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Autonomous Database on Dedicated Exadata Infrastructure

Oracle Autonomous Database uniquely combines automation, machine learning, and cloud agility to deliver the world's first autonomous cloud database management system.

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Autonomous Database foundation

Exadata hardware

Infrastructure comes in different shapes to support workloads of various sizes: traditional quarter, half, and full rack shapes on X7-2 and X8-2 and elastic provisioning in X8M and X9M (public cloud) that range from a quarter rack (2 database and 3 storage servers) up to 32 database and 64 storage servers. These configurations can meet unique CPU processing and database storage requirements. Online scaling of OCPU resources is available so that when combined with cloud-based subscription billing, customers can pay only for the OCPUs that they use, dramatically reducing costs compared to traditionally purchased platforms. All shapes are built on powerful database servers, scale-out intelligent storage servers, Persistent Memory (PMEM), PCI NVMe flash, and high-capacity disk drives. A low-latency cluster network fabric enables internal connectivity between database and storage servers. External connectivity is provided using either standard copper or fiber Ethernet ports.

The database-optimized data tiering between RAM, PMEM, flash, and disk implemented in Exadata provides lower latency, higher capacity, and faster performance than other flash-or PMEM-based solutions. Flash and PMEM storage arrays cannot match the throughput of Exadata's integrated and optimized architecture with full high-speed persistent memory, PCI NVMe flash, offload of data-intensive operations to storage, and algorithms that are specifically optimized for databases.

Exadata compute

- Latest Intel and AMD Processors
- Up to 4,032 Database Server Cores
- Up to 44 TB of DDR4 DRAM

Exadata storage

- Up to 3.1 PB Database Size (Triple-mirrored, Without Compression)
- Up to 1.6 PB PCI NVMe Flash
- Up to 96 TB Persistent Memory
- Latest Intel Processors
- Up to 3,072 Storage Server Cores

Fastest networking

- 40-100 Gbps Cluster Networking
- Up to 50 Gbps Ethernet

Exadata software

The technology that enables Exadata's unparalleled performance without any of the bottlenecks of traditional storage arrays is Exadata System software. This software powers the Exadata Storage Servers, providing an extremely efficient database-optimized storage infrastructure.

One of the many unique features of Exadata System software is Smart Scan technology, which minimizes data movement by offloading data-intensive SQL operations from the database servers directly into the storage servers. By pushing SQL processing to the storage servers, data filtering and processing occur immediately and in parallel across all storage servers, as data is read from disk and flash. Only the rows and columns directly relevant to a query are sent to the database servers. This greatly accelerates analytic queries, eliminates bottlenecks, and significantly reduces the CPU usage of the database servers. Exadata includes a vast array of software capabilities that enable unparalleled scalability, performance, and availability. Some of these Exadata software features are:

- Storage Indexes avoid unnecessary I/O operations by replacing them with a few in memory lookups.
- Exhaustion Direct-to-Wire Protocol allows database processes to read and send Oracle RAC messages directly over the high-speed cluster network, improving OLTP response time and scalability in Exadata.
- Smart Fusion Block Transfer improves OLTP performance further by eliminating the impact of redo log write latency when moving blocks between nodes.
- Shared Persistent Memory Accelerator uses RDMA to read data from persistent memory with unprecedented low latency

Exadata software

All Exadata Software features, such as:

- Smart Scan
- Storage Indexes
- Data Mining Offload
- Hybrid Columnar Compression
- Smart Flash Cache
- Smart Flash Logging
- In-Memory Fault Tolerance
- I/O Resource Management
- Network Resource Management
- Instant Failure Detection
- Sub-sec I/O Latency Capping
- Columnar Flash Cache
- JSON/XML Smart Scan
- Direct-to-Wire OLTP protocol
- Test/Dev Cloning
- Fastest RAC Node Failure Recovery
- Fastest Data Guard Redo Apply
- Fastest Backup using Offload to Storage

- Persistent Memory Commit Accelerator uses RDMA to write commit records to persistent memory providing 8x faster log writes
- Smart Flash Logging accelerates OLTP by using the flash memory in Exadata storage combined with the high-speed RAM in the Exadata disk controllers to reduce the average latency of database commits.
- Hybrid Columnar Compression utilizes a combination of row and columnar methods to significantly compress data, enabling tremendous cost-savings and performance improvements due to reduced storage capacity and reduced I/O, especially for analytic workloads.
- In-Memory columnar formats in Flash Cache extend the Exadata Columnar Flash Cache by automatically transforming data into In-Memory columnar structures as it's loaded into flash cache. Smart Scans then leverage ultra-fast Single Instruction Multiple Data (SIMD) Vector instructions, thus processing multiple column values with a single instruction.

