Query Optimization: From 0 to 10 (and up to 5.7)

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dbahire.com/pleu15

Agenda – First 3 hours

1. Introduction	5. FULLTEXT Search
2. Access Types and Basic Indexing Techniques	6. Joins
3. Break	7. Subqueries
4. Multi-Column Indexing	8. Query Profiling

Agenda – Last 3 hours

1. General Optimizer Improvements	6. SQL Mode Changes
2. Computed/Virtual Columns	7. GIS Improvements and JSON Type
3. Query Rewrite Plugins	8. Results and Conclusions
4. Break	9. Q&A
5. Optimizer Hints	

Query Optimization: From 0 to 10 (and up to 5.7)

INTRODUCTION

This is me fighting bad query performance

- Sr. Database Administrator at Wikimedia Foundation
- Used to work as a trainer for Oracle (MySQL), as a Consultant (Percona) and as a Freelance administrator (DBAHire.com)

MySQL Versions

- 5.1 no longer has official support
- I will be showing you the results on mysql versions 5.5-5.7/10.1
- MySQL 5.7 and MariaDB 10.1 in RC with great new features

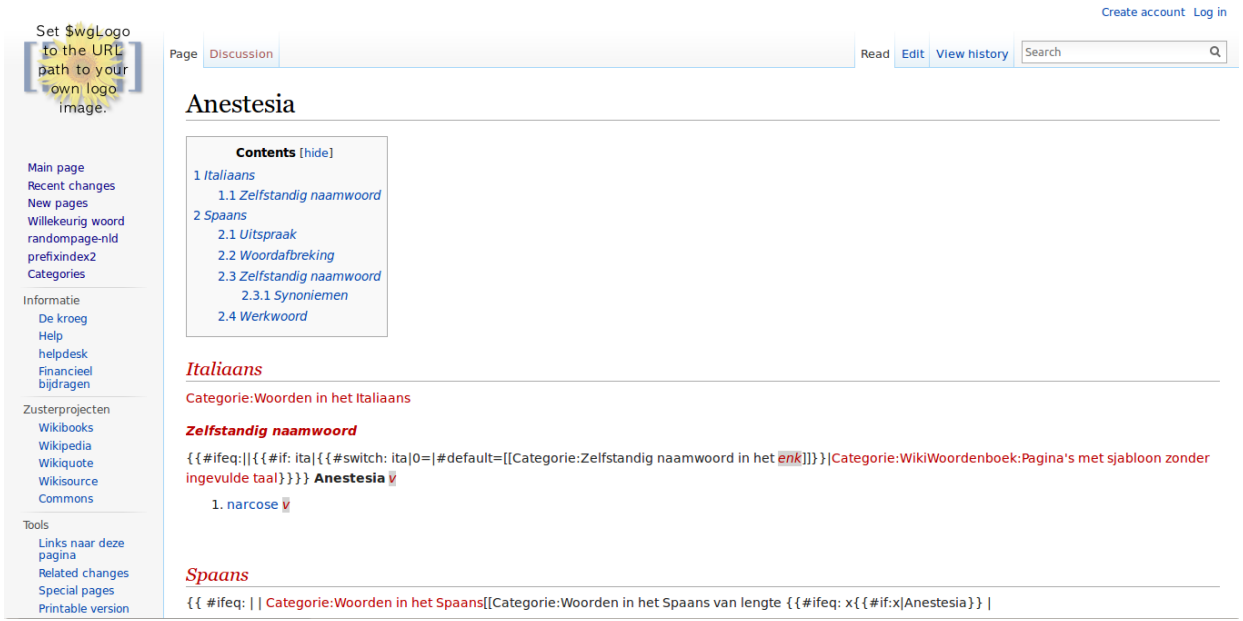
Recently Added Features Related to Query Optimization

- Index Condition Pushdown
- Subquery Optimizations materialization and semijoin)
- IN-to-EXISTS/EXISTS-to-IN
- JOIN-to-WHERE
- Multi-Range Read
- Batched Key Access
- Persistent InnoDB Statistics
- UNION ALL optimization
- Improved GIS support
- EXPLAIN FORMAT=JSON
- EXPLAIN INSERT/UPDATE/DELETE
- Hash Join
- New optimizer hints
- New cost-based optimizer
- Optimizer Trace
- Filesort optimizations
- Virtual/computed columns and “functional indexes”
- New JSON type

