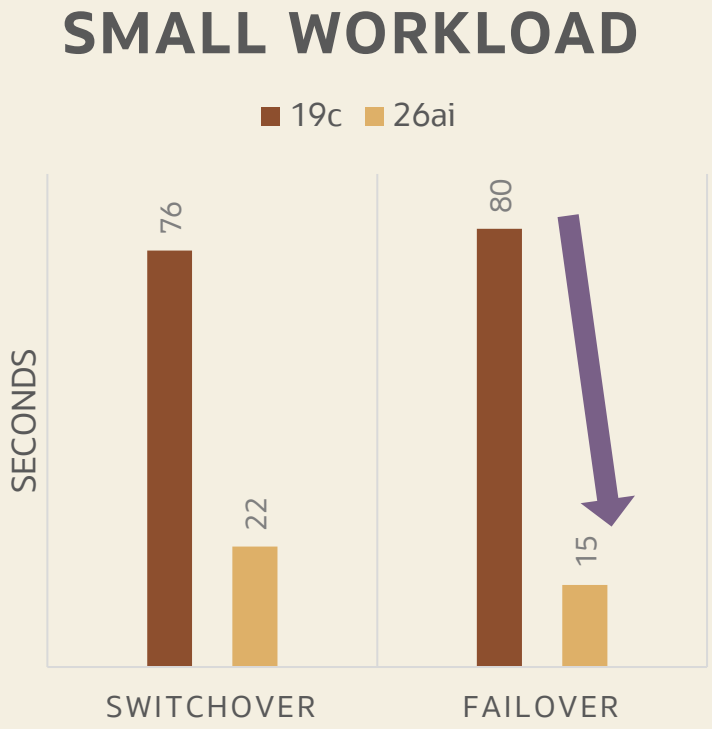
Oracle Data Guard 26ai Provides Lower RTO

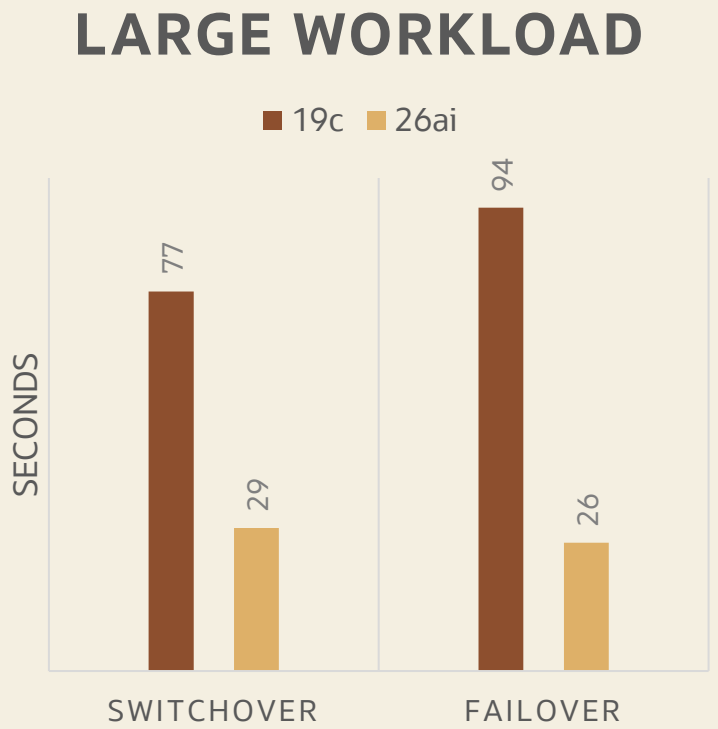
Faster role transitions regardless of the size of the workload



UP TO

400%

FASTER



Workload	System	PDBs	Data Files	Services	Redo Rate
SMALL	2-node Exadata RAC	5	50	10	60 MB/s
LARGE	4-node Exadata RAC	12	500	12	100 MB/s

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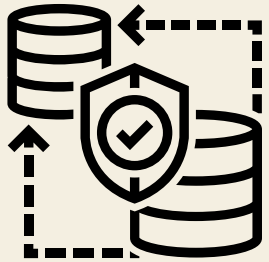
Why is Exadata extraordinary and unique for resiliency & scalability?

Exadata and RAC – The Foundation for Platinum MAA

Highest Availability

Engineered for zero-downtime software updates for standard outages and near-zero downtime for outages, with mitigation for severe gray failures



Proactive Data Protection

Exadata actively detects and repairs data corruption, ensuring data integrity.

Quality of Service

Application maintains extreme performance and low latency, adjusting dynamically when changes or issues occur

Ongoing Health Checks

Exadata is deployed by default with integrated MAA. Exachk and health checks maintain extreme stability and availability

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Exadata is extraordinary and unique for resiliency & scalability

HA Use Case	Application Impact
Database Node Rolling software Update (Exadata, Grid Infrastructure and Database)	No application delay
Storage Server Rolling Software Update	No application delay
RDMA Network Fabric Switch Rolling Upgrade	10 seconds or less application delay
Hard Disk and Flash Failure	No application delay
Database Node and Instance Failure	10 seconds or less application delay
RDMA Network Fabric Switch or Port Failure	10 seconds or less application delay

Near Zero Application Impact for Most Common Planned and Unplanned Outages

Striving for Much Better!!!

Mitigation Solutions for Toughest “Gray Failures”

Gray Failure HA Use Case	Exadata Feature and Handling
Oversubscribed Resources	Exadata leverages MS alerting, Exadata AWR Support, and Real Time Insight to proactively notify and report on resource oversubscription so it can be addressed.
RoCE network port dropped packets	Exadata leverages the Exaportmon feature to detect sick network ports and take them down if traffic is not flowing correctly
Exadata Storage Cell slow / sick flash disk and hard disk	Exadata leverages the cell side IO latency capping features to cancel IO and route to secondary partners when primary partners are very slow
I/O hang	Exadata leverages the I/O hang detection to reboot a cell when the I/O are not being serviced due to, for example a sick controller.

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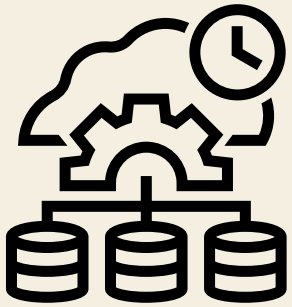
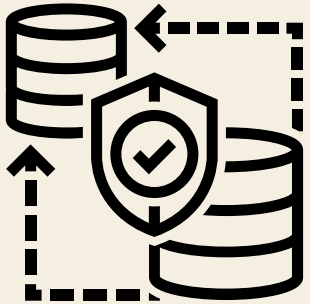
Exadata extraordinary examples



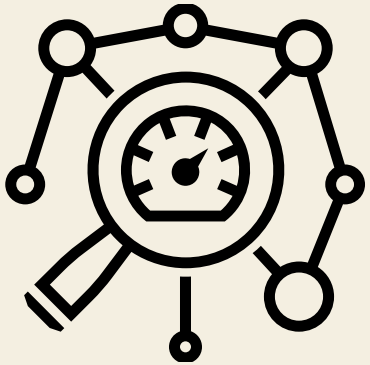
Highest Application Availability

- 15 X Faster for Node Failure
- Only Exadata HA enables the lowest brownout



Data Guard Redo Apply Performance

- 5-10 X Faster due to scale-out network and storage



Exadata Performance and Scalability

- 33 X better performance
- 4-10 X better OLTP latency

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PLATINUM

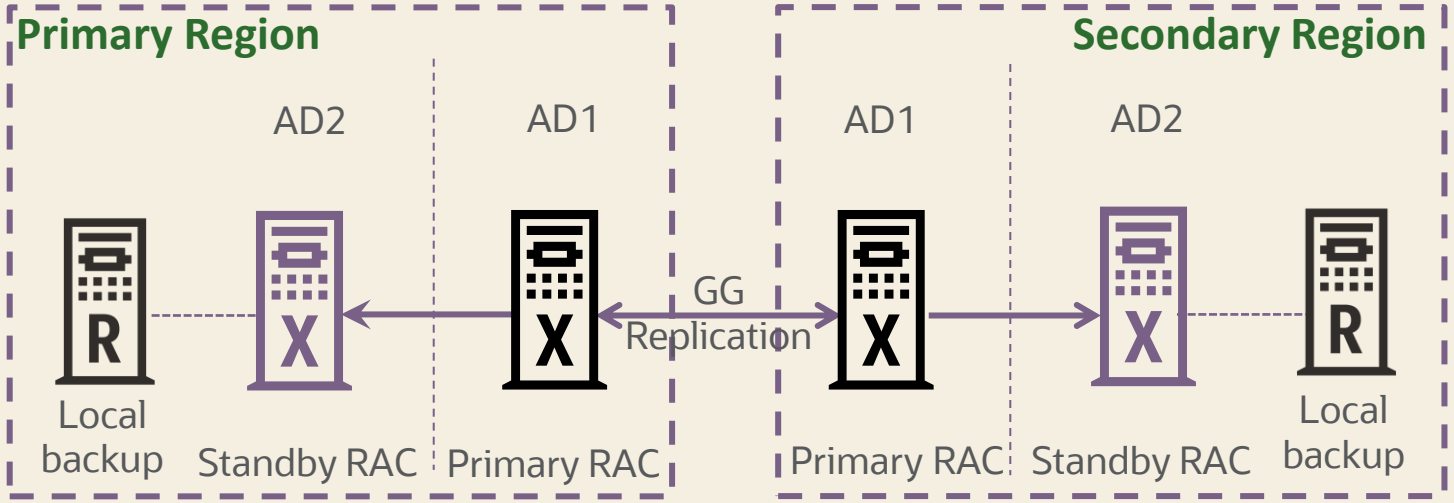
Mission Critical (Option 2)

Gold +

- GoldenGate Active/Active Replication
- Exadata
- Edition-based Redefinition (Optional)

MAA Architecture:

- Each GoldenGate "primary" replica protected by Exadata, RAC and Active Data Guard
- Primary in one data center (or AD) replicated to another Primary in remote data center (or AD)
- Oracle GG & Edition-based Redefinition for zero downtime application upgrade
- Achieve zero downtime through custom failover to GG replica



