ORACLE TECHNOLOGY NETWORK

Virtual Technology Summit

Hands-On Learning With Oracle and Community Experts

Where Technology and Community Meet

How to Analyze and Tune MySQL Queries for Better Performance

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March/April, 2016

Please Stand By. This session will begin promptly at the time indicated on the agenda. Thank You.

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Program Agenda

1. Cost-based query optimization in MySQL
2. Tools for monitoring, analyzing, and tuning queries
3. Data access and index selection
4. Join optimizer
5. Sorting
6. Influencing the optimizer

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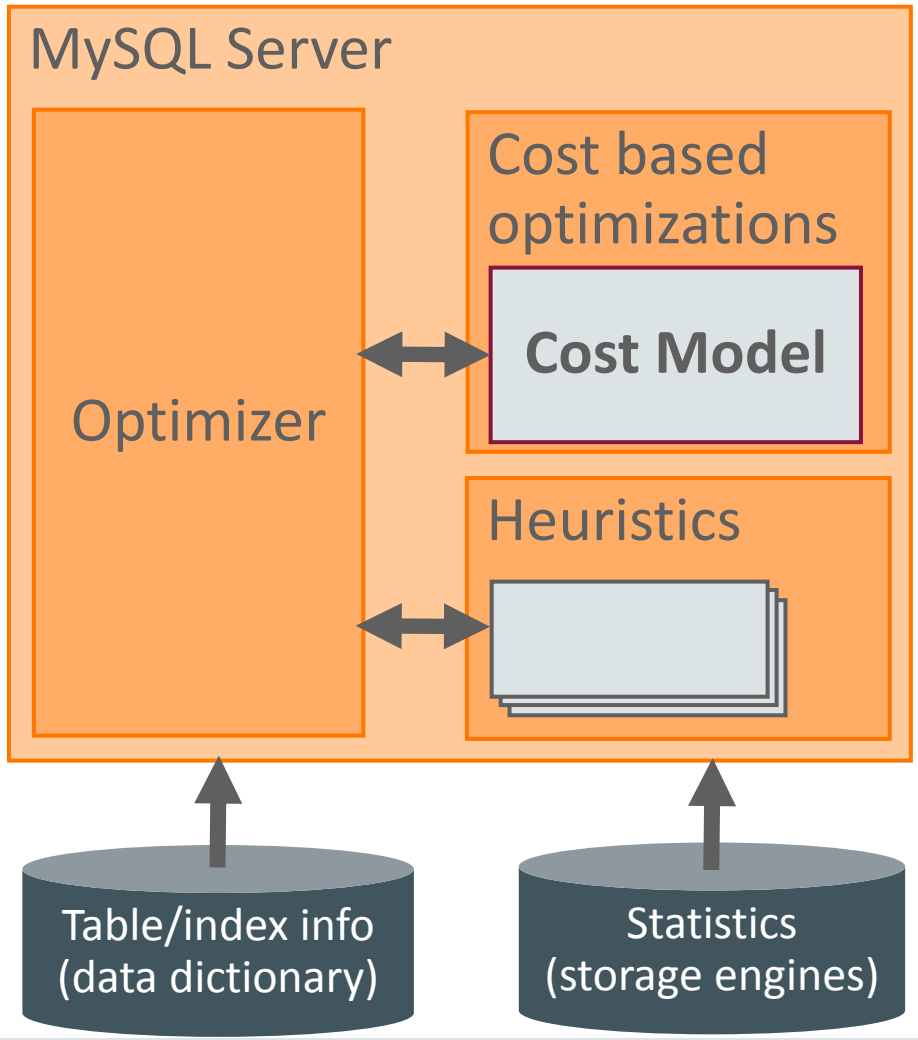
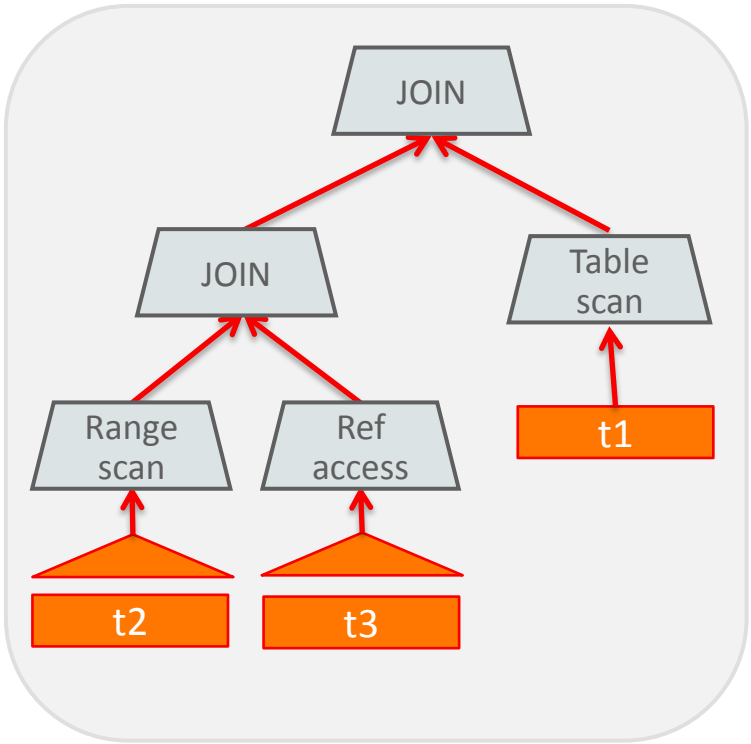
MySQL Optimizer

```
SELECT a, b
FROM t1, t2, t3
WHERE t1.a = t2.b
    AND t2.b = t3.c
    AND t2.d > 20
    AND t2.d < 30;
```

