MySQL 5.7: Performance Improvements in Optimizer

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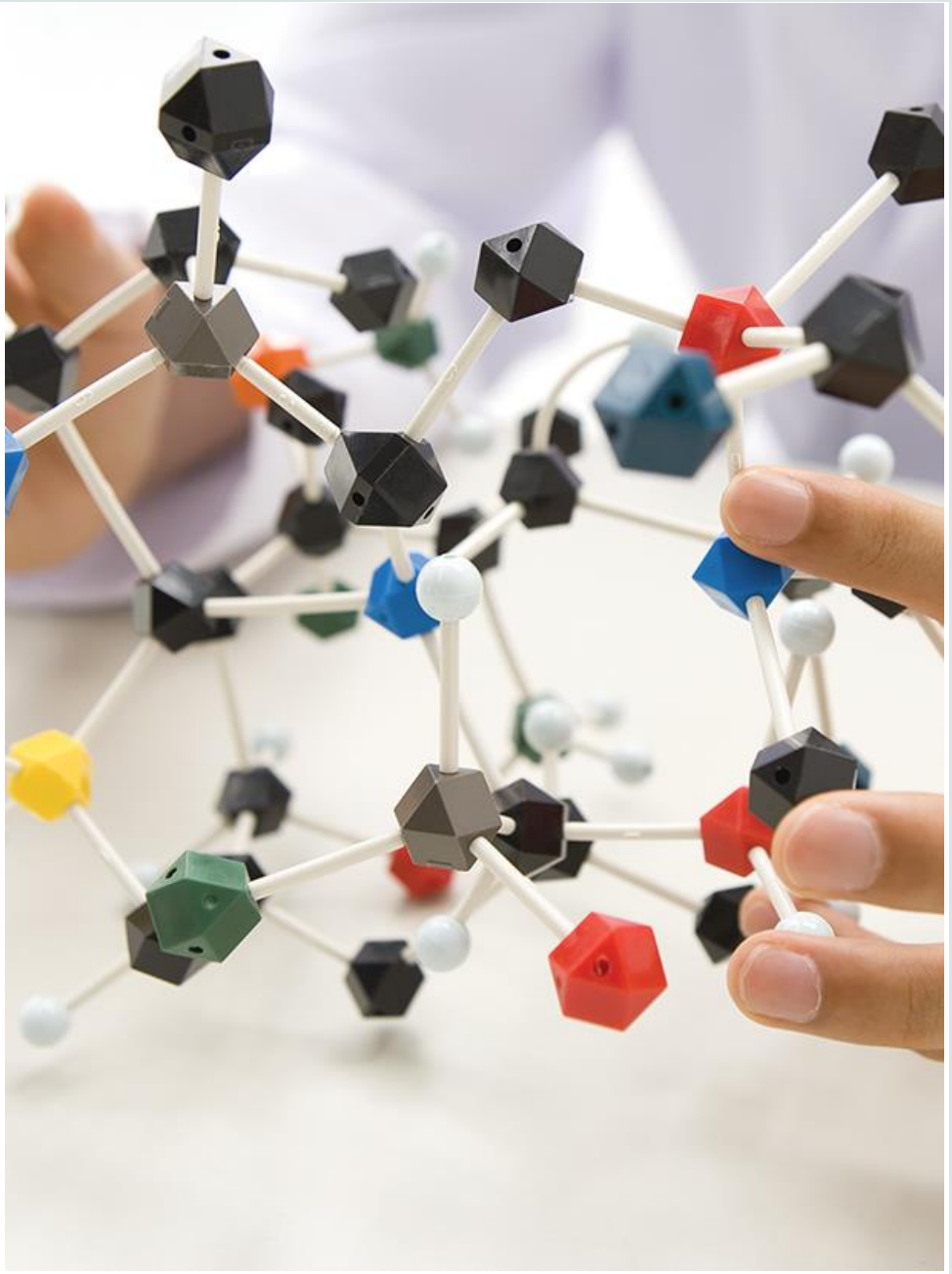
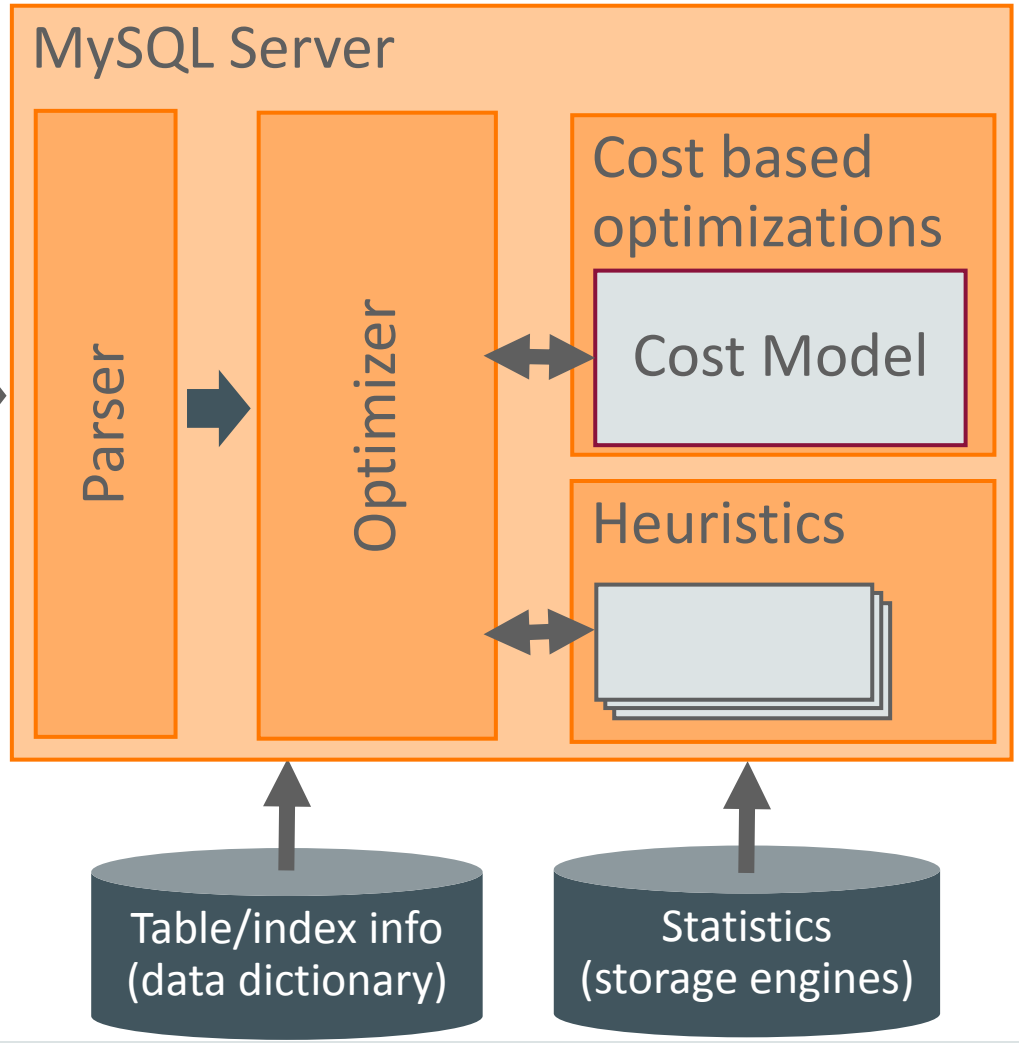
Program Agenda