Outage Matrix

Unplanned Outage	RTO/RPO Service Level Objectives (f1)
Recoverable node or instance failure	**< 10 secs (f2/f3)**
Disasters including corruptions and site failures	**< 3 secs (f3)**
Planned Maintenance	
Most common software/hardware updates	Zero (f2)
Major database upgrade, application upgrade	**Zero (f3)**

f1: RPO=0 unless explicitly specified
f2: To achieve zero downtime or lowest impact, apply application checklist best practices
f3: Application failover is custom or with Global Data Services

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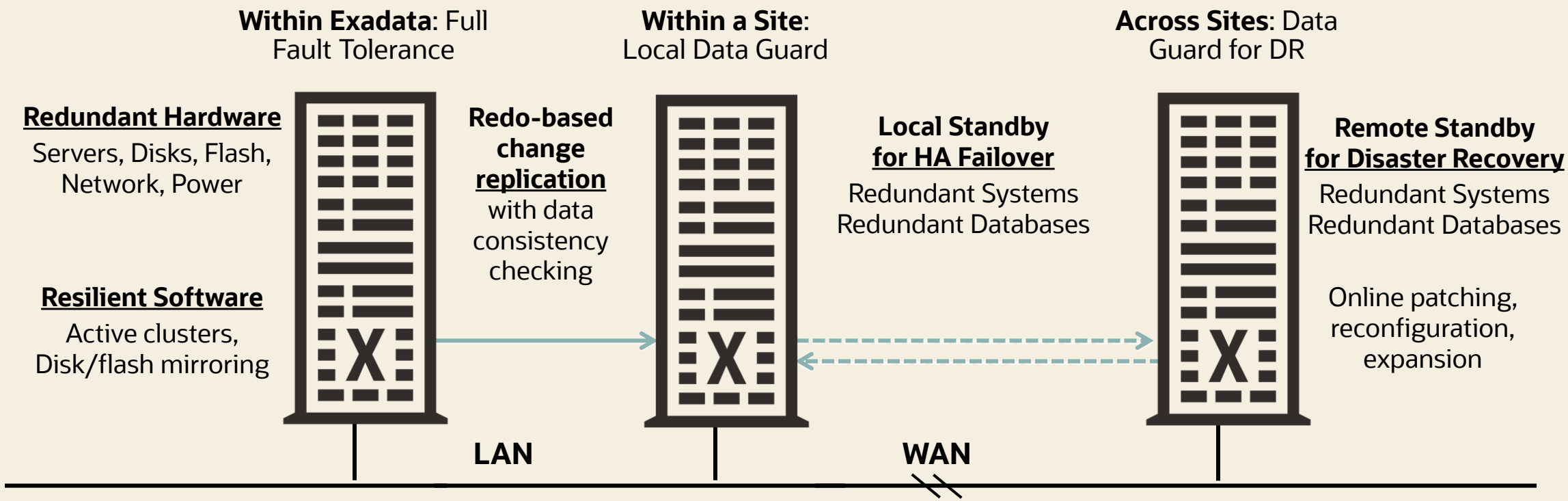
Exadata Maximum Availability Architecture (MAA)

Optimized on-premises blueprint for HA: designed/tested against failure scenarios



Fastest RAC recovery after node or instance failure | Fastest Backup - RMAN Offloads to Storage
Seamless ASM Integration | Fastest Data Guard Redo Apply | Automated Chaos Engineering injection testing

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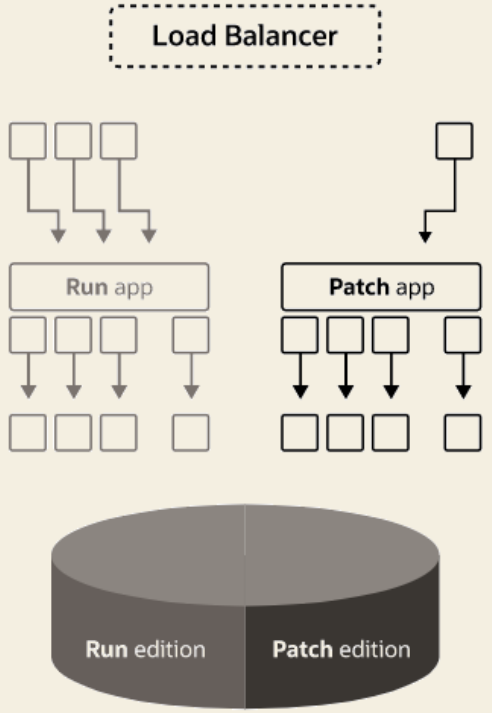
GoldenGate or Alternatively Edition-based Redefinition to Further Protect Your Applications

Use Oracle Golden Gate

Standard Approach



Use Edition-based Redefinition

Alternative

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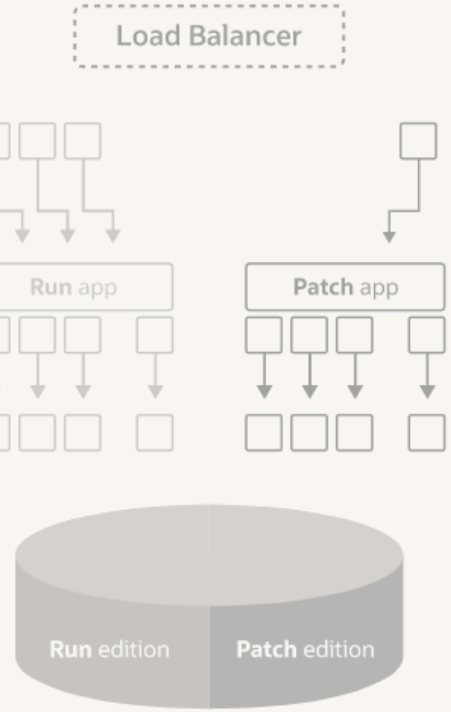
GoldenGate or Alternatively Edition-based Redefinition to Further Protect Your Applications

Use Oracle Golden Gate

Standard Approach



Use Edition-based Redefinition

Alternative

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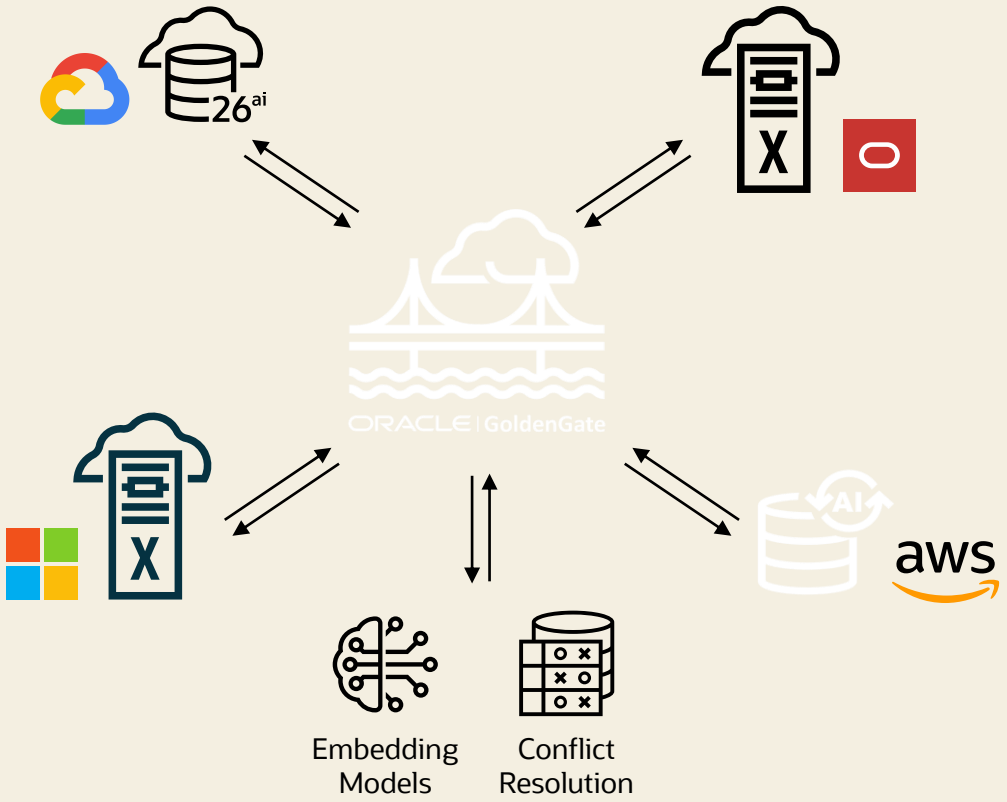
Oracle GoldenGate 26ai: enabling MAA Diamond with logical replication

Trusted Data. Lowest Latency. Any Distance.



Active-Active / Bi-Directional

- Highest Availability: recovery time objective (RTO) of 0-10 seconds, near-zero data loss
- Active-Active: all sites active at the same time, built-in conflict detection and resolution and support for blue-green deployment patterns
- All Oracle Databases: any version, any deployment, any infrastructure, no shard keys
- Real-world Performance:
  - >5TB of REDO/hr at large European bank
  - >1M TPS at global tech manufacturer
  - Sub-second replication at top 5 retailer
  - 16-way bi-directional at Canadian FSI

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Oracle GoldenGate Architecture

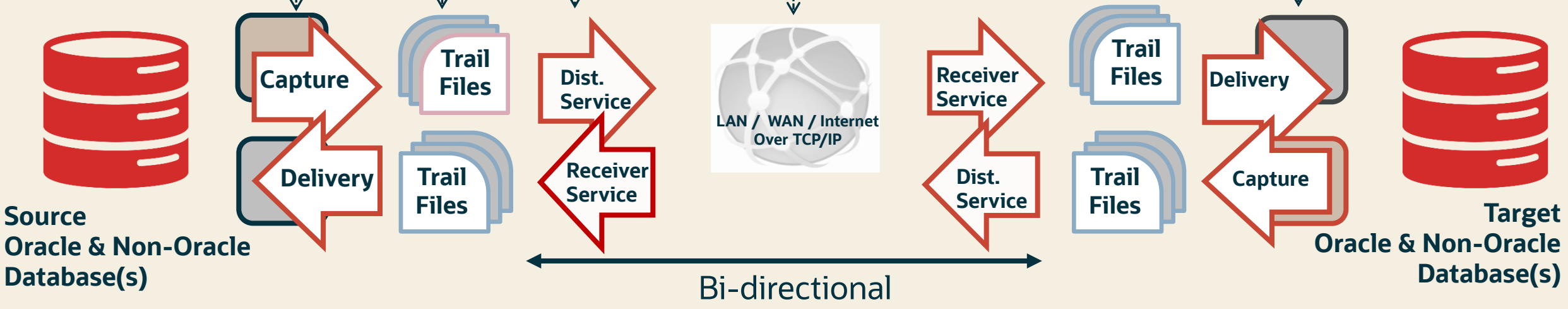
Capture: committed transactions are captured (and can be filtered) as they occur by reading the transaction logs.