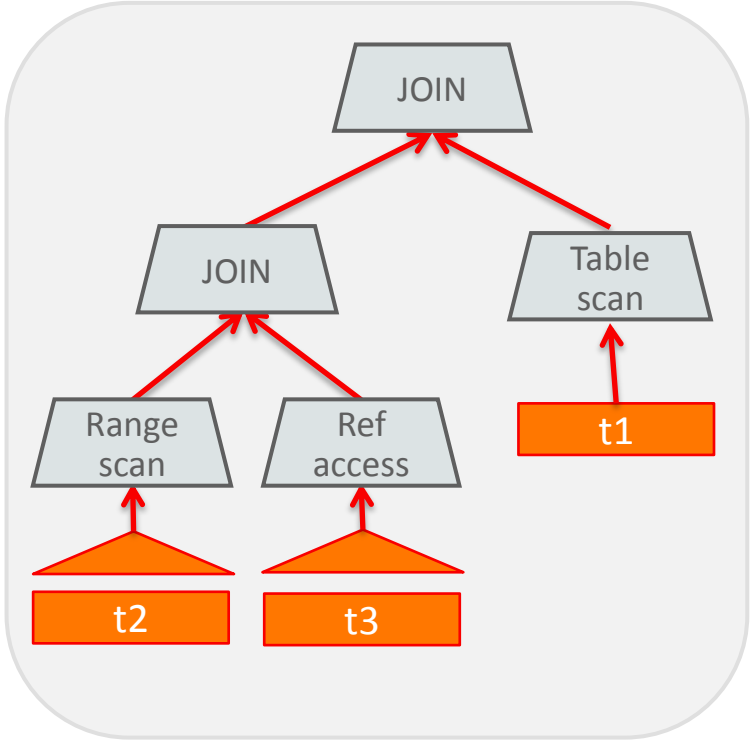




Cost-based Query Optimization

General idea

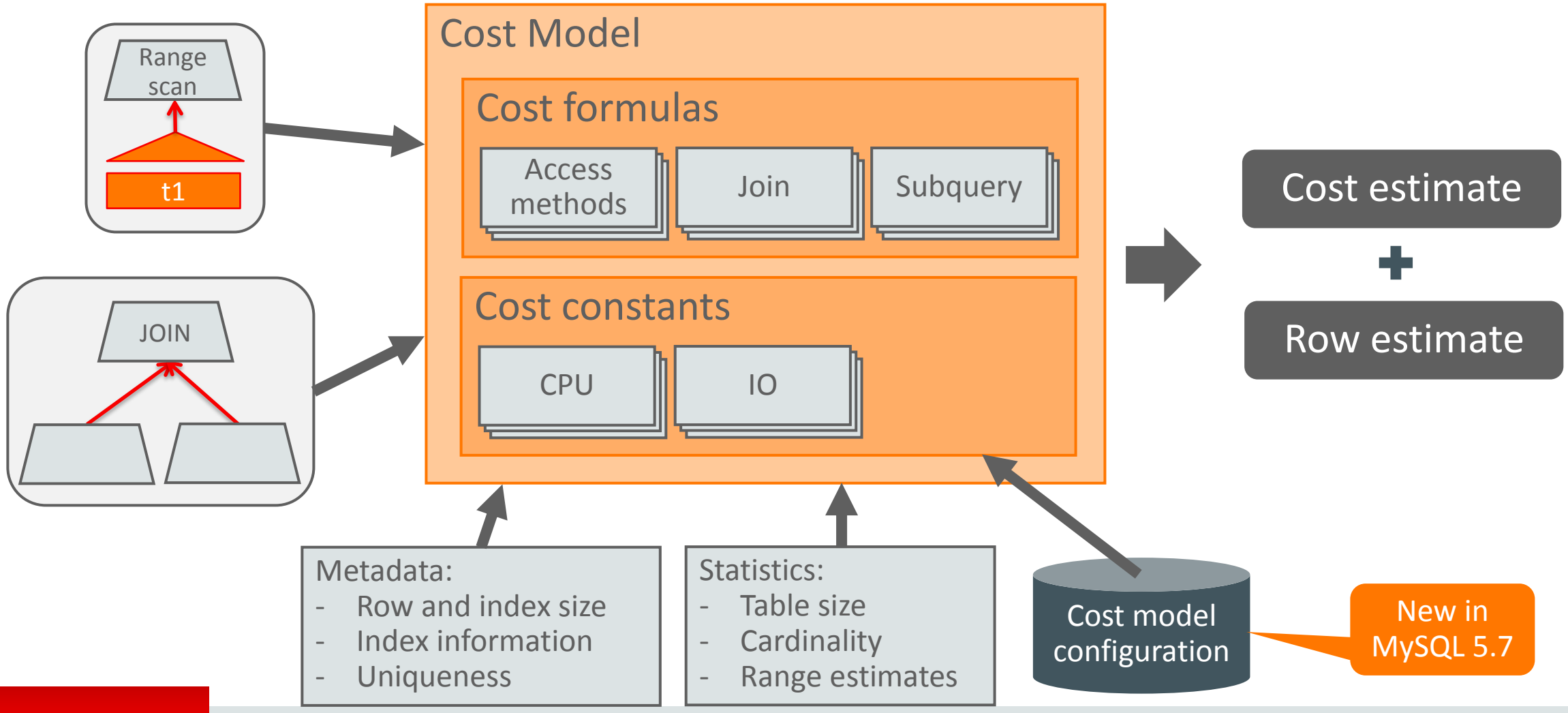
- Assign cost to operations
- Assign cost to partial or alternative plans
- Search for plan with lowest cost



- Cost-based optimizations:

Access method | Join order | Subquery strategy

Optimizer Cost Model

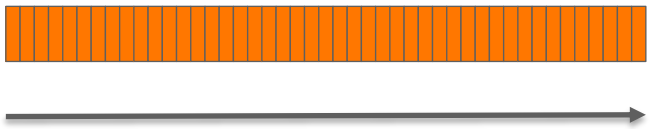


Cost Model Example

SELECT SUM(o_totalprice) FROM orders
WHERE o_orderdate BETWEEN '1994-01-01' AND '1994-12-31';

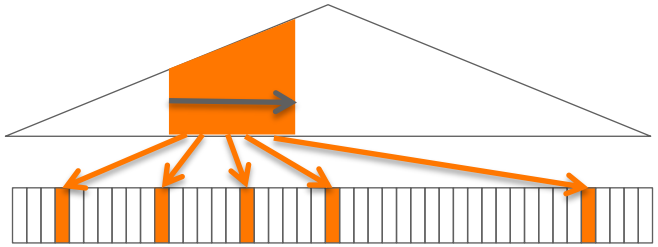
Table scan:

- IO-cost: #pages in table * IO_BLOCK_READ_COST
- CPU cost: #rows * ROW_EVALUATE_COST



Range scan (on secondary index):

- IO-cost: #rows_in_range * IO_BLOCK_READ_COST
- CPU cost: #rows_in_range * ROW_EVALUATE_COST



Cost Model Example

EXPLAIN SELECT SUM(o_totalprice) FROM orders
WHERE o_orderdate BETWEEN '1994-01-01' AND '1994-12-31';

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	ALL	i_o_orderdate	NULL	NULL	NULL	15000000	Using where

EXPLAIN SELECT SUM(o_totalprice) FROM orders
WHERE o_orderdate BETWEEN '1994-01-01' AND '1994-06-30';

Id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	range	i_o_orderdate	i_o_orderdate	4	NULL	2235118	Using index condition

Cost Model Example: Optimizer Trace

join_optimization / row_estimation / table : orders / range_analysis

```
"table_scan": {
  "rows": 15000000,
  "cost": 3.12e6
} /* table_scan */,
"potential_range_indices": [
  {
    "index": "PRIMARY",
    "usable": false,
    "cause": "not_applicable"
  },
  {
    "index": "i_o_orderdate",
    "usable": true,
    "key_parts": [ "o_orderDATE", "o_orderkey" ]
  }
] /* potential_range_indices */,
...
```

```
"analyzing_range_alternatives": {
  "range_scan_alternatives": [
    {
      "index": "i_o_orderdate",
      "ranges": [ "1994-01-01 <= o_orderDATE <= 1994-12-31"
      ],
      "index_dives_for_eq_ranges": true,
      "rowid_ordered": false,
      "using_mrr": false,
      "index_only": false,
      "rows": 4489990,
      "cost": 5.39e6,
      "chosen": false,
      "cause": "cost"
    }
  ] /* range_scan_alternatives */,
  ...
} /* analyzing_range_alternatives */
```

Cost Model vs Real World

Measured Execution Times

	Data in Memory	Data on Disk	Data on SSD
Table scan	6.8 seconds	36 seconds	15 seconds
Index scan	**5.2 seconds**	2.5 hours	30 minutes

Force Index Scan:

```
SELECT SUM(o_totalprice)
FROM orders FORCE INDEX (i_o_orderdate)
WHERE o_orderdate BETWEEN '1994-01-01' AND '1994-12-31';
```

Performance Schema

Disk I/O

```
SELECT event_name, count_read, avg_timer_read/1000000000.0 "Avg Read Time (ms)",
       sum_number_of_bytes_read   "Bytes Read"
  FROM performance_schema.file_summary_by_event_name
  WHERE event_name='wait/io/file/innodb/innodb_data_file';
```

Table Scan

event_name	count_read	Avg Read Time (ms)	Bytes Read
wait/io/file/innodb/innodb_data_file	115769	0.0342	1896759296

Index Scan

event_name	count_read	Avg Read Time (ms)	Bytes Read
wait/io/file/innodb/innodb_data_file	2188853	4.2094	35862167552

