18c ORACLE Database

Introducing Oracle Database 18c

ORACLE WHITE PAPER | JULY 2018

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Introduction

Oracle Database 18c, is the latest generation of the world's most popular database, and may be deployed on-premises and/or in Oracle Cloud running on general purpose hardware or engineered systems specifically designed for database workloads such as Oracle Exadata and Oracle Database Appliance. It provides businesses of all sizes with access to the world's fastest, most scalable and reliable database technology for secure and cost-effective deployment of transactional and analytical workloads in the Cloud, on-premises and Hybrid Cloud configurations. Oracle Database 18c adds new functionality and enhancements to features previously introduced in Oracle Database 12c, including:

- **Multitenant Architecture** for massive cost savings and agility.
- **In-Memory Column Store** for massive performance gains for real-time analytics.
- **Native Database Sharding** for high availability of massive web applications.
- **Many more critical capabilities** for enhanced database performance, availability, security, analytics and application development.

In July 2017, Oracle transitioned to a more flexible and responsive strategy for the database software release process designed to bring new features to market every year. The general availability of Oracle Database 18c was the first annual release in Oracle's database software release model. For comparative purposes, Oracle Database 18c may be viewed as what would have been the first patch set to Oracle Database 12c Release 2 in the previous release model. Looking forward, customers will no longer have to wait multiple years for the latest generation of Oracle Database, and can anticipate the introduction of new database features and enhancements on a regular annual basis. Oracle Database 18c (and subsequent annual releases) also features prominently as a core component of Oracle's Autonomous Database Cloud.

This white paper discusses some of the critical capabilities of Oracle Database 18c that can help customers deliver the best performance, scalability, reliability and security for all their transactional and analytical workloads, and application development requirements.

"With a history of established leadership in the database software market segment, it is no surprise that Oracle is pioneering a next-generation data management platform."

CARL OLOFSON

RESEARCH VICE PRESIDENT, IDC

Journey to Autonomous Database Cloud

Over successive database releases, Oracle has introduced innovative automated features that have helped administrators deliver a superior level of service to their end users. These innovations include:

- **Cost-based Optimization.** Automatic SQL query optimization, automatic statistics gathering, automatic query rewrite automatic SQL Plan management and automatic SQL tuning.
- **Performance Tuning and Diagnostics.** Automatic memory and resource management, automatic index and materialized view advisors, Automatic Database Diagnostic Monitor, Automatic Database Workload capture & replay and Automatic Workload Repository.
- **Data Optimization.** Automatic undo management, automatic segment space management, Automatic Storage Management, Automatic Data Optimization and automatic columnar cache.
- **Cloud-Scale Operations.** Automatic standby management (broker), Diagnostic Framework, Multitenant Architecture, automatic database clone refresh and machine learning in Cluster Health Advisor.

In October 2017, Oracle announced the Autonomous Database Cloud, a range of database services tailored for specific Data Warehousing, OLTP, and NoSQL workloads. By utilizing existing database functionality with machine-learning techniques, the Autonomous Database Cloud can provide a level of performance and reliability that manually managed databases struggle to deliver. The Autonomous Database Cloud is specifically designed to provide customers with a higher level of service at lower cost by automating routine administrative tasks and eliminating human error through:

- **Self-Driving.** Users simply define workloads and policies, and database automation makes them happen.
- **Self-Securing.** Protection from both external attacks and internal users.
- **Self-Repairing.** Automated protection from all downtime.

The Autonomous Database Cloud is built on top of the world's most widely proven and sophisticated database: Oracle Database, it runs on the world's best database platform: Oracle Exadata, and will be available as pay-as-you-go services on Oracle Cloud and Exadata Cloud at Customer (for public cloud and private cloud deployment respectively).

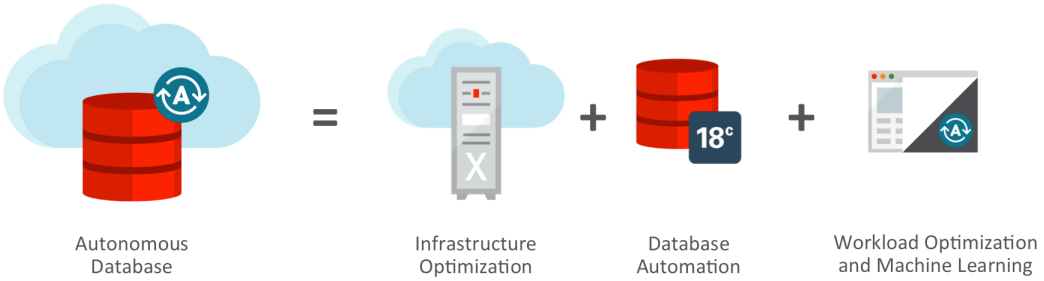

Figure 1. Key Components of Oracle Autonomous Database

The Autonomous Data Warehouse Cloud for Data Warehouse, Data Mart, Data Science and Data Lake use cases, has been available in Oracle Cloud since March 2018.