Trail: stages and queues data for routing.

Distribution Server/Receiver: distributes data for routing to target(s).

Route: data is compressed, encrypted for routing to target(s).

Delivery: applies data with transaction integrity.



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Key GoldenGate Improvements Simplify Platinum

1. GoldenGate Hub simplifies migration and administration by offloading work from source and target
   - New GoldenGate cloud marketplace automates GG hub deployment
   - Cross endianness capture enables cross platform migration
   - Zero Downtime Migration integration with GoldenGate
2. GoldenGate Microservices simplifies administration and management

Zero Downtime Migration
www.oracle.com/goto/zdm

Resource Link: Oracle Database Migration with an Oracle GoldenGate Hub Configuration

Resource Link: Oracle Maximum Availability Architecture (MAA) GoldenGate Hub

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Oracle GoldenGate

MAA Best Practices

- Transparent Role Transitions in Data Guard Configurations
  - No manual intervention required with FSFO and DG Broker
- Configuration makes use of:
  - Oracle Grid Infrastructure Bundled Agent (XAG)
  - DBFS or ACFS for shared GoldenGate files (trails and checkpoint files)
  - Role based services
  - Integrated Extract (with HANDLEDLFAILOVER option for ASYNC DG)
  - Microservices Architecture for simpler administration

Resource Link: Transparent Role Transitions with Data Guard and Oracle GoldenGate

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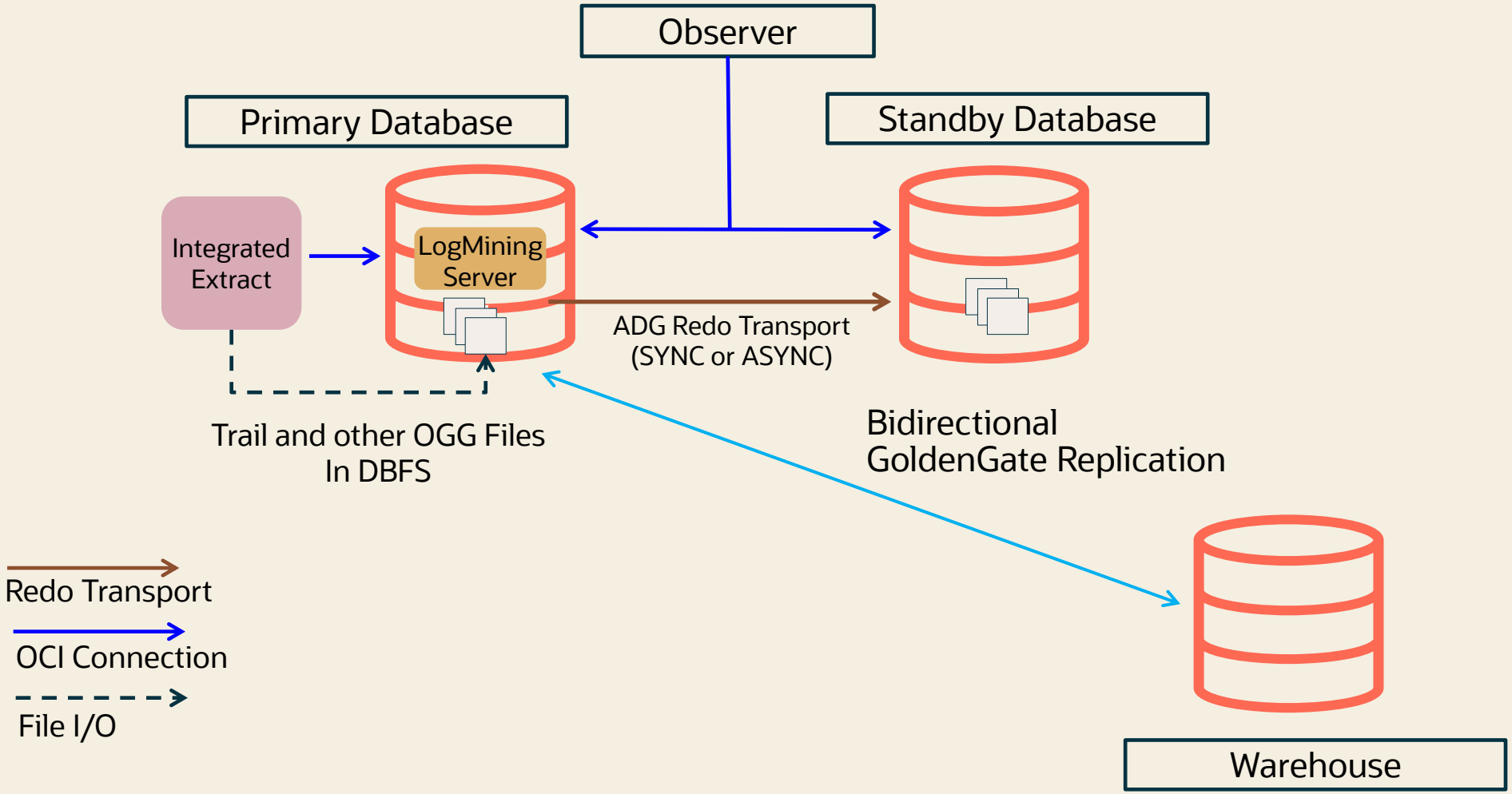
Sample GoldenGate MAA Deployment



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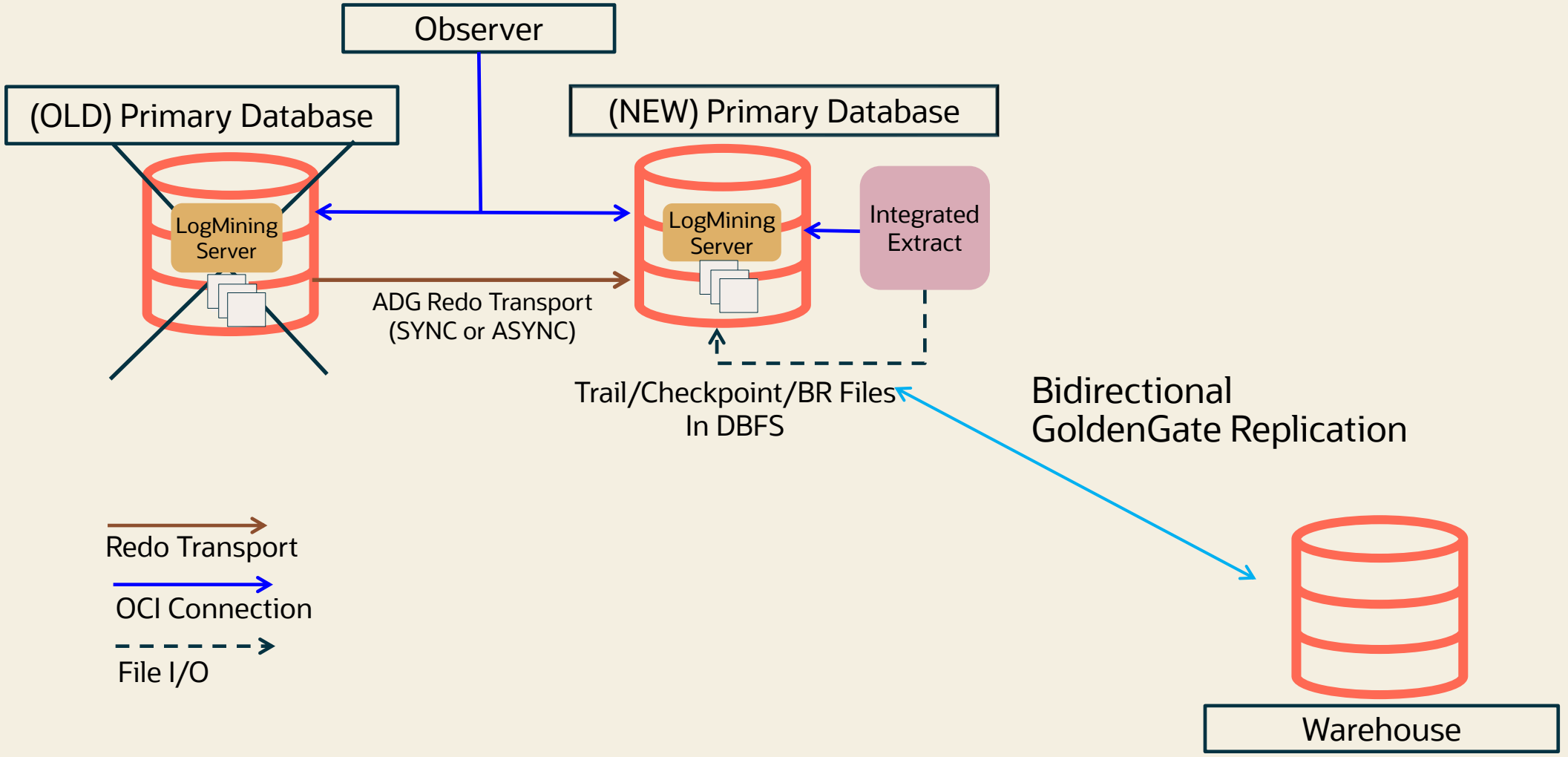
Sample GoldenGate MAA Deployment – Post Role Transition



