How to Analyze and Tune MySQL Queries for Better Performance

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Program Agenda

1. Introduction to MySQL cost-based optimizer
2. Selecting data access method
3. Join optimizer
4. Sorting
5. Tools for monitoring, analyzing, and tuning queries
6. Influencing the Optimizer

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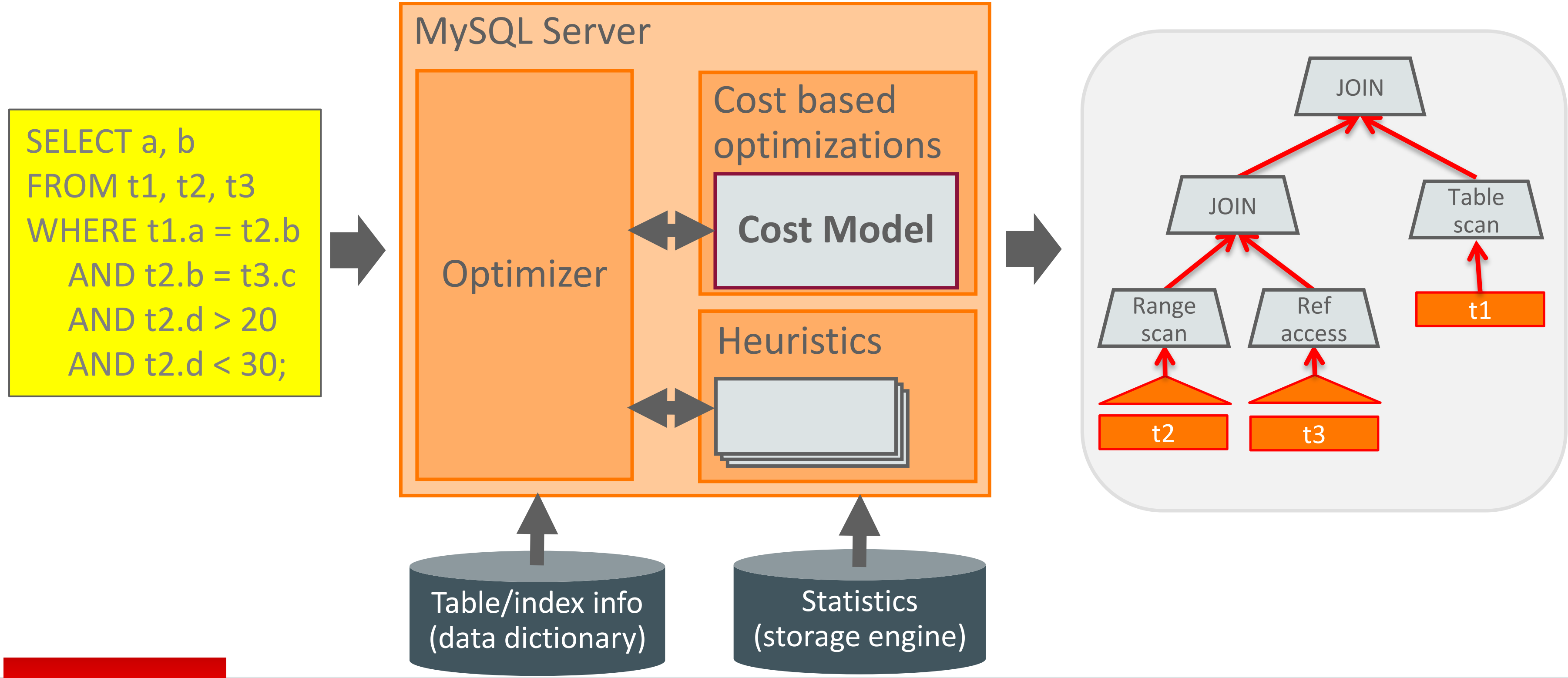
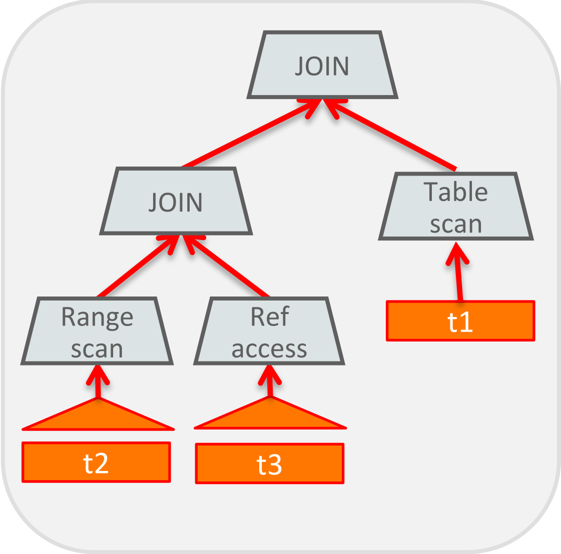
MySQL Optimizer