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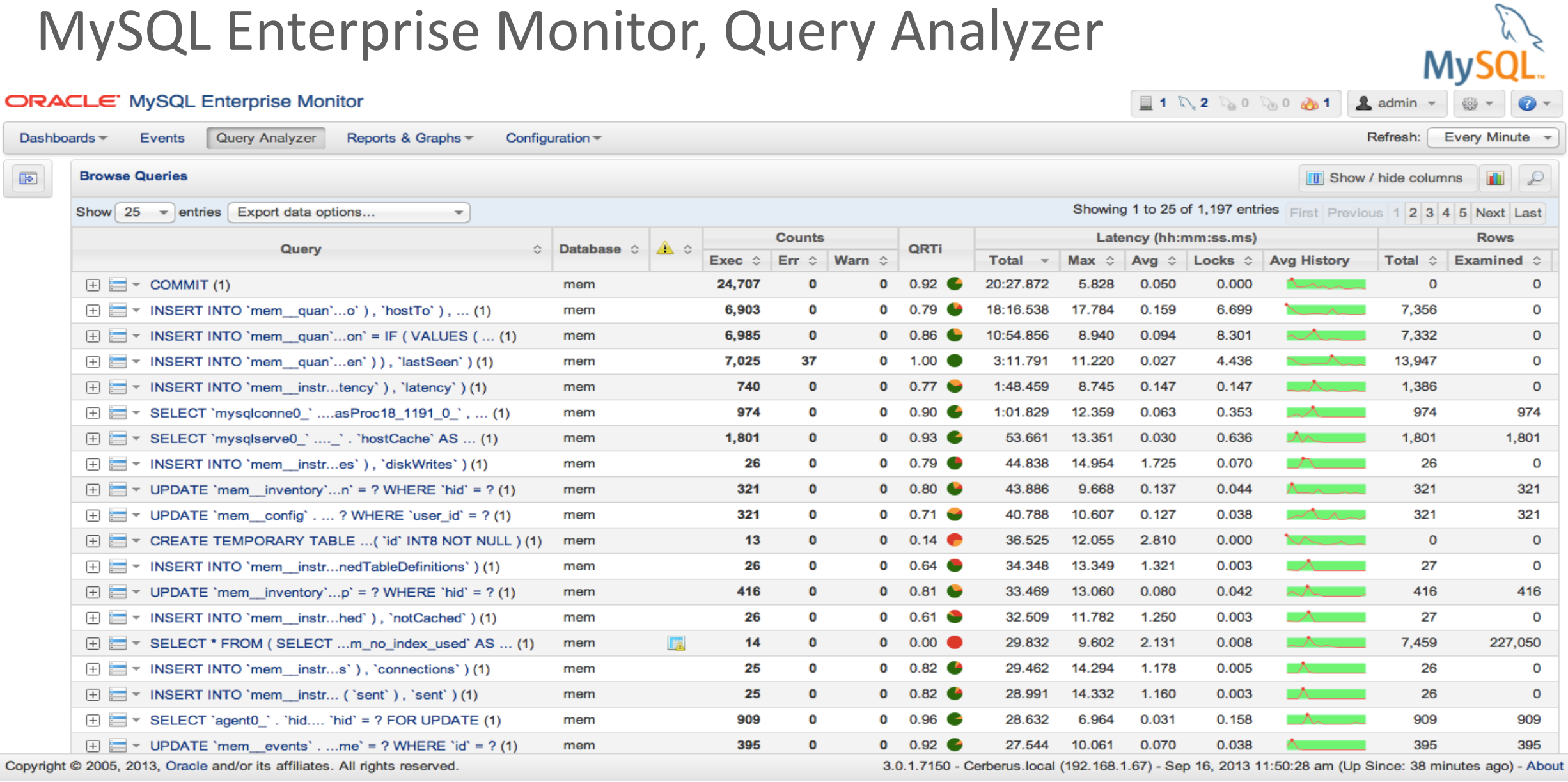
Useful tools

- MySQL Enterprise Monitor (MEM), Query Analyzer
  - Commercial product
- Performance schema, MySQL sys schema
- EXPLAIN
  - Tabular EXPLAIN
  - Structured EXPLAIN (FORMAT=JSON)
  - Visual EXPLAIN (MySQL Workbench)
- Optimizer trace
- Slow log
- Status variables (SHOW STATUS LIKE 'Sort%')

MySQL Enterprise Monitor, Query Analyzer



Query Analyzer Query Details

Canonical Query | **Example Query** | Explain Query | Graphs

The query with the longest execution time during the Time Span (usually the slowest but not always).

Sampled Query

truncated | full | formatted

```
SELECT
    mysqlserve0_.hid AS hid1124_0_, mysqlserve0_.`id` AS id2_1124_0_,
    mysqlserve0_.`lastContact` AS lastCont3_1124_0_,
    mysqlserve0_.`hasLastContact` AS hasLastC4_1124_0_,
    mysqlserve0_.`startTime` AS startTime5_1124_0_,
    mysqlserve0_.`hasStartTime` AS hasStart6_1124_0_,
    mysqlserve0_.`timestamp` AS timestamp7_1124_0_,
    mysqlserve0_.`capabilities` AS capabili8_1124_0_,
    mysqlserve0_.`hasCapabilities` AS hasCapab9_1124_0_,
    mysqlserve0_.`characterSet` AS charact10_1124_0_,
    mysqlserve0_.`hasCharacterSet` AS hasChar11_1124_0_,
    mysqlserve0_.`collation` AS collation12_1124_0_,
    mysqlserve0_.`hasCollation` AS hasColl13_1124_0_,
    mysqlserve0_.`connection` AS connection14_1124_0_,
    mysqlserve0_.`hasConnection` AS hasConn15_1124_0_,
    mysqlserve0_.`environment` AS environ16_1124_0_,
```

Execution Time
27,084 ms

Date
Sep 16, 2013 1:07:17 PM

User
service_manager

Thread ID
10,712

From Host
localhost

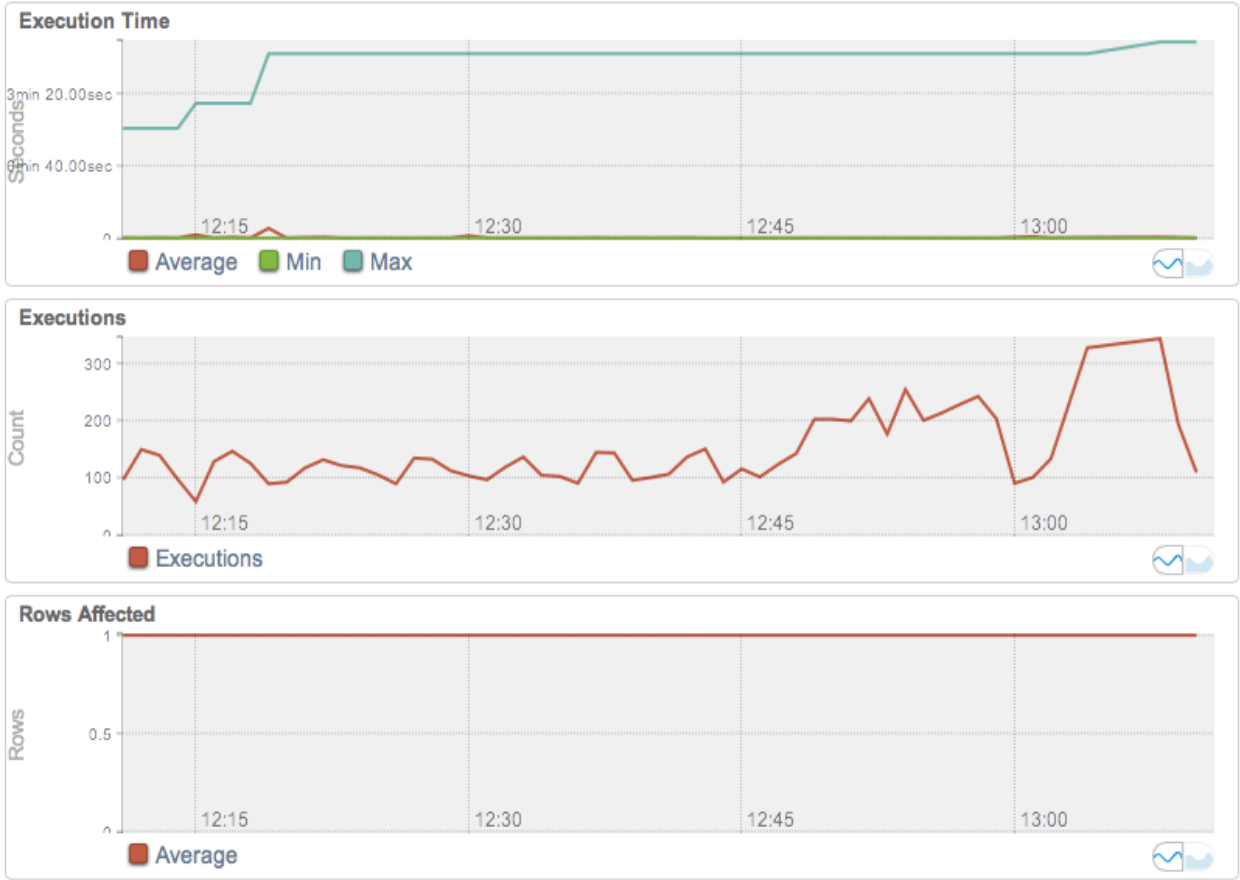
To Host

Source Location
None found.

