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Oracle Spatial and Graph User Conference

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Washington, DC USA

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Performance, Performance, Performance
What You Need To Know About Exadata

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The following is intended to outline our general product direction. It is intended for information purposes only, and may not be incorporated into any contract.

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Program Agenda

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- Oracle Exadata Database Machine
- Parallel Enabled Spatial Operators and Functions
- Hybrid Columnar Compression (HCC) and Spatial
- Massive Spatial Data Ingests with Spatial Index Enabled

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Oracle Exadata Database Machine
Engineered System

What Is the Oracle Exadata Database Machine?

- Oracle SUN hardware uniquely engineered to work together with Oracle database software
- Key features:
  - Database Grid – Up to 160 Intel cores connected by 40 Gb/second InfiniBand fabric, for massive parallel query processing.
  - Raw Disk – Up to 504 TB of uncompressed storage (high performance or high capacity)
  - Memory – Up to 2 TB
  - Hybrid Columnar Compression (HCC) – Query and archive modes available. 3x to 30x compression.
  - Storage Servers – Up to 14 storage servers (168 Intel cores) that can perform massive parallel smart scans. Smart scans offloads SQL predicate filtering to the raw data blocks. Results in much less data transferred, and dramatically improved performance.
  - Flash memory – Up to 22.4 TB with I/O resource management

Exadata X3-2 Quarter Rack Diagram

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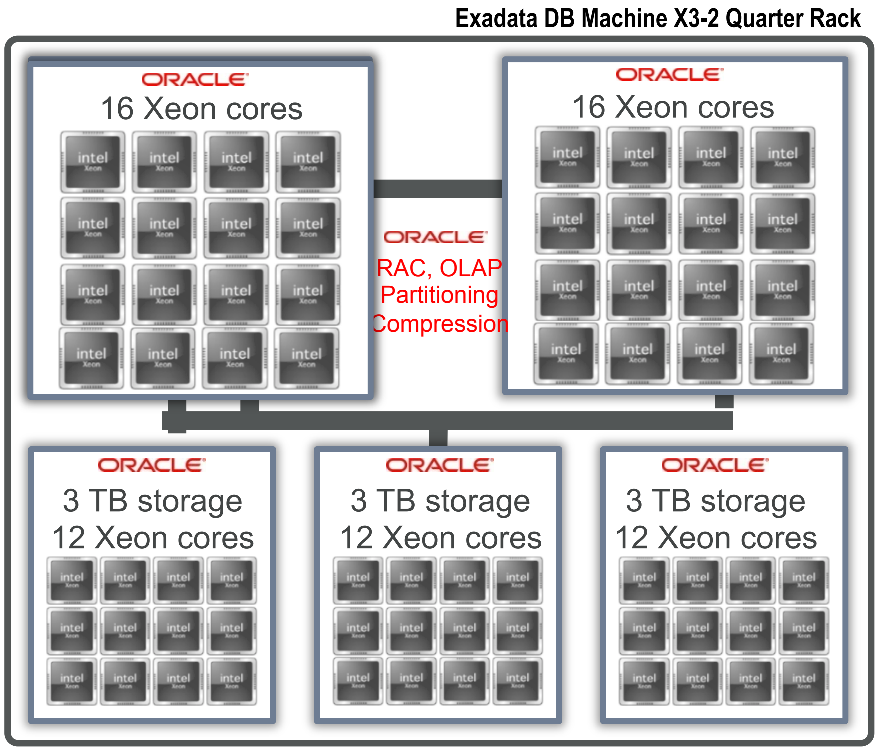

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Parallel Enabled
Spatial Operators and Functions

Oracle Spatial and Graph Is Parallel Enabled

Key Differentiator

- Parallel enabled Spatial Operators and Functions a major focus
- Designed for highly parallel architectures, like Exadata:
  - Parallel spatial queries
  - Parallel spatial index creation
  - Parallel geometry validation
  - Parallel Geocoding
  - Parallel raster operations
  - Spatial batch spatial operations
  - And more…