I Already Mentioned Some of Those Topics during the Last Years

- Check my presentations here: http://www.slideshare.net/jynus/

Example Application (I)



- Wiktionary (and all Wikimedia project's data) is licensed under the Creative Commons BY-SA-2.5 License and is Copyright its Contributors

Example Application (II)

- OSM Database is licensed under the Open DataBase License and is Copyright OpenStreetMap Contributors

Install the example databases

- Downloads and instructions at: http://dbahire.com/pleu15
  - Requirements: a MySQL or MariaDB installation (MySQL Sandbox is suggested)
  - The wiktionary and OSM extracts
- Import them by doing:

```
$ bzcat <file> | mysql <database>
```

Query Optimization: From 0 to 10 (and up to 5.7)

ACCESS TYPES AND BASIC INDEXING TECHNIQUES

EXPLAIN

- Essential to understand the execution plan of our queries
  - Works on SELECTs, INSERTs, UPDATEs, REPLACEs, DELETEs and connections
  - Fully documented on: http://dev.mysql.com/doc/refman/5.6/en/explain-output.html

EXPLAIN Example

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title = 'Dutch';

+------+-------------+------+------+---------------+------
+---------+------+------+-------------+

| id   | select_type | table | type | possible_keys | key  |
key_len | ref  | rows | Extra       |

+------+-------------+------+------+---------------+------
+---------+------+------+-------------+

|    1 | SIMPLE      | page  | ALL  | NULL          | NULL
  | NULL |  90956 | Using where |

+------+-------------+------+------+---------------+------
+---------+------+------+-------------+

1 row in set (0.00 sec)
```

Difficult to see something

EXPLAIN Example (vertical format)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title = 'Dutch'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 90956
        Extra: Using where
1 row in set (0.00 sec)
```

Use \G for vertical formatting

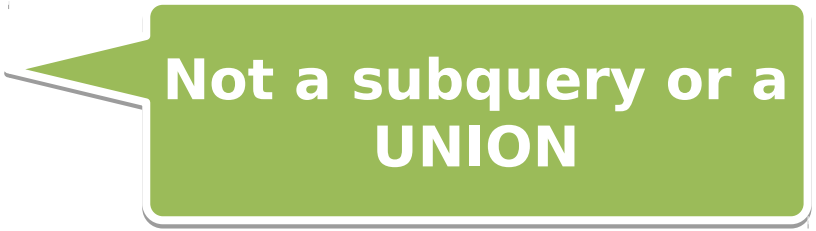
EXPLAIN Example (id)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title = 'Dutch'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 90956
        Extra: Using where
1 row in set (0.00 sec)
```

Indicates hierarchy level, not execution order

EXPLAIN Example (select_type)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title = 'Dutch'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 90956
        Extra: Using where
1 row in set (0.00 sec)
```



EXPLAIN Example (table)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title = 'Dutch'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 90956
        Extra: Using where
1 row in set (0.00 sec)
```

EXPLAIN Example (type)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title = 'Dutch'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 90956
        Extra: Using where
1 row in set (0.00 sec)
```

EXPLAIN Example (rows)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title = 'Dutch'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 90956
        Extra: Using where
1 row in set (0.00 sec)
```

Estimated number of rows to be read (all table rows)

How to improve performance?

```
MariaDB [nlwiktionary]> SELECT * FROM page
WHERE page_title = 'Dutch';
1 row in set (0.11 sec)
```

- Let's add an index on page.page_title:

```
MariaDB [nlwiktionary]> ALTER TABLE page ADD INDEX
page_title (page_title);
Query OK, 0 rows affected (0.19 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

Index creation results (type)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title = 'Dutch'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ref
possible_keys: page_t
          key: page_titl
      key_len: 257
          ref: const
         rows: 1
        Extra: Using index condition
1 row in set (0.00 sec)
```

type: ref means that an equality comparison will be checked against an index and several results could be returned

Index creation results (possible_keys and key)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title = 'Dutch'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ref
possible_keys: page_title
          key: page_title
      key_len: 257
          ref: const
         rows: 1
        Extra: Using index condition
1 row in set (0.00 sec)
```

index(es) that the optimizer considered potentially useful, and final index chosen