Cost-based Query Optimization

General idea

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



- Cost-based optimizations:

Access method | Join order | Subquery strategy

Input to Cost Model

- **IO-cost:**
  - Estimates from storage engine based on number of pages to read
  - Both index and data pages
- **Schema:**
  - Length of records and keys
  - Uniqueness for indexes
  - Nullability

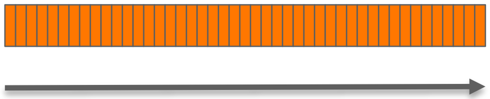
- **Statistics:**
  - Number of rows in table
  - Key distribution/Cardinality:
    - Average number of records per key value
    - Only for indexed columns
    - Maintained by storage engine
  - Number of records in an index range

Cost Model Example

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

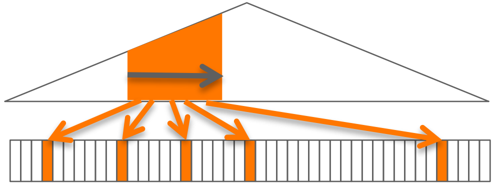
Table scan:

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



Range scan (on secondary index):

- IO-cost: #pages to read from index + #rows_in_range
- 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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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
- 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

Ref Access

Join Queries, continued

EXPLAIN SELECT *
FROM orders JOIN customer ON c_custkey = o_custkey
WHERE c_acctbal < -1000;

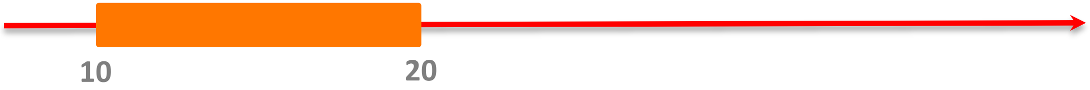
Id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	customer	ALL	PRIMARY	NULL	NULL	NULL	1500000	Using where
1	SIMPLE	orders	ref	i_o_custkey	i_o_custkey	5	dbt3.customer.c_custkey	7	NULL

Range Optimizer

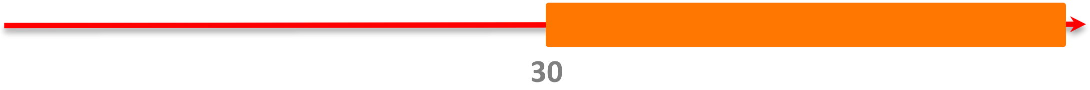
- Goal: find the “minimal” ranges for each index that needs to be read
- Example:

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

- Range scan using INDEX(key1):



- Range scan using INDEX(key2):



Range Optimizer

Optimizer Trace show ranges

```
SELECT a, b FROM t1
WHERE a > 10
    AND a < 25
    AND a NOT IN (11, 19))
    AND (b < 5 OR b > 10);
```

```
"analyzing_range_alternatives": {
  "range_scan_alternatives": [
    {
      "index": "i_a",
      "ranges": [
        "10 < a < 11",
        "11 < a < 19",
        "19 < a < 25"
      ],
      "index_dives_for_eq_ranges": true,
      "rowid_ordered": false,
      "using_mrr": false,
      "index_only": false,
      "rows": 3,
      "cost": 6.61,
      "chosen": true
    },
    {
      "index": "i_b",
      "ranges": [
        "NULL < b < 5",
        "10 < b"
      ],
      "index_dives_for_eq_ranges": true,
      "rowid_ordered": false,
      …
```

Range Optimizer: Case Study

Why table scan?

SELECT * FROM orders
WHERE YEAR(o_orderdate) = 1997 AND MONTH(o_orderdate) = 5
AND o_clerk LIKE '%01866';

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 LIKE '%01866';