Exadata is engineered to provide the highest levels of availability. Each Exadata system has completely redundant hardware components and is pre-integrated with Oracle Maximum Availability Architecture (MAA) best practices for Database High Availability (HA) technologies such as RAC, ASM, RMAN, Flashback, and Data Guard. Further, Exadata-specific HA capabilities such as Instant Detection of Compute and Storage Server Failures and Exadata I/O Latency Capping significantly enhance the availability of Exadata. One single rack can be used to deploy a large number of databases, enabling high database consolidation. Exadata provides unique end-to-end prioritization and resource management capabilities spanning database servers, networking, and storage to ensure consistent performance in a highly consolidated environment.

Autonomous Database service overview

Oracle Autonomous Database

The Oracle Autonomous Database is a Cloud Database Management System for organizations that require enterprise-grade Oracle Database support and desire the administrative simplicity and automation of cloud services.

Autonomous Database uses machine learning and automation to eliminate human labor, human error, and manual tuning, thereby reducing cost and complexity while ensuring higher reliability, security, and operational efficiency. Built on Oracle's Exadata Database Machine, Autonomous Database delivers the highest performance and cost-effective operation customers require for their most demanding and mission-critical applications.

The underlying converged database capabilities of the Oracle Database enable the Autonomous Database to be offered with default configurations that are optimized for common workloads, including transaction processing or JSON document management, and data warehousing. Autonomous Transaction Processing (ATP) is tailored to online transaction processing, JSON document management, batch, reporting, IoT, machine learning, and mixed workload applications. Autonomous Database when used for JSON document storage and retrieval comes with a developer-oriented simple document access API (SODA) and works seamlessly with Oracle SQL data tables. Autonomous Data Warehouse (ADW) is tailored to data warehousing, data marts, data lakes, and machine learning workloads.

Dedicated Exadata Infrastructure

Autonomous key benefits

- Most powerful Oracle Database
- All Exadata capabilities, ensuring extremely high levels of performance, availability, and security
- Easy and rapid Infrastructure and database provisioning in a few clicks or an API call.
- Lower total cost of ownership from pay-per-use, elimination of manual labor
- Lower risk thru automated security updates and no human error
- Increased pace of innovation thru skilled DBAs focusing on business change instead of administration
- Win-win for IT and Development. IT governance and best practices with self-service agility for developers

Autonomous key features

Autonomous Database supports two Exadata deployment choices, shared and dedicated. In a shared environment, multiple customers may share the resources of a single Exadata infrastructure; the focus is on simplicity and elasticity with a standardized configuration and lifecycle. In a dedicated environment, the Exadata infrastructure is wholly dedicated to the subscribing customer, isolated from other cloud tenants, with no shared processor, storage, and memory resource.

Autonomous Database on Dedicated Exadata Infrastructure provides customers governance controls and automated best practices for the overall health, availability, and cost management of Autonomous Database. Customers can customize operational policies to meet their corporate governance requirements and use a clean separation of roles between fleet administrators who setup operating environments and database consumers (developers and application DBAs) who self-service Autonomous Database in their assigned environments. Autonomous Database on Dedicated Exadata Infrastructure provides customers with a simple, complete, and private Database as a Service to enable developers of new database applications.

- Self-service database cloud running on dedicated Exadata infrastructure
- Dynamic online auto-scaling of CPU triggered by real-time workload
- Online scaling of storage
- Customizable operational policies supporting mission-critical requirements
- Multi-level workload isolation
- Managed backup and recovery
- Deploy anywhere, public cloud or on-premises
- Autonomous configuration management
- Autonomous performance management with real-time stats capture and auto-indexing
- Secure, external encryption key management

Subscription overview

Autonomous Database on Dedicated Exadata Infrastructure is available through two flexible subscription offerings:

- License Included
- Bring Your Own License (BYOL)