Parallel Query and Spatial

With Spatial Operators and Partitioned Tables

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Parallel Query And Spatial Operators

Partitioned Tables

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- If a spatial operator's query window spans multiple partitions, partitions are spatially searched in parallel.
- True for all spatial operators

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Parallel Query And Spatial Operators

Partitioned Tables

- Example:
  - A re-insurance company maintains portfolios for hundreds of insurance companies.
  - Which companies will be affected by the projected path of hurricane Ike.
  - 36 million rows, 64 partitions, each with about 571,000 rows.
    - 50 seconds serial
    - 1.28 second parallel on ½ rack Exadata database machine (39 times faster)

Parallel Query and Spatial

With Spatial Operators

Parallel Query And Spatial Operators

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- Spatial operators can parallelize when multiple candidates feed the second argument

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Parallel Query and Spatial

US Rail Application

Parallel Query And Spatial Operators

US Rail Application

- Requirement
  - GPS locations for each train collected throughout the day
  - Each location has other attributes (time, speed, and more)
  - GPS locations have a degree of error, so they don't always fall on a track.
  - Bulk nearest neighbor queries to find closest track, and project reported train positions onto tracks
- This information is used for:
  - Tracking trains
  - Analysis for maintenance, ensure engineers are within parameters,etc

Parallel Query And Spatial Operators

What we tested

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- 45,158,800 GPS train positions.
- For each train position:
  - Find the closest track to the train (with SDO_NN)
  - Then calculate the position on the track closest to the train

Parallel Query and Spatial Operators

US Rail Application

```
ALTER SESSION FORCE PARALLEL ddl PARALLEL 72;
ALTER SESSION FORCE PARALLEL query PARALLEL 72;

CREATE TABLE results NOLOGGING AS
SELECT /*+ ordered  index (b tracks_spatial_idx) */
            a.locomotive_id,
            sdo_lrs.find_measure (b.track_geom, a.locomotive_pos)
FROM locomotives a,
         tracks b
WHERE sdo_nn (b.track_geom, a.locomotive_pos,
                      'sdo_num_res=1')  = 'TRUE';
```


Parallel Query And Spatial Operators

Exadata Results

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- On Exadata X2-2 Half RAC:
  - 34.75 hours serially vs. 44.1 minutes in parallel
  - 48 database cores - 47x faster
- On Exadata X3-2 Full Rack
  - 128 database cores – about 125x faster
  - About 16.6 minutes in parallel
- X3-8 (160 cores) even faster

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Parallel Query and Spatial

Government Sponsored Enterprise Validation of Home Appraisals

Validation Of Home Appraisals

Exadata Results

- Validate home appraisals for a Government Sponsored Enterprise (GSE)
- Requirement - Find all the parcels touching parcels to validate appraisals
- Processed 2,018,429 parcels
  - Exadata X2-2 ½ RAC:
    - Serially – **38.25 minutes**
    - Parallel - 48 cores (45x faster) - **50 seconds**
  - Exadata X3-2 Full RAC (128 cores) about 120x faster
  - Exadata X3-8 (160 cores) even faster

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Parallel Query and Spatial

Parallel Enabled Pipeline Table Functions

Parallel Enabled Pipeline Table Function

- Parallelize a function that’s called a massive amount of times.
  - Batch geocoding (sdo_gcdr.geocode_address)
  - Batch reverse geocoding (sdo_gcdr.reverse_geocode)
  - Batch Digital Elevation Model (DEM) raster lookups (sdo_geor.get_cell_value)
- Pipeline Table Function returns a table of results
  - Table of geocodes
  - Table of reverse geocodes
  - Table of elevation values

Parallel Enabled Pipeline Table Function

How does it work?

- Define cursor that selects the input to the batch process:
  - SELECT customer_addresses
    FROM address_table
    WHERE state = ‘NY’;
  - SELECT vehicle_location
    FROM vehicles
    WHERE sdo_anyinteract (location,:region) = ‘TRUE’
- Parallel Query distributes the batch process over a specified number of database cores.