Multitenant Architecture

Designed for the cloud (public or private), Oracle's multitenant database offers a unique architecture that simplifies consolidation and delivers the high density of schema-based consolidation, but without requiring changes to existing applications. In this architecture, a single multitenant container database (CDB) can host many 'pluggable' databases (PDBs). Each database consolidated or 'plugged in' to a multitenant container looks and feels to applications the same as for pre-multitenant Oracle databases. By consolidating multiple databases into a multitenant container, many pluggable databases share the container memory and processor resources, thereby enabling a greater level of database consolidation density. In addition, all PDBs in a CDB are all effectively "managed as one" for database backup, patching, upgrading and standby operations.

Oracle's multitenant database also enables rapid database provisioning, cloning and movement. For example, if the underlying filesystem supports copy on writes (e.g. ZFS Filesystem, ASM Cluster Filesystem, etc.), cloning of pluggable databases can occur almost instantaneously. Other agility features of Oracle's multitenant database include:

- **PDB Hot Clone** enables fast instantiation of PDBs without having to take users offline.
- **PDB Refresh** enables cloned PDBs to be regularly updated with latest data.
- **PDB Relocate** enables PDBs to be relocated between CDBs with near zero downtime.

In addition, the Application Container capabilities of Oracle's multitenant database allow an application, formerly architected for standalone deployment on-premises, to be converted to an instant Software-as-a-Service (SaaS) architecture, with no code changes. The application is simply installed, unchanged, into an Application Root, and tenant PDBs (e.g. for separate customers) can share the application code while retaining secure isolation of tenant data. Application upgrades need only be applied to the single Application Root master and tenant PDBs simply synchronize with the upgraded master.

Since its introduction in 2013, Oracle's multitenant database has been widely adopted by ISVs and customers alike and deployed both on-premises and in the Cloud. Indeed, many Oracle Cloud Database Services including the Exadata Express Service and Autonomous Data Warehouse Cloud rely on multitenant for tenant isolation, agility and scalability. The release of Oracle Database 18c introduces a number of enhancements to existing multitenant functionality including:

- **Faster Deployment of Upgrades, Updates and Revisions**. A new infrastructure further reduces the execution time of database upgrades, updates and revisions.
- **Transportable Backups** support the use of backups performed on a PDB prior to it being unplugged and plugged into a new container. This facilitates agile relocation of PDBs between CDBs, perhaps for load balancing or migration between on-premises and cloud, without requiring backups to be taken immediately before, and after, each PDB relocation.
- **Snapshot Carousel** enables customers to define regular snapshots of PDBs that can then be used for a full point in time recovery or to a specific point in time clone. The Snapshot Carousel is ideally suited to development environments, that typically require multiple copies of databases at different points in time, or to augment a non mission critical back and recovery process.
- **Refreshable PDB Switchover** enables customers to create a PDB, which is an incrementally updated copy of a "master" PDB (e.g. from on-prem to Cloud), that may subsequently be switched over between each other. When this happens the "master" PDB becomes the clone and the old clone the master. This capability will make it even easier for customers to gracefully switch workloads between different CDBs.

The multitenant architecture of Oracle Database cost-effectively enables tenant isolation, and agility with economies of scale, whether deployed in the Oracle Cloud, on-premises or hybrid cloud environments.

Performance

Oracle Database 18c inherits the raft of innovations in the areas of SQL query and data optimizations, and performance and tuning diagnostics that have helped customers deliver on database performance level expectations for transactional, analytic and mixed workloads, on both single server and clustered server configurations. In addition, the unique performance features of Oracle Exadata, such as Smart Scans, Smart Flash Cache and Storage Indexes, offer customers even greater levels of performance for all Oracle Database 18c workloads running on Exadata, either on-premises or in Cloud deployments.

