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**Oracle NoSQL Database –
A Distributed Key-Value Store**

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Agenda

- Oracle and NoSQL
- Oracle NoSQL Database Architecture
- Oracle NoSQL Database Technical Details



What Does NoSQL Mean To Oracle?

- Distributed
- Large data (Terabyte – Petabyte range)
- Two categories
 - OLTP ← Our focus is here
 - BI (M/R & Hadoop) ← ... and we integrate here
- Data Models
 - Key-Value ← Our focus is here
 - Document
 - Columnar
- Berkeley DB by itself is not really “NoSQL” by this definition



Target Use Cases

- Large schema-less data repositories
 - Web applications (click-through capture)
 - Online retail
 - Sensor/statistics/network capture (factory automation for example)
 - Backup services for mobile devices
 - Scalable authentication
 - Personalization
 - Social Networks



Design Requirements

- Terabytes to Petabytes of data
- 10K's to 1M's ops/sec
- No single point of failure
- Elastic scalability on commodity hardware
- Fast, *predictable* response time to simple queries
- Flexible ACID transactions, a la Berkeley DB
- Unstructured or semi-structured data, with clustering capability
- Simple administration, enterprise support
- **Commercial-grade** NoSQL solution



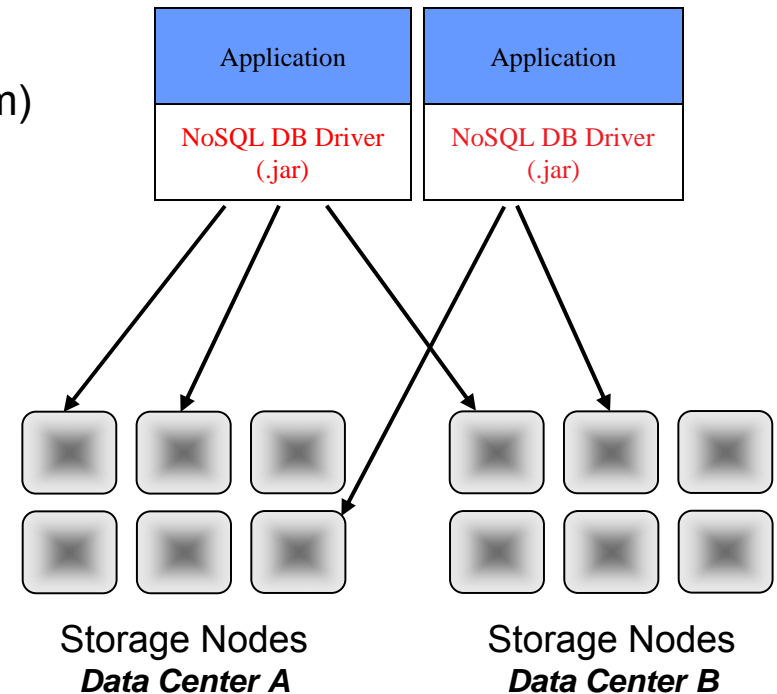
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Oracle NoSQL Database Overview

A Distributed, Scalable Key-Value Database

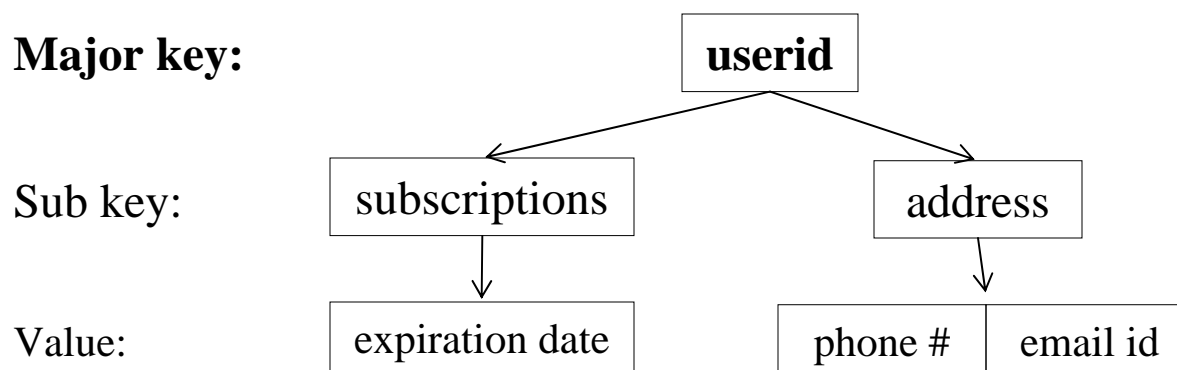
- Simple Data Model
 - Key-value pair (with major/minor key paradigm)
 - CRUD + iteration
- Scalability
 - Data partitioning and distribution
 - Optimized data access via intelligent driver
- High availability
 - One or more replicas
 - Resilient to partition master failures
 - No single point of failure
 - Disaster recovery through location of replicas
- Transparent load balancing
 - Reads from master or replicas
 - Driver is network topology & latency aware
- Elasticity (Release 2)
 - Online addition/removal of storage nodes and automatic data redistribution