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 LIKE '%01866';
```

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

New index not considered

Range Optimizer: Case Study

Rewrite query, again

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

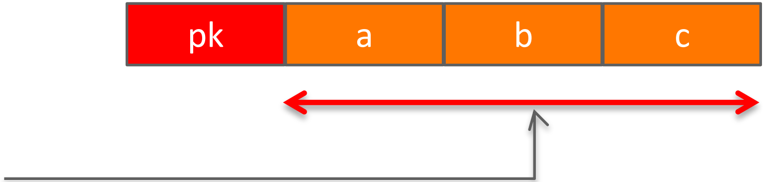
id	select type	table	type	possible keys	key	key len	ref	rows	extra
1	SIMPLE	orders	range	i_o_orderdate, i_o_clerk	i_o_clerk	16	NULL	1504	Using index condition; Using where

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

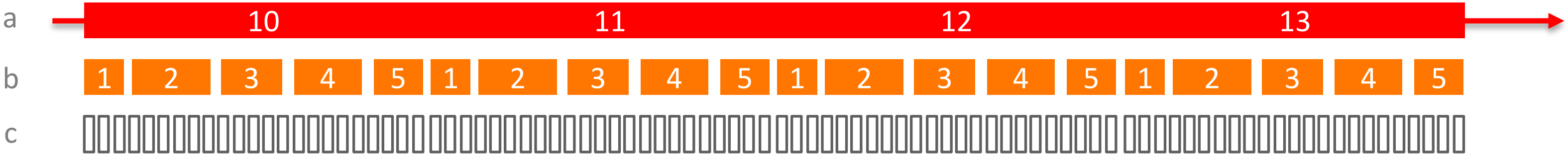
Range Access for Multi-part Index

Example table with multi-part index

- Table:
- INDEX idx(a, b, c);



- Logical storage layout of index:



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

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

```
mysql> SELECT sql_text, (timer_wait)/1000000000.0 “Time (ms)”, rows_examined FROM
  performance_schema.events_statements_history ORDER BY timer_start;
  +---------------------------------------------------------------+--------+------+
  | sql_text                                                      | Time (ms) | rows_examined |
  +---------------------------------------------------------------+--------+------+
  | 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 |
  +---------------------------------------------------------------+--------+------+
```

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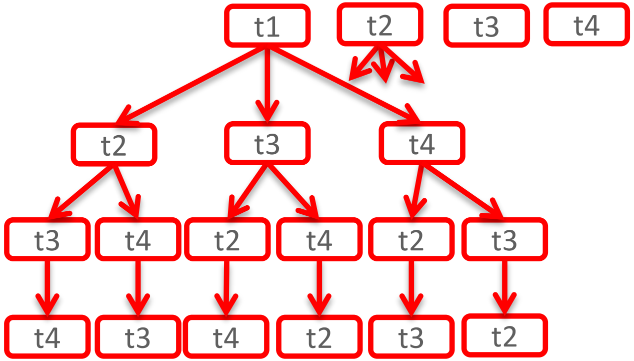
Join Optimizer

”Greedy search strategy”

- Goal: Given a JOIN of N tables, find the best JOIN ordering
- Strategy:
  - Start with all 1-table plans
  - 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**)

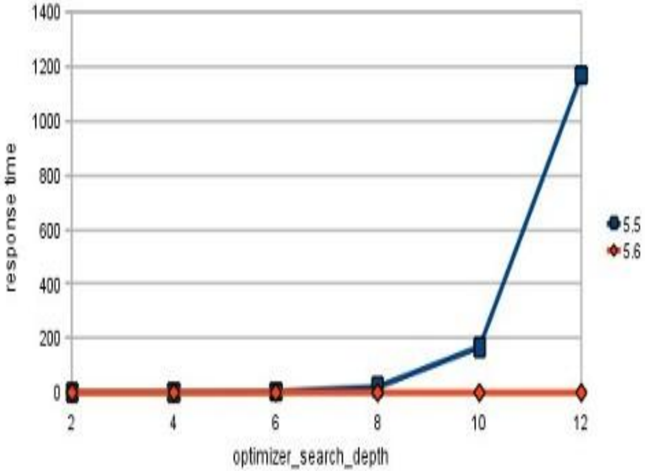


Complexity and Cost of Join Optimizer

Join of N tables: *N!* possible plans to evaluate

Heuristics to reduce the number of plans to evaluate:

- Use **optimizer_search_depth** to limit the number of tables to consider
- Pre-sort tables on *size* and *key dependency* order (Improved in MySQL 5.6)
- When adding the next table to a partial plan, add all tables that it has an equality reference to (New in MySQL 5.6)



Join Optimizer: Case study

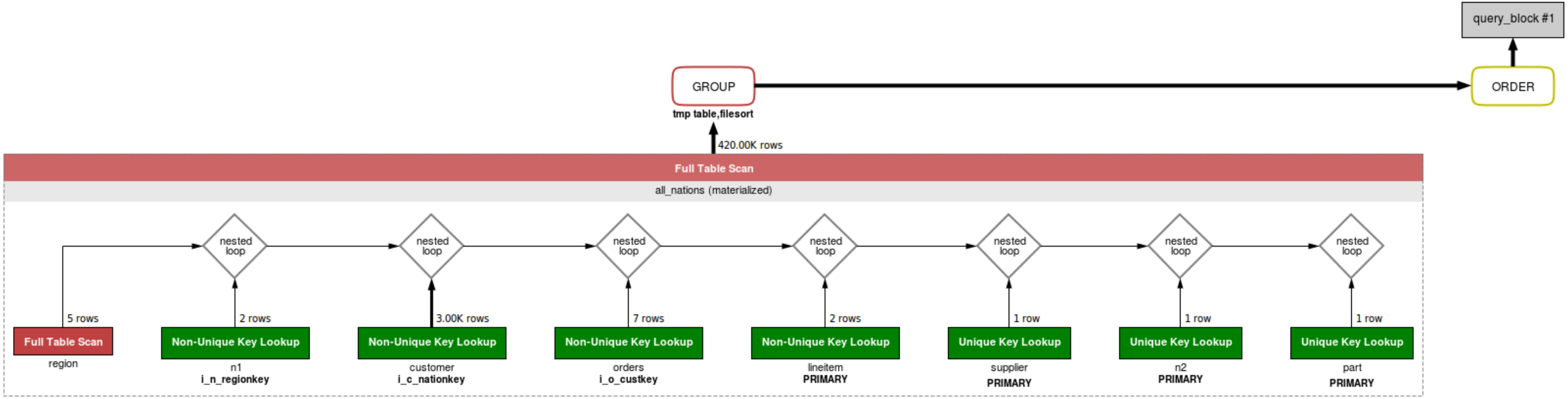
DBT-3 Query 8: National Market Share Query