Oracle Database also provides customers access to in-memory columnar formatted data with Oracle Database In-Memory. This can accelerate analytic queries by orders of magnitude and improve the performance of transactional queries by removing the need for analytic reporting indexes. Oracle Database In-Memory uses a unique dual-format architecture that simultaneously represents table data in its traditional row format, and in a pure in-memory columnar format. The In-Memory column store (IM column store) is accessed through specialized software and hardware routines that amplify the performance of memory-resident data. Oracle Database 18c further improves Oracle Database In-Memory automation and increases its flexibility and performance, while maintaining complete compatibility with existing applications and all Oracle Database 18c functionality, including Multitenant, Real Application Clusters, Maximum Availability Architecture, and database security.

Simple To Implement

Unlike other in-memory databases, Oracle Database In-Memory does not require the entire database to fit into main memory. It simply requires setting the size of the IM column store and identifying performance sensitive tables or partitions. With Oracle Database 18c, the management of the IM column store content can now be automated, which means that the database automatically takes care of populating objects into the IM column store and removing those that are no longer relevant. A unique feature of Database In-Memory is that no changes to existing applications are required to take advantage of the IM column store. The optimizer automatically routes analytic queries to the columnar format and transactional queries to the row format. In addition, the IM column store is extended to flash on Exadata storage (both on-premises and Oracle Cloud), dramatically enlarging the capacity of columnar formatted data.

Memory-Optimized Performance

Oracle Database In-Memory's state-of-the-art algorithms for in-memory scans, joins and aggregations are widely proven to deliver orders-of-magnitude performance improvements for customers' analytical and mixed workloads. In addition, other typical use-cases for Oracle Database In-Memory include hybrid transactional analytic processing (HTAP), where analytics are an integral component of business transactions, as well as data warehouse query and reporting systems. Oracle Database In- Memory's performance-enhancing features include; In-Memory Join Groups, In-Memory Expressions and in-memory processing of JSON queries.

Distributed Real-Time Analytics

Oracle Database In-Memory enables real-time analytics by delivering performance similar to having an index on every column, but without the index overheads. Consequently, analytics that previously took hours or longer to run can now can complete in seconds. Indeed, customers can eliminate secondary analytical indexes on transactional databases that are no longer required for analytic query performance. Customers can also maintain an IM column store on an Active Data Guard standby database running on Oracle Cloud and Oracle Exadata. This allows customers to make more productive use of their standby databases. It completely isolates transactional users from analytic users, and still delivers high performance analytics against near-real-time data.

MemOptimized RowStore

In addition to Oracle Database In-Memory column store and non-volatile memory support, Oracle Database 18c introduces a Memoptimized Rowstore designed for fast query performance such as Internet of Things (IoT) workloads that require very fast and low latency lookups based on primary key values. A new table level attribute, MEMOPTIMIZE FOR READ, is used to indicate which tables are to be pinned into the buffer cache with this new hash index. Key-value lookups then bypass the SQL execution layer and execute directly in the data access layer via an in-memory hash index. This feature enables clients to perform very low-latency reads from the in-memory buffer, which can significantly increase the throughput of key-value lookups compared to conventional methods. This fast lookup performance can be further enhanced when used with Exadirect for Infiniband high-speed networks by leveraging the ability to use Remote Direct Memory Access (RDMA).

High Availability

Oracle Database offers customers the highest levels of availability with Oracle's Maximum Availability Architecture; an integrated set of database availability feature and best practice blueprints that address the common causes on unplanned and planned downtime for both on-premises and in-Cloud deployments.

Unplanned Downtime

IT infrastructures are prone to failures such as server faults, disk crashes or storage corruption, site outages and human error that can incur costly unplanned downtime. In order to prevent and mitigate unplanned downtime Oracle Database 18c offers a number of critical high availability capabilities including:

» **Real Application Clusters (RAC)** enables multiple database instances to run on multiple servers in a cluster against a shared database. Since the servers run independently, the failure of one or more does not affect the others; RAC effectively removes the database server as a single point of failure.

» **Automatic Storage Management (ASM)** is the underlying (clustered) volume manager technology recommended for used with Oracle Database. ASM stripes and mirrors everything for faster performance and higher availability, with a choice 2-or 3-way disk mirroring to protect data from disk failures.

» **Recovery Manager (RMAN)** manages Oracle database backup, restore, and recovery processes. It maintains configurable backup and recovery policies, and keeps historical records of all database backup and recovery activities, thereby ensuring that all files required to successfully restore and recover a database are included in database backups..