Oracle NoSQL Database

What the Programmer Sees

- Simple data model – key-value pair (major/minor key paradigm)
- Simple operations – CRUD, RMW (CAS), iteration
 - Conflict resolution not required
- ACID transactions for records within a major key, single API call
- Unordered scan of all data (non-transactional)
- Ordered iteration across sub keys within a key
- Consistency (read) and durability (write) spec'd per operation





Oracle NoSQL Database

No Single Point of Failure

- App Servers can be replicated by user
- Nodes are kept current (underlying BDB-JE HA technology)
- Driver (Request Dispatcher) is linked into each App Server
- Nodes may live in multiple Data Centers
- Node Replacement
 - Graceful degradation until
 - Node is fixed, or ...
 - ... node is replaced
 - Automatic recovery



Oracle NoSQL Database

Easy Management

- Web-based console and CLI commands
- Manages and Monitors
 - Topology
 - Configuration changes
 - Load: Number of operations, data size
 - Performance: Latency, throughput. Min, max, average, trailing, ...
 - Events: Failover, recovery, load distribution
 - Alerts: Failure, poor performance, ...
 - We couldn't develop the product without this stuff



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Oracle NoSQL Database Building Blocks

Berkeley DB Java Edition

- Robust storage for a distributed key-value database
 - ACID transactions
 - Persistence
 - High availability
 - High throughput
 - Large capacity
 - Simple administration
- Already used in
 - Amazon Dynamo
 - Voldemort (LinkedIn)
 - GenieDB



Oracle NoSQL Database

Building upon Berkeley DB Java Edition

- Data Distribution
- Dynamic Partitioning (aka “sharding”)
- Load Balancing
- Monitoring and Administration
- Predictable Latency
- Multi-Node Backup
- One-stop Support for entire stack
- Optimized Hardware (Oracle Big Data Appliance)



Distributed Data Storage Network Traffic

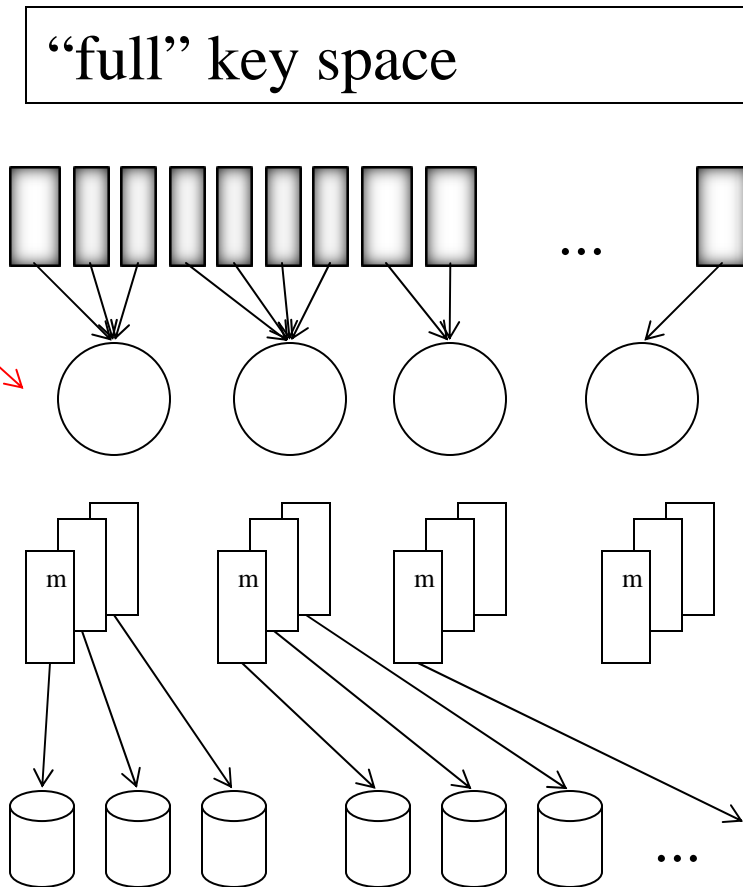
Minimizing latency is key

- Design Target: High volume -- 100K-1M ops/second
- Many concurrent threads
- Driver is topology aware
 - Directs operations to the proper node
 - Performs load balancing
 - Single network hop except when node fails or topology changes
 - Topology changes returned with results
- Single and multi-record operations
- Common use case will access single key-value pair or related set of sub-keys