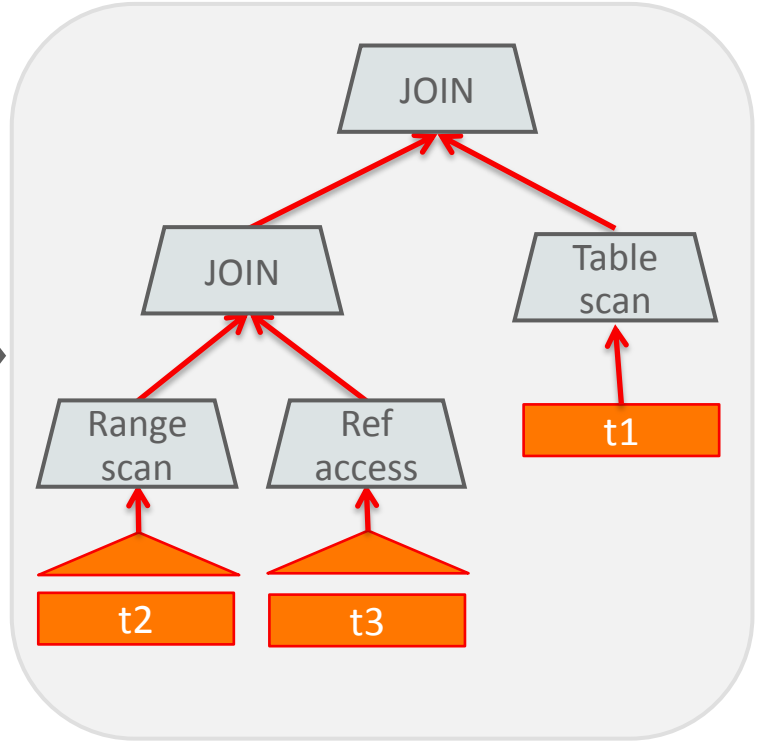
1. Improvements in optimizer
   - Cost model
   - New optimizations
2. Understanding query performance
   - Explain extensions
   - Optimizer trace
3. Tools for improving query plans
   - New hints
   - Query rewrite plugin



