Query Optimization Time: The New Bottleneck in Real-time Data Analytics

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Problem Statement

In-memory distributed databases everywhere..

What do we expect from in-memory today?

- OLTP
  - Improve transactional throughput
  - Ingest more per second

- OLAP
  - Load data faster
  - Generate reports faster
  - *Enable real-time data analytics*

Real-time Data Analytics Today

- Answer analytical queries in “real-time”
  - within a second or few second, not minutes
- Data mostly in the ~100s TB range
- Demands query execution to finish within a second or few seconds
- Queries could be ad-hoc (analytical dashboards)
- Queries could be complex
  - A few joins (star or snowflake schema)
  - Groupby, Aggregates
  - Sub-queries

Example Query 1: Big Financial Services

- **Distributed Join Order, Outer Join to Inner Join rewrite**

```
SELECT …..
 FROM
    REFERRAL T1 LEFT OUTER JOIN REFERRALASSIGNMENT T2
    ON T1.REFERRAL_ID = T2.REFERRAL_ID LEFT OUTER JOIN ENTITYTOEXTERNAL T3
    ON T1.REFERRAL_ID = T3.ENTITY_KEY
    AND T3.RELATIONSHIP_TP_CD = 1000008
    AND T3.RELATIONSHIP_OWNER = 'R' LEFT OUTER JOIN APPOINTMENT T6
    ON T6.APPOINTMENT_ID = CAST(T3.EXTERNAL_REFERENCE_KEY AS DECIMAL(10, 0))
WHERE T2.ASSIGNED_TO_CO_CC_NO = '00342|3425352'
    AND T6.START_TIME >= '2014-07-02-07.00.00.000000'
    AND T6.END_TIME <= '2014-07-03-06.59.59.000000'
```

Example Query 2: TPC-DS Q25 (Simplified)

Distributed Join Order, Bushy Joins

```
SELECT ....
FROM  store_sales ss, store_returns sr,  catalog_sales cs,
      date_dim d1, date_dim d2, date_dim d3,
      store s, item i
WHERE  d1.d_moy = 4 AND d1.d_year = 2000
      AND d1.d_date_sk = ss_sold_date_sk AND i_item_sk = ss_item_sk
      AND s_store_sk = ss_store_sk AND ss_customer_sk = sr_customer_sk
      AND ss_item_sk = sr_item_sk AND ss_ticket_number = sr_ticket_number
      AND sr_returned_date_sk = d2.d_date_sk
      AND d2.d_moy BETWEEN 4 AND 10 AND d2.d_year = 2000
      AND sr_customer_sk = cs_bill_customer_sk  AND sr_item_sk = cs_item_sk
      AND cs_sold_date_sk = d3.d_date_sk
      AND d3.d_moy BETWEEN 4 AND 10 AND d3.d_year = 2000
```

Query Optimization Frequency

- Ad-hoc queries from analytical dashboards always require optimization

- Queries that are not ad-hoc may also require optimization
  - The first invocation of the query
  - If the data statistics have changed significantly
  - If the query parameters differ from previous invocations

Why is optimization time important?

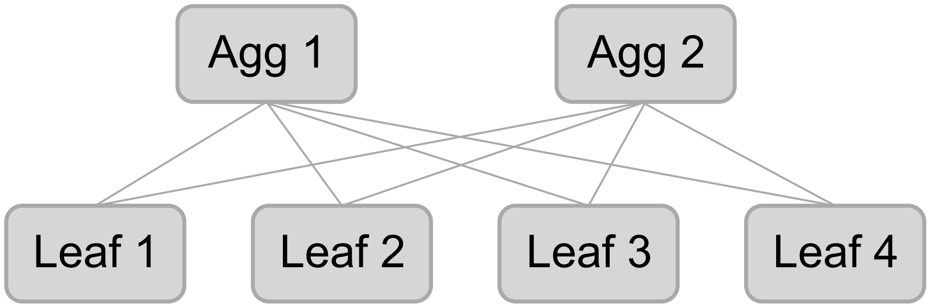
- Query Optimization time cannot afford to be the bottle-neck in real-time analytics
- Very small time budgets (<100ms) for query optimization
- Optimizer still should be able to produce efficient execution plans with near-optimal runtime performance

