ORACLE

Introduction into MySQL Query Tuning

for Dev[Op]s.

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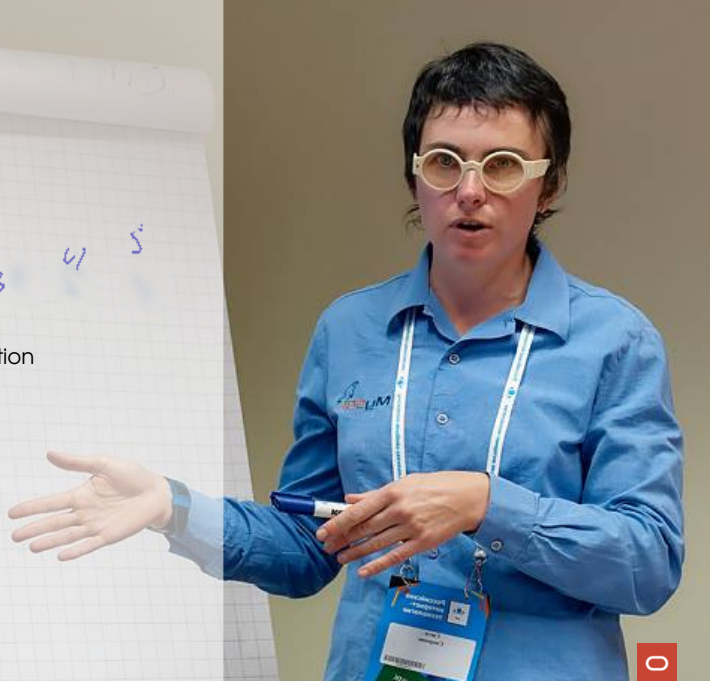
July 22, 2025

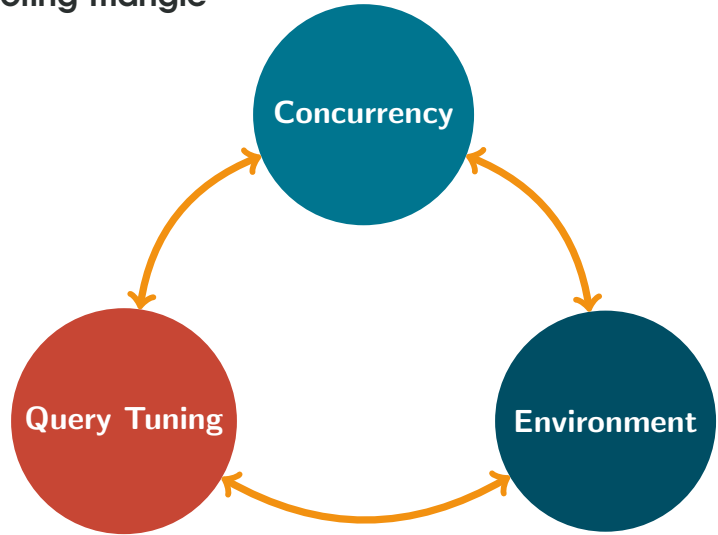
Sveta Smirnova

- MySQL Support Engineer
- Author of MySQL Troubleshooting
- Author of MySQL Cookbook, 4th Edition
- Maintainer of Percona Toolkit
- Product Manager of PMM Dump

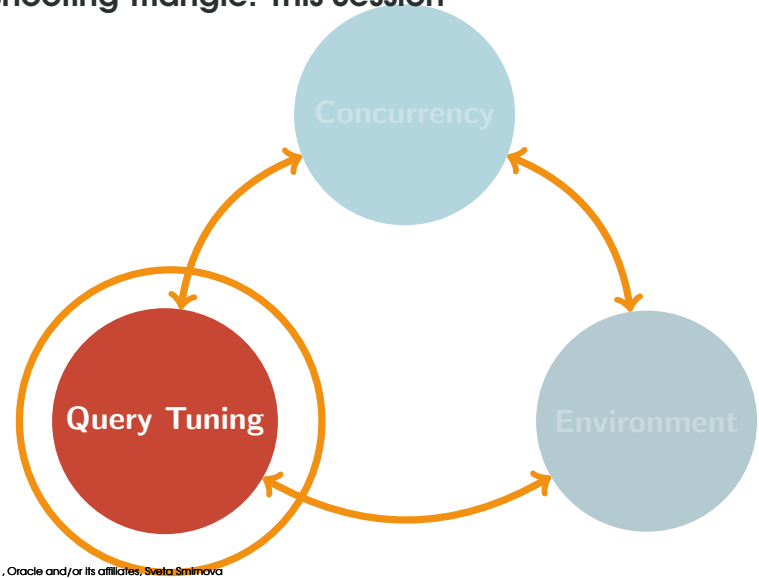


Introduction

Troubleshooting Triangle



Troubleshooting Triangle: This Session



Slow Query

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  - More chances for the local transaction to be rolled back due to conflict on multiple primary
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- Synchronous Writer
  - Performance decreases with scale factor of number of nodes
  - More chances for the local transaction to be rolled back due to conflict on multiple primary
  - Overall usage increase of CPU, disk, and memory slows down all the operations
- Synchronous Reader
  - Higher resource usage may delay or even stop replication