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

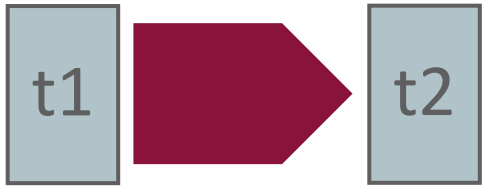
Cost Model for Query Conditions

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";
```

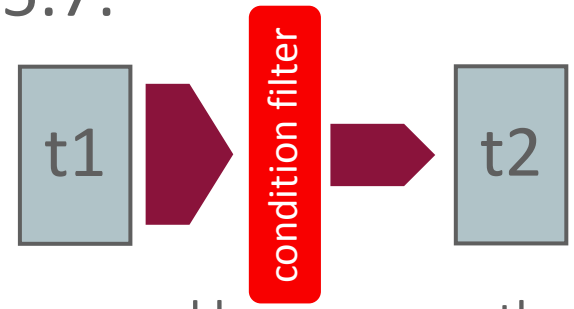
In 5.6 we do not consider the entire WHERE condition when calculating fanout

MySQL 5.6:



Fanout= #rows read by access metod

MySQL 5.7:



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

How to Calculate Condition Filter Effect

```
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";
```

0.1 (guesstimate)

0.89 (range)

0.11 (guesstimate)

Filter estimate based on what is available:

1. Range estimate
2. Index statistics
3. Guesstimate

=	0.1
<=,<,>,>=	1/3
BETWEEN	1/9
NOT <op>	1 – SEL(<op>)
AND	P(A and B) = P(A) * P(B)
OR	P(A or B) = P(A) + P(B) – P(A and B)
…	…

Example: Two Table JOIN in MySQL 5.7

```
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	Type	Possible keys	Key	Ref	Rows	Filtered	Extra
office	ALL	PRIMARY	NULL	NULL	100	100.00	NULL
employee	ref	office	office	office.id	99	100.00	Using where

Explain for 5.7:

Table	Type	Possible keys	Key	Ref	Rows	Filtered	Extra
employee	ALL	NULL	NULL	NULL	9991	1.23	NULL
office	eq_ref	PRIMARY	PRIMARY	employee.office	1	100.00	Using where

Condition filter estimate

JOIN ORDER HAS CHANGED!

