MySQL 5.7: Performance Improvements in Optimizer

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April 25, 2016
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Program Agenda

1. Improvements in optimizer
   - Cost model
   - New optimizations

2. Understanding query performance
   - Explain extensions
   - Optimizer trace

3. Tools for improving query plans
   - New hints
   - Query rewrite plugin
MySQL Optimizer

```
SELECT a, b
FROM t1
JOIN t2
  ON t1.a = t2.b
JOIN t3
  ON t2.b = t3.c
WHERE t2.d > 20
  AND t2.d < 30;
```
Optimizer Performance Improvements in MySQL 5.7

Cost model improvements:

• Cost model for WHERE conditions (condition filtering effect)
  – Improved JOIN order
• Improved index statistics
  – Better index selection, better join order
• Configurable “cost constants”

New optimizations:

• Merging of derived tables
• Optimization of IN queries
• Union ALL optimization
Condition Filtering Effect

Cost Model for Query Conditions

**Goal:** Low-fanout tables should be early in the join order

```
SELECT office_name
FROM office JOIN employee ON office.id = employee.office
WHERE employee.name = "John" AND age > 21 AND
hire_date BETWEEN "2014-01-01" AND "2014-06-01";
```

MySQL 5.6:

![Diagram showing join order and fanout calculation]

**Fanout = #rows read by access method**

MySQL 5.7:

![Diagram showing join order with condition filter effect]

**Fanout = #rows read by access method * condition filter effect**

In 5.6 we do not consider the entire WHERE condition when calculating fanout.
How to Calculate Condition Filter Effect

Filter estimate based on what is available:

1. Range estimate
2. Index statistics
3. Guesstimate

SELECT office_name
FROM office
JOIN employee ON office.id = employee.office

<table>
<thead>
<tr>
<th>Condition</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>=</td>
<td>0.1</td>
</tr>
<tr>
<td>&lt;=, &lt;, &gt;, &gt;=</td>
<td>1/3</td>
</tr>
<tr>
<td>BETWEEN</td>
<td>1/9</td>
</tr>
<tr>
<td>NOT &lt;op&gt;</td>
<td>1 – SEL(&lt;op&gt;)</td>
</tr>
<tr>
<td>AND</td>
<td>P(A and B) = P(A) * P(B)</td>
</tr>
<tr>
<td>OR</td>
<td>P(A or B) = P(A) + P(B) – P(A and B)</td>
</tr>
</tbody>
</table>

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Example: Two Table JOIN in MySQL 5.7

```sql
SELECT office_name
FROM office
JOIN employee ON office.id = employee.office
WHERE employee.name = "John" AND age > 21 AND
hire_date BETWEEN "2014-01-01" AND "2014-06-01";
```

**Explain for 5.6:**

<table>
<thead>
<tr>
<th>Table</th>
<th>Type</th>
<th>Possible keys</th>
<th>Key</th>
<th>Ref</th>
<th>Rows</th>
<th>Filtered</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>office</td>
<td>ALL</td>
<td>PRIMARY</td>
<td>NULL</td>
<td>NULL</td>
<td>100</td>
<td>100.00</td>
<td>NULL</td>
</tr>
<tr>
<td>employee</td>
<td>ref</td>
<td>office</td>
<td>office</td>
<td>office.id</td>
<td>99</td>
<td>100.00</td>
<td>Using where</td>
</tr>
</tbody>
</table>

**Explain for 5.7:**

<table>
<thead>
<tr>
<th>Table</th>
<th>Type</th>
<th>Possible keys</th>
<th>Key</th>
<th>Ref</th>
<th>Rows</th>
<th>Filtered</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>employee</td>
<td>ALL</td>
<td>NULL</td>
<td>NULL</td>
<td>NULL</td>
<td>9991</td>
<td>1.23</td>
<td>NULL</td>
</tr>
<tr>
<td>office</td>
<td>eq_ref</td>
<td>PRIMARY</td>
<td>PRIMARY</td>
<td>employee.office</td>
<td>1</td>
<td>100.00</td>
<td>Using where</td>
</tr>
</tbody>
</table>

Condition filter estimate

JOIN ORDER HAS CHANGED!
Disable Condition Filtering

• In case of performance regressions:

```
SET optimizer_switch=`condition_fanout_filter=OFF`;
```
Configurable Cost Model

• Replaced hard-coded “cost constants” with configurable “cost constants”

• Stored in “mysql” database:
  – server_cost
  – engine_cost

• “Cost constants” are changed by updating these tables
## Configurable Cost Constants