License included

This subscription model includes all the features of Oracle Database Enterprise Edition, plus all the Oracle Database Enterprise Manager Packs and all Database Enterprise Edition Options. These industry-leading capabilities include Database In-Memory, Real Application Clusters (RAC), Automatic Storage Management (ASM). Active Data Guard, Partitioning, Advanced Compression, Advanced Security, Label Security, Database Vault, Real Application Testing, OLAP, Advanced Analytics, and Spatial and Graph. Also included in an Autonomous Database Dedicated PaaS subscription is Oracle Multitenant, enabling high consolidation density, rapid provisioning, and cloning. This subscription model is ideal for customers without existing Oracle database licenses, customers seeking to use Oracle database features beyond those currently licensed, and customers with variable workloads who can reduce their costs by paying for only what they use.

Bring your own license (BYOL)

Autonomous Database on Dedicated Exadata Infrastructure Bring Your Own License (BYOL) is designed to minimize costs when migrating to the cloud. In a BYOL model, customers can deploy their existing Oracle Database and Database Option licenses. When a customer brings an Oracle Database license entitlement, they are additionally granted the rights to use Oracle Transparent Data Encryption (TDE), Diagnostics Pack, Tuning Pack, Data Masking and Subsetting Pack, and Real Application Testing without having on-premises license entitlements for those Database Options. The Exadata System software is also included in a BYOL subscription, so BYOL customers do not have to bring a license entitlement for the Exadata System Software. Users of BYOL are required to have Oracle Database Enterprise Edition licenses and the Real Application Cluster (RAC) Option if any given database will be larger than 16 OCPUs; they must also have Oracle Active Data Guard if Autonomous Data Guard will be used.

Oracle Cloud controls and customization

Oracle Cloud Control Plane

Customers perform life cycle operations for autonomous databases running on Exadata Infrastructure using an Oracle Cloud Control Plane. It is a sophisticated software suite that runs in the Oracle Public Cloud. Customers can connect to the Cloud Control Plane using a web browser, command-line interface (CLI), or REST APIs. Autonomous Database life

cycle operations such as create, delete, clone, backup, restore, audit, and OCPU scaling are examples of operations customers can perform using the Cloud Control Plane. Another key function of the Control Plane is to track a customer's usage and bill only for what they use.

The Cloud Control Plane includes a sophisticated Identity Access Management (IAM) system, which allows multiple departments or groups to share an Oracle Cloud Infrastructure (OCI) tenancy. IAM compartments are used as a logical resource grouping construct within OCI that enables access control across resources and provides an effective mechanism to organize and control access to resources within a single tenancy. Policies can be used to grant fine-grain permissions on resources within a compartment for separation of duty and privileged access to specific resources. For example, users can be isolated to only specific databases, and within a given database, one user could be responsible for create/scale and another for restore/audit.

Oracle Cloud Operations

Oracle Cloud Operations monitors and maintains the Database, Virtualization Stack, and infrastructure components of the Autonomous Database on Dedicated Exadata Infrastructure service. Key components and activities include:

1. Components managed
    - Exadata storage servers and physical database servers
    - Power distribution units (PDUs)
    - RoCE/InfiniBand network and switches
    - Management switch
    - Control plane servers
    - Virtual Machine (hypervisor)
    - Exadata system software and all firmware
    - VM Clusters
    - Database Homes
    - Grid Infrastructure
    - Operating System
2. Monitoring activities
    - Autonomous infrastructure layer incident monitoring, management, and root cause analysis
    - Threshold performance analysis
3. Maintenance Activities
    - Bug and security fixes
    - Exadata System Software updates and upgrades
    - Firmware updates and upgrades to any of the hardware components including networking components and InfiniBand/RoCE switches
    - Proactive infrastructure upgrades to update software and firmware as required
    - Grid Infrastructure and Database updates
    - Operating System updates

Customizable operational policies

Autonomous Database on Dedicated Exadata Infrastructure provides the customer customizations over operational policies, including software and hardware isolation for the highest levels of performance and security governance; it is well suited for customers wanting to deploy Oracle Database in cloud with common enterprise lifecycle controls.

Users can configure Autonomous VM clusters* with one or more container databases on their dedicated infrastructure, each of which can have one or more autonomous databases (a mixture of ADW and ATP) within it. Customers can customize the policies used to control the provisioning of new databases, the timing of updates, the availability configuration, the backup retention period, and the density of databases that can run on the infrastructure. Having control over database versions and the timing of updates is essential for critical applications that require a version validation check

against pre-production environments before a new software version is applied to production deployments. Although customers can customize these operational policies, all operations are still fully automated by Oracle autonomous software.