Comments
None found.

Canonical Query | Example Query | Explain Query | **Graphs**

Graphs of a query during the Time Span



Performance Schema

Some useful tables

- **`events_statements_history`**
  `events_statements_history_long`
  - Most recent statements executed
- **`events_statements_summary_by_digest`**
  - Summary for similar statements (same statement digest)
- **`file_summary_by_event_name`**
  - Interesting event: **wait/io/file/innodb/innodb_data_file**
- **`table_io_waits_summary_by_table`**
  `table_io_waits_summary_by_index_usage`
  - Statistics on storage engine access per table and index

Performance Schema

Statement events

- Tables:
  `events_statements_current` (Current statement for each thread)
  `events_statements_history` (10 most recent statements per thread)
  `events_statements_history_long` (10000 most recent statements)
- Columns:

  THREAD_ID, EVENT_ID, END_EVENT_ID, EVENT_NAME, SOURCE, TIMER_START, TIMER_END, TIMER_WAIT, LOCK_TIME, SQL_TEXT, DIGEST, DIGEST_TEXT, CURRENT_SCHEMA, OBJECT_TYPE, OBJECT_SCHEMA, OBJECT_NAME, OBJECT_INSTANCE_BEGIN, MYSQL_ERRNO, RETURNED_SQLSTATE, MESSAGE_TEXT, ERRORS, WARNINGS, ROWS_AFFECTED, ROWS_SENT, ROWS_EXAMINED, CREATED_TMP_DISK_TABLES, CREATED_TMP_TABLES, SELECT_FULL_JOIN, SELECT_FULL_RANGE_JOIN, SELECT_RANGE, SELECT_RANGE_CHECK, SELECT_SCAN, SORT_MERGE_PASSES, SORT_RANGE, SORT_ROWS, SORT_SCAN, NO_INDEX_USED, NO_GOOD_INDEX_USED, NESTING_EVENT_ID, NESTING_EVENT_TYPE

Performance Schema

Statement digest

- Normalization of queries to group statements that are similar to be grouped and summarized:

  SELECT * FROM orders WHERE o_custkey=10 AND o_totalprice>20
  SELECT * FROM orders WHERE o_custkey = 20 AND o_totalprice > 100

  ➡ **SELECT * FROM orders WHERE o_custkey = ? AND o_totalprice > ?**

- **`events_statements_summary_by_digest`**

  DIGEST, DIGEST_TEXT, COUNT_STAR, SUM_TIMER_WAIT, MIN_TIMER_WAIT, AVG_TIMER_WAIT, MAX_TIMER_WAIT, SUM_LOCK_TIME, SUM_ERRORS, SUM_WARNINGS, SUM_ROWS_AFFECTED, SUM_ROWS_SENT, SUM_ROWS_EXAMINED, SUM_CREATED_TMP_DISK_TABLES, SUM_CREATED_TMP_TABLES, SUM_SELECT_FULL_JOIN, SUM_SELECT_FULL_RANGE_JOIN, SUM_SELECT_RANGE, SUM_SELECT_RANGE_CHECK, SUM_SELECT_SCAN, SUM_SORT_MERGE_PASSES, SUM_SORT_RANGE, SUM_SORT_ROWS, SUM_SORT_SCAN, SUM_NO_INDEX_USED, SUM_NO_GOOD_INDEX_USED, FIRST_SEEN, LAST_SEEN

MySQL sys Schema

- A collection of views, procedures and functions, designed to make reading raw Performance Schema data easier
- Implements many common DBA and Developer use cases
  - File IO usage per user
  - Which indexes is never used?
  - Which queries use full table scans?
- Examples of very useful functions:
  - format_time() , format_bytes(), format_statement()
- Included with MySQL 5.7
- Bundled with MySQL Workbench

MySQL sys Schema

Example

statement_analysis: Lists a normalized statement view with aggregated statistics, ordered by the total execution time per normalized statement

```
mysql> SELECT * FROM sys.statement_analysis LIMIT 1\G
*************************** 1. row ***************************
query: INSERT INTO `mem__quan` . `nor ... nDuration` = IF ( VALUES ( ...
db: mem
full_scan: 0
exec_count: 1110067
err_count: 0
warn_count: 0
total_latency: 1.93h
max_latency: 5.03 s
avg_latency: 6.27 ms
lock_latency: 00:18:29.18
rows_sent: 0
rows_sent_avg: 0
rows_examined: 0
rows_examined_avg: 0
tmp_tables: 0
tmp_disk_tables: 0
rows_sorted: 0
sort_merge_passes: 0
digest: d48316a218e95b1b8b72db5e6b177788!
first_seen: 2014-05-20 10:42:17
```

EXPLAIN

Understand the query plan

- Use EXPLAIN to print the final query plan:

```
EXPLAIN SELECT * FROM t1 JOIN t2 ON t1.a = t2.a WHERE b > 10 AND c > 10;
+----+--------+-------+------------+------+---------------+-----+---------+-----+------+----------+------------+
| id | select…| table | partitions | type | possible_keys | key | key_len | ref | rows | filtered | Extra      |
+----+--------+-------+------------+------+---------------+-----+---------+-----+------+----------+------------+
|  1 | SIMPLE | t1    | NULL       | range| idx1          | idx1| 4       | NULL|   12 |    33.33 | Using where|
|  1 | SIMPLE | t2    | NULL       | ref  | idx2          | idx2| 4       | t1.a|    1 |   100.00 | NULL       |
+----+--------+-------+------------+------+---------------+-----+---------+-----+------+----------+------------+
```

- Explain for a running query (New in MySQL 5.7):

EXPLAIN FOR CONNECTION *connection_id*;

Structured EXPLAIN

- JSON format:

  EXPLAIN FORMAT=JSON SELECT …

- Contains more information:
  - Used index parts
  - Pushed index conditions
  - Cost estimates
  - Data estimates

Added in MySQL 5.7

```
EXPLAIN FORMAT=JSON
SELECT * FROM t1 WHERE b > 10 AND c > 10;
EXPLAIN
{
  "query_block": {
    "select_id": 1,
    "cost_info": {
      "query_cost": "17.81"
    },
    "table": {
      "table_name": "t1",
      "access_type": "range",
      "possible_keys": [
        "idx1"
      ],
      "key": "idx1",
      "used_key_parts": [
        "b"
      ],
      "key_length": "4",
      "rows_examined_per_scan": 12,
      "rows_produced_per_join": 3,
      "filtered": "33.33",
      "index_condition": "(`test`.`t1`.`b` > 10)",
      "cost_info": {
        "read_cost": "17.01",
        "eval_cost": "0.80",
        "prefix_cost": "17.81",
        "data_read_per_join": "63"
      },
      .........
      "attached_condition": "(`test`.`t1`.`c` > 10)"
    }
  }
}
```

Structured EXPLAIN

Assigning Conditions to Tables

EXPLAIN FORMAT=JSON SELECT * FROM t1, t2
WHERE t1.a=t2.a AND t2.a=9 AND (NOT (t1.a > 10 OR t2.b >3) OR (t1.b=t2.b+7 AND t2.b = 5));

EXPLAIN


```
{
 "query_block": {
  "select_id": 1,
  "nested_loop": [
   {
    "table": {
     "table_name": "t1",
     "access_type": "ALL",
     "rows": 10,
     "filtered": 100,
     "attached_condition": "(t1.a = 9)"
    } /* table */
   },
   {
    "table": {
     "table_name": "t2",
     "access_type": "ALL",
     "rows": 10,
     "filtered": 100,
     "using_join_buffer": "Block Nested Loop",
     "attached_condition": "((t2.a = 9) and ((t2.b <= 3) or ((t2.b = 5) and (t1.b = 12))))"
    } /* table */
   }
  ] /* nested_loop */
 } /* query_block */
}
```