Parallel Enabled Pipeline Table Function

Exadata X2-2 ¼ RAC has 2 nodes, each with 12 cores (24 total)

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```
ALTER SESSION FORCE PARALLEL DML PARALLEL 24;
ALTER SESSION FORCE PARALLEL QUERY PARALLEL 24;
-- To balance parallel slaves across nodes.
ALTER SESSION SET "_parallel_load_balancing"=false;
CREATE TABLE results (id NUMBER, geom SDO_GEOMETRY);

INSERT /*+ append */ INTO results
  SELECT id,
             sdo_geometry (2001,8307,sdo_point_type(longitude,latitude,null),null,null) geom
  FROM TABLE( geocode_pipelined ( CURSOR(SELECT id, streetname, city,
                                                    state, zip, housenum
                                         FROM ascii_addrs)              ));
COMMIT;
```

Parallel Enabled Pipeline Table Function

Exadata X2-2 ¼ RAC has 2 nodes, each with 12 cores (24 total)

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```
ALTER SESSION FORCE PARALLEL DML PARALLEL 48;
ALTER SESSION FORCE PARALLEL QUERY PARALLEL 48;
ALTER SESSION SET "_parallel_load_balancing"=true;   (or don't specify, true default)

CREATE TABLE results (id NUMBER, geom SDO_GEOMETRY);

INSERT /*+ append */ INTO results
  SELECT id,
                sdo_geometry (2001,8307,sdo_point_type(longitude,latitude,null),null,null) geom
  FROM TABLE( geocode_pipelined ( CURSOR(SELECT id, streetname, city,
                                                  state, zip, housenum
                                          FROM ascii_addrs)                 ));
COMMIT;
```

Parallel Pipelined Table Function

Exadata Results

- Exadata X2-2 ¼ RAC with 24 Cores

- Batch geocoding – 1365/second
- Batch reverse geocoding – 3388/second
- Batch DEM get_cell_value raster lookups – 8951/second

Hybrid Columnar Compression (HCC) and Spatial

HCC and Spatial

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- HCC is primarily for static or almost static data. Updates will uncompress compressed data (true for spatial and non-spatial data).
- Point, Line and Polygon geometries can all benefit from HCC
- Lines and Polygons, they must be stored inline (less than 4K in size).
- Options include:
  - COMPRESS FOR QUERY LOW
  - COMPRESS FOR QUERY HIGH
  - COMPRESS FOR ARCHIVE LOW
  - COMPRESS FOR ARCHIVE HIGH

HCC and Spatial

- Two ways to compress:
  - Create Table As Select
  - Direct Path Inserts

1. Create Table As Select

```
CREATE TABLE edges_compressed
 COMPRESS FOR QUERY LOW
 NOLOGGING AS SELECT * FROM edges;
```


HCC and Spatial

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2. Direct Path Inserts (full code example in presentation appendix)

```
-- PL/SQL Example with append_values hint.
DECLARE
  id_tab      ID_TAB_TYPE;
  edge_tab  GEOM_TAB_TYPE;
BEGIN
   -- Population of id_tab and edge_tab shown in presentation appendix
   FORALL i IN edge_tab.first .. edge_tab.last
       INSERT /*+ append_values */ INTO edge_ql VALUES (id_tab(i), edge_tab(i));
   COMMIT;
```

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HCC and Spatial – Uniform Geometries

Strategy For Much Higher Compression Rates

- Uniform geometries spatial layers have the same number of coordinates in every row.
- Some examples:
  - Point data (x NUMBER, y NUMBER)
  - Box polygon (llx NUMBER, lly NUMBER, urx NUMBER, ury NUMBER)
  - Two point line (x1 NUMBER, y1 NUMBER, x2 NUMBER, y2 NUMBER)
  - Four point polygon (x1 NUMBER, y1 NUMBER, …, x5 NUMBER, y5 NUMBER)
- For much higher compression rates, store uniform geometries as a series of NUMBER columns instead of SDO_GEOMETRY

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HCC and Spatial – “Uniform” Geometries

Box Polygon With Function Based Index - Example

- Create a function based index on uniform geometries to perform spatial queries
- The following ANYINTERACT queries were run on a 116 million row table
- Query High compression – 18.17x… queries still very fast.