** Autonomous VM clusters on Exadata Cloud@Customer allow you to configure density, memory to OCPU ratio, and license type.*

Administrative role separation

Autonomous Database on Dedicated Exadata Infrastructure allows a clean separation of roles between IT and database consumers. An IT group of Fleet Administrators would oversee capacity of Exadata Infrastructure, governance policies, and resource quotas. Database consumers, project team developers and application DBAs consume Autonomous Database without visibility into the underlying infrastructure. This separation of fleet versus database consumer allows simple budgeting controls and resource isolation without getting in the way of the line of business execution. A dedicated database deployment will support the entire spectrum of needs, from simple apps to those that require the highest governance, consistent performance, and operational controls.

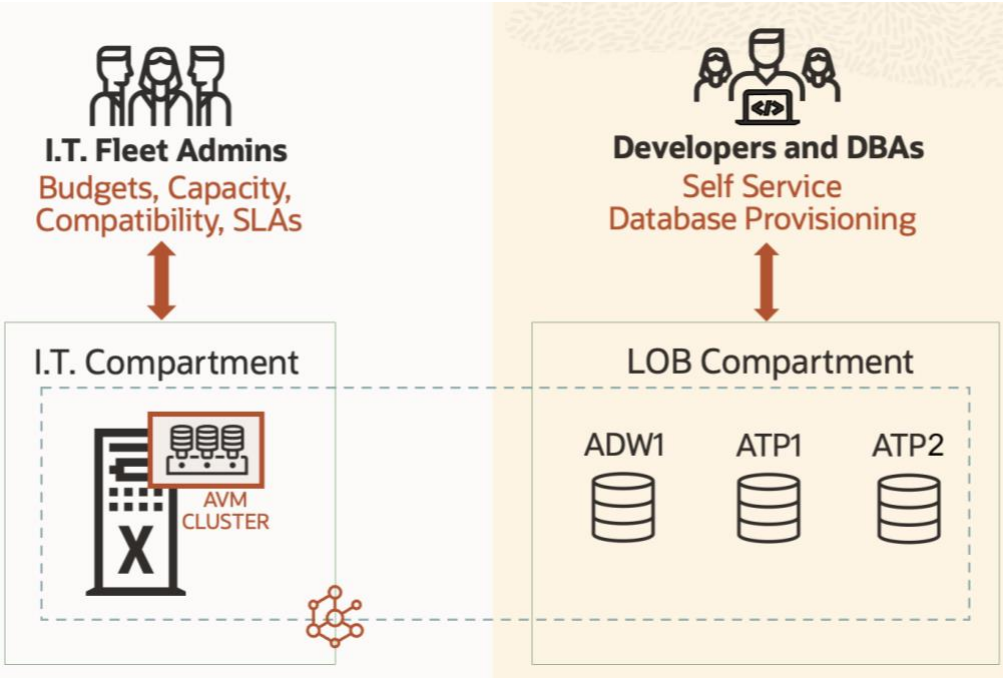

Figure 1. Dedicated fleet and database consumer roles

Enterprise class security with the simplicity of cloud

Autonomous Database on Dedicated Exadata Infrastructure benefits from scrutiny by Oracle Security experts and by hundreds of industry experts around the world. Autonomous Database delivers Exadata as an Oracle Cloud Service based on comprehensive security measures deployed in the hardware infrastructure, network, Exadata platform, and Oracle database. The security features of Autonomous Database segregate customer data access and Oracle Cloud Operations and ensure that data that enters or leaves the Autonomous service is secure, data that resides on the system is secure, access to the system is secure, and the code that runs on the system is secure. Oracle cloud automation further enhances security by enforcing strong passwords and data encryption on all databases and making it fast and easy for customers to keep databases updated with the latest security patches from Oracle.

Exadata Infrastructure Security protects the physical servers and components that are the building blocks of the system. Infrastructure security features include:

- Vendor signed firmware on hardware components to ensure hardware components will only run valid code from the vendor that supplied that component
- Hardware acceleration that delivers near-native encryption and decryption speed so that encryption can always be used for all Oracle database data

- Infrastructure optimizations that uniquely move decryption processing to Exadata Storage Server infrastructure
- Virtual machines that provide secure isolation between customer virtual machines and Oracle Cloud Operations.