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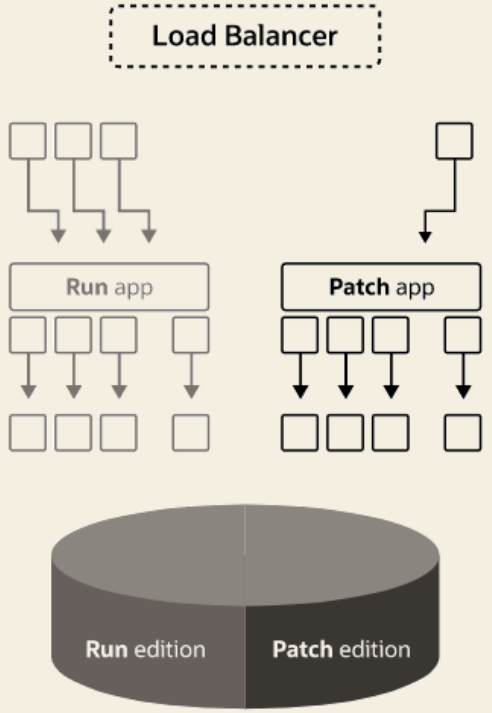
GoldenGate or Alternatively Edition-based Redefinition to Further Protect Your Applications

Use Oracle Golden Gate

Standard Approach



Use Edition-based Redefinition

Alternative

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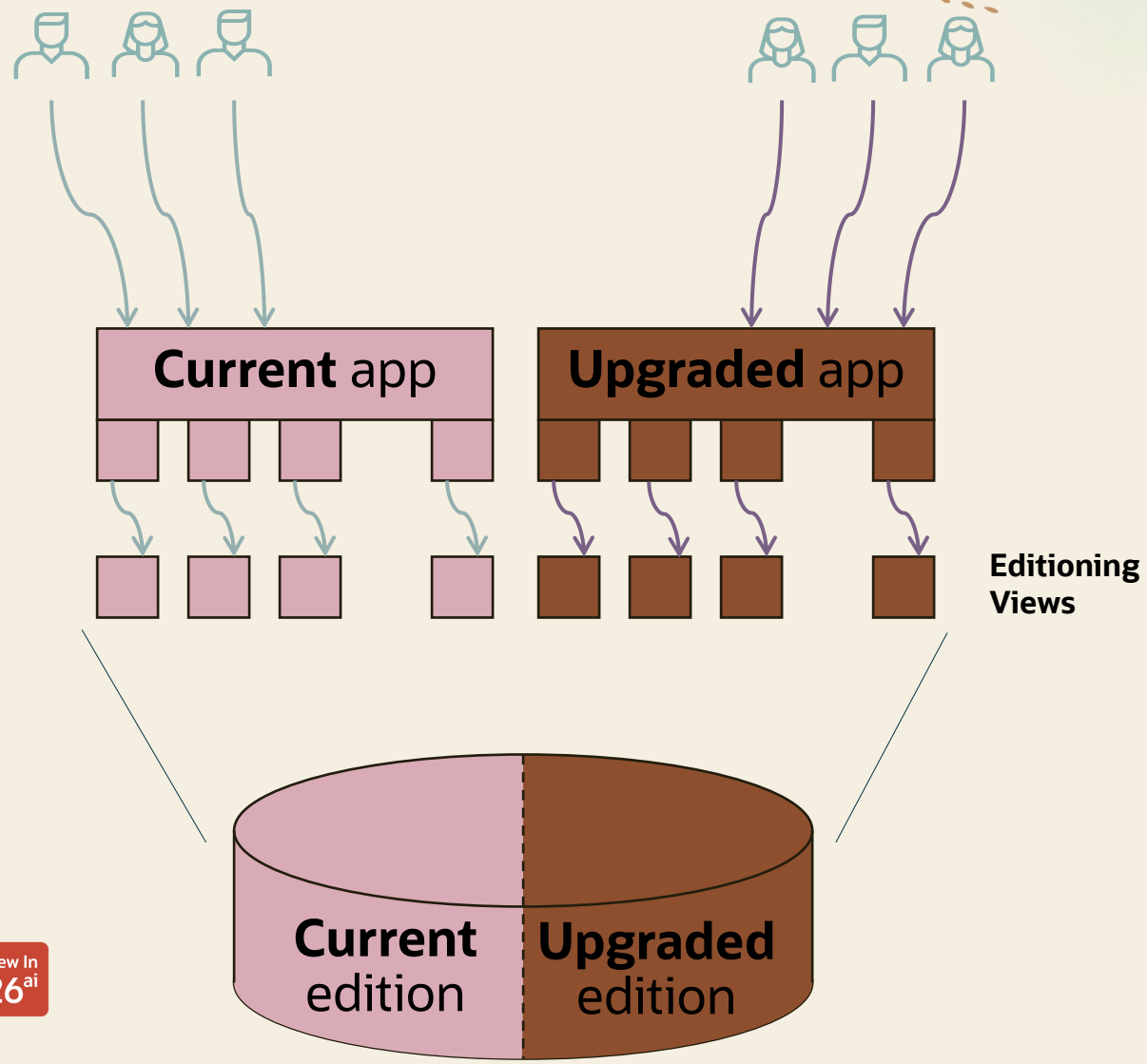
Edition-Based Redefinition

Online Application Upgrade

- Enables application upgrades to be performed online
- Code changes installed in the privacy of a new ***edition***
- Data changes are made safely by writing only to new columns or new tables not seen in the old edition
- An **editioning view** exposes a different projection of a table into each edition to allow each to see just its own columns
- A ***cross-edition trigger*** propagates data changes made by the old edition into the new edition's columns, or (in hot-rollover) vice-versa
- With Oracle AI Database 26ai, EBR is now compatible with Oracle GoldenGate thanks to supplemental logging enhancements

New In 26ai



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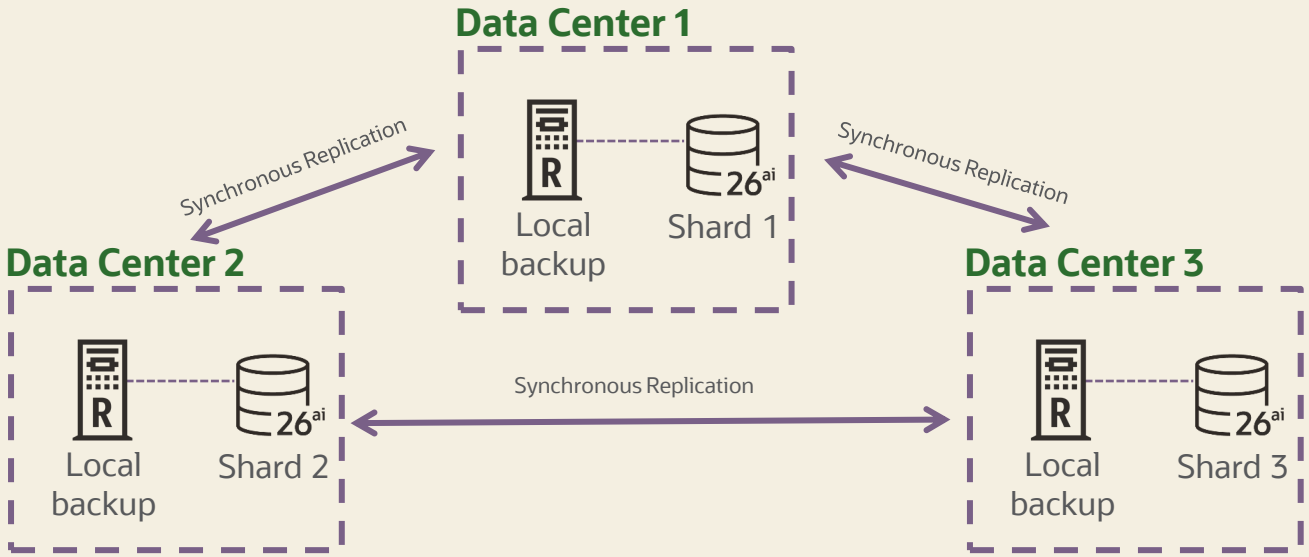
DIAMOND

Extreme Availability

- Oracle Globally Distributed AI Database with Raft (*Option 1*)
- GoldenGate 26ai Active/Active Replication (*Option 2*)
  - Oracle AI Database 26ai on Exadata
  - MAA GGHub with Automation
    - Deployment and configuration best practices
    - ACFS failover & switchover automation

Single Logical Globally Distributed AI Database with Raft Replication



Outage Matrix

Unplanned Outage	**RTO/RPO Service Level Objectives** (f1)
Recoverable node or instance failure	**< 3 secs**
Disasters including corruptions and site failures	**< 3 secs. RPO zero or seconds**
Planned Maintenance	
Most common software/hardware updates	Zero
Major database upgrade, **application upgrade**	**Zero**

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Global scale with Globally Distributed Database

Horizontal partitioning of data across independent databases (shards)

- Each shard holds a subset of the data
- Replicated for high availability

Shared-nothing architecture

- Shards don't share any hardware (CPU, memory, disk), or software (Clusterware)