» **Oracle Secure Backup (OSB)** delivers scalable, centralized tape backup management for both database and file system data in distributed, heterogeneous IT environments. This includes RMAN backups to Oracle object store and Amazon S3 object storage..

» **Flashback** enables reversing of human errors by efficiently undoing the effects of a mistake (e.g. an accidental table drop).

» **Active Data Guard (ADG)** enables protection from site failures by maintaining replica standby databases (synchronously or asynchronously) in alternative (typically remote) location. ADG also enable customers and offload read-only processing (e.g. backups, reports, analytics, etc.) to standby databases.

Oracle Exadata and many of Oracle Cloud's database services (e.g. Exadata Service and Autonomous Services) are built using these critical high availability capabilities using Oracle's Maximum Availability Architecture to offer customers the highest levels of database availability, both on-premises and on Oracle Cloud.

Planned Downtime

Planned downtime for essential maintenance such as hardware upgrades, software upgrades and patching are part and parcel of every IT operation. Nonetheless, downtime (planned or otherwise) can be costly and Oracle Database 18c offers a number of capabilities to help customers reduce the amount of planned downtime required for maintenance activities, including:

» **Hardware Maintenance and Migration Operations** Using Automatic Storage Management, disks can be added or removed online and the data is automatically rebalanced. Database servers can also be easily added or removed to a clustered database infrastructure while users remain connected. Cross platform incremental backup and recovery minimizes downtime for cross-platform hardware migrations, as does fast unplug and plug of PDBs between multitenant containers on different servers.

» **Online Patching** of database software can be applied to server nodes in a 'rolling' manner using Oracle Real Application Clusters. Users are simply migrated from one server to another; the server is quiesced from the cluster, patched, and then put back online. The same operation is then repeated for every server in the cluster. With Oracle Database 18c, zero impact patching of grid infrastructure patches each of the nodes Grid Infrastructure software in a rolling fashion whist the databases running on that node continue to be available to the application users.

» **Rolling Database Upgrades** Oracle Data Guard or Oracle Active Data Guard enables upgrading of a standby database, testing of the new (upgraded) environment and then switching users to the new environment, without any downtime.

» **Online Redefinition** Oracle Database allows changes to a table structure while continuing to support an online production system, and data files and partitions may be moved around storage devices while users continue to access underlying data.

» **Edition Based Redefinition** enables online application upgrades. Using edition-based redefinition, changes to program code can be made in the privacy of a new edition within the database, separated from the current production edition. An editioning view exposes different projections of the same table into each edition, ensuring that the code in each edition only sees its own specific view of the table. Cross edition triggers propagate the data changes made by the old production edition into the new edition's columns, and vice-versa. This then allows both the old production environment and the new production environment to be used at the same time, for testing, and allows users to be moved online from one edition to the other.

Enhancing Database Availability

Oracle Database 18c continues to evolve the Maximum Availability Architectures with new and enhanced capabilities that help customers maximize their database availability, these include:

» Data Guard Far Sync provides zero data loss protection for a production database by maintaining a synchronized standby database located at any distance from the primary location, without impacting database performance and with minimal cost or complexity. A far sync instance receives changes synchronously from a primary database and forwards them asynchronously to a remote standby. It's a lightweight entity that manages only a control file and log files, and only requires a fraction of the CPU, memory, and I/O resources of a standby database to relieve a primary database from serving remote destinations. Production can be quickly failed over, manually or automatically, to the remote standby database with zero data loss.

» Global Data Services provides inter-region and intra-region load balancing across Active Data Guard and Golden Gate replicated databases. It effectively provides Real Application Cluster failover and load balancing capabilities to Active Data Guard and Golden Gate distributed databases. Global Data Services extends the familiar notion of Database Services to span multiple database instances in near and far locations and can be used to distribute workloads across a reader farm composed of standby databases.

» Auto Propagation of Nologged Data is enabled in Oracle Database 18c which means that customers no longer have to make compromises between no-logging to rapidly load data into their data warehouses and maintaining a replica standby database. Customers can now ensure that standby databases receive non-logged data changes with minimal impact on the speed of loading data into the primary data warehouse.

» Continuous Application Availability effectively manages database failures from user-facing applications. For example, when a web application encounters any database outage it can result in transactions not completing properly or transactions being re-entered by the user. While the database outage can be easily recovered, the same may not be true for the application itself. Application Continuity enables failed transaction replay, effectively masking database outages from the end user.