Optimizer Trace: Query Plan Debugging

- EXPLAIN shows the selected plan
- Optimizer trace shows WHY the plan was selected

```
SET optimizer_trace= "enabled=on";
SELECT * FROM t1,t2 WHERE f1=1 AND f1=f2 AND f2>0;
SELECT trace FROM information_schema.optimizer_trace
        INTO OUTFILE <filename> LINES TERMINATED BY '';
SET optimizer_trace="enabled=off";
```

QUERY	SELECT * FROM t1,t2 WHERE f1=1 AND f1=f2 AND f2>0;
TRACE	"steps": [{ "join_preparation": { "select#": 1,... } ... } ...]
MISSING_BYTES_BEYOND_MAX_MEM_SIZE	0
INSUFFICIENT_PRIVILEGES	0

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Selecting Access Method

Finding the optimal method to read data from storage engine

- For each table, find the best access method:
  - Check if the access method is useful
  - Estimate cost of using access method
  - Select the cheapest to be used
- Choice of access method is cost based

Main access methods:

- Table scan
- Index scan
- Index look-up (ref access)
- Range scan
- Index merge
- Loose index scan

Ref Access

Single Table Queries

EXPLAIN SELECT * FROM customer WHERE c_custkey = 570887;

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	customer	const	PRIMARY	PRIMARY	4	const	1	NULL

EXPLAIN SELECT * FROM orders WHERE o_orderdate = '1992-09-12';

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	ref	i_o_orderdate	i_o_orderdate	4	const	6271	NULL

Ref Access

Join Queries

EXPLAIN SELECT *
FROM orders JOIN customer ON c_custkey = o_custkey
WHERE o_orderdate = '1992-09-12';

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	ref	i_o_orderdate, i_o_custkey	i_o_orderdate	4	const	6271	Using where
1	SIMPLE	customer	eq_ref	PRIMARY	PRIMARY	4	dbt3.orders. o_custkey	1	NULL

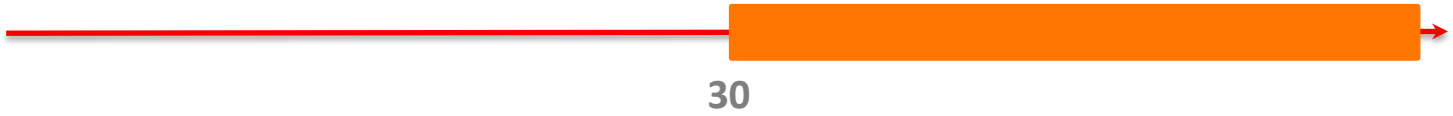
Range Optimizer

- Goal: find the "minimal" ranges for each index that needs to be read
- Example:

  SELECT * FROM t1 WHERE (key1 > 10 AND key1 < 20) AND key2 > 30

- Range scan using INDEX(key1):

- Range scan using INDEX(key2):



Range Optimizer: Case Study

Why table scan?

SELECT * FROM orders
WHERE YEAR(o_orderdate) = 1997 AND MONTH(o_orderdate) = 5
AND o_clerk = 'Clerk#000001866';

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	ALL	NULL	NULL	NULL	NULL	15000000	Using where

Index not considered

```
mysql> SELECT * FROM orders WHERE year(o_orderdate) = 1997 AND MONTH(…
...
15 rows in set (8.91 sec)
```

Range Optimizer: Case Study

Rewrite query to avoid functions on indexed columns

SELECT * FROM orders
WHERE o_orderdate BETWEEN '1997-05-01' AND '1997-05-31'
AND o_clerk = 'Clerk#000001866';

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	range	i_o_orderdate	i_o_orderdate	4	NULL	376352	Using index condition; Using where

```
mysql> SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' AND …
...
15 rows in set (0.91 sec)
```

Range Optimizer: Case Study

Adding another index

CREATE INDEX i_o_clerk ON orders(o_clerk);

SELECT * FROM orders
WHERE o_orderdate BETWEEN '1997-05-01' AND '1997-05-31'
AND o_clerk = 'Clerk#000001866';

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	range	i_o_orderdate, i_o_clerk	i_o_clerk	16	NULL	1504	Using index condition; Using where

```
mysql> SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' AND …
...
15 rows in set (0.01 sec)
```

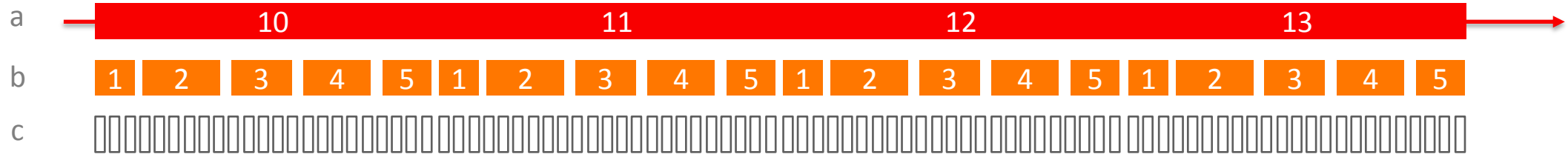
Range Access for Multi-Column Indexes

Example table with multi-part index

- Table:

- INDEX idx(a, b, c);

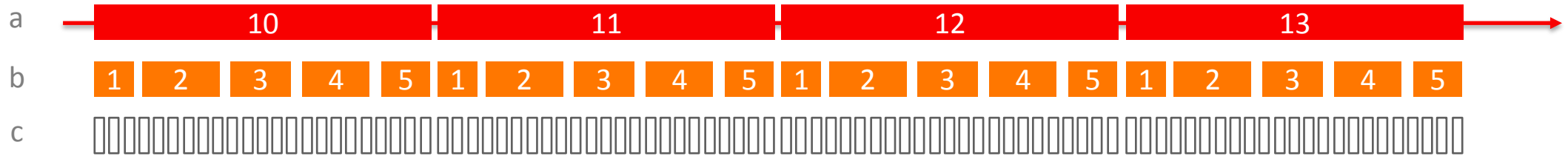
- Logical storage layout of index:



Range Access for Multi-Column Indexes, cont

- Equality on 1st index column?
  - Can add condition on 2nd index column to range condition
- Example:

  SELECT * from t1 WHERE a IN (10,11,13) AND (b=2 OR b=4)

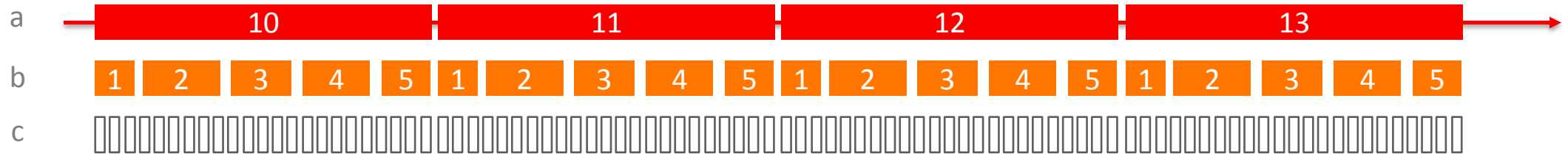


- Resulting range scan:

Range Access for Multi-Column Indexes, cont

- Non-Equality on 1st index column:
  - Can **NOT** add condition on 2nd index column to range condition
- Example:

  SELECT * from t1 WHERE a > 10 AND a < 13 AND (b=2 OR b=4)



- Resulting range scan:

Range Optimizer: Case Study

Create multi-column index

CREATE INDEX i_o_clerk_date ON orders(o_clerk, o_orderdate);

SELECT * FROM orders
WHERE o_orderdate BETWEEN '1997-05-01' AND '1997-05-31'
AND o_clerk = 'Clerk#000001866';

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	range	i_o_orderdate, i_o_clerk, i_o_clerk_date	i_o_clerk_date	20	NULL	14	Using index condition

```
mysql> SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' AND …
...
15 rows in set (0.00 sec)
```