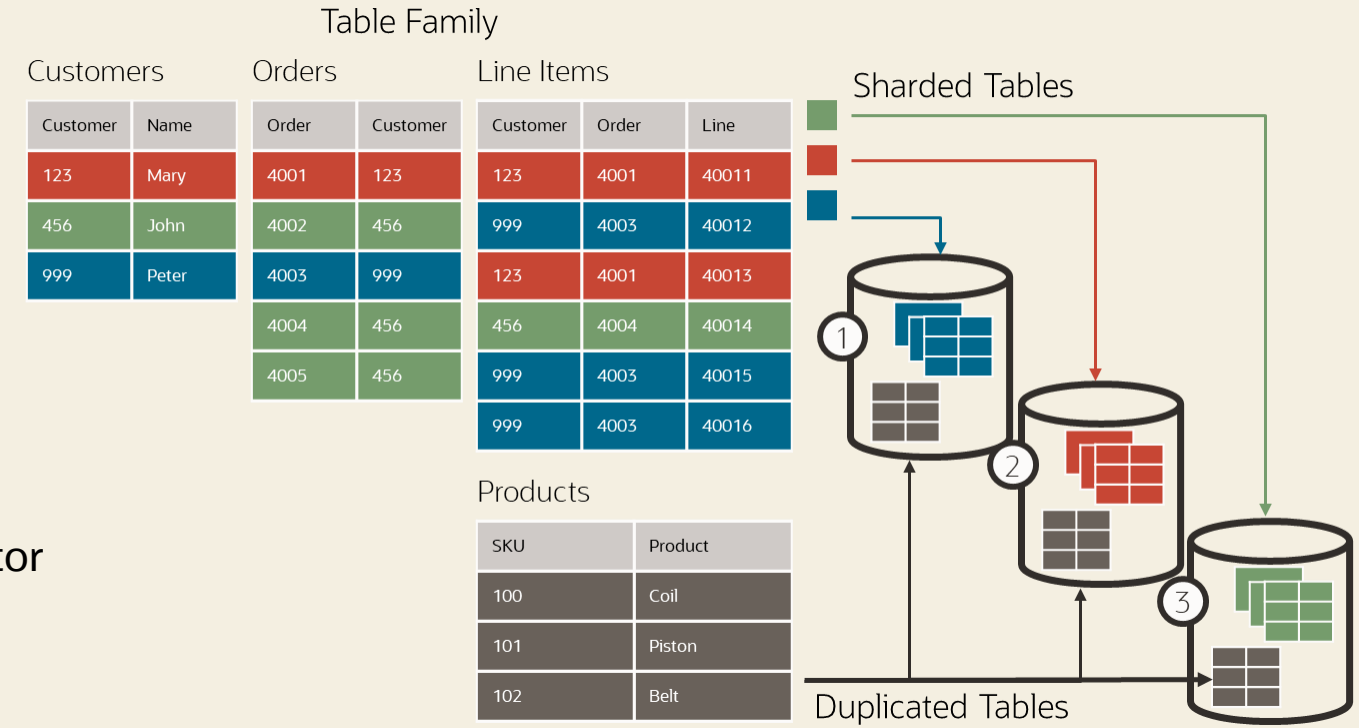
Massively Parallel Processing

- Application connects directly to a shard
- Multi-Shard queries go through the coordinator

Ideal for data sovereignty

- User-defined data placement for complying with regulatory requirements
- New in Oracle AI Database 26ai:
  - RAFT replication option for Globally Distributed Database

New In 26ai



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Active-active Globally Distributed Database

Raft Replication

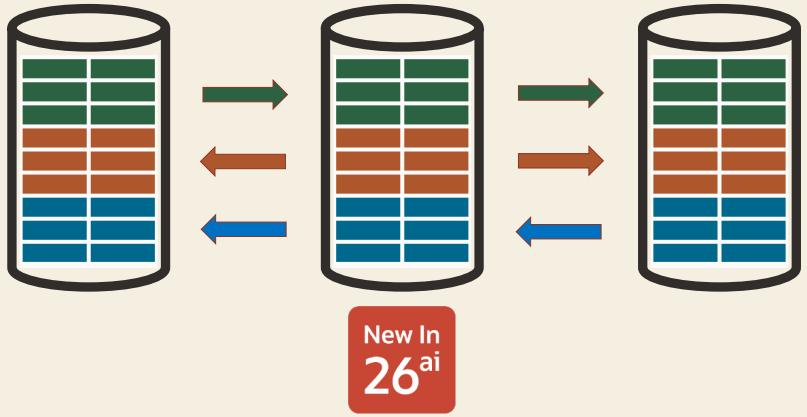
Built-in replication, integrated with transaction execution

Fast and automatic sub-3-second failover with zero data loss

Active-active, symmetric configuration

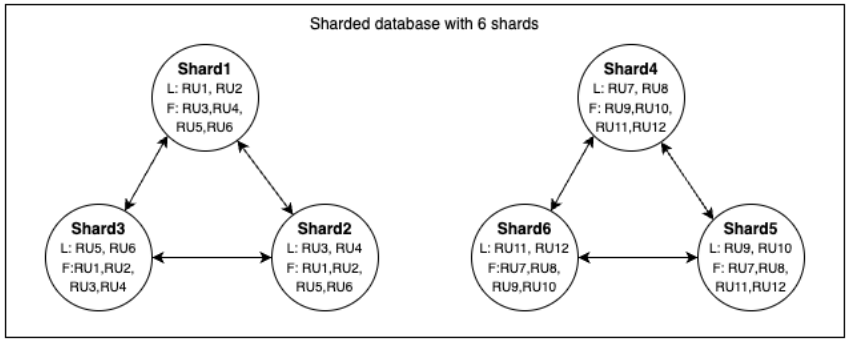
- Each shard accepts writes and reads for a subset of data

Easy: no need to configure Data Guard or GoldenGate for shards



Globally Distributed Database is divided into multiple replication units

- Replication unit replicas are spread evenly across 3 (or more) shards
- Each shard is both a primary (leader) for some replication units and a follower (replica) for other replication units



Builds on popular Raft distributed consensus protocol

- Guarantees consistency among replicas in case of failures, network partition, message loss, or delay
- Automatic reconfiguration after failure, or when the number of shards changes

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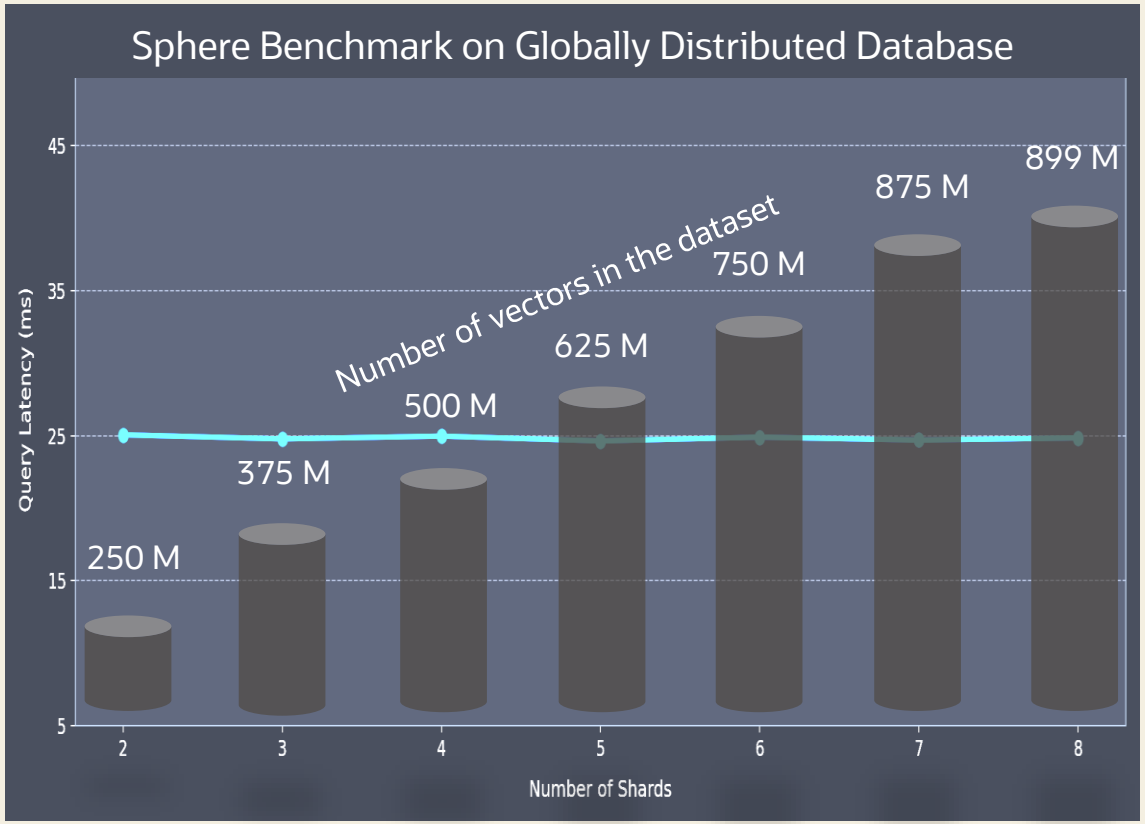
Globally Distributed Database: Built for the Demands of AI Workloads

- Built for AI-scale data
  - Supports petabyte-scale vector datasets while maintaining low search latency
- Performance stays stable as the system grows
  - When scaling from 2 to 8 shards, query latency remains almost unchanged (~24.6 ms → ~25.0 ms)
- Predictable response times
  - Applications experience consistent performance even as the system expands, seeing a total variation of only 0.42 ms

Horizontally scale AI vector search workloads



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Diamond MAA Tier with Oracle GoldenGate

Bringing it all together by building on the previous MAA tiers

- Maximizing uptime and data protection simultaneously for both planned maintenance and unexpected outages
  - Oracle GoldenGate 26ai is required to provide an active-active platform for HA, where a simple load balancer switch allows administrators to switch workloads.
  - Oracle Active Data Guard in Oracle AI Database 26ai is providing data protection simultaneously to both primary databases, either with local or remote standby databases, depending on the data center configuration
  - Oracle Real Application Clusters provides the high availability foundation with Oracle Exadata, providing the infrastructure that maximizes the highest application availability, data protection, quality of service, and stability.
  - MAA GoldenGate Hub provides deployment and life cycle automation to ensure best practices are incorporated for streamlined replication and failover, and HA and DR for the GoldenGate Hub