Customers can use advanced access controls like Oracle Database Vault to ensure data in the Oracle database can only be accessed by users with explicit rights to access that data. Oracle Cloud Operations does not access customer data to carry out their duties of infrastructure support.

Exadata Network Security is implemented with isolated networks, and each network is equipped with additional security measures to secure critical data processing tasks. Network security features include:

- Internal Network Fabric: isolates and protects storage and RAC interconnect traffic
- Customer client network: Oracle Net Encryption secures application traffic to databases
- Dedicated backup network: Oracle Net Encryption secures traffic for high-bandwidth use cases such as backup, data loading, and disaster protection using Data Guard
- Customer controlled client network mapped directly to the database VMs

Exadata Platform Security is based on virtual machines that deliver the Exadata Compute Node platform. The operating system deployment for the Exadata platform includes:

- A minimal Linux distribution ensures that just the packages needed to run Oracle Database are installed and enabled
- Minimal open ports and running services that minimize attack surfaces
- Comprehensive logging and auditing that tracks access and modification

Exadata Database Security is based on the enterprise security features of the Oracle database. Autonomous Database subscriptions includes all Oracle Advanced Security features, such as Transparent Data Encryption (TDE), Database Vault, Label Security, Redaction, Subsetting, and Masking. BYOL customers are also entitled to use Transparent Data Encryption (TDE) and the Data Masking and Subsetting pack on any Oracle Database license they move to Autonomous Database.

TDE master encryption keys are generated and managed by the cloud automation by default. Customers with stricter corporate security policies that mandate tighter control of encryption keys may choose to manage their own keys in the OCI Vault service. The vault service uses a FIPS-140 security level 3 certified HSM device to meet the highest security standard. The autonomous database on dedicated Exadata infrastructure provides integration with the OCI Vault service so that database master encryption keys may be generated and stored in the Vault. Customers have full control over the lifecycle and rotation of their keys in both cases.

Oracle Operator Access Control

Oracle Operator Access Control (OpCtl) is an Oracle Cloud Infrastructure access management service for Autonomous Database on Dedicated Exadata Infrastructure. OpCtl provides the customer interfaces to:

- Control access to Exadata infrastructure and Autonomous VM Clusters by Oracle staff, limiting when they have access, components they can access, and commands they can execute.
- Observe and record Oracle operator commands and keystrokes Oracle staff execute.
- Terminate Oracle operator connections at the customer's discretion.

OpCtl is ideal for regulated industries such as banking and financial services, energy utilities, and defense, and any industry where risk management is a key pillar of application success. These controls are a standard part of Autonomous Dedicated on Exadata Infrastructure and are available at no extra cost to Oracle customers.

Backup and recovery

Autonomous Database on Dedicated Exadata Infrastructure provides automatic built-in database backup facilities, with weekly full backups and daily incremental backups that are available for a selectable timeframe up to 60 days in the Oracle

Public Cloud. Manual backups can be taken at any time and recovery can be done from a backup or any point in time in the backup retention window.

In Oracle public cloud or your data centers

Autonomous Database on Dedicated Exadata Infrastructure is available in the Oracle Public Cloud and in the customer's data centers via Cloud@Customer.

Many companies cannot simply move to the public cloud due to challenges involving the regulatory nature of their data, data sovereignty laws requiring data to stay in the country of origin, and the complexities of systems entanglement present in enterprise architectures. Systems entanglement happens because individual applications are coupled to others in such a way that changes to one impact the others, thereby complicating a move to the public cloud. To mitigate these challenges while providing customers the benefits of cloud self-service and a pay-per-use financial model, Oracle introduced its Cloud@Customer offerings bringing the cloud to customers who cannot simply transform to public cloud

Oracle Dedicated Region Cloud@Customer delivers an entire stack of Oracle Cloud Infrastructure and its portfolio of Platform as a Service offerings to the customer datacenter, including Autonomous Database on Dedicated Exadata Infrastructure.