```
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: 3 min. 28 sec.



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;
```

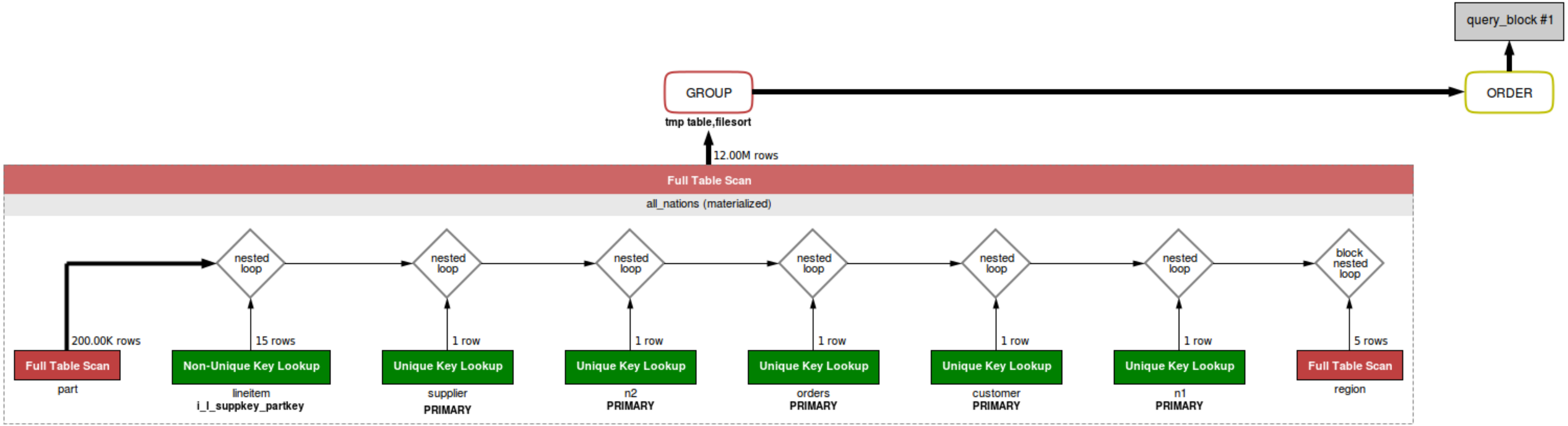
part before lineitem

Highest selectivity

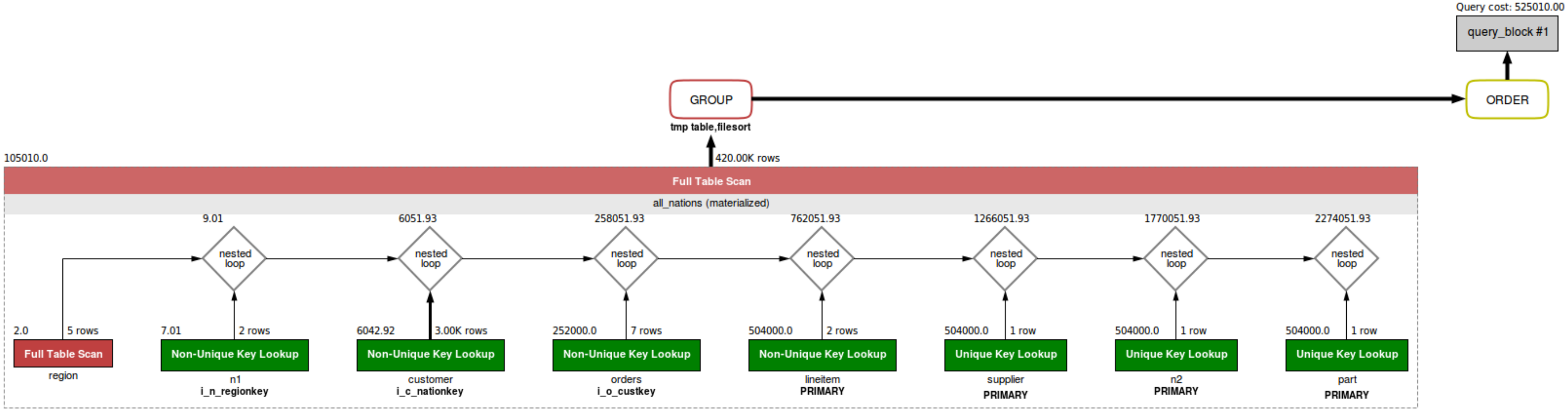
Join Optimizer: Case study

Improved join order

Execution time: 7 seconds



MySQL 5.7: Cost Information in Structured EXPLAIN



Query cost: 525010.00

query_block #1

ORDER

GROUP

tmp table,filesort

420.00K rows

105010.0

Full Table Scan

all_nations (materialized)

9.01 nested loop

6051.93 nested loop

258051.93 nested loop

762051.93 nested loop

1266051.93 nested loop

1770051.93 nested loop

2274051.93 nested loop

2.0 5 rows Full Table Scan region

7.01 2 rows Non-Unique Key Lookup n1 i_n_regionkey

6042.92 3.00K rows Non-Unique Key Lookup customer i_c_nationkey

252000.0 7 rows Non-Unique Key Lookup orders i_o_custkey

504000.0 2 rows Non-Unique Key Lookup lineitem PRIMARY

504000.0 1 row Unique Key Lookup supplier PRIMARY

504000.0 1 row Unique Key Lookup n2 PRIMARY

504000.0 1 row Unique Key Lookup part PRIMARY

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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. (New in 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: 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> FLUSH STATUS;

Query OK, 0 rows affected (0.00 sec)

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> SHOW STATUS LIKE 'sort%';
+-------------------+--------+
| Variable_name     | Value  |
+-------------------+--------+
| Sort_merge_passes |    229 |
| Sort_range        |      0 |
| Sort_rows         | 100000 |
| Sort_scan         |      1 |
+-------------------+--------+
4 rows in set (0.00 sec)
```

Filesort: Case Study

Increase sort buffer (1 MB)

Default is 256 kB

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

mysql> FLUSH STATUS;

Query OK, 0 rows affected (0.00 sec)

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> SHOW STATUS LIKE 'sort%';
+-------------------+--------+
| Variable_name     | Value  |
+-------------------+--------+
| Sort_merge_passes |     57 |
| Sort_range        |      0 |
| Sort_rows         | 100000 |
| Sort_scan         |      1 |
+-------------------+--------+
4 rows in set (0.00 sec)
```

Filesort: Case Study

Increase sort buffer even more (8 MB)

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

mysql> FLUSH STATUS;

Query OK, 0 rows affected (0.00 sec)

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

NB! Bigger sort buffer than needed will give unnecessary overhead

Use Index to Avoid Sorting

CREATE INDEX i_o_totalprice ON orders(o_totalprice);

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)
```