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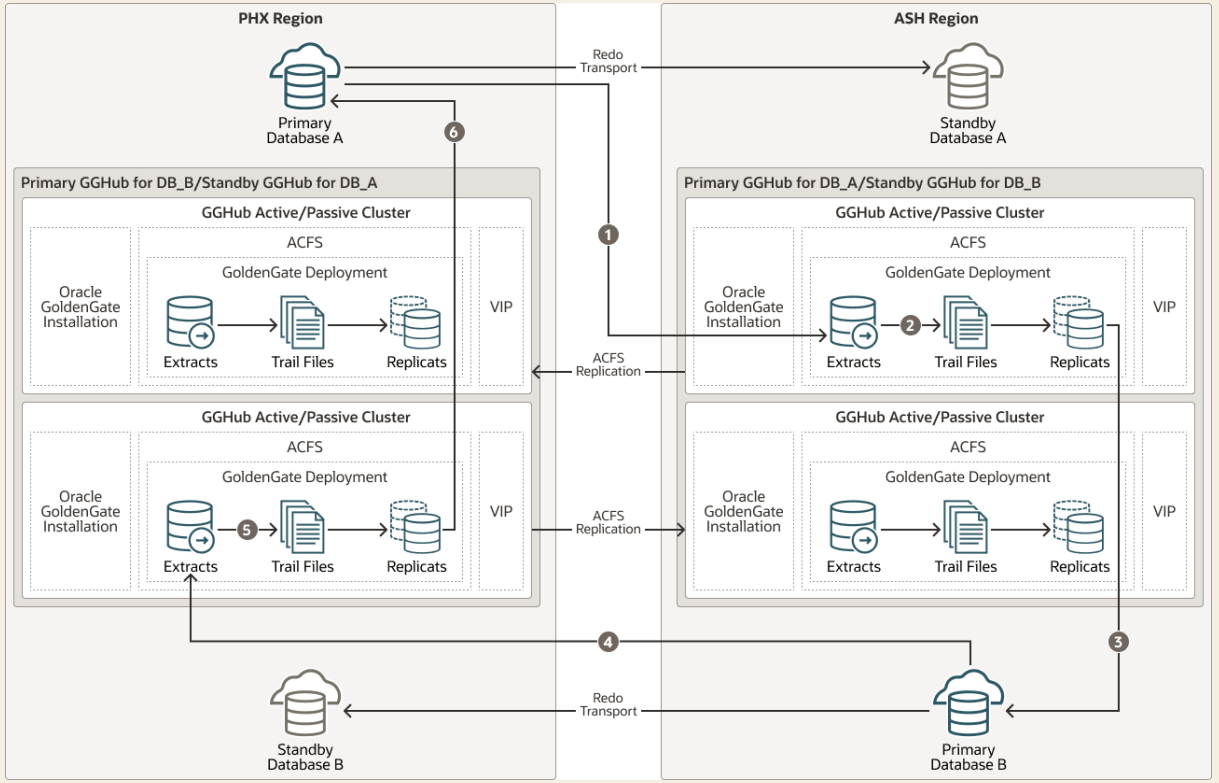
Diamond MAA: Redundancy Throughout the Architecture

Extreme Availability Goal: Provides near-zero downtime and near-zero data loss

- **Core Components**: Architecture relies on Oracle Active Data Guard with Fast-Start Failover (FSFO) for database redundancy and MAA OGG Hub for data replication.
- **Cross-Region Placement**: The primary/active OGG Hub is co-located in the same OCI region as its target database to ensure optimal Replicat performance (≤4 ms latency).
- **Zero Data Loss**: Achieved by configuring Data Guard with SYNC redo transport and GoldenGate resynchronization after any Data Guard failover.
- **GGHub High Availability**: Both the Primary and Standby GGHubs are configured as Active/Passive clusters, using ACFS replication to preserve all GoldenGate trail files and metadata between regions.



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MAA in the Cloud

Maximum Availability Architecture

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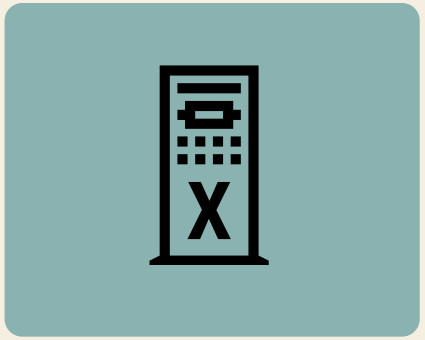
Unique: Consistent Database Experience Across Deployments



Exadata Database Machine
(on-premises)

Exadata Cloud@Customer
(hybrid cloud)

Exadata Cloud Infrastructure
(Oracle public cloud)

Same Oracle Database | 100% compatible | No app changes | Zero downtime migration

Oracle AI Database@Azure
(multicloud)

Oracle AI Database@Google Cloud
(multicloud)

Oracle AI Database@AWS
(multicloud)

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It's Official - Oracle MAA Platinum for all Oracle AI Database@Hyperscalers

Exadata Database Service on Dedicated Infrastructure and Autonomous Database

Oracle AI Database@Azure

- ✓ MAA Silver
- ✓ MAA Gold cross-regions
- ✓ MAA Gold cross-zones
- ✓ MAA Platinum (Active Data Guard 26ai)

Oracle AI Database@Google Cloud

- ✓ MAA Silver
- ✓ MAA Gold cross-regions
- ✓ MAA Gold cross-zones
- ✓ MAA Platinum (Active Data Guard 26ai)

Oracle AI Database@AWS

- ✓ MAA Silver
- ✓ MAA Gold cross-regions
- ✓ MAA Gold cross-zones
- ✓ MAA Platinum (Active Data Guard 26ai)

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Multiple Standby Databases in Exadata Database Service

Up to 6 standby databases can now be managed by the OCI control plane

By taking advantage of multiple standbys in different regions, applications can immediately benefit from improved data protection, increased flexibility and scalability, and better ROI

Using the new Data Guard Group feature, multiple standby databases can be easily deployed and managed via the OCI console feature

Data Guard group

Add standby

Member	VM Cluster	Role	Region	Protection mode	Transport type	Apply lag	Transport lag	Lag as of	Data Guard type
DB1200	VMCluster-A	Primary	US East (Ashburn)	Maximum Availability	Async	—	—	—	Data Guard
DB1200	VMCluster-B	Standby	US East (Ashburn)	Maximum Availability	Sync	0 seconds	0 seconds	Mon, Dec 16, 2024, 15:57:46 UTC	Data Guard
DB1200	VMCluster-202404251654	Standby	US East (Ashburn)	Maximum Availability	Async	0 seconds	0 seconds	Mon, Dec 16, 2024, 15:58:01 UTC	Active Data Guard
DB1200	CGBCK	Standby	US East (Ashburn)	Maximum Availability	Async	0 seconds	0 seconds	Mon, Dec 16, 2024, 15:58:07 UTC	Active Data Guard
DB1200	VMCluster-202411184690	Standby	US East (Ashburn)	Maximum Availability	Async	0 seconds	0 seconds	Mon, Dec 16, 2024, 15:58:12 UTC	Active Data Guard
DB1200	VMCluster-202411184300	Standby	US West (Phoenix)	Maximum Availability	Async	0 seconds	0 seconds	Mon, Dec 16, 2024, 15:58:18 UTC	Active Data Guard
DB1200	VMCluster-202411184311	Standby	US West (Phoenix)	Maximum Availability	Async	0 seconds	0 seconds	Mon, Dec 16, 2024, 15:58:23 UTC	Active Data Guard

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Eliminates Site Downtime

Oracle Autonomous Data Guard

Maintains a real-time remote copy of a production database

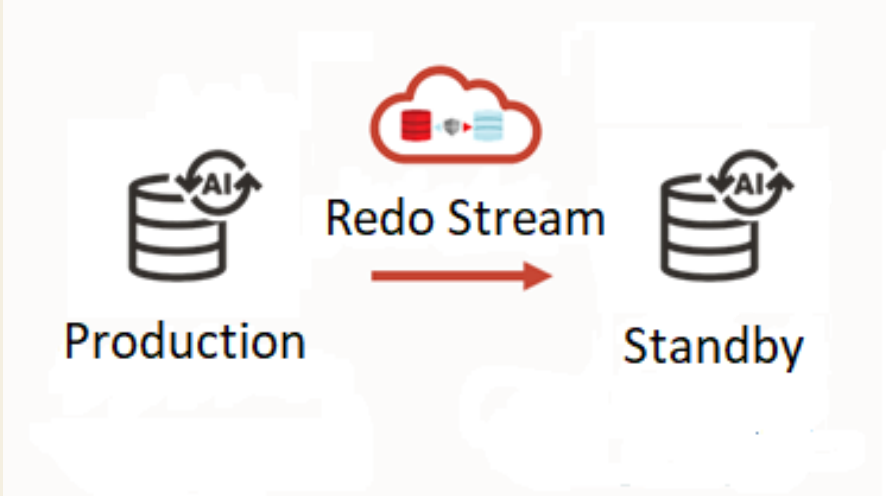
- Protects from physical disasters, network outages
- Can automatically switch from primary to remote copy

Maintains copy by applying physiological changes

- Protects against database corruption
- Validates data consistency as changes are applied