Emergency Situations

- No time for query tuning

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- No time for query tuning
- When?
  - Black Friday
  - Cyber Monday
  - Competitions
  - **Any time-limited event**

Emergency Situations

- No time for query tuning
- When?
- Typical Support suggestion
  - Adjust options
    - **Ensure performance configuration is optimal**
    - Turn off safety
    - Pray no hardware would fail
  - Buy hardware

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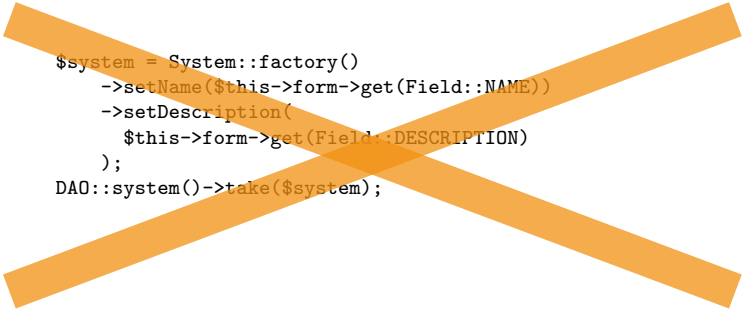
- **You have!**

Always Tune Raw Query



```
$system = System::factory()
    ->setName($this->form->get(Field::NAME))
    ->setDescription(
      $this->form->get(Field::DESCRIPTION)
    );
DAO::system()->take($system);
```

Always Tune Raw Query

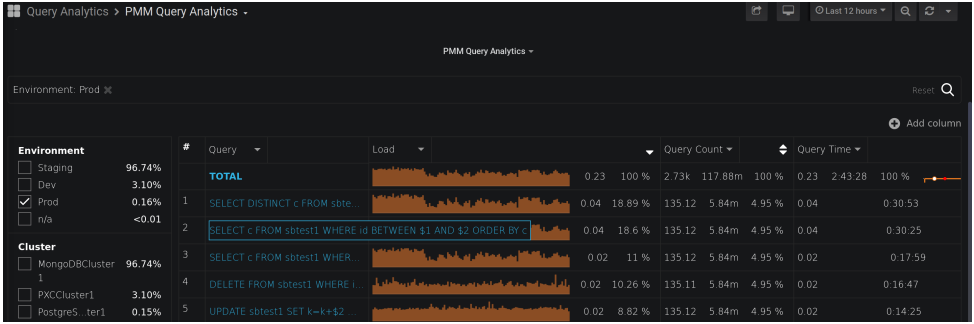
```
cursor = conn.cursor()
q = '''UPDATE `foo` SET my_date=NOW(),
    subject = %s,
    msg = %s,
    address = %s,
    updated_at = NOW()
    WHERE id=%s
    '''
cursor.execute(q, [
  remote_resp.get('subject'),
  remote_resp.get('msg'),
  remote_resp.get('address'),
  my_id
])
```

Always Tune Raw Query

```
SELECT dept_name, title, gender,
       min(salary) AS mins,
       max(salary) AS maxs
FROM employees
JOIN salaries USING(emp_no)
JOIN titles USING(emp_no)
JOIN dept_emp USING(emp_no)
JOIN departments USING(dept_no)
JOIN dept_manager USING(dept_no)
WHERE dept_manager.to_date = '9999-01-01'
GROUP BY dept_name, title, gender
ORDER BY gender, maxs DESC;
```

Sources of the Raw Query

- Application log
- Slow Query Log
- Performance Schema
- Monitoring software, e.g. PMM QAN



Slow is Relative

- Mind your data!
- 75,000,000 rows
  - `(INT, INT)`
    - 75,000,000 * (4 + 4) = **600,000,000 B** = **572 MB**
  - `(INT, INT, DATETIME, VARCHAR(255), VARCHAR(255))`
    - 75,000,000 * (4 + 4 + 8 + 256 + 256) = **39,600,000,000** bytes = **37 G**
  - 39,600,000,000 / 600,000,000 = 66

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  - Admin interface
  - Weekly cron job