<table>
<thead>
<tr>
<th>Name</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>row_evalulate_cost</td>
<td>0.2</td>
</tr>
<tr>
<td>key_compare_cost</td>
<td>0.1</td>
</tr>
<tr>
<td>memory_temptable_create_cost</td>
<td>2.0</td>
</tr>
<tr>
<td>memory_temptable_row_cost</td>
<td>0.2</td>
</tr>
<tr>
<td>disk_temptable_create_cost</td>
<td>40.0</td>
</tr>
<tr>
<td>disk_temptable_row_cost</td>
<td>1.0</td>
</tr>
<tr>
<td>memory_block_read_cost</td>
<td>1.0</td>
</tr>
<tr>
<td>io_block_read_cost</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Online update of cost constants:

```
UPDATE mysql.server_cost
SET cost_value=0.1
WHERE cost_name="row_evaluated_cost";

FLUSH OPTIMIZER_COSTS;
```

### Tip 1:

All data fits in InnoDB buffer, set:  
- `memory_block_read_cost = 0.5`  
- `io_block_read_cost = 0.5`

### Tip 2:

Working set larger than InnoDB buffer, set:  
- `memory_block_read_cost = 0.5`
Merging Derived Tables into Outer Query

MySQL 5.6:
• Derived table always materialized in temporary table

MySQL 5.7:
• Merged into outer query or materialized
• Derived table optimized as part of outer query:
  – Faster queries
• Derived tables and views are now optimized the same way

SELECT * FROM (SELECT * FROM t1 WHERE ..... ) AS derived WHERE .....
Avoid Creating Temporary Table for UNION ALL

MySQL 5.6:
• Always materialize results of UNION ALL in temporary tables

MySQL 5.7:
• Do not materialize in temporary tables unless used for sorting, rows are sent directly to client
• Client will receive the first row faster, no need to wait until the last query block is finished
• Less memory and disk consumption

Customer request

SELECT * FROM table_a UNION ALL SELECT * FROM table_b;
Optimizations for IN Expressions

CREATE TABLE t1 (a INT, b INT, c INT, INDEX idx (a, b));
SELECT a, b FROM t1 WHERE (a, b) IN ((0, 0), (1, 1));

MySQL 5.6:
• IN queries with row value expressions can not use index scans or range scans even though all the columns in the query are indexed
• Need to rewrite to de-normalized form:
  SELECT a, b FROM t1 WHERE (a = 0 AND b = 0) OR (a = 1 AND b = 1)

MySQL 5.7:
• IN queries with row value expressions executed using range scans
## Optimizations for IN Expressions

```sql
SELECT a, b FROM t1 WHERE (a, b) IN ((0, 0), (1, 1));
```

The table has 10,000 rows, 2 match the where condition

### MySQL 5.6:

<table>
<thead>
<tr>
<th>Table</th>
<th>Type</th>
<th>Possible keys</th>
<th>Key</th>
<th>Key_len</th>
<th>Ref</th>
<th>Rows</th>
<th>Filtered</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>t1</td>
<td>index</td>
<td>idx</td>
<td>idx</td>
<td>10</td>
<td>NULL</td>
<td>10000</td>
<td>100.00</td>
<td>Using where; Using index</td>
</tr>
</tbody>
</table>

### MySQL 5.7:

<table>
<thead>
<tr>
<th>Table</th>
<th>Type</th>
<th>Possible keys</th>
<th>Key</th>
<th>Key_len</th>
<th>Ref</th>
<th>Rows</th>
<th>Filtered</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>t1</td>
<td>range</td>
<td>idx</td>
<td>idx</td>
<td>10</td>
<td>NULL</td>
<td>2</td>
<td>100.00</td>
<td>Using where; Using index</td>
</tr>
</tbody>
</table>
Performance improvements: DBT-3 (SF10, CPU bound)

7 out of 22 queries get an improved query plan

MySQL 5.6
MySQL 5.7

7 out of 22 queries get an improved query plan
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Understanding 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;
```

<table>
<thead>
<tr>
<th>id</th>
<th>type</th>
<th>table</th>
<th>type</th>
<th>possible keys</th>
<th>key</th>
<th>key len</th>
<th>ref</th>
<th>rows</th>
<th>filtered</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SIMPLE</td>
<td>t1</td>
<td>range</td>
<td>PRIMARY,idx1</td>
<td>idx1</td>
<td>4</td>
<td>NULL</td>
<td>12</td>
<td>33.33</td>
<td>Using index condition</td>
</tr>
<tr>
<td>2</td>
<td>SIMPLE</td>
<td>t2</td>
<td>ref</td>
<td>idx2</td>
<td>idx2</td>
<td>4</td>
<td>t1.a</td>
<td>1</td>
<td>100.00</td>
<td>NULL</td>
</tr>
</tbody>
</table>

Condition filter effect
Explain on a Running Query

- Shows query plan on connection `<id>`
- Useful for diagnostic on long running queries
- Plan isn’t available when query plan is under creation
- Applicable to SELECT/INSERT/DELETE/UPDATE