Native Database Sharding

Oracle Database offers customers native database sharding for massive scalability and reliability for transactional applications. Critical high availability capabilities such as Real Application Clusters and Active Data Guard are widely proven to meet the needs of over 99% of transactional applications, while preserving application transparency. However, some global-scale transactional applications prefer to shard massive databases into a farm of smaller databases for scalability and reliability purposes. This requires designing applications around a sharding key, so that workloads are automatically routed to specific shards in a database farm. Sharding with Oracle Database 18c introduces an explicit user defined model of "Range" and "List" sharding, giving users the ability to ensure that data is placed in a location appropriate for its access.

Zero Data Loss Recovery Appliance (Recovery Appliance)

The Oracle Recovery Appliance is an engineered system for standardizing backup and recovery process of Oracle Databases throughout the enterprise. It's an innovative data protection solution that is completely integrated with RMAN and designed to eliminate data loss exposure and dramatically reduces data protection overhead on database servers. The Recovery Appliance can easily standardize the protection of all Oracle databases in the data center with its massive cloud-scale architecture, end-to-end data validation, and fully automated management of the entire data protection lifecycle through Enterprise Manager Cloud Control.

Security

Enterprise data is increasingly under threat from malicious attacks, and regulations such as EU GDPR require organizations demonstrate stronger controls to protect sensitive data. From the outset, Oracle has adopted a multi-layered, defense-in-depth approach providing customers with evaluative controls for assessing the security posture of their databases and sensitivity of their data, preventive controls to block unauthorized access to data, detective controls to monitor user and application data access behavior, and data driven security to enforce user-and application-level data access controls at the source, within the database. These controls protect enterprise data stored in Oracle Database both on-premises and in the Oracle Cloud, include:

» Transparent Data Encryption helps protect against threats that target database storage and backup media devices. Encryption can be easily applied to sensitive columns in tables or entire tablespaces and prevents access to data when database files are lost, stolen or read directly from media.

» Dynamic Data Masking with Oracle Data Redaction helps protect sensitive data in production applications by enforcing controls inside the database that redact data before it is returned to the application. It effectively hides the true values of sensitive data in a way that is transparent to applications, delivering (for example) just the last few digits of social security or bank account numbers. By defining and enforcing data redaction policies in the database, and not the application, customers can effectively protect sensitive data without changing their applications.

» Separation-of-duties and Least Privilege Access Policies The privilege analysis feature effectively records existing privilege and role usage in order to help customers deploy 'least privilege' models that accurately reflect the privileges required for day-to-day business and administration activities. This helps reduce the security risk of over-provisioning user access to enterprise data. Customer's least privilege model may be further secured using Database Vault to enforce separation of duties enterprise-wide for all constituent users and roles, including those of privileged users.

» First Line of Defense using Oracle Database Firewall provides a first line of defense with both detective and preventive controls for monitoring and blocking unauthorized SQL traffic before it reaches the database. Database Firewall employs a sophisticated SQL grammar analysis engine that inspects SQL statements going to the database and determines with high accuracy whether to allow, log, alert, substitute, or block the SQL, making it an effective control for detecting and blocking SQL injection attacks.

» Unified Audit Oracle Database offers customers an auditing architecture that is both policy-based and context-aware, complete with roles for managing auditing policies (e.g. based on factors such as time of day, IP address, program name, and proxy user name) and the viewing of audit data. Oracle Audit Vault collects audit data from systems and databases both on-premises and in the cloud, providing a secure retention policy and compliance reporting

» Active Directory Integration Oracle Database 18c simplifies the integration with Microsoft's Active Directory. It allows customers to use Active Directory for authentication and authorization of users directly, without the need to utilize Oracle Internet Directory (which was required prior to Oracle Database 18c). This change significantly reduces the complexity (with less component required) needed to manage authentication and authorization, while also improving user security and LDAP availability enterprise-wide.

» Encryption Key Management Comprehensive management of encryption keys, certificates, wallets, and credentials has become a vital part of organization's security ecosystem. Oracle Key Vault is a secure key management platform that helps facilitate the deployment of encryption throughout the enterprise, both on-premises and in the Cloud. It enables customers to centrally manage encryption keys, Oracle Wallets, Java Keystores, and credential files. Oracle Key Vault includes a browser-based management console for administration tasks such as provisioning server endpoints, securely managing key groups, and reporting on access to keys.