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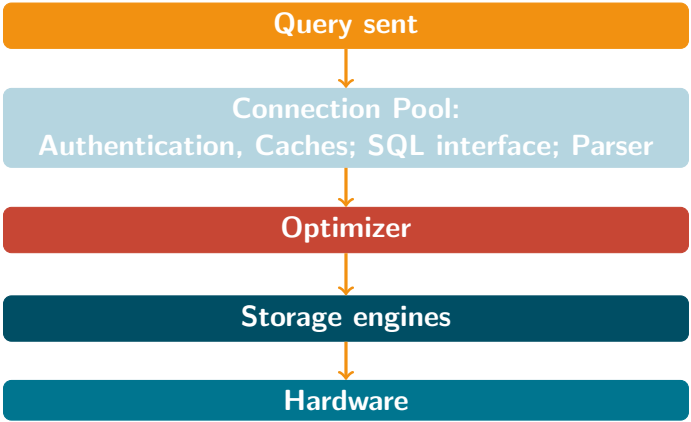
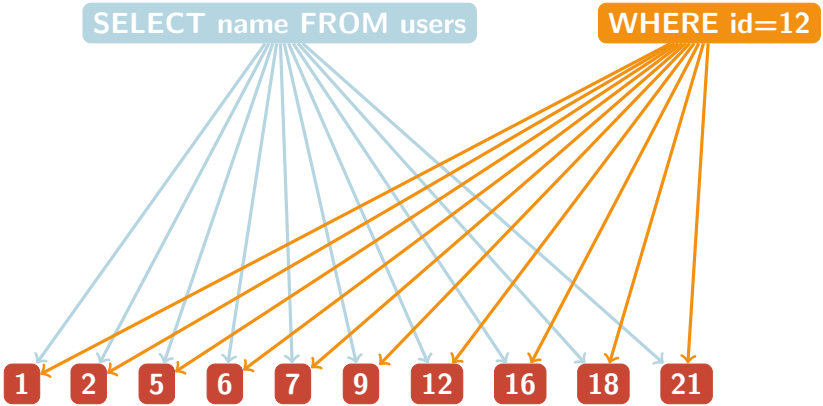
- Mind use case
  - Popular website
  - Admin interface
  - Weekly cron job
- Mind location
  - Server, used by multiple connections
  - Dedicated for OLAP queries

Query Execution Workflow

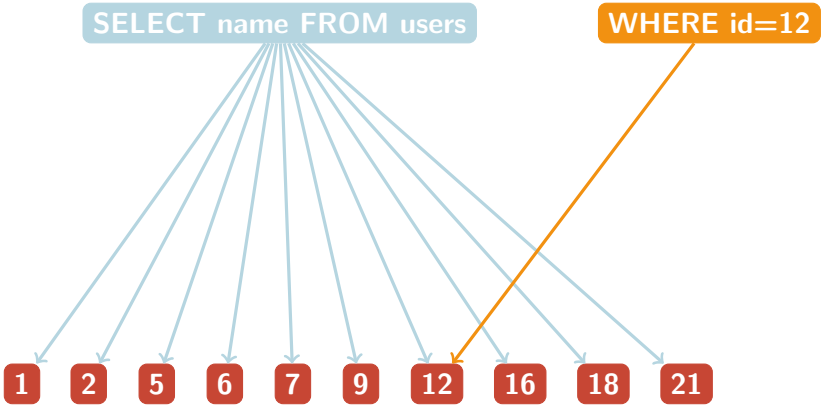


MySQL Indexes

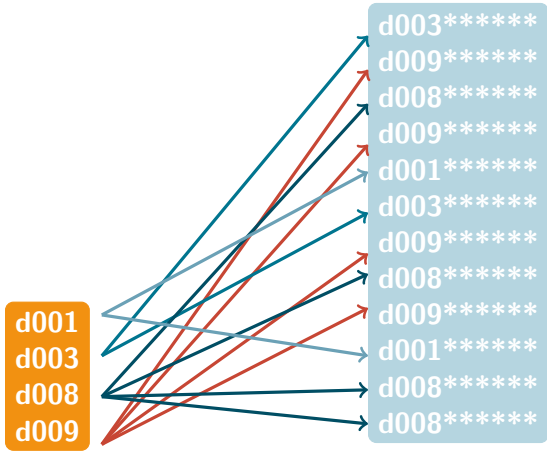
Full Table Scan



Index Access



MySQL Indexes



How to Create an Index

- Single column

```
CREATE INDEX index_name ON the_table(the_column)
```

- Multiple columns

```
CREATE INDEX index_name ON the_table(column1, column2)
```

How to Create an Index

- Single column

```
CREATE INDEX index_name ON the_table(the_column)
ALTER TABLE table_name ADD INDEX [index_name] (the_column)
```

- Multiple columns

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CREATE INDEX index_name ON the_table(column1, column2)
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```

When MySQL Uses Indexes

- Conditions
  - `WHERE the_column = a_value`
  - `WHERE the_column IN(value1, value2, value3)`
  - `WHERE the_column LIKE 'value%'`
  - ~~`WHERE the_column LIKE '%value'`~~