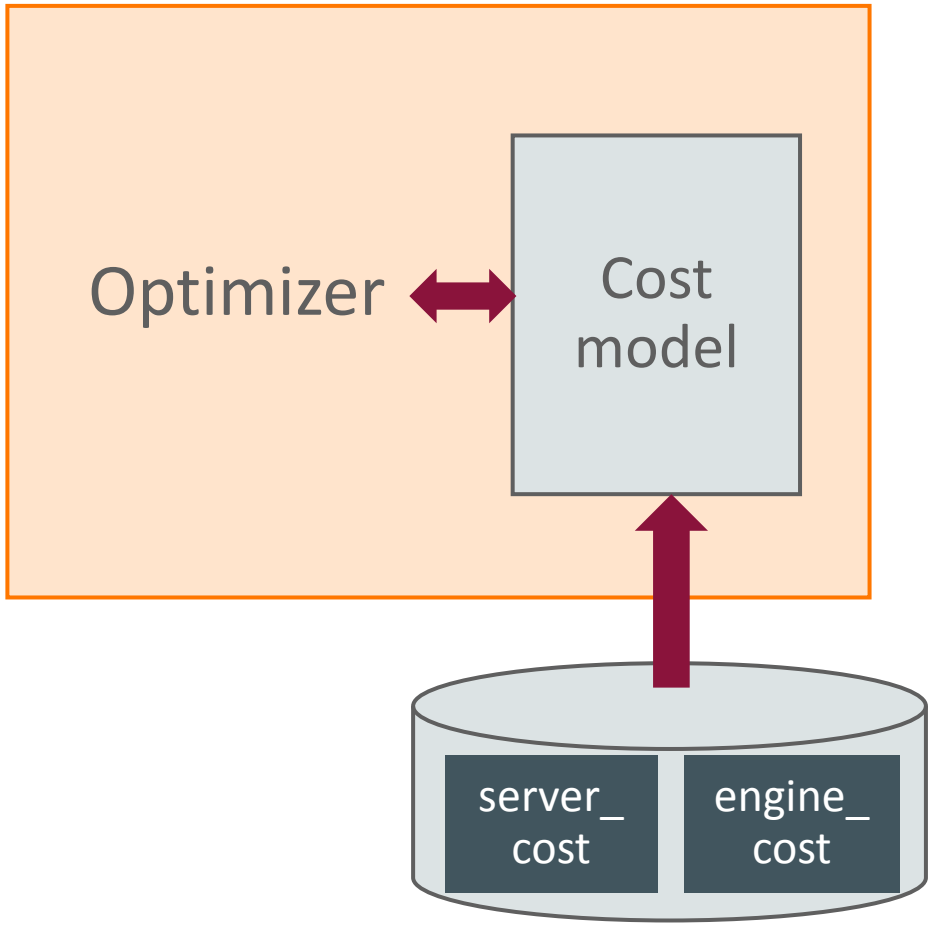
Disable Condition Filtering

- 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

Name	Default value
row_evalute_cost	0.2
key_compare_cost	0.1
memory_temptable_create_cost	2.0
memory_temptable_row_cost	0.2
disk_temptable_create_cost	40.0
disk_temptable_row_cost	1.0
memory_block_read_cost	1.0
io_block_read_cost	1.0

Online update of cost constants:

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

```
SELECT * FROM (SELECT * FROM t1 WHERE  .....) AS derived
WHERE .....
```

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

Avoid Creating Temporary Table for UNION ALL


```
SELECT * FROM table_a UNION ALL SELECT * FROM table_b;
```

MySQL 5.6:

- Always materialize results of UNION ALL in temporary tables

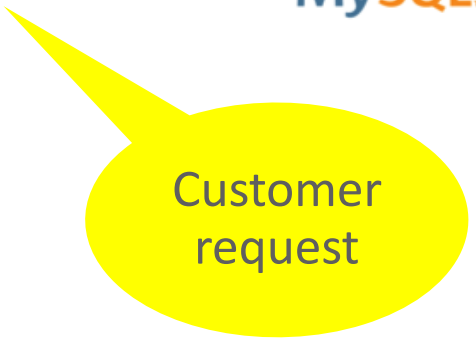
MySQL 5.7:

- 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

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

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

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

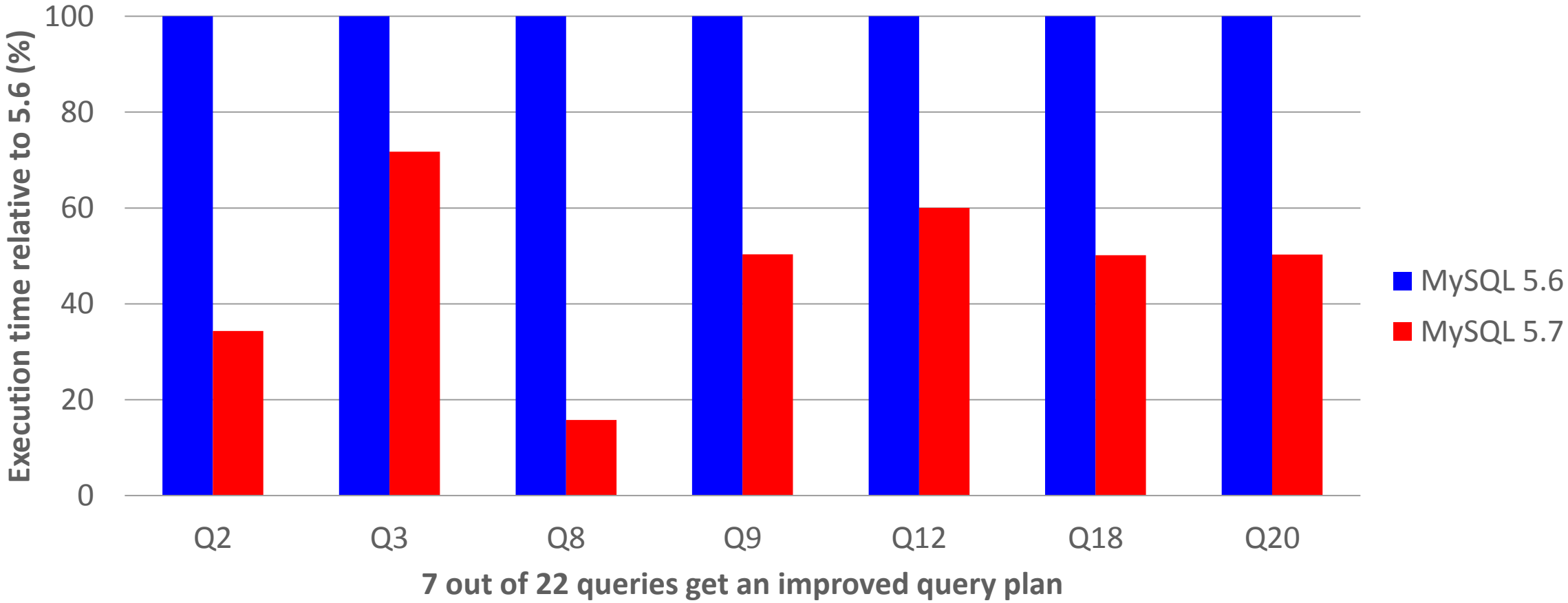
MySQL 5.6:

Table	Type	Possible keys	Key	Key_len	Ref	Rows	Filtered	Extra
t1	index	idx	idx	10	NULL	10000	100.00	Using where; Using index

MySQL 5.7:

Table	Type	Possible keys	Key	Key_len	Ref	Rows	Filtered	Extra
t1	range	idx	idx	10	NULL	2	100.00	Using where; Using index

Performance improvements: DBT-3 (SF10, CPU bound)