```
EXPLAIN [FORMAT=(JSON|TRADITIONAL)] FOR CONNECTION `<id>`;
```

New in MySQL 5.7
Understanding the Query Plan

Structured EXPLAIN

• JSON format:

```
EXPLAIN FORMAT=JSON SELECT * FROM t1 WHERE b > 10 AND c > 10;
```

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

Added in MySQL 5.7
Understanding the Query Plan

Visual Explain in MySQL Work Bench
Optimizer Trace
Understand HOW a query is optimized

• Trace of the main steps and decisions done by the optimizer

SET optimizer_trace="enabled=on";
SELECT * FROM t1 WHERE a > 10;
SELECT * FROM INFORMATION_SCHEMA.OPTIMIZER_TRACE;

"table": "t1",
"range_analysis": {
  "table_scan": {
    "rows": 54,
    "cost": 13.9
  },
  "best_covering_index_scan": {
    "index": "idx",
    "cost": 11.903,
    "chosen": true
  },
  "analyzing_range_alternatives": {
    "range_scan_alternatives": [
      {
        "index": "idx",
        "ranges": [
          "10 < a"
        ],
        "rowid_ordered": false,
        "using_mrr": false,
        "index_only": true,
        "rows": 12,
        "cost": 3.4314,
        "chosen": true
      }
    ]
  }
}
Program Agenda

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Influencing the Optimizer

When the optimizer does not do what you want:

• Add indexes

• Use hints:
  – Index hints: USE INDEX, FORCE INDEX, IGNORE INDEX
  – Join order: STRAIGHT_JOIN
  – Subquery strategy: /*+ SEMIJOIN(FirstMatch) */
  – Join buffer strategy: /*+ BKA(table1) */

• Adjust optimizer_switch flags:
  – set optimizer_switch=“condition_fanout_filter=OFF”

New hint syntax and new hints in MySQL 5.7
Improved HINT support

• Introduced new hint syntax: /*+ . . . */

• Examples for new hints:
  – Join buffer strategy (BNL/NO_BNL, BKA/NO_BKA)
  – Semijoin and subquery strategy (SEMIJOIN/NO_SEMIJOIN, SUBQUERY)
  – Multi-range read optimization (MRR/NO_MRR)
  – Max execution time (MAX_EXECUTION_TIME)

• Hints apply at different scope levels: global, query block, table, index

• Most hints are in two forms:
  – Enabling means optimizer should try to use it, but not forced to use it (eg. BKA)
  – Disabling prevents optimizer from using it (eg. NO_BKA)
Hint Example: MAX_EXECUTION_TIME

```sql
SELECT /*+ MAX_EXECUTION_TIME(1) */ * FROM t1 a, t1 b, t1 c, t1 d, t1 e LIMIT 1;
ERROR 3024 (HY000): Query execution was interrupted, maximum statement execution time exceeded
```