When MySQL Uses Indexes

- Conditions
  - `WHERE the_column = a_value`
  - `WHERE the_column IN(value1, value2, value3)`
  - `WHERE the_column LIKE 'value%'`
  - ~~`WHERE the_column LIKE '%value'`~~
  - `WHERE left_part = value1 AND right_part = value2`
  - `WHERE left_part = value1 OR right_part = value2`
  - `WHERE right_part = value1 AND left_part = value2`
  - ~~`WHERE right_part = value1 OR left_part = value2`~~

When MySQL Uses Indexes

- Conditions
- Joins
  - `table1 JOIN table2 ON table1.column1 = table2.column2`
  - Same as `FROM table1, table2 WHERE table1.column1 = table2.column2`

When MySQL Uses Indexes

- Conditions
- Joins
- `GROUP BY`
  - `GROUP BY the_column`
  - `GROUP BY left_part, right_part`
  - ~~`GROUP BY right_part, left_part`~~
  - ~~`GROUP BY the_index, another_index`~~

When MySQL Uses Indexes

- Conditions
- Joins
- `GROUP BY`
- `ORDER BY`
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  - `ORDER BY left_part, right_part`
  - ~~`ORDER BY right_part, left_part`~~
  - ~~`ORDER BY the_index, another_index`~~

5.7 ~~`ORDER BY left_part DESC, right_part ASC`~~

8.0+ `ORDER BY left_part DESC, right_part ASC`

- `left_part` **must** be **de**scending
- `right_part` **must** be **a**scending
- `the_index(left_part DESC, right_part ASC)`

When MySQL Uses Indexes

- Conditions
- Joins
- `GROUP BY`
- `ORDER BY`
- Expressions
  - Deterministic, **built-in**
    - Return same value for the same argument
    - `WHERE the_column = FLOOR(123.45)`

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  - Non-deterministic
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    - ~~`WHERE the_column = RAND() * 100`~~

When MySQL Uses Indexes

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  - Deterministic, **built-in**
    - Return same value for the same argument
    - `WHERE the_column = FLOOR(123.45)`
  - Non-deterministic
    - Return different values for different invocations
    - ~~`WHERE the_column = RAND() * 100`~~
  - Stored functions and UDFs
    - Indexes are not used

Use generated column indexes

When to Add Indexes?

- Identify queries not using indexes
  - Status variables

```
mysql> select * from performance_schema.session_status
    -> where variable_name in ('Created_tmp_tables',
    -> 'Created_tmp_disk_tables', 'Select_full_join',
    -> 'Select_full_range_join', 'Select_range',
    -> 'Select_range_check', 'Select_scan',
    -> 'Sort_merge_passes', 'Sort_range', 'Sort_rows',
    -> 'Sort_scan') and variable_value > 0;
+------------------------+----------------+
| VARIABLE_NAME          | VARIABLE_VALUE |
+------------------------+----------------+
| Select_scan            | 2              |
+------------------------+----------------+
1 row in set (0,00 sec)
```

When to Add Indexes?

- Identify queries not using indexes

```
mysql> show global status like 'Handler_read%';
+-----------------------+-------+
| Variable_name         | Value |
+-----------------------+-------+
| Handler_read_first    | 31    |
| Handler_read_key      | 1909  |
| Handler_read_last     | 0     |
| Handler_read_next     | 4393  |
| Handler_read_prev     | 0     |
| Handler_read_rnd      | 0     |
| Handler_read_rnd_next | 1135  |
+-----------------------+-------+
```

When to Add Indexes?

- Identify queries not using indexes
  - PERFORMANCE_SCHEMA.EVENTS_STATEMENTS_*

```
mysql> select * from events_statements_history_long
    -> where sql_text like 'select count(*) from employees join %'\G
*************************** 1. row ***************************
...
ROWS_SENT: 1                          SELECT_RANGE_CHECK: 0
ROWS_EXAMINED: 541058                 SELECT_SCAN: 1
CREATED_TMP_DISK_TABLES: 0            SORT_MERGE_PASSES: 0
CREATED_TMP_TABLES: 0                 SORT_RANGE: 0
SELECT_FULL_JOIN: 0                   SORT_ROWS: 0
SELECT_FULL_RANGE_JOIN: 0             SORT_SCAN: 0
SELECT_RANGE: 0                       NO_INDEX_USED: 0
```

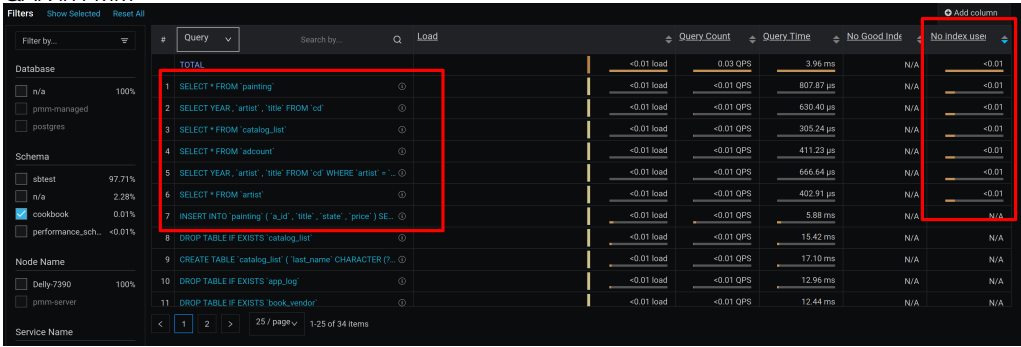
When to Add Indexes?