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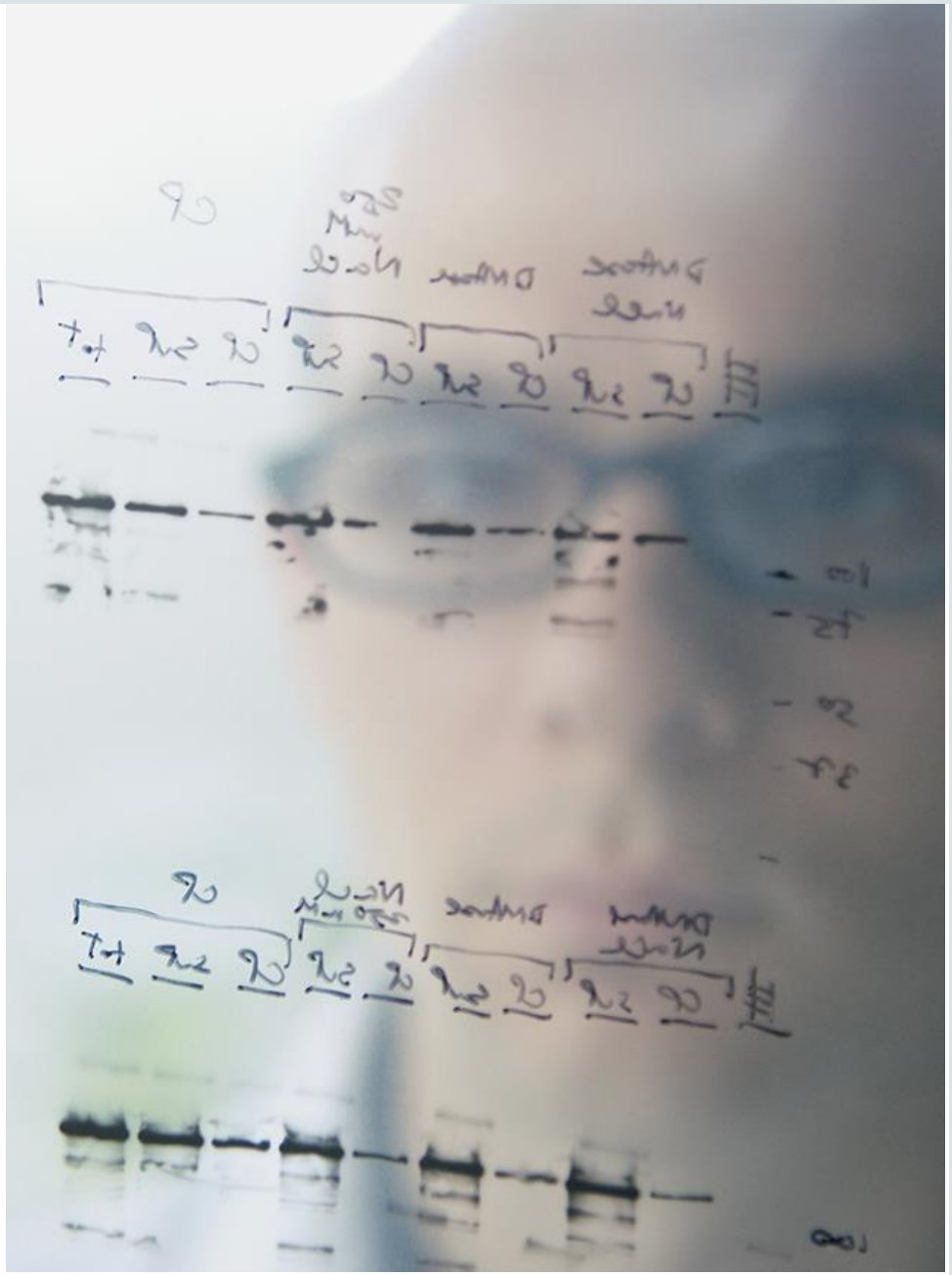
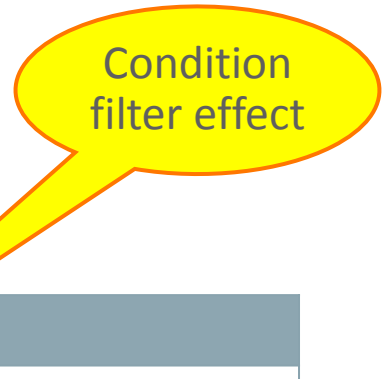


Understanding the Query Plan

EXPLAIN

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	type	table	type	possible keys	key	key len	ref	rows	filtered	Extra
1	SIMPLE	t1	range	PRIMARY,idx1	idx1	4	NULL	12	33.33	Using index condition
2	SIMPLE	t2	ref	idx2	idx2	4	t1.a	1	100.00	NULL

Explain on a Running Query

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

New in MySQL 5.7

- 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

Understanding the Query Plan

Structured EXPLAIN

- JSON format:

EXPLAIN FORMAT=JSON SELECT …

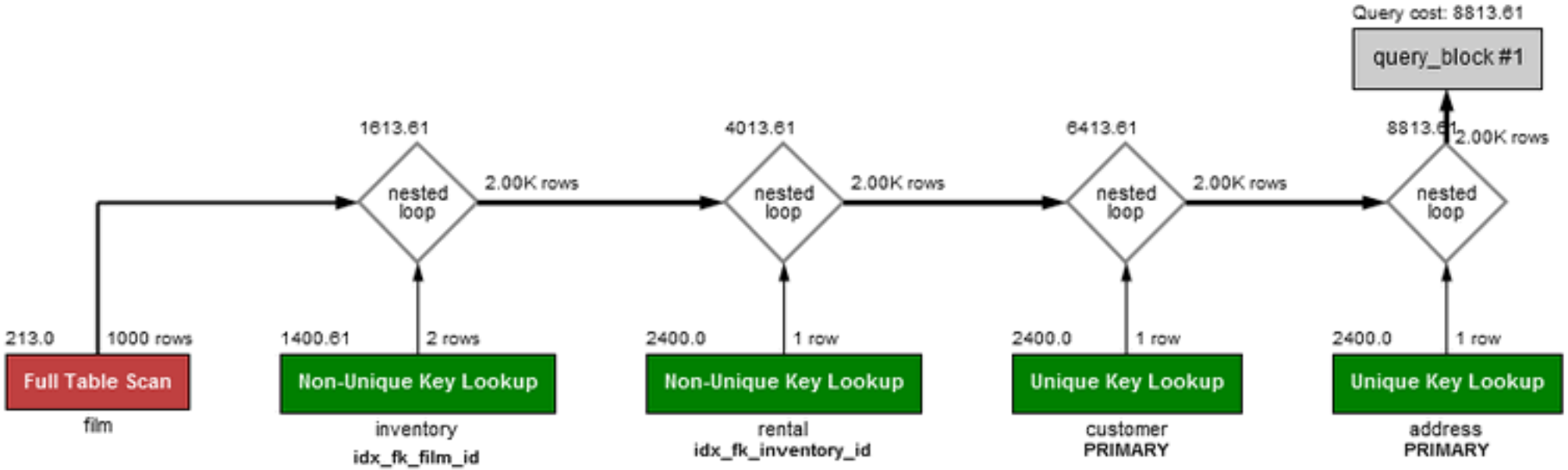
- Contains more information:
  - Used index parts
  - Pushed index conditions
  - Cost estimates
  - Data estimates

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)"
    }
  }
}
```

Understanding the Query Plan

Visual Explain in MySQL Work Bench

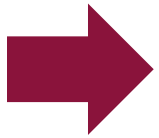


Optimizer Trace

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
     }
```