Program Agenda

1 Introduction to MySQL optimizer

2 Selecting data access method

3 Join optimizer

4 Sorting

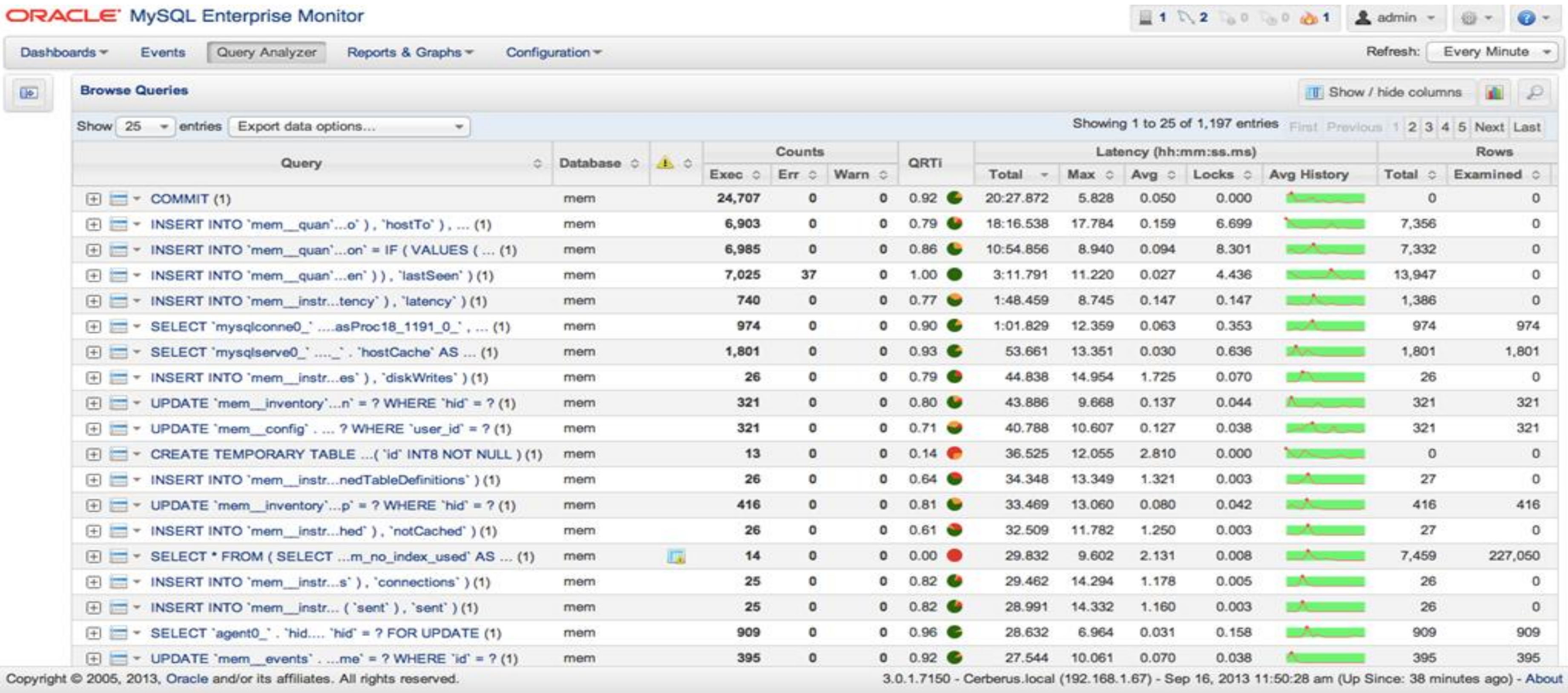
5 Tools for monitoring, analyzing, and tuning queries

6 Influencing the Optimizer

Useful tools

- MySQL Enterprise Monitor (MEM), Query Analyzer
  - Commercial product
- Performance schema, MySQL sys schema
- EXPLAIN
- EXPLAIN FORMAT=JSON
- Optimizer trace
- Slow log
- Status variables (SHOW STATUS LIKE ’Handler%’)