Anyinteract Query	Uncompressed	Query Low 3.92x comp	Query High 18.17x comp	Archive High 21.57x comp
10 acre polygon (487739 rows returned)	1.86 sec	2.02 sec (1.08x perf)	2.7 sec (1.45x perf)	12.75 sec (6.85x perf)

HCC and Spatial – “Uniform” Geometries

Box Polygon With Function Based Index - Example

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- SDO_Within_Distance queries against compressed “uniform” geometries

Within_Distance Query	Uncompressed	Query Low 3.92x comp	Query High 18.17x comp	Archive High 21.57x comp
0.1 mile (1096 rows)	0.10 sec	0.12 sec (1.2x perf)	0.24 sec (2.4x perf)	1.63 sec (16.3x perf)
0.5 mile (25996 rows)	0.84 sec	1.17 sec (1.39x perf)	2.98 sec (3.54x perf)	24.34 sec (28.97x perf)
1 mile (103226 rows)	3.00 sec	4.26 sec (1.42x perf)	10.83 sec (3.61x perf)	88.30 sec (29.43x perf)

SDO_ANYINTERACT + SDO_BUFFER vs SDO_WITHIN_DISTANCE

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- Not conclusive… sdo_anyinteract with sdo_buffer () as query window may be faster than sdo_within_distance.
- Still under investigation…. May be worth a try.

```
SELECT count(*)
FROM businesses
WHERE SDO_ANYINTERACT (geometry,
                              sdo_geom.sdo_buffer(sdo_geometry(2001,8307,
                                                  sdo_point_type (-122.3, 37.7,null),
                                                  null, null),
                              4, 0.05, 'unit=mile')) = 'TRUE‘;
```

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HCC – Non Uniform Geometries

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- Non-uniform geometries layers can have a different number of coordinates in every row.
- Some examples:
  - Zip code polygons
  - County polygons
  - Road line strings
- Use SDO_GEOMETRY for non-uniform geometry columns

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HCC and Spatial (SDO_GEOMETRY)

Point data

- Point data is uniform, storing it as two Oracle NUMBERs (instead of SDO_GEOMETRY) can achieve much better compression rates than the ones below.
- See compression rates for uniform data on previous slides.

Within_distance Query	Uncompressed	Query Low 3.5x comp	Query High 5.3x comp	Archive High 6.8x comp
4 mile (323 rows)	0.02 sec	0.02 sec (0.0x perf)	0.06 sec (3.0x perf)	1.36 sec (68x perf)
5 mile (1251 rows)	0.03 sec	0.06 sec (2.0x perf)	0.12 sec (4.0x perf)	2.77 sec (92x perf)
10 mile (31466 rows)	0.29 sec	0.61 sec (2.1x perf)	1.3 sec (4.5x perf)	32.11 sec (110x perf)

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HCC and Spatial (SDO_GEOMETRY)

Line / Polygon data

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Within_distance Query (lines)	Uncompressed	Query Low 3.5x comp	Query High 5.3x comp
4 mile (809 rows)	0.08 sec	0.18 sec (2.25x perf)	0.48 sec (6x perf)
5 mile (3079 rows)	0.16 sec	0.38 sec (2.375x perf)	0.99 sec (6.188x perf)
10 mile (80771 rows)	1.75 sec	3.91 sec (2.23x perf)	10.34 sec (5.91x perf)

- SDO_ANYINTERACT with SDO_BUFFER query window could produce faster response times.... May want to give it a try.

HCC and INSERT /*+ append_values */

- Currently, INSERT /*+ append_values */ can HCC compress points, lines and polygons
- Lines and Polygons must be less than 4K (stored inline)
- INSERT /*+ append_values */ does not compress if the column contains a spatial index.
  - The lifting of this restriction is under investigation.