Fully Autonomous – Automates Everything

- Creation, operation, patching, and backup
- Database and Data Guard management



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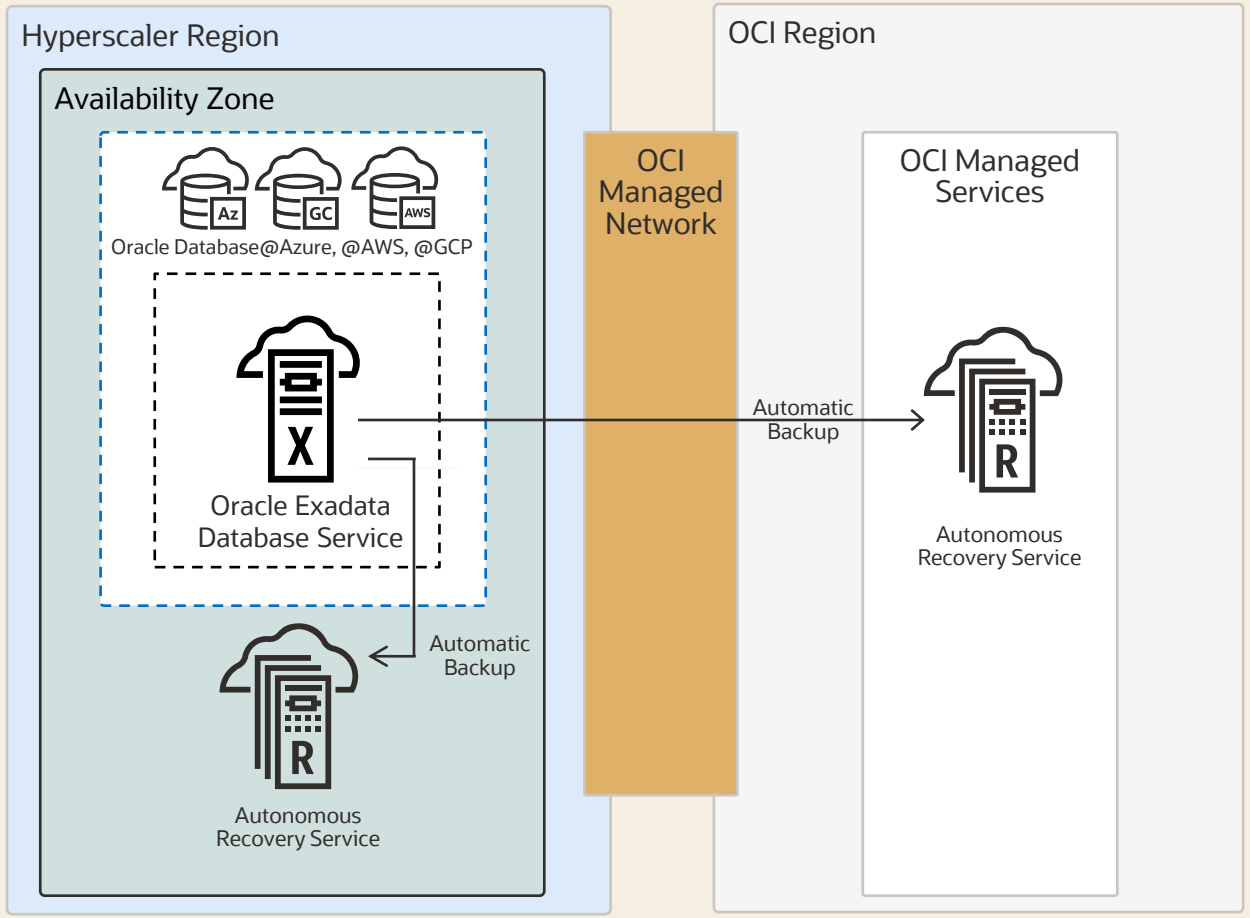
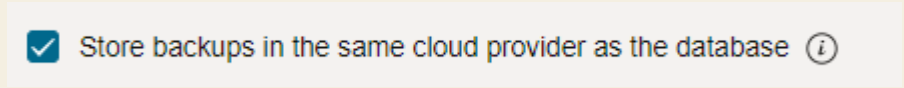
Exadata Database Service@Hyperscaler | MAA Silver Level

High Availability and Data Protection Built-in by Default



- ✓ Oracle Exadata and Oracle RAC
  - ✓ Agility to scale storage, compute, and memory without downtime
  - ✓ Node failure protection
  - ✓ Zero downtime software maintenance
- ✓ Zero Data Loss Autonomous Recovery Service
  - ✓ Available in OCI and in multicloud hyperscaler
  - ✓ One click to choose the backup destination



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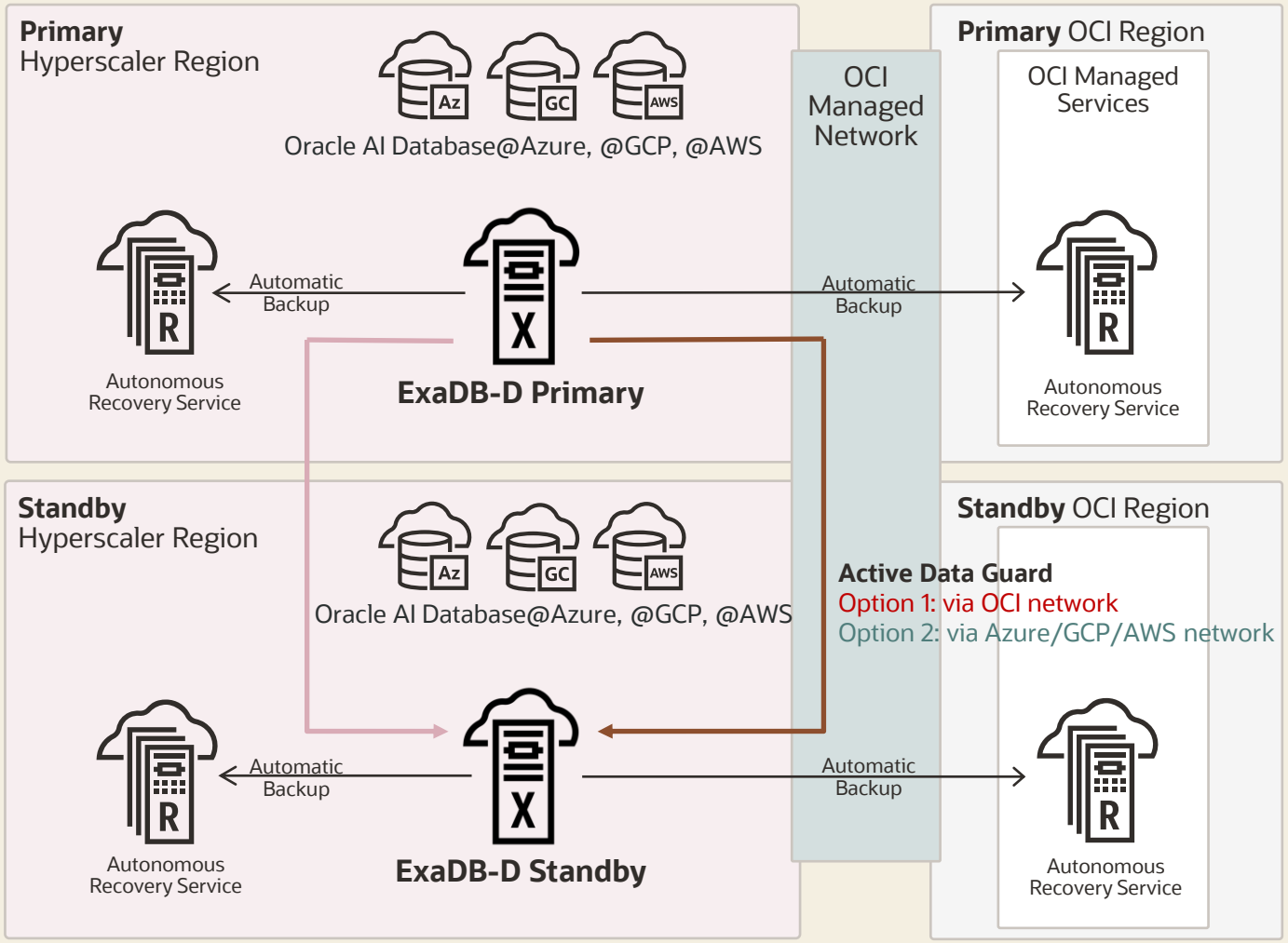
Exadata Database Service | MAA Platinum Level - Cross-regions

Mission-Critical Deployments with Disaster Recovery



MAA Silver Level +

- ✓ Fully Automated Oracle Active Data Guard setup
  - ✓ **Regional disaster recovery protection with *Oracle AI Database 26ai***
  - ✓ Comprehensive data corruption prevention
  - ✓ Defense from ransomware attacks
  - ✓ Online upgrades and migrations
  - ✓ Offload backup and workload to the standby with read-mostly scale-out
  - ✓ Network traffic through OCI network (**recommended**) or Azure/GCP/AWS Network

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OCI Full Stack Disaster Recovery

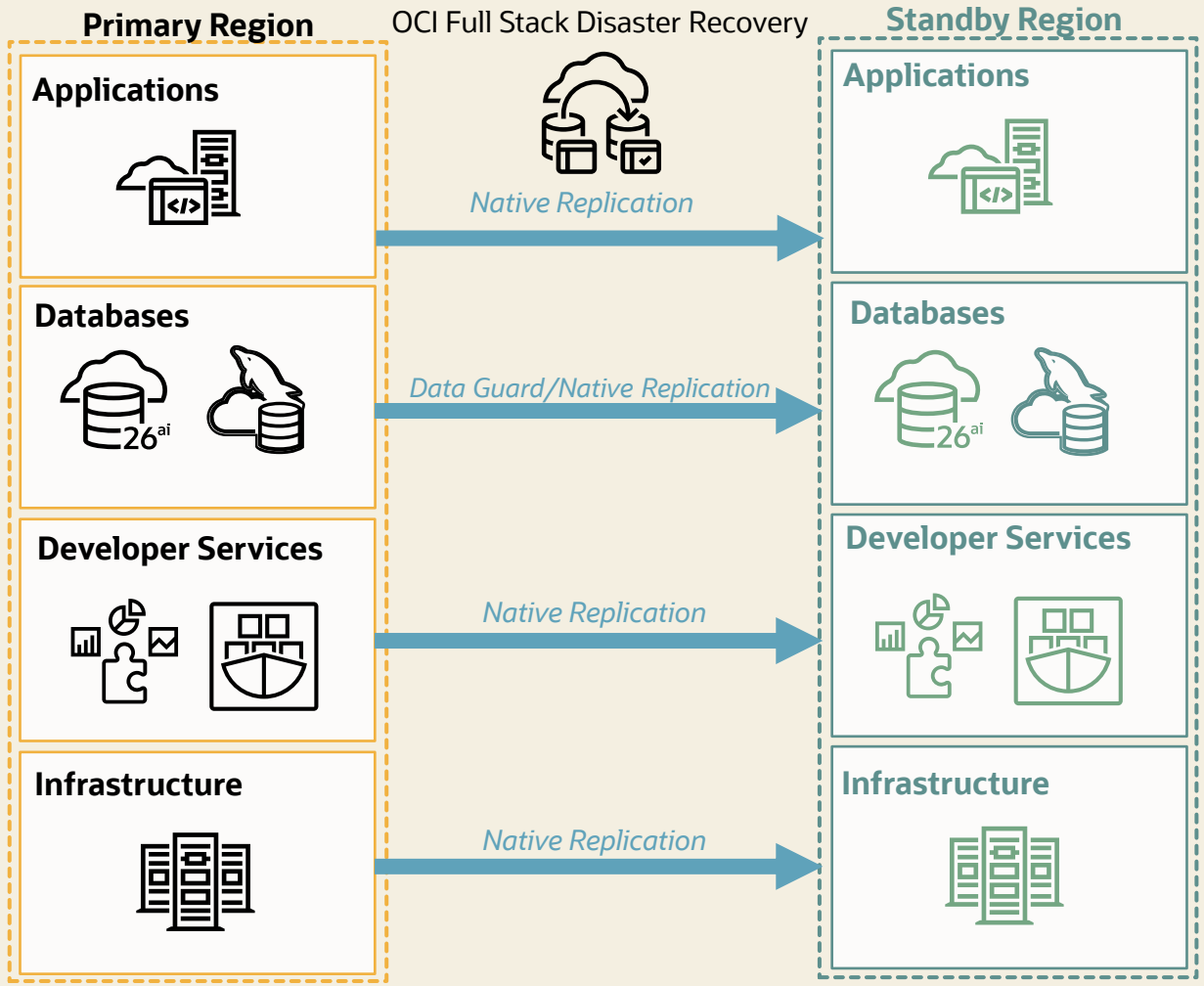
Recovery orchestration across your entire OCI stack — end to end, service by service

Why OCI Full Stack Disaster Recovery?