MySQL Enterprise Monitor, Query Analyzer



ORACLE MySQL Enterprise Monitor

Browse Queries

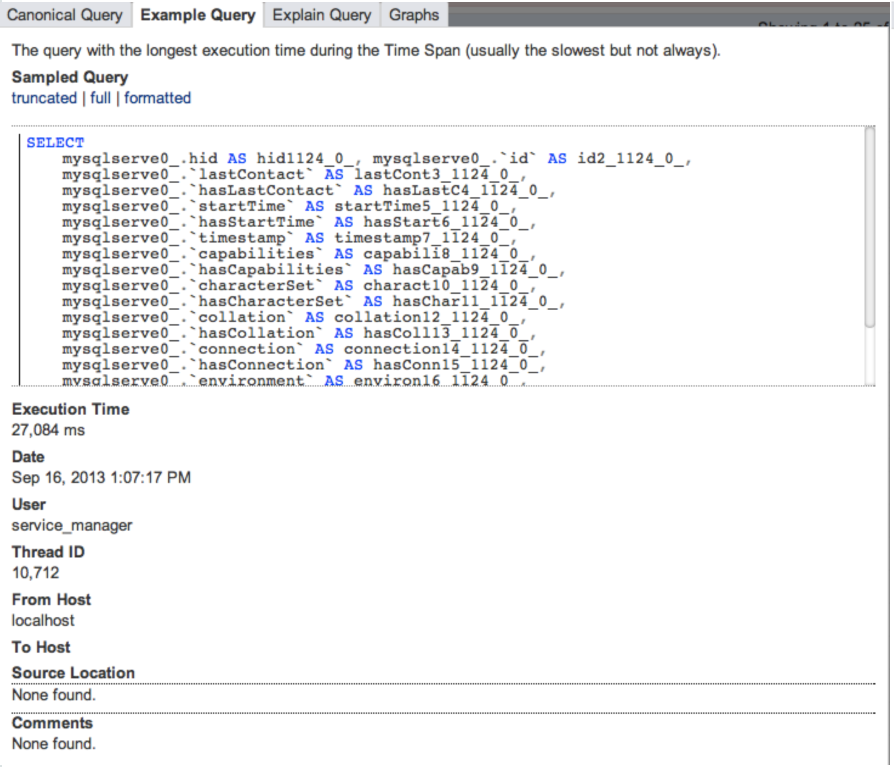
Show 25 entries Export data options...

Showing 1 to 25 of 1,197 entries First Previous 1 2 3 4 5 Next Last

Query	Database	⚠	Counts			QRTi	Latency (hh:mm:ss.ms)					Rows	
			Exec	Err	Warn		Total	Max	Avg	Locks	Avg History	Total	Examined
COMMIT (1)	mem		24,707	0	0	0.92	20:27.872	5.828	0.050	0.000		0	0
INSERT INTO 'mem__quan'...o') , 'hostTo') , ... (1)	mem		6,903	0	0	0.79	18:16.538	17.784	0.159	6.699		7,356	0
INSERT INTO 'mem__quan'...on' = IF (VALUES (... (1)	mem		6,985	0	0	0.86	10:54.856	8.940	0.094	8.301		7,332	0
INSERT INTO 'mem__quan'...en')) , 'lastSeen') (1)	mem		7,025	37	0	1.00	3:11.791	11.220	0.027	4.436		13,947	0
INSERT INTO 'mem__instr...tency') , 'latency') (1)	mem		740	0	0	0.77	1:48.459	8.745	0.147	0.147		1,386	0
SELECT 'mysqlconne0_' ....asProc18_1191_0_' , ... (1)	mem		974	0	0	0.90	1:01.829	12.359	0.063	0.353		974	974
SELECT 'mysqlserve0_' ...._' . 'hostCache' AS ... (1)	mem		1,801	0	0	0.93	53.661	13.351	0.030	0.636		1,801	1,801
INSERT INTO 'mem__instr...es') , 'diskWrites') (1)	mem		26	0	0	0.79	44.838	14.954	1.725	0.070		26	0
UPDATE 'mem__inventory'...n' = ? WHERE 'hid' = ? (1)	mem		321	0	0	0.80	43.886	9.668	0.137	0.044		321	321
UPDATE 'mem__config' . ... ? WHERE 'user_id' = ? (1)	mem		321	0	0	0.71	40.788	10.607	0.127	0.038		321	321
CREATE TEMPORARY TABLE ...('id' INT8 NOT NULL) (1)	mem		13	0	0	0.14	36.525	12.055	2.810	0.000		0	0
INSERT INTO 'mem__instr...nedTableDefinitions') (1)	mem		26	0	0	0.64	34.348	13.349	1.321	0.003		27	0
UPDATE 'mem__inventory'...p' = ? WHERE 'hid' = ? (1)	mem		416	0	0	0.81	33.469	13.060	0.080	0.042		416	416
INSERT INTO 'mem__instr...hed') , 'notCached') (1)	mem		26	0	0	0.61	32.509	11.782	1.250	0.003		27	0
SELECT * FROM (SELECT ...m_no_index_used' AS ... (1)	mem		14	0	0	0.00	29.832	9.602	2.131	0.008		7,459	227,050
INSERT INTO 'mem__instr...s') , 'connections') (1)	mem		25	0	0	0.82	29.462	14.294	1.178	0.005		26	0
INSERT INTO 'mem__instr... ('sent') , 'sent') (1)	mem		25	0	0	0.82	28.991	14.332	1.160	0.003		26	0
SELECT 'agent0_' . 'hid.... 'hid' = ? FOR UPDATE (1)	mem		909	0	0	0.96	28.632	6.964	0.031	0.158		909	909
UPDATE 'mem__events' . ...me' = ? WHERE 'id' = ? (1)	mem		395	0	0	0.92	27.544	10.061	0.070	0.038		395	395