Oracle Exadata Cloud@Customer is a slice of Oracle Cloud delivered to the customer datacenter that is specific to Exadata based database Platform-as-a-Service offerings and includes Autonomous Database. Autonomous Database on Exadata Cloud@Customer is a low-cost entry point for on-premises users providing all the feature functionality found in Autonomous Database on public cloud, but users also have the option of backing up their autonomous database to a local Zero Data Loss Recovery Appliance or local network-attached storage. The minimum term for an Autonomous Cloud@Customer infrastructure subscription is four years, and the same BYOL or license included (billed per second) models exist.

The Cloud Control Plane used by Autonomous Database in the public cloud is also used by the Autonomous Database on Exadata Cloud@Customer. This allows customers to work with both Public Cloud and Cloud@Customer, using the exact same UX and REST APIs. Any investments in automated scripting developed for a Cloud@Customer environment will be preserved should a customer eventually choose to migrate to the Oracle Public Cloud.

Multiple VM Autonomous Database

Multiple VM Autonomous Database is an enhancement to Exadata Cloud@Customer that increases value through greater consolidation. Multiple VM Clusters isolate database environments with separate access rules, network configurations, and maintenance schedules, each including customizable compute, memory, and storage resources. This allows Autonomous Database to be deployed alongside Exadata Database Service on the same infrastructure, eliminating the need to deploy separate systems for these services.

Secure access to Exadata Cloud@Customer

Platform control plane commands are sent to the Exadata Cloud@Customer system through a dedicated WebSocket secure tunnel between the Cloud Control Plane and the Exadata Cloud@Customer platform. Oracle Cloud Operations staff use the same tunnel to monitor Autonomous Database on Exadata Cloud@Customer for maintenance and troubleshooting. Two remote Control Plane Servers installed in the Exadata Cloud@Customer rack host the secure tunnel endpoint and act as a gateway for access to the infrastructure. They also host components that orchestrate the cloud automation, aggregate and route telemetry messages from the Exadata Cloud@Customer platform to the Oracle Support Services infrastructure, and host images for service patching. The minimum network bandwidth from the Control Plane Server to the Cloud Control Plane is 50 Mbps.

The following diagram shows a typical access configuration of Autonomous Database on Exadata Cloud@Customer.

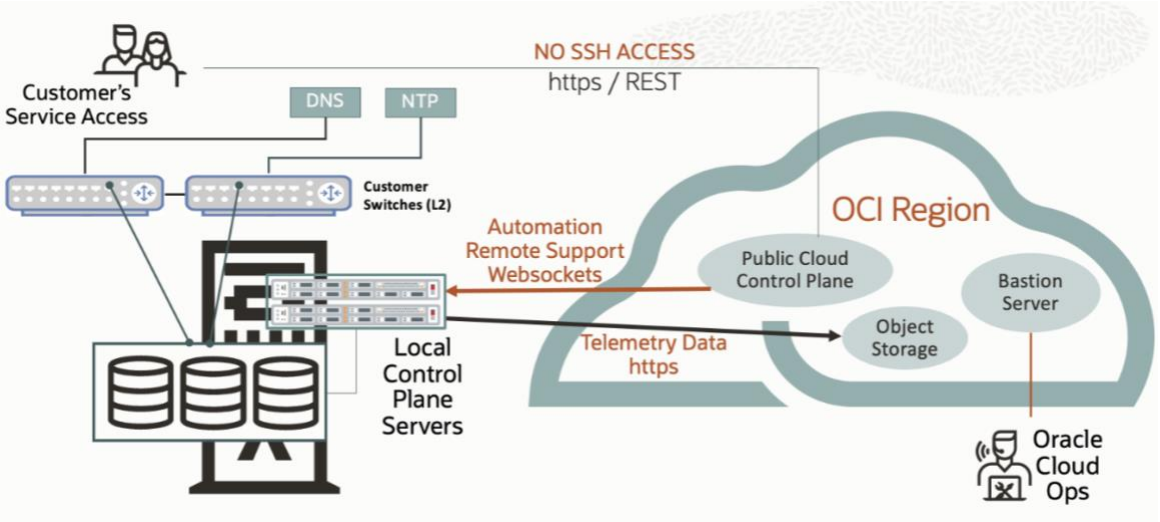

Figure 2. Access architecture for Exadata Cloud@Customer

Conclusion

Autonomous Database on Dedicated Exadata Infrastructure, available both in public cloud and on-premises via Cloud@Customer is an ideal solution for customers looking to leverage cloud-based database service to modernize the use of database for all database deployments, including for their most demanding and mission critical solutions. Autonomous Database will help to lower costs, reduce security risks, and enable customers to focus on adding business value instead of worrying about technology.