- Identify queries not using indexes
  - Slow query log

```
# Time: 2020-10-11T23:34:03.701871Z
# User@Host: root[root] @ localhost [127.0.0.1]  Id:   506
# Query_time: 0.024106  Lock_time: 0.000091
Rows_sent: 1  Rows_examined: 1000
SET timestamp=1602459243;
SELECT c FROM sbtest1 WHERE id=996;
```

When to Add Indexes?

- Identify queries not using indexes
  - QAN in PMM



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When to Add Indexes?

- Identify queries not using indexes
- Analyze if adding an index will help
- Add the index
- **Test first!**
  - `ADD INDEX` is an expensive operation

Use `pt-online-schema-change`

Play with index visibility while testing

EXPLAIN: How Optimizer Works

EXPLAIN: rows

```
mysql> EXPLAIN SELECT first_name, last_name, title, salary FROM employees
    -> JOIN salaries USING(emp_no) JOIN titles USING(emp_no)
    -> WHERE salary = (SELECT MAX(salary) FROM salaries
    ->                 JOIN titles WHERE titles.to_date > CURDATE());
+----+-------------+-----------+------------+------+---------------+---------+---------+
| id | select_type | table     | partitions | type | possible_keys | key     | key_len |
+----+-------------+-----------+------------+------+---------------+---------+---------+
|  1 | PRIMARY     | employees | NULL       | ALL  | PRIMARY       | NULL    | NULL ...
|  1 | PRIMARY     | salaries  | NULL       | ref  | PRIMARY       | PRIMARY | 4    ...
|  1 | PRIMARY     | titles    | NULL       | ref  | PRIMARY       | PRIMARY | 4    ...
|  2 | SUBQUERY    | titles    | NULL       | ALL  | NULL          | NULL    | NULL ...
|  2 | SUBQUERY    | salaries  | NULL       | ALL  | NULL          | NULL    | NULL ...
+----+-------------+-----------+------------+------+---------------+---------+---------+
+----+-...-+---------------------------+---------+----------+-----------------------------+
| id | ... | ref                       | rows    | filtered | Extra                       |
+----+-...-+---------------------------+---------+----------+-----------------------------+
|  1 | ... | NULL                      |  299113 |   100.00 | NULL                        |
|  1 | ... | employees.employees.emp_no |       9 |    10.00 | Using where                 |
|  1 | ... | employees.employees.emp_no |       1 |   100.00 | Using index                 |
|  2 | ... | NULL                      |  442189 |    33.33 | Using where                 |
|  2 | ... | NULL                      | 2838426 |   100.00 | Using join buffer (hash join) |
+----+-...-+---------------------------+---------+----------+-----------------------------+
5 rows in set, 1 warning (0,01 sec)
```

```
299113 * 9 * 1 * 442189 * 2838426 = 3,378,806,408,204,514,738
```

EXPLAIN: type

```
mysql> EXPLAIN SELECT title, MAX(salary) AS maxs FROM employees
    -> JOIN salaries USING(emp_no) JOIN titles USING(emp_no)
    -> GROUP BY title ORDER BY maxs DESC;
+----+-------------+-----------+------------+-------+---------------+---------+---------+
| id | select_type | table     | partitions | type  | possible_keys | key     | key_len |
+----+-------------+-----------+------------+-------+---------------+---------+---------+
|  1 | SIMPLE      | employees | NULL       | index | PRIMARY       | PRIMARY | 4 ...   |
|  1 | SIMPLE      | titles    | NULL       | ref   | PRIMARY,title | PRIMARY | 4 ...   |
|  1 | SIMPLE      | salaries  | NULL       | ref   | PRIMARY       | PRIMARY | 4 ...   |
+----+-------------+-----------+------------+-------+---------------+---------+---------+
```

Query Execution Type

ALL Read all rows

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ALL	Read all rows
index	Read all rows from the index

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index	Read all rows from the index
range	Range: `N ... M`

Query Execution Type

ALL	Read all rows
index	Read all rows from the index
range	Range: `N ... M`
subquery	Subqueries

- `index_subquery`
- `unique_subquery`

Query Execution Type

ALL	Read all rows
index	Read all rows from the index
range	Range: `N ... M`
subquery	Subqueries
merge	Combination of two indexes