3.0.1.7150 - Cerberus.local (192.168.1.67) - Sep 16, 2013 11:50:28 am (Up Since: 38 minutes ago) - About

Query Analyzer Query Details



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

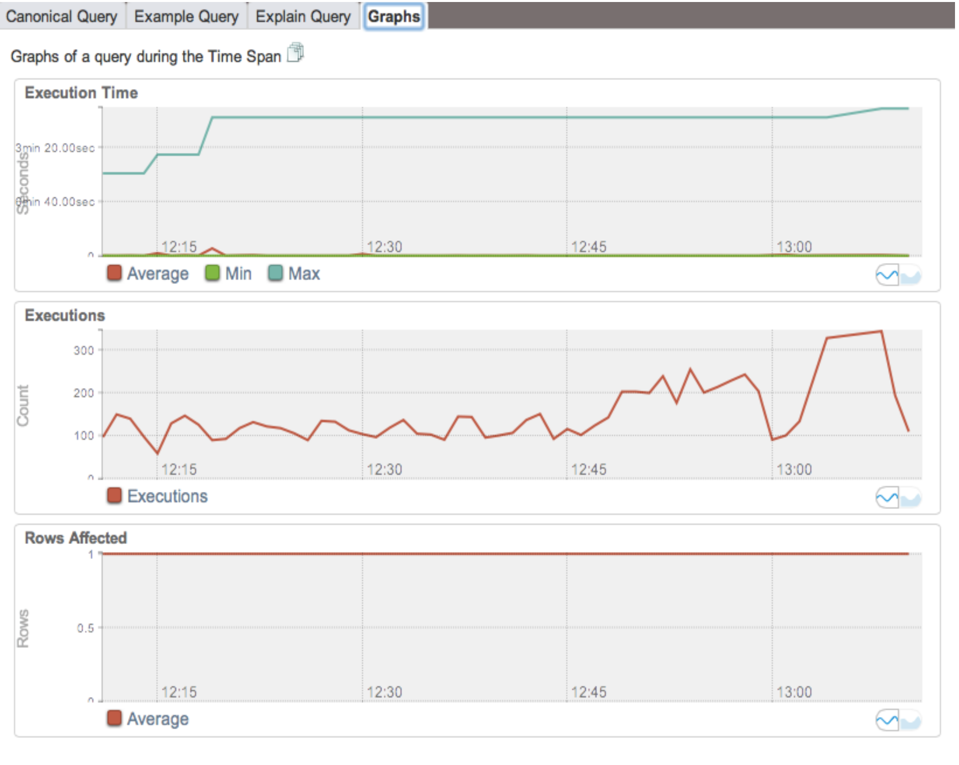
Thread ID
10,712

From Host
localhost

To Host

Source Location
None found.

Comments
None found.



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 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

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

MySQL sys Schema / ps_helper

- Started as a collection of views, procedures and functions, designed to make reading raw Performance Schema data easier
- Implements many common DBA and Developer use cases
- Now bundled within MySQL Workbench
- Available on GitHub
  - https://github.com/MarkLeith/mysql-sys
- Examples of very useful functions:
  - format_time() , format_bytes(), format_statement()

MySQL sys Schema

Example

statement_analysis: Lists a normalized statement view with aggregated statistics, mimics the MySQL Enterprise Monitor Query Analysis view, ordered by the total execution time per normalized statement

```
mysql> select * from statement_analysis limit 1\G
   *************************** 1. row ***************************
   query: INSERT INTO `mem__quan` . `nor ... nDuration` = IF ( VALUES ( ...
   db: mem
   full_scan:
   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
```

Optimizer Trace: Query Plan Debugging

- EXPLAIN shows the selected plan
- TRACE shows WHY the plan was selected:
  - Alternative plans
  - Estimated costs
  - Decisions made
- JSON format

Optimizer Trace: Example

```
SET optimizer_trace= “enabled=on“, end_markers_in_json=on;
SELECT * FROM t1, t2 WHERE f1=1 AND f1=f2 AND f2>0;
SELECT trace INTO DUMPFILE <filename>
    FROM information_schema.optimizer_trace;
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

Program Agenda

1. Introduction to MySQL optimizer
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4. Sorting
5. Tools for monitoring, analyzing, and tuning queries
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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_prune_level = 0;

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

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Q&A