Performance Schema: Query History

MySQL 5.7:
Enabled by default

UPDATE performance_schema.setup_consumers
SET enabled='YES' WHERE name = 'events_statements_history';

```
mysql> SELECT sql_text, (timer_wait)/1000000000.0 "t (ms)", rows_examined rows
         FROM performance_schema.events_statements_history ORDER BY timer_start;
+-----------------------------------------------------------+--------+------+
| sql_text                                                  | t (ms) | rows |
+-----------------------------------------------------------+--------+------+
| SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' … | 8.1690 | 1505 |
| SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' … | 7.2120 | 1505 |
| SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' … | 8.1613 | 1505 |
| SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' … | 7.0535 | 1505 |
| CREATE INDEX i_o_clerk_date ON orders(o_clerk,o_orderdate) |82036.4190 |    0 |
| SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' … | 0.7259 |   15 |
| SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' … | 0.5791 |   15 |
| SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' … | 0.5423 |   15 |
| SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' … | 0.6031 |   15 |
| SELECT * FROM orders WHERE o_orderdate BETWEEN '1997-05-01' … | 0.2710 |   15 |
+-----------------------------------------------------------+--------+------+
```

Program Agenda

1. Cost-based query optimization in MySQL
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6. Influencing the optimizer

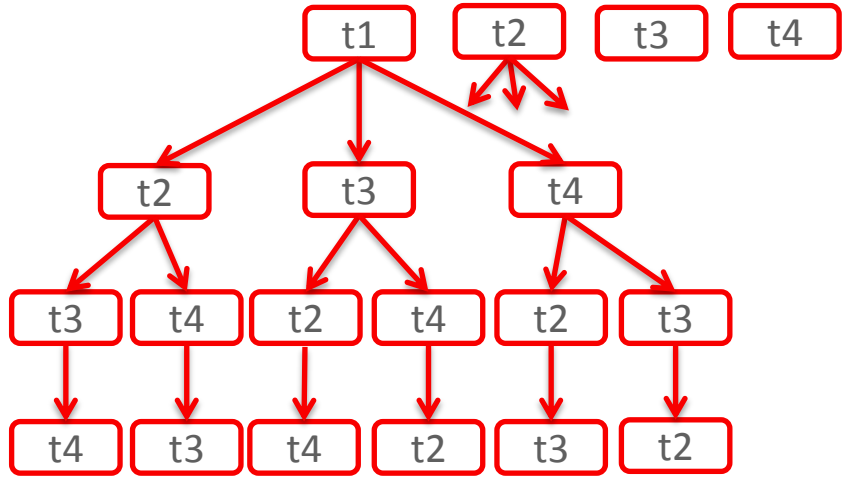
Join Optimizer

”Greedy search strategy”

- Goal: Given a JOIN of N tables, find the best JOIN ordering

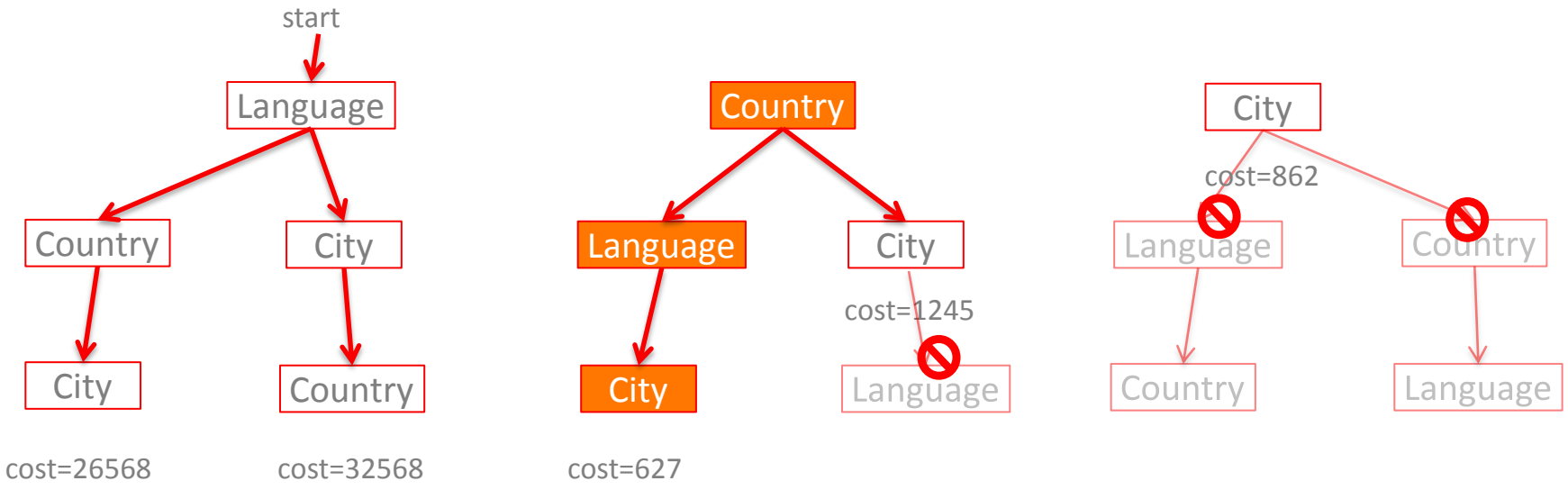
N! possible plans

- Strategy:
  - Start with all 1-table plans (Sorted based on *size* and *key dependency*)
  - Expand each plan with remaining tables
    - Depth-first
  - If “cost of partial plan” > “cost of best plan”:
    - “prune” plan
  - Heuristic pruning:
    - Prune less promising partial plans
    - May in rare cases miss most optimal plan (turn off with **set optimizer_prune_level = 0**)



JOIN Optimizer Illustrated

```
SELECT City.Name, Language FROM Language, Country, City
WHERE City.CountryCode = Country.Code
  AND City.ID = Country.Capital
  AND City.Population >= 1000000
  AND Language.Country = Country.Code;
```



Join Optimizer: Case study

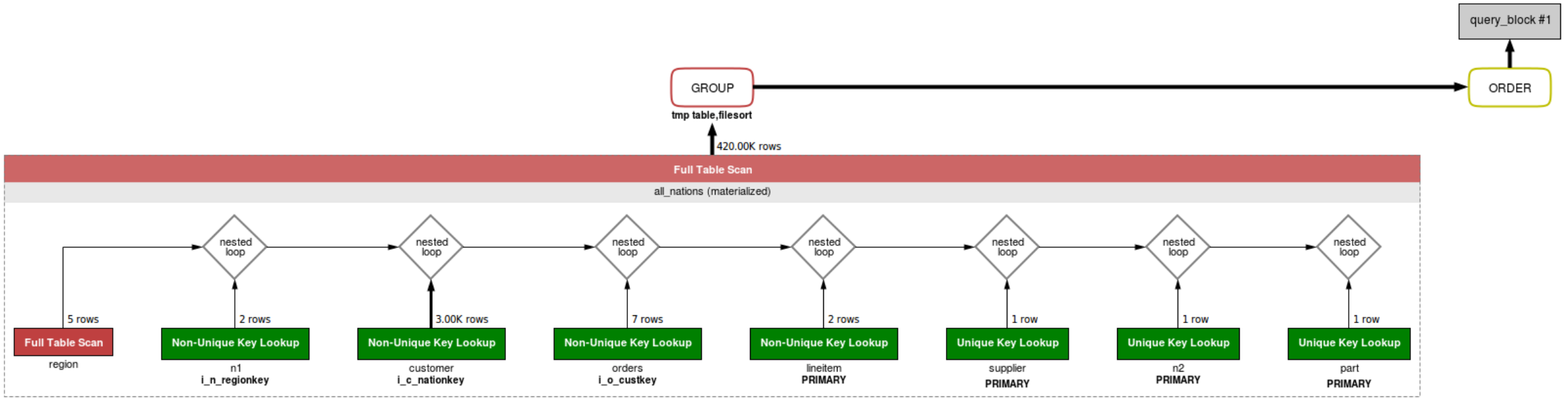
DBT-3 Query 8: National Market Share Query

```
SELECT o_year, SUM(CASE WHEN nation = 'FRANCE' THEN volume ELSE 0 END)  / SUM(volume) AS
        mkt_share
FROM (
        SELECT EXTRACT(YEAR FROM o_orderdate) AS o_year,
                l_extendedprice * (1 - l_discount) AS volume, n2.n_name AS nation
        FROM part
          JOIN lineitem ON p_partkey = l_partkey
          JOIN supplier ON s_suppkey = l_suppkey
          JOIN orders ON l_orderkey = o_orderkey
          JOIN customer ON o_custkey = c_custkey
          JOIN nation n1 ON c_nationkey = n1.n_nationkey
          JOIN region ON  n1.n_regionkey = r_regionkey
          JOIN nation n2 ON s_nationkey = n2.n_nationkey
        WHERE r_name = 'EUROPE' AND o_orderdate BETWEEN '1995-01-01' AND '1996-12-31'
            AND p_type = 'PROMO BRUSHED STEEL'
 ) AS all_nations GROUP BY o_year ORDER BY o_year;
```