- `index_merge`

Query Execution Type

ALL	Read all rows
index	Read all rows from the index
range	Range: `N ... M`
subquery	Subqueries
merge	Combination of two indexes
ref	Comparision with single value

- `ref_or_null`
- `ref`
- `eq_ref`

Query Execution Type

ALL	Read all rows
index	Read all rows from the index
range	Range: `N ... M`
subquery	Subqueries
merge	Combination of two indexes
ref	Comparision with single value
fulltext	Fulltext index

Query Execution Type

ALL	Read all rows
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subquery	Subqueries
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ref	Comparision with single value
fulltext	Fulltext index
const	Single row

Query Execution Type

ALL	Read all rows
index	Read all rows from the index
range	Range: `N ... M`
subquery	Subqueries
merge	Combination of two indexes
ref	Comparision with single value
fulltext	Fulltext index
const	Single row
system	Table has single row

EXPLAIN: key and possible_keys

```
mysql> EXPLAIN SELECT title, MAX(salary) AS maxs FROM employees
    -> JOIN salaries USING(emp_no) JOIN titles USING(emp_no)
    -> GROUP BY title ORDER BY maxs DESC;
+----+-------------+-----------+------------+-------+---------------+---------+---------+
| id | select_type | table     | partitions | type  | possible_keys | key     | key_len |
+----+-------------+-----------+------------+-------+---------------+---------+---------+
|  1 | SIMPLE      | employees | NULL       | index | PRIMARY       | PRIMARY | 4 ...   |
|  1 | SIMPLE      | titles    | NULL       | ref   | PRIMARY,title | PRIMARY | 4 ...   |
|  1 | SIMPLE      | salaries  | NULL       | ref   | PRIMARY       | PRIMARY | 4 ...   |
+----+-------------+-----------+------------+-------+---------------+---------+---------+
```

EXPLAIN: JOIN order

```
mysql> EXPLAIN SELECT title, MAX(salary) AS maxs FROM employees
    -> JOIN salaries USING(emp_no)
    -> JOIN titles USING(emp_no)
    -> GROUP BY title ORDER BY maxs DESC;
+----+-------------+-----------+------------+-------+---------------+---------+---------+
| id | select_type | table     | partitions | type  | possible_keys | key     | key_len |
+----+-------------+-----------+------------+-------+---------------+---------+---------+
|  1 | SIMPLE      | employees | NULL       | index | PRIMARY       | PRIMARY | 4 ...
|  1 | SIMPLE      | titles    | NULL       | ref   | PRIMARY,title | PRIMARY | 4 ...
|  1 | SIMPLE      | salaries  | NULL       | ref   | PRIMARY       | PRIMARY | 4 ...
+----+-------------+-----------+------------+-------+---------------+---------+---------+
```

Actual Query

```
mysql> EXPLAIN SELECT first_name, last_name, title, salary FROM employees
    -> JOIN salaries USING(emp_no) JOIN titles USING(emp_no)
    -> WHERE salary IN (SELECT MAX(salary) FROM salaries
    ->                  JOIN titles WHERE titles.to_date > CURDATE());
    ...
5 rows in set, 1 warning (0,01 sec)

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
Level: Note
Code: 1003
Message: /* select#1 */ select `employees`.`employees`.`first_name` AS `first_name`,
`employees`.`employees`.`last_name` AS `last_name`,`employees`.`salaries`.`salary` AS `salary`
from `employees`.`employees` join `employees`.`salaries`
where ((`employees`.`salaries`.`emp_no` = `employees`.`employees`.`emp_no`)
and <in_optimizer>(`employees`.`salaries`.`salary`,`employees`.`salaries`.`salary` in
  ( <materialize> (/* select#2 */
    select max(`employees`.`salaries`.`salary`)
      from `employees`.`salaries` join `employees`.`titles`
    where (`employees`.`titles`.`to_date` > <cache>(curdate())) having true ),
     <primary_index_lookup>(`employees`.`salaries`.`salary` in
       <temporary table> on <auto_distinct_key>
     where ((`employees`.`salaries`.`salary` = `<materialized_subquery>`.`MAX(salary)`)))))
1 row in set (0,00 sec)
```

Effect of Indexes: Before

```
mysql> explain select * from t1\G
*************************** 1. row ***************************
...
rows: 12
Extra: NULL

mysql> explain select * from t1 where f2=12\G
*************************** 1. row ***************************
...
key: NULL
...
rows: 12
Extra: Using where
```

Effect of Indexes: After

```
mysql> alter table t1 add index(f2);
Query OK, 12 rows affected (0.07 sec)
Records: 12  Duplicates: 0  Warnings: 0

mysql> explain select * from t1 where f2=12\G
*************************** 1. row ***************************
...
key: f2
key_len: 5
ref: const
rows: 1
Extra: NULL
1 row in set (0.00 sec)
```