Oracle NoSQL Database

Storage Terminology

- Key space hashes into multiple hash buckets (**partitions**)
- Set of partitions maps to a **replication group** (logical container for subset of data)
- Set of **replication nodes** for each replication group provides HA and read scalability for each replication group
- **Storage node** (physical or virtual machine) runs each replication node



Showing only a subset of the storage nodes



Oracle NoSQL Database Driver

Locating Data: Partition Map

- MD5(major key) % nPartitions → Partition ID
- Partition Map maps Partition ID to Rep Group
- Each Driver has a copy of the Partition Map
 - Initialized on the first request to any node
 - Allows direct contact with a node capable of servicing the request



Oracle NoSQL Database Driver

Locating Data: Rep Node State Table

- Rep Node State Table (RNST) locates optimum Rep Node within a Rep Group to handle a request
- Partition ID/Operation Type/Consistency →
Rep Node in Rep Group
- RNST Contains ...
 - Rep Node in Rep Group that is currently the Master
 - VLSN lag at a replica (how far behind a replica is)
 - RNST Entry's last update time
 - Number outstanding requests
 - Trailing average time associated with a request
 - Allows for varying topology and response times as seen from the drivers
- RNST updated by responses



Resolving a Request

- Hash Major Key to determine Partition id
- Use Partition Map to map Partition id to Rep Group
- Use State Table to determine eligible Rep Node(s) within Rep Group
- Use Load Balancer to select best eligible Rep Node
- Contact Rep Node directly
- Rep Node handles (almost always) or forwards request (almost never)
 - Operation result + new Partition Map/RNST information returned to client



Oracle NoSQL Database

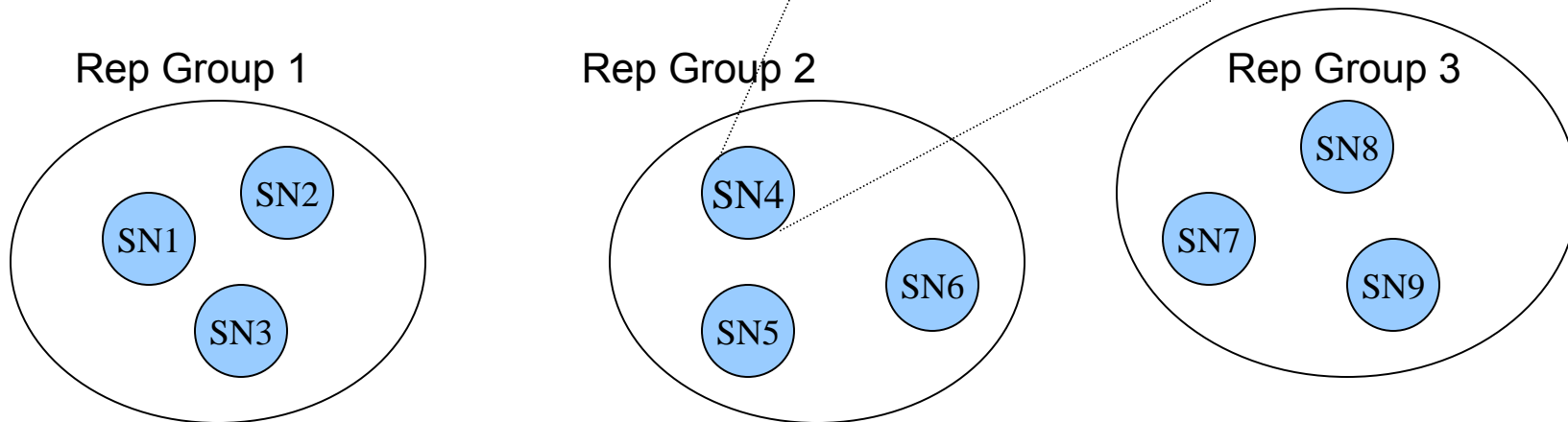
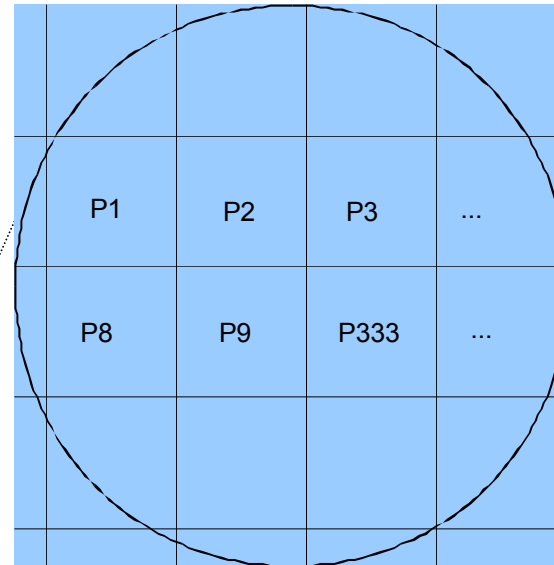
Storage Nodes