Table 1. Resource Limits and Characteristics of Infrastructure Shapes

Enforced Resource Limits (Maximum)

RESOURCE	QUARTER RACK	HALF RACK	FULL RACK
Autonomous Databases	1,000	2,000	4,000
Autonomous Container Database	12	12	12

Recommended Resource Limits (Maximum)

RESOURCE	QUARTER RACK	HALF RACK	FULL RACK
Autonomous Databases per Autonomous Container Database	200	200	200
Autonomous Databases per Autonomous Container Database with Autonomous Data Guard Configured	25	25	25

Exadata X9M-2 Typical Hardware Configurations Public Cloud

SPECIFICATION	X9M QUARTER RACK[5]	X9M HALF RACK[5]	X9M FULL RACK[5]
Number of Compute Nodes	2	4	8
Total Maximum Number of Enabled CPU Cores	252	504	1008
Total RAM Capacity (GB)	2,780	5,560	11,120
Persistent Memory (TB)	4.5	9	18
Number of Exadata Storage Servers	3	6	12
Total Flash Storage Capacity (TB)	76.8	153.6	307.2
Max SQL Flash Bandwidth[2] (GB/s)	135	270	540
Max SQL Phemy/Flash Read IOPS[3]	5,600,000	11,200,000	22,400,000
Max SQL PMem/Flash Write IOPS[4]	1,842,000	3,684,000	7,368,000
Max SQL Disk Bandwidth[2] (GB/s)	5.4	10.8	21.5
Max SQL Disk IOPS	7,800	15,600	31,000
Max Database Size, No Local Backup[1] (TB)	152	305	610
Max Database Size, Local Backup (Exadata Cloud@Customer only)[1] (TB)	76	152	305

Exadata X9M-2 Public Cloud: Elastic Server Expansion[5]

SERVER TYPE	MAXIMUM OCPUS	TOTAL MEMORY AVAILABLE
X9M Database Server (32 Maximum)	126	1,390 GB

SERVER TYPE	TOTAL CORES	PERSISTENT MEMORY	TOTAL FLASH CAPACITY	TOTAL USABLE DISK CAPACITY[1]
X9M Storage Server (64 Maximum)	48	1.5 TB	25.6 TB	63.6 TB

Exadata X9M-2 Public Cloud: Individual Server Performance Metrics[5]

SERVER TYPE	MAXIMUM SQL FLASH BANDWIDTH[2]	MAXIMUM SQL READ IOPS[3]	MAXIMUM SQL WRITE IOPS[4]
X9M Database Server	n/a	2,800,000	1,500,000
X9M Storage Server	45 GB/s	2,300,000	614,000

Exadata X9M-2 Systems Cloud@Customer

SPECIFICATION	X9M QUARTER RACK	X9M HALF RACK	X9M FULL RACK
Number of Compute Nodes	2	4	8
Total Maximum Number of Enabled CPU Cores	124	248	496
Total RAM Capacity (GB)	2,780	5,560	11,120
Persistent Memory (TB)	4.5	9	18
Number of Exadata Storage Servers	3	6	12
Total Flash Storage Capacity (TB)	76.8	153.6	307.2
Max SQL Flash Bandwidth[2] (GB/s)	135	270	540
Max SQL Phemy/Flash Read IOPS[3]	5,600,000	11,200,000	22,400,000
Max SQL PMem/Flash Write IOPS[4]	1,842,000	3,684,000	7,368,000
Max SQL Disk Bandwidth[2] (GB/s)	5.4	10.8	21.5
Max SQL Disk IOPS	7,800	15,600	31,000
Max Database Size, No Local Backup[1] (TB)	152	305	610
Max Database Size, Local Backup (Exadata Cloud@Customer only)[1] (TB)	76	152	305