Real Numbers

Handler_* Status Variables

- EXPLAIN is optimistic

```
mysql> explain select * from ol
    -> where thread_id=10432 and site_id != 9939
    -> order by id limit 3\G
*************************** 1. row ***************************
id: 1                     |         ref: NULL
select_type: SIMPLE       |        rows: 33
table: ol                 |    filtered: 8.07
partitions: NULL          |       Extra: Using where
type: index
possible_keys: thread_id
key: PRIMARY
key_len: 4
1 row in set, 1 warning (0,00 sec)
```

Handler_* Status Variables

- 'Handler_*' show truth

```
mysql> FLUSH STATUS;
mysql> select * from ol
    -> where thread_id=10432 and site_id != 9939
    -> order by id limit 3;
mysql> show status like 'Handler%';
+----------------------------+--------+
| Variable_name              | Value  |
+----------------------------+--------+
...
| Handler_read_first         | 1      |
| Handler_read_key           | 1      |
| Handler_read_last          | 0      |
| Handler_read_next          | 100000 |
...
```

PROCESSLIST

- `SHOW [FULL] PROCESSLIST`
- `performance_schema.processlist`
- `INFORMATION_SCHEMA.PROCESSLIST`
- `performance_schema.threads`
- Your first alert of performance issues shows all running queries

Execution Stages

- Can be seen in the PROCESSLIST

```
mysql> show processlist\G
*********************** 1. row ***********************
     Id: 7
   User: root
   Host: localhost:48799
     db: employees
Command: Query
   Time: 2
  State: Sending data
   Info: select count(*) from employees
         join titles using(emp_no)
         where title='Senior Engineer'
...
```

  - Very useful when you need to answer on the question: "What is my server doing now?"

Execution Stages

- PERFORMANCE_SCHEMA.EVENTS_STAGES_*

```
mysql> select eshl.event_name, substr(sql_text, 1, 15) ‘sql‘,
    -> eshl.timer_wait/1000000000000 w_s
    -> from  events_stages_history_long
    -> eshl join  events_statements_history_long esthl on
    -> (eshl.nesting_event_id = esthl.event_id) where
    -> esthl.current_schema=’employees’ and sql_text like
    -> ’select count(*) from employees%’
    -> order by eshl.timer_start asc;
+-------------------------------+-----------------+--------+
| event_name                    | sql             | w_s    |
+-------------------------------+-----------------+--------+
| stage/sql/starting            | select count(*) | 0.0002 |
| stage/sql/checking permissions | select count(*) | 0.0000 |
...
```

Execution Stages

- PERFORMANCE_SCHEMA.EVENTS_STAGES_*

```
...
| stage/sql/checking permissions | select count(*) | 0.0000 |
| stage/sql/Opening tables       | select count(*) | 0.0000 |
| stage/sql/init                 | select count(*) | 0.0001 |
| stage/sql/System lock          | select count(*) | 0.0000 |
| stage/sql/optimizing           | select count(*) | 0.0000 |
| stage/sql/statistics           | select count(*) | 0.0001 |
| stage/sql/preparing            | select count(*) | 0.0000 |
| stage/sql/executing            | select count(*) | 0.0000 |
| stage/sql/Sending data         | select count(*) | 5.4915 |
| stage/sql/end                  | select count(*) | 0.0000 |
...
```

Temporary Tables and Other Operations

- Status variables

```
mysql> flush status;
Query OK, 0 rows affected (0,01 sec)
mysql> select count(*) from employees join titles using(emp_no)
    -> where title='Senior Engineer';
+----------+
| count(*) |
+----------+
|    97750 |
+----------+
1 row in set (5,44 sec)
```

Temporary Tables and Other Operations

- Status variables

```
mysql> select * from performance_schema.session_status
    -> where variable_name in ('Created_tmp_tables',
    -> 'Created_tmp_disk_tables', 'Select_full_join',
    -> 'Select_full_range_join', 'Select_range',
    -> 'Select_range_check', 'Select_scan', 'Sort_merge_passes',
    -> 'Sort_range', 'Sort_rows', 'Sort_scan')
    -> and variable_value > 0;
+------------------------+----------------+
| VARIABLE_NAME          | VARIABLE_VALUE |
+------------------------+----------------+
| Select_scan            | 2              |
+------------------------+----------------+
1 row in set (0,00 sec)
```

Temporary Tables and Other Operations

- PERFORMANCE_SCHEMA.EVENTS_STATEMENTS_*

```
mysql> select * from events_statements_history_long
    -> where sql_text like
    -> 'select count(*) from employees join %'\G
*************************** 1. row ***************************
...
ROWS_SENT: 1                          SELECT_RANGE_CHECK: 0
ROWS_EXAMINED: 541058                 SELECT_SCAN: 1
CREATED_TMP_DISK_TABLES: 0            SORT_MERGE_PASSES: 0
CREATED_TMP_TABLES: 0                 SORT_RANGE: 0
SELECT_FULL_JOIN: 0                   SORT_ROWS: 0
SELECT_FULL_RANGE_JOIN: 0             SORT_SCAN: 0
SELECT_RANGE: 0                       NO_INDEX_USED: 0
```