Index creation results (ref)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title = 'Dutch'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ref
possible_keys: page_title
          key: page_title
      key_len: 257
          ref: const
         rows: 1
        Extra: Using i
1 row in set (0.00 sec
```

Index is compared with a constant, not with another table

Index creation results (rows)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title = 'Dutch'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ref
possible_keys: page_title
          key: page_title
      key_len: 257
          ref: const
         rows: 1
        Extra: Using
1 row in set (0.00 se
```

Only 1 row read. In this case, estimation is exact (thanks to index dive)

Index creation results (query time)

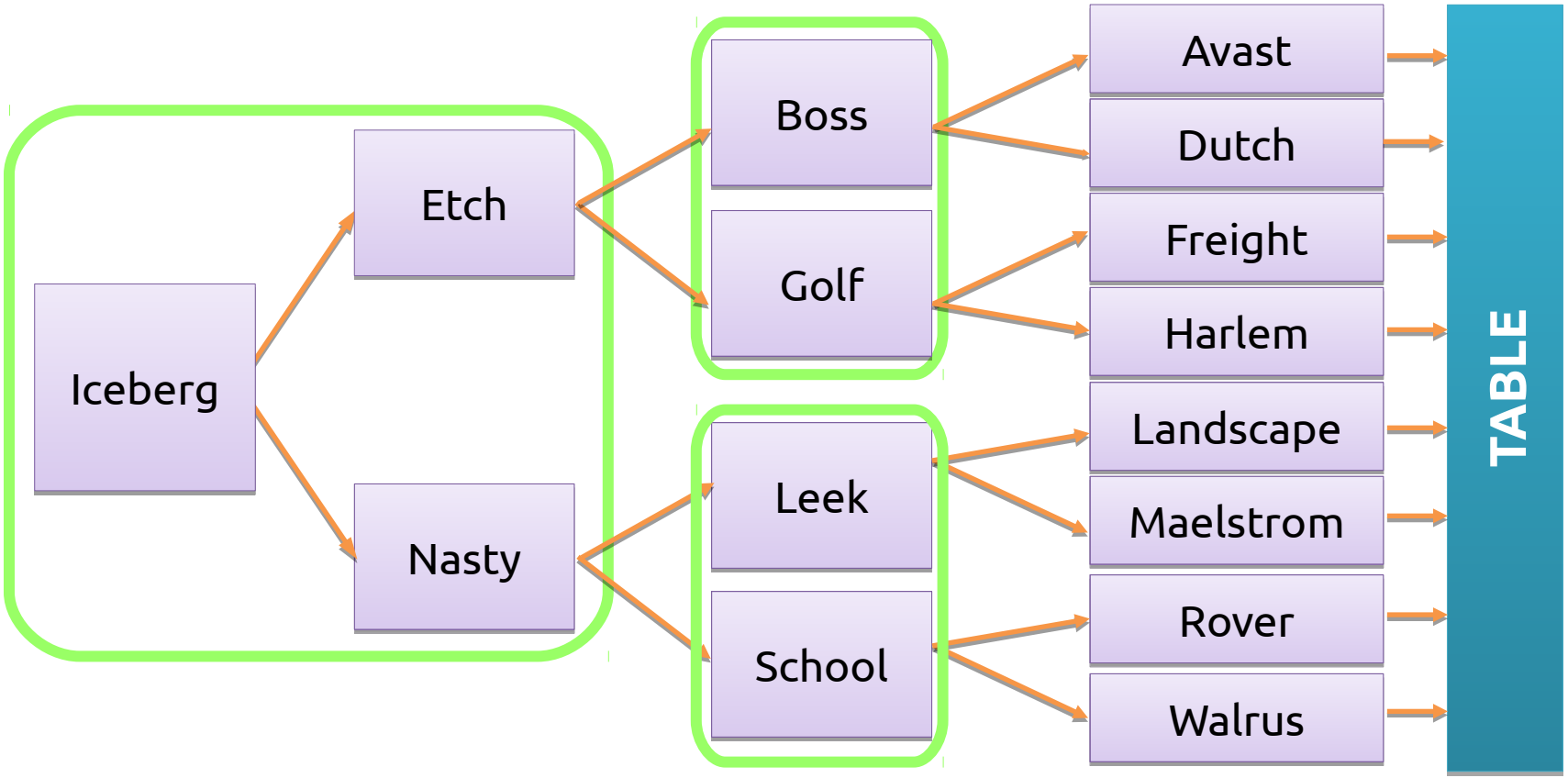
```
MariaDB [nlwiktionary]> SELECT * FROM page
WHERE page_title = 'Dutch';
1 row in set (0.00 sec)
```