Exadata X8M-2 Systems

SPECIFICATION	X8M QUARTER RACK[5]	X8M HALF RACK[5]	X8M FULL RACK[5]
Number of Compute Nodes	2	4	8
Total Maximum Number of Enabled CPU Cores	100	200	400
Total RAM Capacity (GB)	2,780	5,560	11,120
Persistent Memory (TB)	4.5	9	18
Number of Exadata Storage Servers	3	6	12
Total Flash Storage Capacity (TB)	76.8	153.6	307.2
Max SQL Flash Bandwidth[2] (GB/s)	75	150	300
Max SQL PMem/Flash Read IOPS[3]	3,000,000	6,000,000	12,000,000
Max SQL PMem/Flash Write IOPS[4]	1,410,000	2,820,000	5,640,000
Max SQL Disk Bandwidth[2] (GB/s)	5.4	10.8	21.5
Max SQL Disk IOPS	7,800	15,600	31,000
Max Database Size, No Local Backup[1] (TB)	119	239	479
Max Database Size, Local Backup (Exadata Cloud@Customer only)[1] (TB)	59	119	239

Exadata X8-2 Systems

SPECIFICATION	X8 QUARTER RACK[6]	X8 HALF RACK[6]	X8 FULL RACK[6]
Number of Compute Nodes	2	4	8
Total Maximum Number of Enabled CPU Cores	100	200	400
Total RAM Capacity (GB)	1,440	2,880	5,760
Number of Exadata Storage Servers	3	6	12
Total Flash Storage Capacity (TB)	76.8	153.6	307.2
Max SQL Flash Bandwidth[2] (GB/s)	64.5	129	258
Max SQL Flash Read IOPS[3]	1,194,000	2,388,000	4,776,000
Max SQL Flash Write IOPS[4]	1,088,000	2,176,000	4,352,000
Max SQL Disk Bandwidth[2] (GB/s)	5.4	10.8	21.5

Max SQL Disk IOPS	7,800	15,600	31,000
Max Database Size, No Local Backup[1] (TB)	119	238	476
Max Database Size, Local Backup (Exadata Cloud@Customer only)[1] (TB)	59	119	239

Exadata X7-2 Systems

SPECIFICATION	X7 QUARTER RACK[6]	X7 HALF RACK[6]	X7 FULL RACK[6]
Number of Compute Nodes	2	4	8
Total Maximum Number of Enabled CPU Cores	92	184	368
Total RAM Capacity (GB)	1,440	2,880	5,760
Number of Exadata Storage Servers	3	6	12
Total Flash Storage Capacity (TB)	76.8	153.6	307.2
Max SQL Flash Bandwidth[2] (GB/s)	50	100	200
Max SQL Flash Read IOPS[3]	1,167,750	2,335,500	4,671,000
Max SQL Flash Write IOPS[4]	1,033,000	2,066,000	4,132,000
Max SQL Disk Bandwidth[2] (GB/s)	5.4	10.8	21.5
Max SQL Disk IOPS	7,800	15,600	31,000
Max Database Size, No Local Backup[1] (TB)	85.5	171.1	342.1
Maximum Database Size, Local Backup (Exadata Cloud@Customer only)[1] (TB)	42.8	85.5	171.1

[1] Usable capacity is measured using normal powers of 2 space terminology with 1 TB = 1024 * 1024 * 1024 * 1024 bytes. It is the actual space available to create a database after taking into account space needed for high redundancy storage and recovering from a drive failure, but before database compression.

[2] Bandwidth is peak physical scan bandwidth achieved running SQL, assuming no database compression. Effective user data bandwidth is higher when database compression is used

[3] Based on 8K I/O requests running SQL

[4] Based on 8K I/O requests running SQL. Flash write I/Os measured at the storage servers after ASM mirroring, which issues multiple storage I/Os to maintain redundancy

[5] X8M-2 and X9M-2 systems on Oracle cloud do not support fixed shapes such as quarter rack, half rack, and full rack. For these systems, the default configuration is 2 database servers and 3 storage servers. However, elastic provisioning gives you the flexibility to choose a different value for database servers and storage servers (2 to 32 for database servers and 3 to 64 for storage servers). Currently, Autonomous Database only supports creating Autonomous VM Clusters on existing provisioned compute and storage server configurations, those configurations cannot be further expanded for VM Clusters that have already been created.

[6] As X7-2 and X8-2 systems do support fixed shapes such as quarter rack, half rack, and full rack, you can't configure compute and storage for these systems. The number of database servers and storage servers is pre-determined based on the Exadata system shape. You can't select a different value for database servers, but you can select another value for the storage servers as per your requirement.

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