Join Optimizer: Case Study

MySQL Workbench: Visual EXPLAIN

Execution time: 21 seconds



Join Optimizer: Case study

Force early processing of high selectivity predicates

```
SELECT o_year, SUM(CASE WHEN nation = 'FRANCE' THEN volume ELSE 0 END)  / SUM(volume) AS
        mkt_share
FROM (
        SELECT EXTRACT(YEAR FROM o_orderdate) AS o_year,
            l_extendedprice * (1 - l_discount) AS volume, n2.n_name AS nation
        FROM part
          STRAIGHT_JOIN lineitem ON p_partkey = l_partkey
          JOIN supplier ON s_suppkey = l_suppkey
          JOIN orders ON l_orderkey = o_orderkey
          JOIN customer ON o_custkey = c_custkey
          JOIN nation n1 ON c_nationkey = n1.n_nationkey
          JOIN region ON  n1.n_regionkey = r_regionkey
          JOIN nation n2 ON s_nationkey = n2.n_nationkey
        WHERE r_name = 'EUROPE' AND o_orderdate BETWEEN '1995-01-01' AND '1996-12-31'
            AND p_type = 'PROMO BRUSHED STEEL'
) AS all_nations GROUP BY o_year ORDER BY o_year;
```

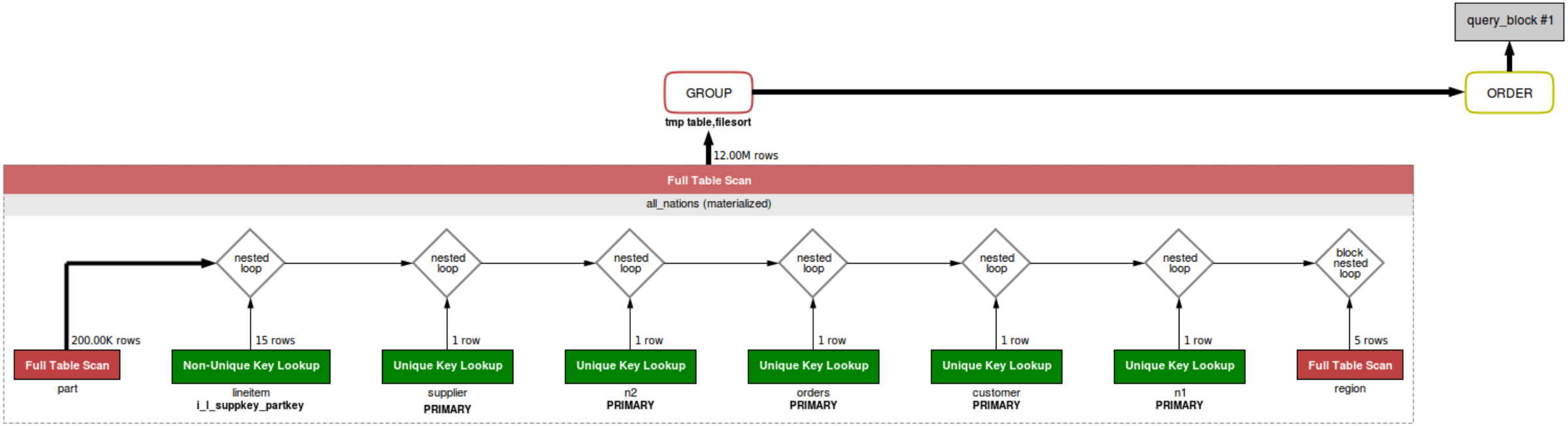
part before lineitem

Highest selectivity

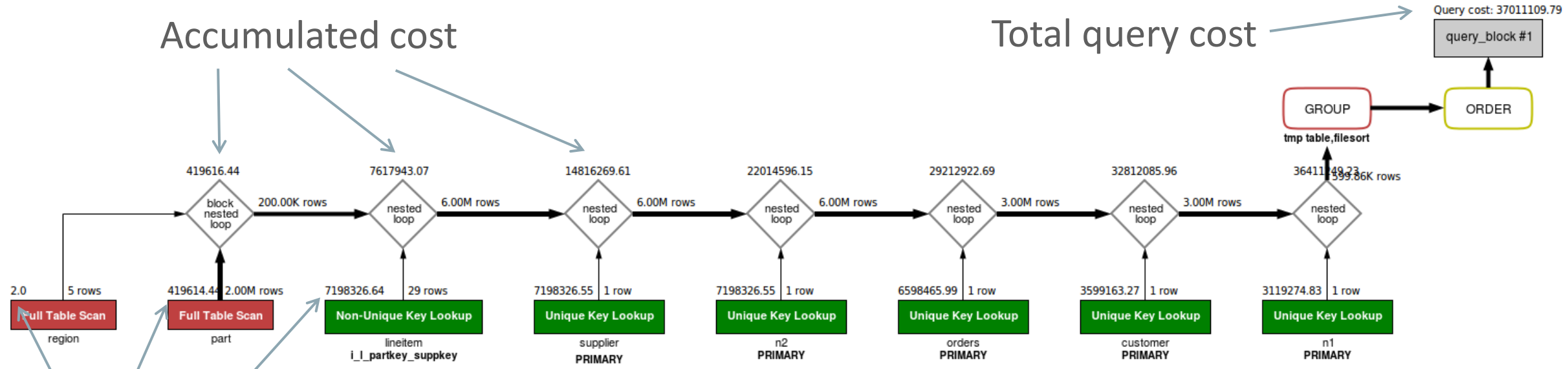
Join Optimizer: Case study

Improved join order

Execution time: 3 seconds



MySQL 5.7: Cost Information in Structured EXPLAIN



Cost per table

Improvements to Query 8 in MySQL 5.7:

- Filtering on non-indexed columns are taken into account
  - No need for hint to force **part** table to be processed early
- Merge derived tables into outer query
  - No temporary table

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ORDER BY Optimizations

- General solution; “Filesort”:
  - Store query result in temporary table before sorting
  - If data volume is large, may need to sort in several passes with intermediate storage on disk.
- Optimizations:
  - Take advantage of index to generate query result in sorted order
  - For ”LIMIT *n*” queries, maintain priority queue of *n* top items in memory instead of filesort. (MySQL 5.6)

Filesort

SELECT * FROM orders ORDER BY o_totalprice ;

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	ALL	NULL	NULL	NULL	NULL	15000000	Using filesort

SELECT c_name, o_orderkey, o_totalprice
FROM orders JOIN customer ON c_custkey = o_custkey
WHERE c_acctbal < -1000 ORDER BY o_totalprice ;

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	customer	ALL	PRIMARY	NULL	NULL	NULL	1500000	Using where; Using temporary; Using filesort
1	SIMPLE	orders	ref	i_o_custkey	i_o_custkey	5	...	7	NULL

Filesort

Status variables

Status variables related to sorting:

```
mysql> show status like 'Sort%';
+--------------------+---------+
| Variable_name      | Value   |
+--------------------+---------+
| Sort_merge_passes  | 1       |
| Sort_range         | 0       |
| Sort_rows          | 136170  |
| Sort_scan          | 1       |
+--------------------+---------+
```

>0: Intermediate storage on disk.
Consider increasing `sort_buffer_size`

Number of sort operations
(range scan or table/index scans)

Number of rows sorted

Filesort

Performance Schema

Sorting status per statement available from Performance Schema

```
mysql> SELECT sql_text,sort_merge_passes,sort_range,sort_rows,sort_scan
       FROM performance_schema.events_statements_history
       ORDER BY timer_start DESC LIMIT 1;

+--------------+--------------------+------------+-----------+-----------+
| sql_text     | sort_merge_passes | sort_range | sort_rows | sort_scan |
+--------------+--------------------+------------+-----------+-----------+
| SELECT ...   |                  1 |          0 |    136170 |         1 |
+--------------+--------------------+------------+-----------+-----------+
```

Filesort: Case Study

```
mysql> FLUSH STATUS;

Query OK, 0 rows affected (0.00 sec)

mysql> SELECT AVG(o_totalprice) FROM
  ( SELECT * FROM orders
    ORDER BY o_totalprice DESC
    LIMIT 100000) td;
+--------------------+
| AVG(o_totalprice)  |
+--------------------+
| 398185.986158      |
+--------------------+
1 row in set (24.65 sec)
```

Unnecessary large data volume!

```
mysql> SHOW STATUS LIKE 'sort%';
+-------------------+--------+
| Variable_name     | Value  |
+-------------------+--------+
| Sort_merge_passes |   1432 |
| Sort_range        |      0 |
| Sort_rows         | 100000 |
| Sort_scan         |      1 |
+-------------------+--------+
4 rows in set (0.00 sec)
```

Many intermediate sorting steps!