- Traditional DR tools protect only one layer, never the full stack
- Manual recovery is slow, error-prone, and outdated the moment it's written

What OCI Full Stack Disaster Recovery Does

- Orchestrates recovery across your entire stack in the correct dependency order, automatically
- Three modes: Switchover (planned), Failover (outages), DR Drill (zero-impact testing)
- 15+ OCI services covered out-of-the-box, extensible for any custom workload



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Zero Data Loss Autonomous Recovery Service (ZRCV)

Intelligent data protection for Oracle AI Databases in OCI, Multicloud, & On-premises

Zero Data Loss Recovery

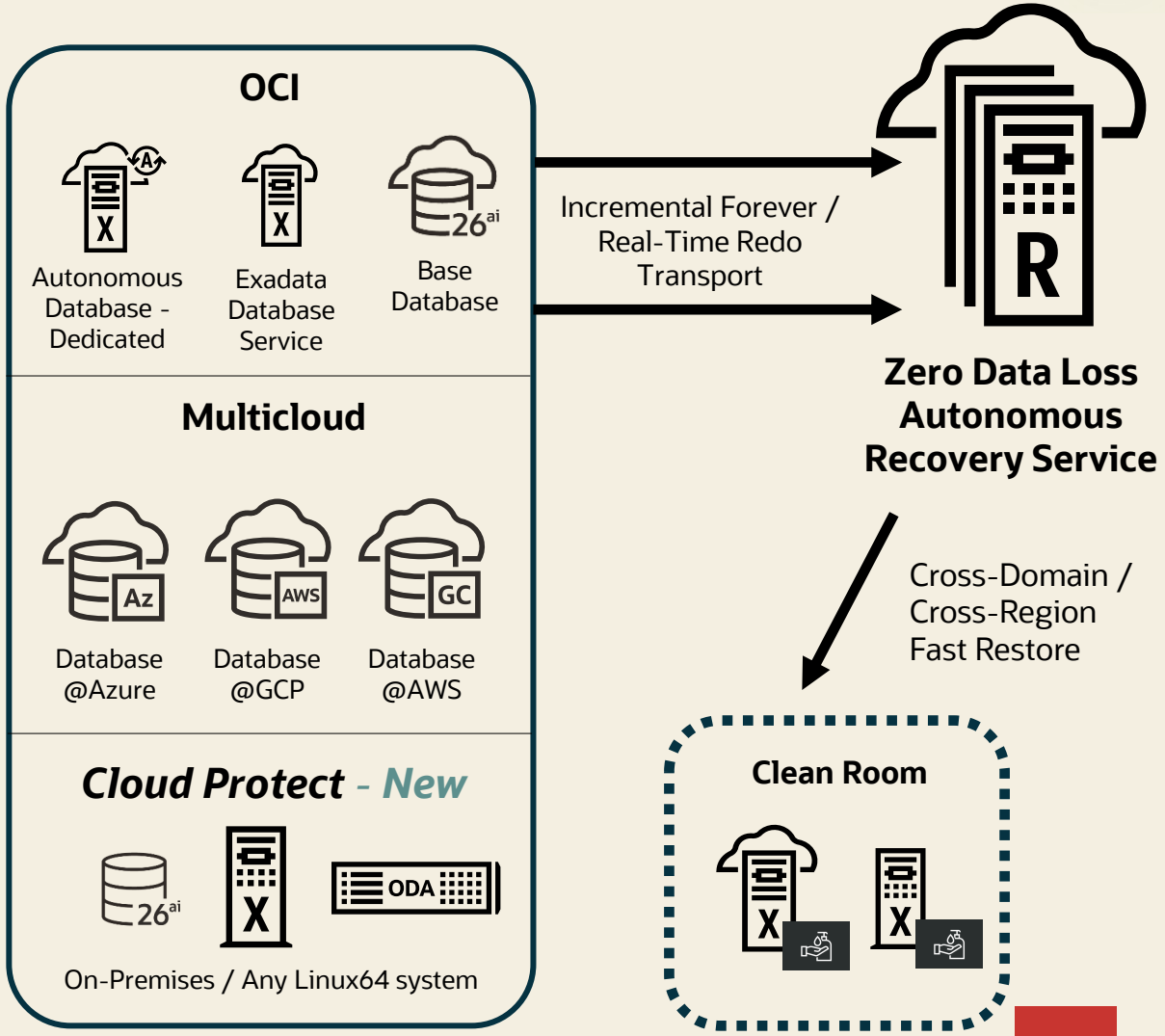
- Real-time transaction protection
- Continuous recovery validation

Fast, Low-Impact Backup and Recovery

- Space-efficient incremental forever
- One-step recovery without needing incremental apply

Database-aware Ransomware Resiliency

- Immutable backups with retention lock
- Separation of duties and granular access control
- Logical airgap between the customer and Oracle Cloud Operations tenancies
- Cross-domain and cross-region clean room support



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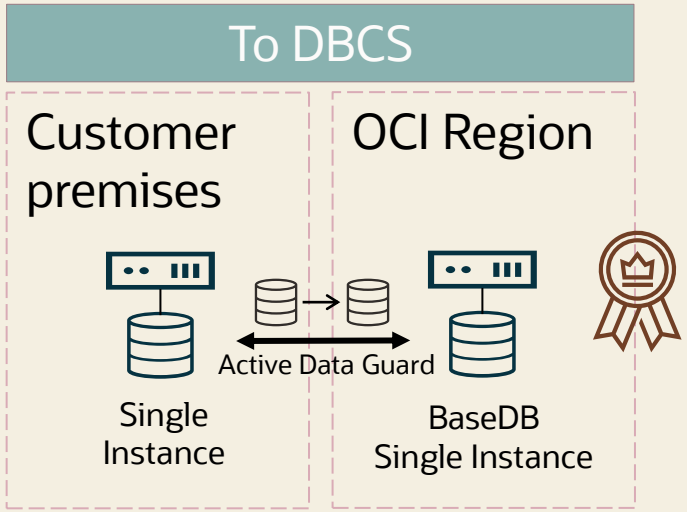
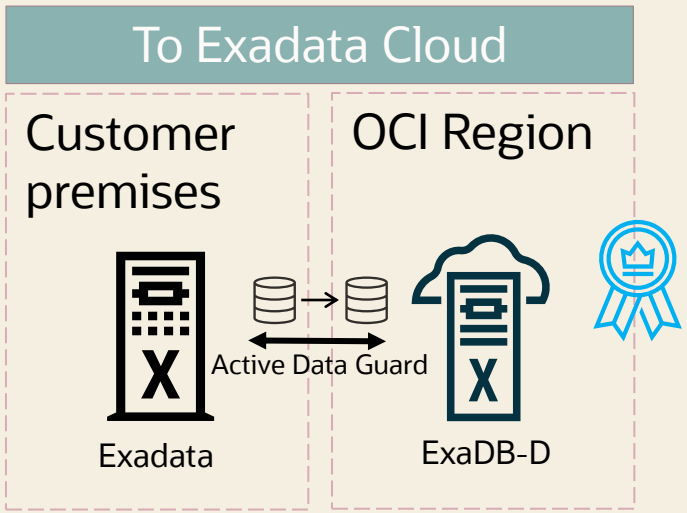
Hybrid Cloud: Recommended Hybrid Sources/Destinations

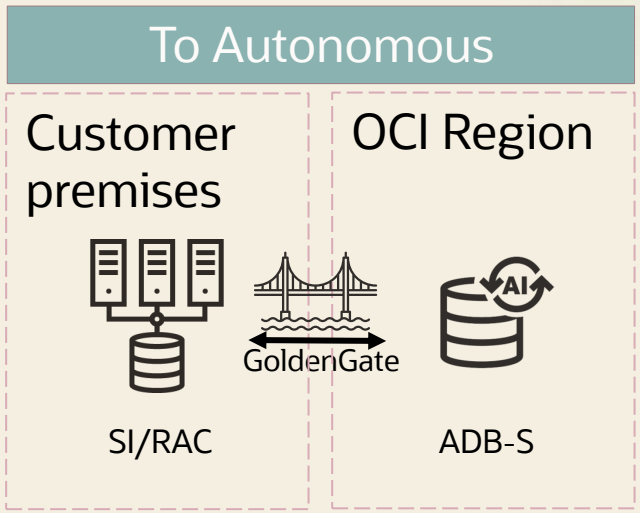
To DBCS



To Exadata Cloud



To Autonomous



- All Hybrid configurations are achieved manually: no Control Plane automation
- On-premises non-Exadata to ExaDB-C@C/ExaDB-D is possible, but beware of exclusive features

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Key Takeaways

Oracle AI Database High Availability and Disaster Recovery technology provides:

- MAA reliability that has evolved over 20 years, deployed by thousands of customers
- Flexible high availability and disaster recovery for the application with no modification
- Zero data loss is an option regardless of distance
- Rolling patching provides zero downtime during the most common planned maintenance operations
- On-demand, reliable, and fully elastic

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External Resources

Maximum Availability Architecture

- MAA Home:
  - http://oracle.com/goto/maa
- On-Premises MAA:
  - https://www.oracle.com/database/technologies/high-availability/oracle-database-maa-best-practices.html
- Exadata MAA:
  - https://www.oracle.com/database/technologies/high-availability/exadata-maa-best-practices.html
- Cloud MAA:
  - https://www.oracle.com/database/technologies/high-availability/oracle-cloud-maa.html

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