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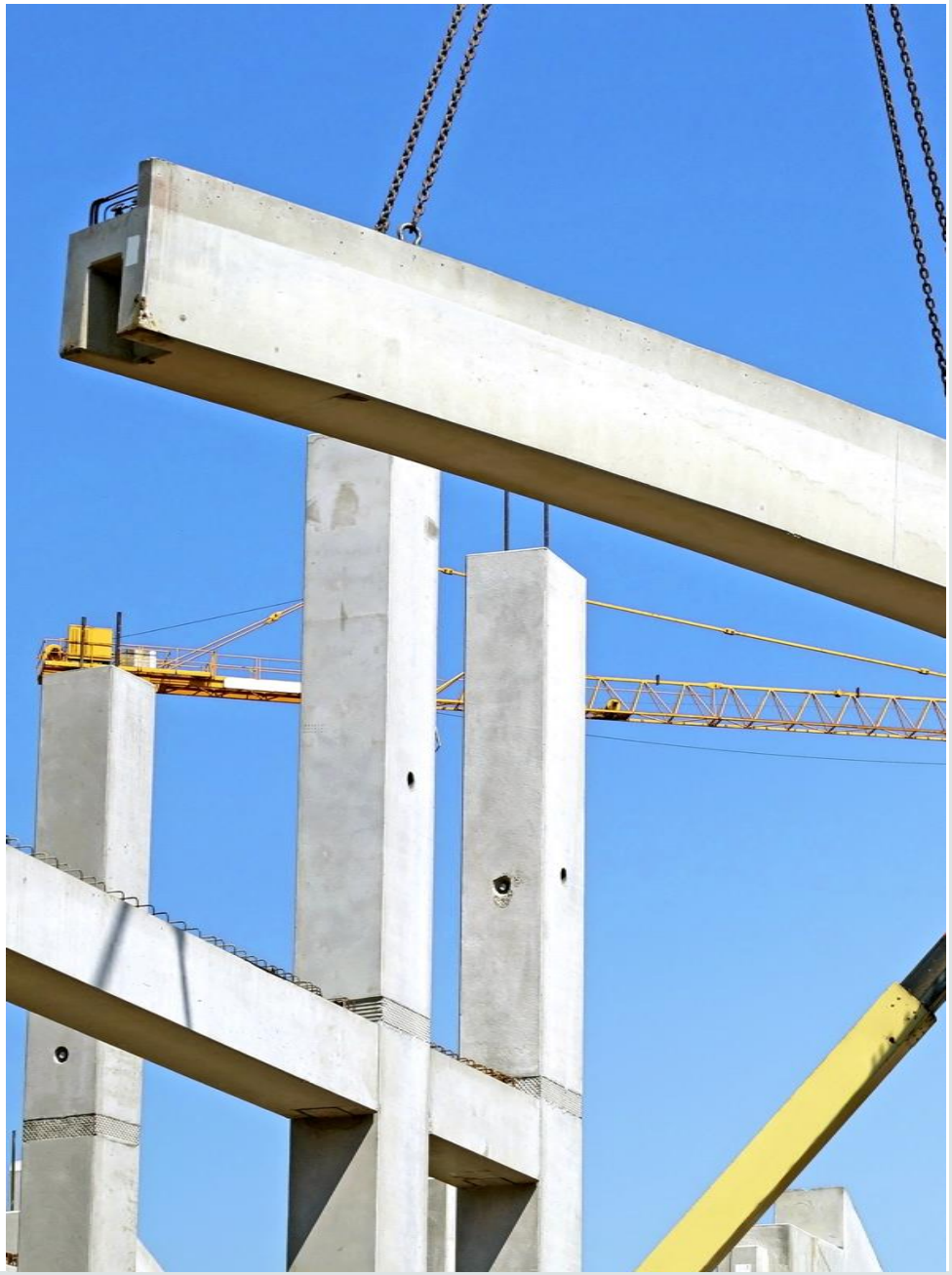

Influencing the Optimizer

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

```
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
```

```
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 loosescan:

id	Select_type	Table	Type	Possible_keys	Key	Key_len	Ref	Rows	Extra
1	simple	t2	index	a	a	4	null	3	Using where; LooseScan
1	simple	t1	ref	a	a	4	test.t2.a	1	Using index

```
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:

id	Select_type	Table	Type	Possible_keys	Key	Key_len	Ref	Rows	Extra
1	primary	t1	index	null	a	4	null	4	Using where; Using index
2	dependent subquery	t2	index_ subquery	a	a	4	func	1	Using index

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

id	Select_type	Table	Type	Possible_keys	Key	Key_len	Ref	Rows	Extra
1	simple	t1	index	a	a	4	null	4	Using where; Using index
1	simple	<subquery2>	eq_ref	<auto_key>	<auto_key>	4	test.t1.a	1	null
2	materialized	t2	index	a	a	4	null	3	Using index

Query Rewrite Plugin

- Problem:
  - Optimizer choses 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:

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

Wrong join order
Wrong index

Rewritten query:

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

Query rewrite plugin

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 =?;
```

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:

pattern	replacement	enabled
SELECT * FROM t1 JOIN t2 ON t1.keycol = t2.keycol WHERE col1 = ? AND col2 =?;	SELECT * FROM t2 STRAIGHT_JOIN t1 FORCE INDEX (col1) ON t1.keycol = t2.keycol WHERE col1 = ? AND col2 =?;	Y

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