- A “machine” with its own local storage and IP address
 - Physical (preferred) or virtual
- Additional Storage Nodes increase throughput, capacity, or decrease latency
- Not necessarily symmetrical
 - Different processors, memory, capacity
- May host one or more Replication Nodes
 - By default, Replication Nodes are 1:1 with Storage Nodes
 - It would be unwise to locate multiple Replication Nodes in the same Replication Group on the same Storage Node

Oracle NoSQL Database

Topology Example

- 100M keys, 9 Storage Nodes might be configured as
 - 1000 Partitions
 - 3 Rep Groups
 - Replication Factor 3
 - 9 Rep/Storage Nodes





High Availability/Replication

Overview

- Replication group consists of single master and multiple replicas
- Logical replication
- Dynamic group membership, failover, elections
- Synchronous or Asynchronous
- Transaction durability and consistency guarantees are specifiable “per operation”
- Uses TCP/IP and standard Java libraries
- Supports nodes with heterogeneous platform hardware/OS
- HA Monitor class tracks Replication Group state



High Availability/Replication

Failure and Recovery

- Nodes join a replication group
 - When quorum is reached, election is held resulting in Master + Replicas
- Node Failure
 - Failed nodes can be replaced from the group via the Administrative API
 - Rejoining nodes automatically synchronize with the master
 - Isolated nodes can still service reads as long as consistency guarantees are met
- Master Failover
 - Nodes detect failure via missing heartbeat or connection failure
 - Automatic election of new master, via a distributed two phase election algorithm (PAXOS)
 - For maximum availability, whenever feasible, elections are overlapped with the normal operation of a node
- System automatically maintains group membership and status



High Availability/Replication Transaction Behavior

- Controlled by a Durability option
- Transactions on the master can fail if
 - Not enough nodes to support durability
 - Node transitions from Master to Replica



Durability (Writes)

- Specified on per-operation basis, default can be changed
- Durability consists of ...
 - Sync policy (Master and Replica)
 - Sync – force to disk
 - Write No Sync – force to OS
 - No Sync – write when convenient
 - Replica Ack Policy
 - All
 - Simple Majority
 - None



Consistency (Reads)

- Specified on per-operation basis, default can be changed
- Consistency
 - Absolute (read from Master)
 - Time-based
 - Version
 - None (read from any node)



CAP

- We focus on “simple_majority” replica ack policy
- Only one version maintained
- No user reconciliation of records
- We might truncate transactions
- We are probably more CA than AP



What We've Been Testing

- YCSB-based QA/benchmarking
 - Key \approx 10 bytes, Data = 1108 bytes
- Prefer Keys up to 10's of bytes, Data up to 100K
 - > 100KB data ok
- Configurations of 10-200 nodes
 - Typical Replication Factor of 3 (master + 2 replicas)
- Minimal I/O overhead
 - B+Tree fits in memory => one I/O per record read
 - Writes are buffered + log structured storage system == fast write throughput




Performance: “Nashua”

- Single Rep Group (3 nodes), Sun X4170, dual Xeon, X5670, 2.93 GHz (3.3 GHz turbo), 2 x 6 core, 2 threads/core (24 contexts), 72GB memory, 8 x 300GB 10k SAS in RAID-5
- 400M records
 - Inserts 15.3k/sec 9ms (95%'ile), 12ms (99%'ile)
- 500M records
 - 50/50 read/update, overall 6,542 ops/sec
 - Read latency: 7/32/58 ms (avg/95/99)
 - Update latency: 8/33/61 ms (avg/95/99)



Performance: “SLC 72”

- 20 Rep Group on 60 VMs on 12 physical servers
 - 2x6 Xeon, 96GB / physical machine
 - 2 core x 2 threads (4 contexts), 16GB per VM
- 100M records/Rep Group
 - Inserts 109k/sec latency: 5/12/60 ms (avg/95/99)
 - 50/50 read/update, overall 33k ops/sec
 - Read latency: 16/74/155 ms (avg/95/99)
 - Update latency: 19/79/171 ms (avg/95/99)
- Remember: these are VMs so we’re only testing scalability, not real performance



Performance: “Intel Dupont”

- 64 Rep Groups on 192 physical servers
 - 2x6 Xeon x5760 (2.93GHz/3.3GHz turbo), 24GB / machine
 - 300GB local disk/machine
- 2.1B total records (YCSB limitation)
 - 50/50 read/update, overall 101.4k ops/sec
 - Read latency: 10/21/73 ms (avg/95/99)
 - Update latency: 23/25/197(*) ms (avg/95/99)
- Ext3 tuning
- (*) multiple YCSB clients may be considering same keys hot – under investigation



QUESTIONS?