Massive Spatial Ingests

Massive Spatial Data Ingest

With Spatial Indexes

- Two types of requirements:
  - Staging Table - Window of time to make the spatial data available.
    - Use a staging table with no indexes for initial load.
    - Create spatial and non spatial indexes in parallel
    - Exchange staging table into an existing partitioned table.
  - No Staging Table - Data must be available immediately for spatial queries. No time for a staging table.
- Different strategies for the two types of requirements.
- Both requirements require data modeling considerations (discussed in upcoming slides).

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Massive Spatial Ingests

With A Staging Table

Massive Spatial Data Ingest

With A Staging Table

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- Major benefits are performance and manageability of very large data sets
- Customer example:
  – Requirement:
    - Ingest and maintain 2 days of weather data online
    - 270,000 samples every 30 seconds (Oracle Spatial can do even more…)
  – Implemented with:
    - 30 second partitions (5760 partitions over 2 days)
    - New partitions rolled on, older partitions rolled off

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Massive Spatial Data Ingest

With A Staging Table

- Load data into a staging table with no indexes (called new_weather_data)
- Parallel create index (spatial index too) on staging table
- Partition P1 is an empty leading partition
- Update partitioned table with new weather data in a fraction of a second.
- No need to maintain an index on INSERT !!!!

```
ALTER TABLE weather_data_part EXCHANGE PARTITION p1
WITH TABLE new_weather_data
INCLUDING INDEXES
WITHOUT VALIDATION;
```


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Massive Spatial Ingests

Without A Staging Table

Massive Spatial Data Ingest

Without A Staging Table

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- Spatial data must be inserted and committed immediately
- No time for a staging table.
- If possible, don’t commit after every insert.
- If possible, perform batch inserts.
- Set sdo_dml_batch_size=15000 when you create the spatial index.
  - PL/SQL - FORALL BULK INSERTS (example in appendix)
  - Java - JDBC UPDATE BATCHING
  - C – Array inserts

Massive Spatial Data Ingest

Without A Staging Table (continued)

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- Very Common Misconception:

"Increasing number of connections in a pool and number of threads performing inserts will increase spatial data insert throughput"

  - **Only true if** no connections in pool write to the same spatial index.
  - For high ingest rates, even two connections writing to the same spatial index can adversely affect spatial index ingest performance.

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Massive Spatial Data Ingest

Without A Staging Table (continued)

- Quick fix… try streaming all writes to one connection in the pool.
  - One connection for writes
  - Many connections for reads
- To really maximize spatial ingest throughput:
  - Use multiple connections in a connection pool
  - Dedicate each connection to one spatial index.
  - This eliminates all spatial index contention.
- Strategy continued on next slide.

Massive Spatial Data Ingest

- Example is hourly, but could be monthly or quarterly
- Multiple threads perform batch inserts, each with a dedicated process id

```
CREATE TABLE composite_example
  ( t               timestamp
  , process_id      number
  , geom            sdo_geometry
  , hour_partition as (substr(t,1,12)))
  PARTITION BY RANGE ( hour_partition, process_id )
   (PARTITION DAY1_H5_1  VALUES LESS THAN ('30-NOV-10 05', 2 ),
    PARTITION DAY1_H5_2  VALUES LESS THAN ('30-NOV-10 05', 3 ),
    PARTITION DAY1_H5_3  VALUES LESS THAN ('30-NOV-10 05', 4 ),
    PARTITION DAY1_H6_1  VALUES LESS THAN ('30-NOV-10 06', 2 ),
    PARTITION DAY1_H6_2  VALUES LESS THAN ('30-NOV-10 06', 3 ),
    PARTITION DAY1_H6_3  VALUES LESS THAN ('30-NOV-10 06', 4 ),
    PARTITION REST   VALUES LESS THAN (MAXVALUE,MAXVALUE));
```

Massive Spatial Data Ingest

X2-2 Quarter RAC Exadata - Results

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- Inserts per second with spatial index enabled
  - Parallel Degree - how many threads performing bulk inserts in parallel
  - For 1 million row partition, 15K batches, 66,123.57 inserts per second