Temporary Tables and Other Operations

- sys.statement_analysis

```
mysql> select * from statement_analysis where query like
    -> 'SELECT COUNT ( * ) FROM `emplo%` and db='employees'\G
*************************** 1. row ***************************
query: SELECT COUNT ( * ) FROM `emplo ...  `emp_no` ) WHE...
db: employees              max_latency: 5.59 s
full_scan:                 avg_latency: 5.41 s
exec_count: 7              lock_latency: 2.24 ms
err_count: 0               rows_sent: 7
warn_count: 0              rows_sent_avg: 1
total_latency: 37.89 s     rows_examined: 3787406
```

Temporary Tables and Other Operations

- `sys.statement_analysis`

```
rows_examined_avg: 541058
    rows_affected: 0
rows_affected_avg: 0
       tmp_tables: 0
  tmp_disk_tables: 0
      rows_sorted: 0
sort_merge_passes: 0
           digest: 4086bc3dc6510a1d9c8f2fe1f59f0943
       first_seen: 2016-04-14 15:19:19
        last_seen: 2016-04-14 16:13:14
```

How to Affect Query Plans

What has an Effect on Query Optimizer Plans?

- Index statistics
- Histogram statistics
- Optimizer switches
- Bugs in optimizer

Index Statistics

- Collected by storage engine

Index Statistics

- Collected by storage engine
- Used by Optimizer

Index Statistics

- Can be examined by `SHOW INDEX`

```
mysql> show index from sbtest1;
+---------+----------+-------------+-------------+
| Table   | Key_name | Column_name | Cardinality |
+---------+----------+-------------+-------------+
| sbtest1 | k_1      | k           |       49142 |
+---------+----------+-------------+-------------+
mysql> select count(distinct id),
    -> count(distinct k) from sbtest1;
+--------------------+-------------------+
| count(distinct id) | count(distinct k) |
+--------------------+-------------------+
|             100000 |             17598 |
+--------------------+-------------------+
```

Index Statistics

- Can be updated
  - `ANALYZE TABLE`
  - If does not help: rebuild the table
    - `OPTIMIZE TABLE`
    - `ALTER TABLE ENGINE=INNODB; ANALYZE TABLE`

Histogram Statistics

- Since version 8.0
- Collected and used by the Optimizer
- Visible in Information Schema

```
mysql> select HISTOGRAM from information_schema.column_statistics
    -> where table_name='example'\G
*************************** 1. row ***************************
HISTOGRAM: {"buckets": [[1, 0.6], [2, 0.8], [3, 1.0]],
"data-type": "int", "null-values": 0.0, "collation-id": 8,
"last-updated": "2018-11-07 09:07:19.791470",
"sampling-rate": 1.0, "histogram-type": "singleton",
"number-of-buckets-specified": 3}
1 row in set (0.00 sec)
```

More details

Optimizer Switches

```
mysql> select @@optimizer_switch\G
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=on,index_merge_sort_union=on,
index_merge_intersection=on,engine_condition_pushdown=on,index_condition_pushdown=on,
mrr=on,mrr_cost_based=on,block_nested_loop=on,batched_key_access=off,
materialization=on,semijoin=on,loosescan=on,firstmatch=on,
duplicateweedout=on,subquery_materialization_cost_based=on,
use_index_extensions=on,condition_fanout_filter=on,derived_merge=on
1 row in set (0,00 sec)
```

Optimizer Switches

- Turn `ON` and `OFF` particular optimization
- Work with them as with any other option
  - Turn `OFF` and try

```
SET optimizer_switch = 'use_index_extensions=off';
SELECT ...
EXPLAIN SELECT ...
```

  - If helps implement in queries

```
SELECT /*+ SEMIJOIN(FIRSTMATCH, LOOSESCAN) */ * FROM t1 ...;
SELECT /*+ BKA(t1) NO_BKA(t2) */ * FROM t1 INNER JOIN t2 WHERE ...;
```

Bugs in Optimizer

- Optimizer choses wrong plan for no reason
- Statistics are up to date
- Histograms are not usable
- Solution
  - Use index hints
    - `FORCE INDEX`
    - `IGNORE INDEX`
- On every upgrade
  - Remove index hints
  - Test if the query improved
  - **You must do it even for minor version upgrades!**

Summary

- `EXPLAIN` is essential for query tuning
- Real job is done by storage engine
- Index statistics affect query execution plan
- All index hints, optimizer hints and other workarounds must be validated on each upgrade

More Information

EXPLAIN Syntax

EXPLAIN FORMAT=JSON is Cool!

Troubleshooting add-ons

Optimizer Statistics aka Histograms

Optimizer Hints

Tracing the Optimizer

Thank you!

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