Filesort: Case Study

Reduce amount of data to be sorted

```
mysql> SELECT AVG(o_totalprice) FROM (SELECT o_totalprice FROM orders ORDER BY
  o_totalprice DESC LIMIT 100000) td;
+--------------------+
| AVG(o_totalprice)  |
+--------------------+
| 398185.986158      |
+--------------------+
1 row in set (8.18 sec)

mysql> SELECT sql_text, sort_merge_passes FROM performance_schema.
  events_statements_history ORDER BY timer_start DESC LIMIT 1;
+-----------------------------------------------+--------------------+
| sql_text                                      | sort_merge_passes  |
+-----------------------------------------------+--------------------+
| SELECT AVG(o_totalprice) FROM (SELECT o_totalprice |                229 |
+-----------------------------------------------+--------------------+
```

Filesort: Case Study

Default is 256 kB

Increase sort buffer (1 MB)

```
mysql> SET sort_buffer_size = 1024*1024;

mysql> SELECT AVG(o_totalprice) FROM (SELECT o_totalprice FROM orders ORDER BY
  o_totalprice DESC LIMIT 100000) td;
+--------------------+
| AVG(o_totalprice)  |
+--------------------+
| 398185.986158      |
+--------------------+
1 row in set (7.24 sec)
mysql> SELECT sql_text, sort_merge_passes FROM performance_schema.
  events_statements_history ORDER BY timer_start DESC LIMIT 1;
+-----------------------------------------------+--------------------+
| sql_text                                      | sort_merge_passes  |
+-----------------------------------------------+--------------------+
| SELECT AVG(o_totalprice) FROM (SELECT o_totalprice |                 57 |
+-----------------------------------------------+--------------------+
```

Filesort: Case Study

Increase sort buffer even more (8 MB)

```
mysql> SET sort_buffer_size = 8*1024*1024;

mysql> SELECT AVG(o_totalprice) FROM (SELECT o_totalprice FROM orders ORDER BY
  o_totalprice DESC LIMIT 100000) td;
+--------------------+
| AVG(o_totalprice)  |
+--------------------+
| 398185.986158      |
+--------------------+
1 row in set (6.30 sec)
mysql> SELECT sql_text, sort_merge_passes FROM performance_schema.
  events_statements_history ORDER BY timer_start DESC LIMIT 1;
+-----------------------------------------------+--------------------+
| sql_text                                      | sort_merge_passes  |
+-----------------------------------------------+--------------------+
| SELECT AVG(o_totalprice) FROM (SELECT o_totalprice |                  0 |
+-----------------------------------------------+--------------------+
```

Using Index to Avoid Sorting

CREATE INDEX i_o_totalprice ON orders(o_totalprice);

SELECT o_orderkey, o_totalprice FROM orders ORDER BY o_totalprice ;

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	index	NULL	i_o_totalprice	6	NULL	15000000	Using index

However, still (due to total cost):

SELECT * FROM orders ORDER BY o_totalprice ;

id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	ALL	NULL	NULL	NULL	NULL	15000000	Using filesort

Using Index to Avoid Sorting

Case study revisited

SELECT AVG(o_totalprice) FROM
(SELECT o_totalprice FROM orders ORDER BY o_totalprice DESC LIMIT 100000) td;

id	select type	table	Type	possible keys	key	key len	ref	rows	extra
1	PRIMARY	<derived2>	ALL	NULL	NULL	NULL	NULL	100000	NULL
2	DERIVED	orders	index	NULL	i_o_totalprice	6	NULL	15000000	Using index

```
mysql> SELECT AVG(o_totalprice) FROM (
    SELECT o_totalprice FROM orders
    ORDER BY o_totalprice DESC LIMIT 100000) td;
...
1 row in set (0.06 sec)
```

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Influencing the Optimizer

When the optimizer does not do what you want

- Add indexes
- Force use of specific indexes:
  - USE INDEX, FORCE INDEX, IGNORE INDEX
- Force specific join order:
  - STRAIGHT_JOIN
- Adjust session variables
  - optimizer_switch flags: set optimizer_switch="index_merge=off"
  - Buffer sizes: set sort_buffer=8*1024*1024;
  - Other variables: set optimizer_search_depth = 10;

MySQL 5.7: New Optimizer Hints

- Ny hint syntax:
  - **SELECT /*+ HINT1(*args*) HINT2(*args*) */ … FROM …**
- New hints:
  - BKA(*tables*)/NO_BKA(*tables*), BNL(*tables*)/NO_BNL(*tables*)
  - MRR(*table indexes*)/NO_MRR(*table indexes*)
  - SEMIJOIN/NO_SEMIJOIN(*strategies*), SUBQUERY(*strategy)*
  - NO_ICP(*table indexes*)
  - NO_RANGE_OPTIMIZATION(*table indexes*)
  - QB_NAME(*name*)
- Finer granularilty than **optimizer_switch** session variable

MySQL 5.7: Hint Example: SEMIJOIN

- No hint, optimizer chooses semi-join algorithm LooseScan:

EXPLAIN SELECT * FROM t2 WHERE t2.a IN (SELECT a FROM t3);

id	select_type	table	type	possible_keys	key	key_len	ref	rows	extra
1	SIMPLE	t3	index	a	a	4	NULL	3	Using where; LooseScan
1	SIMPLE	t2	ref	a	a	4	test.t3.a	1	Using index

- Disable semi-join with hint:

EXPLAIN SELECT * FROM t2 WHERE t2.a IN (SELECT /*+ NO_SEMIJOIN() */ a FROM t3);

id	select_type	table	type	possible_keys	key	key_len	ref	rows	extra
1	PRIMARY	t2	index	null	a	4	NULL	4	Using where; Using index
2	DEPENDENT SUBQUERY	t3	Index_subquery	a	a	4	func	1	Using index

MySQL 5.7: Hint Example: SEMIJOIN

- Force Semi-join Materialization to be used

```
EXPLAIN SELECT /*+ SEMIJOIN(@subq MATERIALIZATION) */ * FROM t2
        WHERE t2.a IN (SELECT  /*+ QB_NAME(subq) */ a FROM t3);
```

id	select_type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	t2	index	a	a	4	NULL	4	Using where; Using index
1	SIMPLE	<subquery2>	eq_ref	<auto_key>	<auto_key>	4	test.t2.a	1	NULL
2	MATERIALIZED	t3	index	a	a	4	NULL	3	Using index

MySQL 5.7: Query Rewrite Plugin

- Rewrite problematic queries without the need to make application changes
  - Add hints
  - Modify join order
  - Much more …
- Add rewrite rules to table:

```
INSERT INTO query_rewrite.rewrite_rules (pattern, replacement ) VALUES
  ("SELECT * FROM t1 WHERE a > ? AND b = ?",
    "SELECT * FROM t1 FORCE INDEX (a_idx) WHERE a > ? AND b = ?");
```

- New pre- and post-parse query rewrite APIs
  - Users can write their own plug-ins

More information

- My blog:
  - http://oysteing.blogspot.com/
- Optimizer team blog:
  - http://mysqloptimizerteam.blogspot.com/
- MySQL Server Team blog
  - http://mysqlserverteam.com/
- MySQL forums:
  - Optimizer & Parser: http://forums.mysql.com/list.php?115
  - Performance: http://forums.mysql.com/list.php?24

Q+A

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