<u>Query Optimization has the potential to become the bottleneck in real-time analytics</u>

MemSQL Query Optimizer

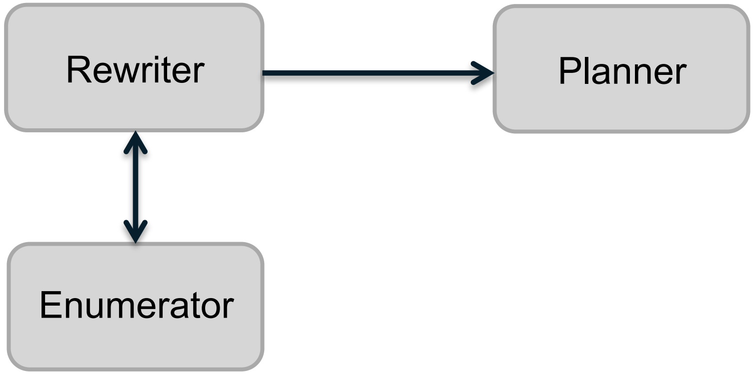
Overview of MemSQL

- Fully distributed in-memory database system
- Supports both OLTP and OLAP workloads
- Extreme performance on commodity hardware
- Designed for infinite scale-out
- Two-tier architecture; scalability on every tier



MemSQL Query Optimizer

- A modular and flexible query optimizer
- Built from scratch using a lot of C++ lambda functions
- Three principal components
  - Rewriter
  - Enumerator
  - Planner



MemSQL Query Optimizer

- Rewriter:
  - Applies query rewrites based on heuristics or cost;
  - Costs rewrites by calling the Enumerator
  - Interleaves mutually beneficial rewrites
- Enumerator
  - Join order based on distributed cost
  - Data movement decisions (e.g. broadcast, reshuffle)
- Planner
  - Converts the chosen logical execution plan to a sequence of distributed query and data movement operations.

Where does the optimizer spend time?

- Time consuming components need to be dealt with efficiently and intelligently
- Cost-based query rewrites
- Join enumeration to choose best join order
  - Generating bushy join plans
- Distributed join order
  - Search space analysis

Reducing Query Optimization Time

Generation of Bushy Plans outside Enumerator

- Considering all bushy joins in join enumeration is extremely expensive
- However, bushy joins are critical for execution performance
  - E.g. several TPC-DS queries benefit by 3-10x
- Consider only promising bushy joins instead of all possible cases
- Look for common query shapes that benefit from bushy plans and introduce bushiness via query rewrite

Extremely Fast Enumeration

- Prune heavily to eliminate a huge majority of the search space
- Enumerator uses several heuristics to generate initial candidate join orders;
  - Cost each candidate join order
  - Cheapest candidate provides an initial upper bound on the cost
- Details are in the paper

Some Experimental Results

Optimization time for TPC-H Queries

Query	Tables	Time (ms.)
Q3	3	5.09
Q5	6	9.99
Q7	6	5.94
Q8	8	20.7
Q9	6	6.36
Q21	6	11.02

Minimal optimization time for most queries

Pruning Percentages for TPC-H Queries

Query	Tables	Pruning %
Q3	3	25.00%
Q5	6	61.46%
Q7	6	72.92%
Q8	8	95.80%
Q9	6	84.90%
Q21	6	62.50%

Pruning percentage huge for most queries

Bushy Join Speedup and Overhead for TPC-DS

Query	Optimization Overhead	Execution Speedup
Q15	13%	5.8x
Q25	16%	10.1x
Q46	12%	2.85x

Significant execution speedup with minimal optimization overhead

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Current Work

Work in progress..

- Parallelizing the join enumeration process
- Refine heuristics based on knowledge from customer experiences
- Getting the costing “right”

Q & A

Thank You

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