Parallel Degree	Inserts/Sec (100k/15k)	Inserts/Sec (1m/15k)
1	3,901.92	3,701.10
2	7,646.74	7,352.68
8	30,757.95	28,870.05
12	44,843.68	41,557.92
8x2	59,547.36	50,237.07
12x2	84,309.38	66,123.57

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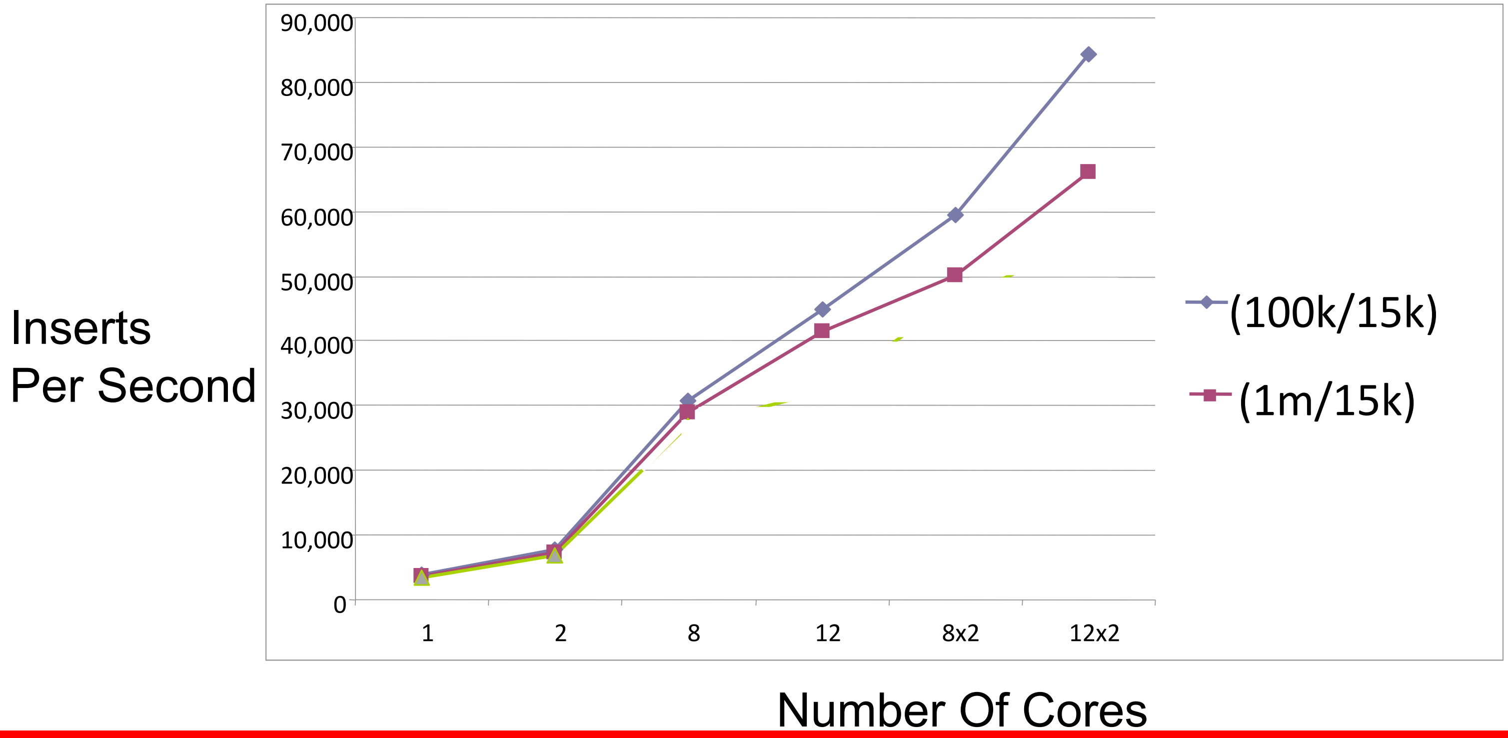
Massive Spatial Data Ingest

X2-2 Quarter RAC Exadata - Results



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Q&A

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