» Masking and Subsetting Data Securing enterprise data is not limited to production systems and the practice of copying databases for development, testing and other purposes can create additional risks of data exposure. Oracle Data Masking and Subsetting helps customers improve security, accelerate compliance, and reduce IT costs by sanitizing copies of production databases for non-production usage. It enables entire copies, or subsets, of enterprise data to be extracted from production databases and obfuscated while preserving referential integrity for development, testing and other purposes. Masking and subsetting of data is fully supported on-premises, on Oracle Cloud and for copying databases between both environments.

Database Security Assessment Tool

A recent addition to Oracle's defense in depth capabilities is the Oracle Database Security Assessment Tool (DBSAT), which helps customers identify areas where their Oracle databases may be at risk and recommends changes and controls to mitigate those risks. DBSAT is provided for use with Oracle Databases and also enables customers to quickly find the location, type, and quantity of sensitive data contained in their applications, and provides actionable reports with prioritized recommendations to quickly address potential vulnerabilities.

Data Warehousing and Big Data

Oracle Database 18c provides customers with industry-leading performance, reliability and security for both transactional and analytic workloads, that can easily scale to meet the most demanding requirements whether deployed on-premises or in the Cloud. From an analytics perspective, Oracle Database features a wide range of optimizations such as analytic views, query approximations, and in-memory property graph analytics that can help customers efficiently measure business performance and perform predictive analytics. Oracle Database is a multi-mode- database that provides full support for relational data and non-relational data, such as JSON, XML, text, spatial, and graph data. This enables customers to take full advantage of the performance, reliability, and security capabilities of Oracle Database, to easily manage and integrate non-relational data into business applications, while eliminating the need for multiple specialty-databases (e.g. JSON and XML Databases). In addition, Oracle Database enables SQL access to non-relational data (e.g. JSON and XML) using SQL extensions or native APIs. It also supports a wide range of business intelligence tools for analyzing enterprise and other data sources on-premises or in the Cloud, including Oracle's Autonomous Data Warehouse Cloud.

Oracle Big Data Platform

Oracle recognizes that enterprise data may be stored in disparate data stores (relational, Hadoop, NoSQL), on different platforms (general purpose hardware, engineered systems), and in various locations (on-premises, in-Cloud). In order to help customers evolve their traditional data warehouses and embrace the opportunity of big data, Oracle offers customers a Big Data Platform that provides integrated access to data stored in Oracle Database, Hadoop and NoSQL The Oracle Big Data Platform can run on general purpose or engineered systems (e.g. Oracle Exadata and Big Data Appliance), be deployed on-premises and/or Oracle Cloud, and be accessed using a familiar SQL interface and familiar development and analytics tools. It effectively eliminates the need to move large volumes of data between disparate data stores, and customers can easily perform different types of analysis (e.g. Machine Learning, Graph, Spark), using different languages (e.g. SQL, REST, R), against different types of data (e.g. relational, XML, JSON), stored in different repositories (e.g. Oracle Database, Hadoop, NoSQL)

Fast SQL Access for Relational, Hadoop and NoSQL

Oracle Big Data SQL is the data-virtualization component of Oracle's Big Data Platform. It enables customers to use Oracle SQL for querying and analyzing data across Hadoop, NoSQL and Oracle Database, using their existing SQL tools, resources and skills. Big Data SQL delivers high-performance queries using Oracle's Smart Scan capability, first developed on Oracle Exadata, to execute SQL operations such as query filtering, joins and scoring, on Hadoop and/or NoSQL servers. Other key performance features of Big Data SQL include massively parallel, distributed query processing and storage indexing. Oracle Big Data SQL also provides centralized metadata (via external tables) for simple access to data regardless where it is stored. Based upon this metadata, organizations can implement standard security policies, and apply Oracle Database security features such as data redaction and access controls, across data stored in Hadoop and NoSQL data stores.

Comprehensive Analytic and Data Science Capabilities

Oracle's philosophy is to move analytics to the data, and Oracle Database 18c offers developers and data scientists a choice of in-database analytics and APIs that can provide more in-depth business analysis. These include:

» **Analytic Views** that embed joins, aggregation rules, hierarchical metadata, and complex measure calculations into a single view that can be queried with any SQL tool. The calculation and aggregation rules are handled by the analytic view (not the SQL statement) enabling an easy-to-traverse representation of business data using simple SQL statements.

» **Approximate Queries** are a new class of data analysis including; APPROX_COUNT_DISTINCT(), APPROX_COUNT(), APPROX_SUM() and APPROX_RANK(), that can return approximate answers, with a high degree of accuracy extremely quickly, without requiring excessive resource utilization.