```sql
SELECT /*+ MAX_EXECUTION_TIME(1000) */ * FROM t1 a, t1 b, t1 c, t1 d, t1 e LIMIT 1;
+---------------------------+---------------------------+---------------------------+---------------------------+---------------------------+
| a | b | a | b | a | b | a | b | a | b |
|---------------------------+---------------------------+---------------------------+---------------------------+---------------------------|
| 1 | 10 | 1 | 10 | 1 | 10 | 1 | 10 | 1 | 10 |
|---------------------------+---------------------------+---------------------------+---------------------------+---------------------------|
1 row in set (0,00 sec)
```
## Hint Example: SEMIJOIN

### EXPLAIN SELECT * FROM t1 WHERE t1.a IN (SELECT a FROM t2);

No hint, optimizer chooses semi-join algorithm loosen scan:

<table>
<thead>
<tr>
<th>id</th>
<th>Select_type</th>
<th>Table</th>
<th>Type</th>
<th>Possible_keys</th>
<th>Key</th>
<th>Key_len</th>
<th>Ref</th>
<th>Rows</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>simple</td>
<td>t2</td>
<td>index</td>
<td>a</td>
<td>a</td>
<td>4</td>
<td>null</td>
<td>3</td>
<td>Using where; LooseScan</td>
</tr>
<tr>
<td>1</td>
<td>simple</td>
<td>t1</td>
<td>ref</td>
<td>a</td>
<td>a</td>
<td>4</td>
<td>test.t2.a</td>
<td>1</td>
<td>Using index</td>
</tr>
</tbody>
</table>

### EXPLAIN SELECT * FROM t1 WHERE t1.a IN (SELECT /*+ NO_SEMIJOIN() */ a FROM t2);

Semi-join disabled with hint, subquery is executed for each row of outer table:

<table>
<thead>
<tr>
<th>id</th>
<th>Select_type</th>
<th>Table</th>
<th>Type</th>
<th>Possible_keys</th>
<th>Key</th>
<th>Key_len</th>
<th>Ref</th>
<th>Rows</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>primary</td>
<td>t1</td>
<td>index</td>
<td>null</td>
<td>a</td>
<td>4</td>
<td>null</td>
<td>4</td>
<td>Using where; Using index</td>
</tr>
<tr>
<td>2</td>
<td>dependent</td>
<td>t2</td>
<td>index_subquery</td>
<td>a</td>
<td>a</td>
<td>4</td>
<td>func</td>
<td>1</td>
<td>Using index</td>
</tr>
</tbody>
</table>
**Hint Example: SEMIJOIN**

EXPLAIN SELECT /*+ SEMIJOIN(@subq MATERIALIZATION) */ * FROM t1
WHERE t1.a IN
(SELECT /*+ QB_NAME(subq) */ a FROM t2);

Hint on a particular algorithm, in this case semi-join materialization

<table>
<thead>
<tr>
<th>id</th>
<th>Select_type</th>
<th>Table</th>
<th>Type</th>
<th>Possible_keys</th>
<th>Key</th>
<th>Key_len</th>
<th>Ref</th>
<th>Rows</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>simple</td>
<td>t1</td>
<td>index</td>
<td>a</td>
<td>a</td>
<td>4</td>
<td>null</td>
<td>4</td>
<td>Using where; Using index</td>
</tr>
<tr>
<td></td>
<td>simple</td>
<td>&lt;subquery2&gt;</td>
<td>eq_ref</td>
<td>&lt;auto_key&gt;</td>
<td>&lt;auto_key&gt;</td>
<td>4</td>
<td>test.t1.a</td>
<td>1</td>
<td>null</td>
</tr>
<tr>
<td>2</td>
<td>materialized</td>
<td>t2</td>
<td>index</td>
<td>a</td>
<td>a</td>
<td>4</td>
<td>null</td>
<td>3</td>
<td>Using index</td>
</tr>
</tbody>
</table>
Query Rewrite Plugin

• Problem:
  – Optimizer chooses a suboptimal query plan
  – User can change the query plan by adding hints or rewrite the query
  – However, database application code can not be changed

• Solution:
  – Query rewrite plugin

• Rewrite problematic queries without having to change application code
  – Add hints
  – Modify join order

• Rewrite rules are defined in a database table
How Rewrite Plugin works

Problematic query:

```sql
SELECT *
FROM t1 JOIN t2
ON t1.keycol = t2.keycol
WHERE col1 = 42 AND col2 = 2;
```

Rewritten query:

```sql
SELECT *
FROM t2 STRAIGHT_JOIN t1
FORCE INDEX (col1)
ON t1.keycol = t2.keycol
WHERE col1 = 42 AND col2 = 2;
```

Pattern for matching:

- SELECT *
- FROM t1 JOIN t2
- ON t1.keycol = t2.keycol
- WHERE col1 = ? AND col2 = ?;

Replacement rule:

- SELECT *
- FROM t2 STRAIGHT_JOIN t1
- FORCE INDEX (col1)
- ON t1.keycol = t2.keycol
- WHERE col1 = ? AND col2 = ?;

Wrong join order
Wrong index

Query rewrite plugin
How to use Query Rewrite Plugin

1. Install query rewrite plugin:
   mysql –u root –p < install_rewriter.sql

2. Insert pattern and replacement rule into query_rewrite.rewrite_rules table:

<table>
<thead>
<tr>
<th>pattern</th>
<th>replacement</th>
<th>enabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT * FROM t1 JOIN t2 &lt;br&gt; ON t1.keycol = t2.keycol &lt;br&gt; WHERE col1 = ? AND col2 =?;</td>
<td>SELECT * FROM t2 STRAIGHT_JOIN t1 &lt;br&gt; FORCE INDEX (col1) ON t1.keycol = t2.keycol &lt;br&gt; WHERE col1 = ? AND col2 =?;</td>
<td>Y</td>
</tr>
</tbody>
</table>

3. Reload the new rules into the plugin:
   mysql> CALL query_rewrite.flush_rewrite_rules();
Query Rewrite Plugin

Performance impact:

• Designed for rewriting problematic queries only!
• ~ Zero cost for queries not to be rewritten
  – Statement digest computed for performance schema anyway
• Cost of queries to be rewritten is insignificant compared to performance gain

Benefits:

• Queries can be rewritten without having to change application code
• Easy to test out alternative rewrites of queries
• Easy to temporarily disable rewrite rules to check if the rewrite still is needed
What is on the Optimizer Roadmap?

• Common table expressions (WITH RECURSIVE)
• Window functions
• Improved prepared statement support / Query plan caching
• Cost model:
  – better support for different hardware: data in memory and SSD
• Statistics:
  – Histograms