» **Polymorphic Table Functions** are a new Oracle Database 18c feature that enable the shape of data to be returned from a function by parameters passed which enable table functions to be more generic in nature.

» **Pattern Matching** enables pattern detection, in a sequence of events, stored in a database table using SQL syntax.

» **Machine Learning** with massively scalable in-database R processing and Spark algorithms that extend and enhance SparkML

» **Property Graph** with over 40 in-memory parallel algorithms that enable Oracle Database 18c to be used as a Graph database using simple standard interfaces.

» **Spatial** with over 50 functions for massively scalable Vector and Raster processing that enable seamless integration of spatial data with analytic and other applications.

» **Multi-Media** with a massively scalable open framework for imaging and video processing commonly used in facial, OCR, and License Plate recognition applications.

Big Data Cloud Service

By integrating software and hardware components together at the factory with engineered systems such as Oracle Exadata and Big Data Appliance, Oracle helps organizations eliminate risk, optimize performance and speed time- to-implementation for their big data projects on-premises. Oracle also brings these same benefits to the cloud with the Big Data Cloud Service. It offers customers a comprehensive, high-performance service for Hadoop, Spark, and NoSQL and includes; Cloudera Enterprise Data Hub, R and Property Graph analytics, and data integration tools. Customers can start small with a 3-node cluster and easily scale out to 100's of nodes as required. Oracle Cloud not only delivers all of the capabilities of Oracle's on-premises solution, it also transforms Big Data deployments from on-premises upfront capital expenditure to a pay-as-you-go operational expenditure model.. Oracle's hybrid strategy of delivering the same architecture and software on Oracle Cloud as on-premises enables organizations to move to the cloud, while maintaining their existing skillsets, applications, and support resources for the Oracle Big Data Platform. Customers have the choice of deploying Oracle Exadata and Big Data Appliance for their data warehouse and big data systems on-premises, or consuming Exadata and Big Data Services in the Oracle Cloud

Autonomous Data Warehouse Cloud

Oracle recently introduced the Autonomous Data Warehouse Cloud, a new service that offers customers enterprise performance, reliability and security for their data marts, reporting databases and data warehouses, which requires zero operational administration. The Autonomous Data Warehouse Cloud is an easy to use service (e.g. it does not require manual intervention normally associated with data warehousing on-premises), it's fast (e.g. it runs on Oracle Exadata) and it's completely elastic (e.g. customers can Independently scale compute and storage with zero downtime). The Autonomous Data Warehouse Cloud offers customers complete analytic freedom, with a choice of interfaces (e.g. SQL and APIs), analytic services (e.g. Machine Learning and Graph, and data management services (e.g. Autonomous Cloud and Object Stores).

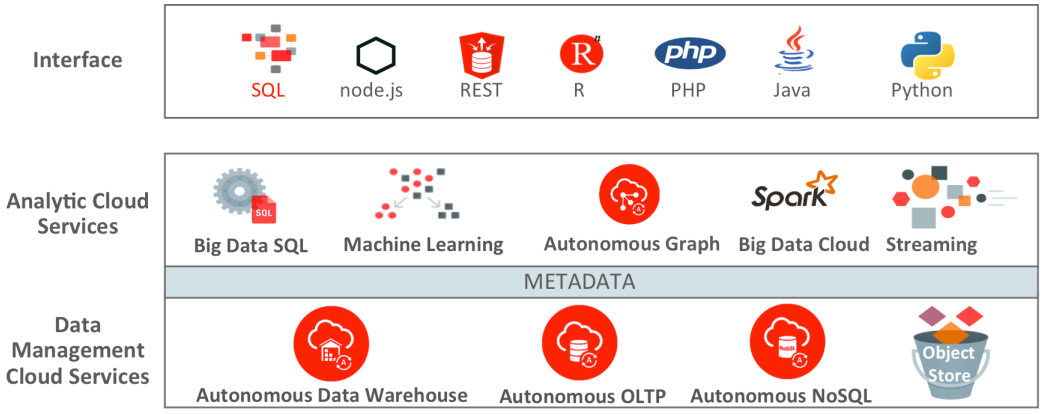

Figure 2. Analytic Freedom in Oracle Cloud

Application Development

Oracle Database not only offers customers the latest generation of the world's most popular database, it also offers developers an integrated data management solution that is supported by all popular application development frameworks in use today. This enables developers to quickly build applications that can easily take full advantage of the performance, reliability, security, and other features of Oracle Database, thereby protecting customer's investments in existing development resources and skill sets.

Application Developer Frameworks

Oracle Database offers developers native programmatic interfaces as well as support for a wide range of development and scripting languages including:

- SQL and PL/SQL
- Oracle Call Interface (OCI)
- Programming languages including Java, C and C++
- Scripting languages including PHP, Ruby and Perl
- .NET with Oracle Developer Tools for Visual Studio, Oracle Data Provider for .NET and Oracle Database Extensions for .NET.

Oracle Application Express

Oracle Application Express (APEX) is a database-centric rapid web application development tool for building a vast array of applications. It's included with every on-premises edition of Oracle Database and every Oracle Database Cloud Service. APEX is completely declarative, and, using only a web browser, end users and experienced developers can quickly build and deploy fast, reliable and secure database applications. It's ideally suited to power users writing reports or simple forms to experienced SQL and PL/SQL developers implementing sophisticated applications that support business operations.

Oracle SQL Developer

Oracle SQL Developer simplifies the development and management of Oracle databases – including pluggable databases. It's also included with every on-premises edition of Oracle Database and every Oracle Database Cloud Service. SQL Developer offers complete end-to-end development of PL/SQL applications, a worksheet for running queries and scripts, a DBA console for managing the database, a reports interface, a complete data modeling solution, and also a migration platform for moving non-Oracle databases to Oracle Database.

Oracle REST Data Services

Oracle REST Data Services (ORDS) is a mid-tier technology that serves up RESTful Services for Oracle Database. ORDS enables developers to transform Oracle Database into an easy-to-use RESTful API Service. ORDS receives REST requests and marshalls those to Oracle Database as SQL or PL/SQL code blocks, returning any output as a JSON collection back to the calling application. With ORDS, any database resource can be made available via REST, and the data access APIs can fully exploit all the power of Oracle Database for the highest levels of performance, reliability and security.

JSON Support

Oracle Database offers full support for storing, querying and processing of JSON data, enabling developers to utilize Oracle as a NoSQL database using the Simple Oracle Document Access (SODA) API, REST or JAVA NoSQL APIs to build applications. It includes a number of functions that return or manipulate JSON inside the database via SQL, and JSON data may also be easily queried for analytical reporting using SQL and SQL generating tools.

Oracle LiveSQL

Live SQL provides the Oracle database community with a simple online way to test and share SQL and PL/SQL application development concepts, tutorials and practices. No on-premises or in-Cloud database hardware or software, installation or configuration is required. Only a web browser is required to access sample SQL and PL/SQL scripts running on Oracle Database 18c, that may be freely created, copied, tested and shared as required.

Oracle Database on Docker

Oracle Database and related developer tools are available in the Docker Store marketplace via the Docker Certification Program, a framework for vendors like Oracle to integrate and certify their technology to the Docker platform. Developers can therefore pull images of Oracle Database in Docker and quickly start developing, testing and deploying modern enterprise applications, using Docker Enterprise Edition as their container platform.

Conclusion

The latest generation of the world's most popular database, Oracle Database 18c, builds upon key architectural, performance and distributed data innovations successfully established in Oracle Database 12c. Its unique multitenant architecture, dual-format in-memory column store and native sharding have enabled customers to evolve their databases, both on premises and in the Cloud, to meet their business and cost control objectives.

Oracle Database 18c now provides customers with a high-performance, reliable and secure platform to easily and cost-effectively modernize their transactional and analytical workloads either in the Cloud, or on-premises, or in a Hybrid Cloud configuration. It offers the same familiar database software running on-premises and in the Cloud that enables customers to take their in-house developed Oracle applications and ISV applications and run them on Oracle Cloud without incurring any application changes. Customers can therefore continue to utilize all their existing IT skills and resources, and get the same support for their Oracle Databases both on-premises and in Oracle Cloud.

Unique, critical database capabilities such as Real Application Clusters and Active Data Guard, and unique Engineered Systems such as Oracle Exadata and Database Appliance, have helped establish Oracle as the database market leader by a wide margin. Indeed, Oracle has been widely proven to provide the performance, reliability and security required for some of the world's most demanding transactional and analytical workloads. Oracle Database 18c takes the management of customer's enterprise data to the next level, helping customers on their journey to the cloud.

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White Paper Title
February 2018
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