Query time has been reduced substantially

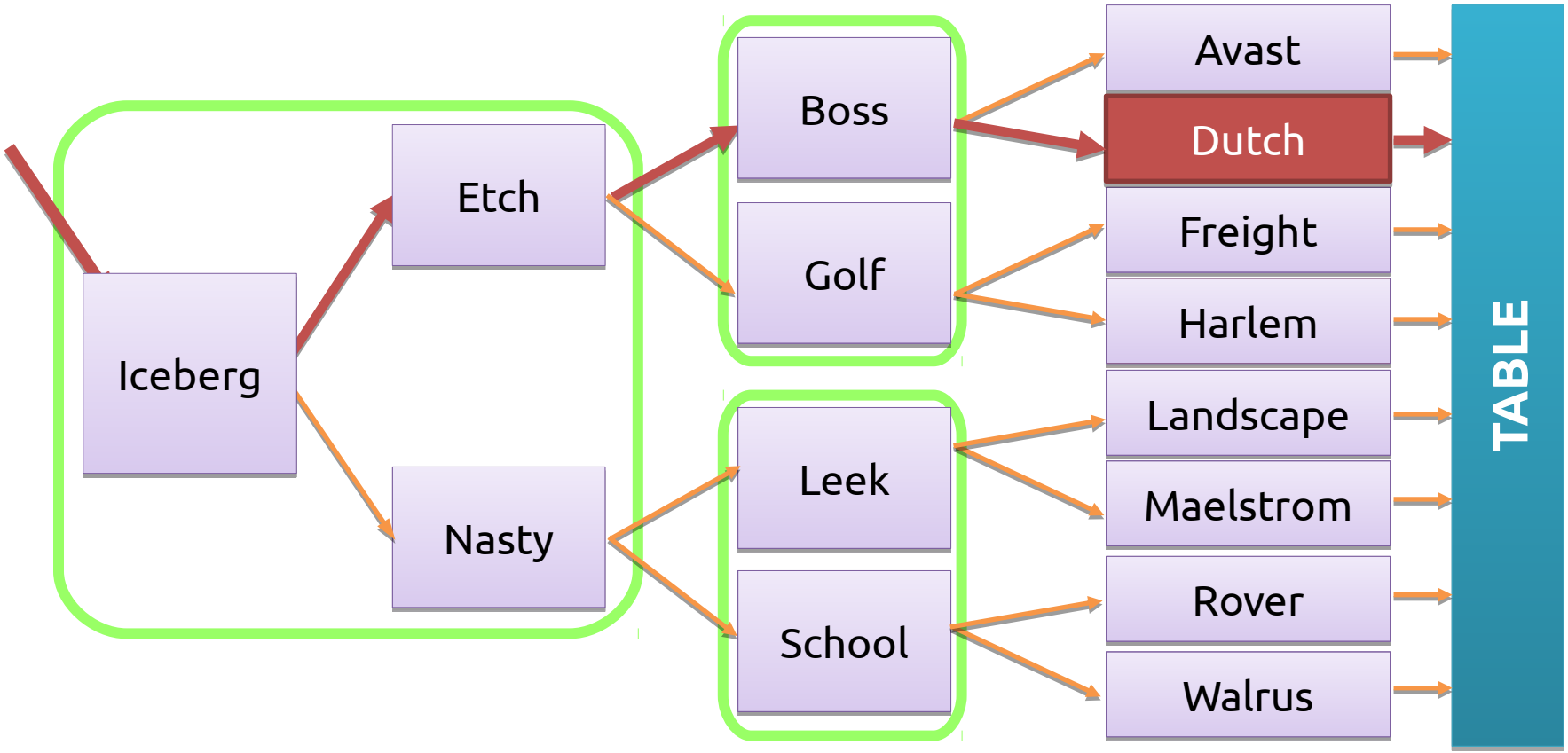
Types of indexes

- BTREE
  - B-TREE in MyISAM, B+TREE in InnoDB
- HASH
  - Only available for MEMORY and NDB
- FULLTEXT
  - Inverted indexes in MyISAM and InnoDB
- SPATIAL
  - RTREEs in MyISAM and InnoDB

Finding “Dutch” with a BTREE



Finding “Dutch” with a BTREE



Do indexes always work? (1/2)

- Can we use an index to make this query faster?

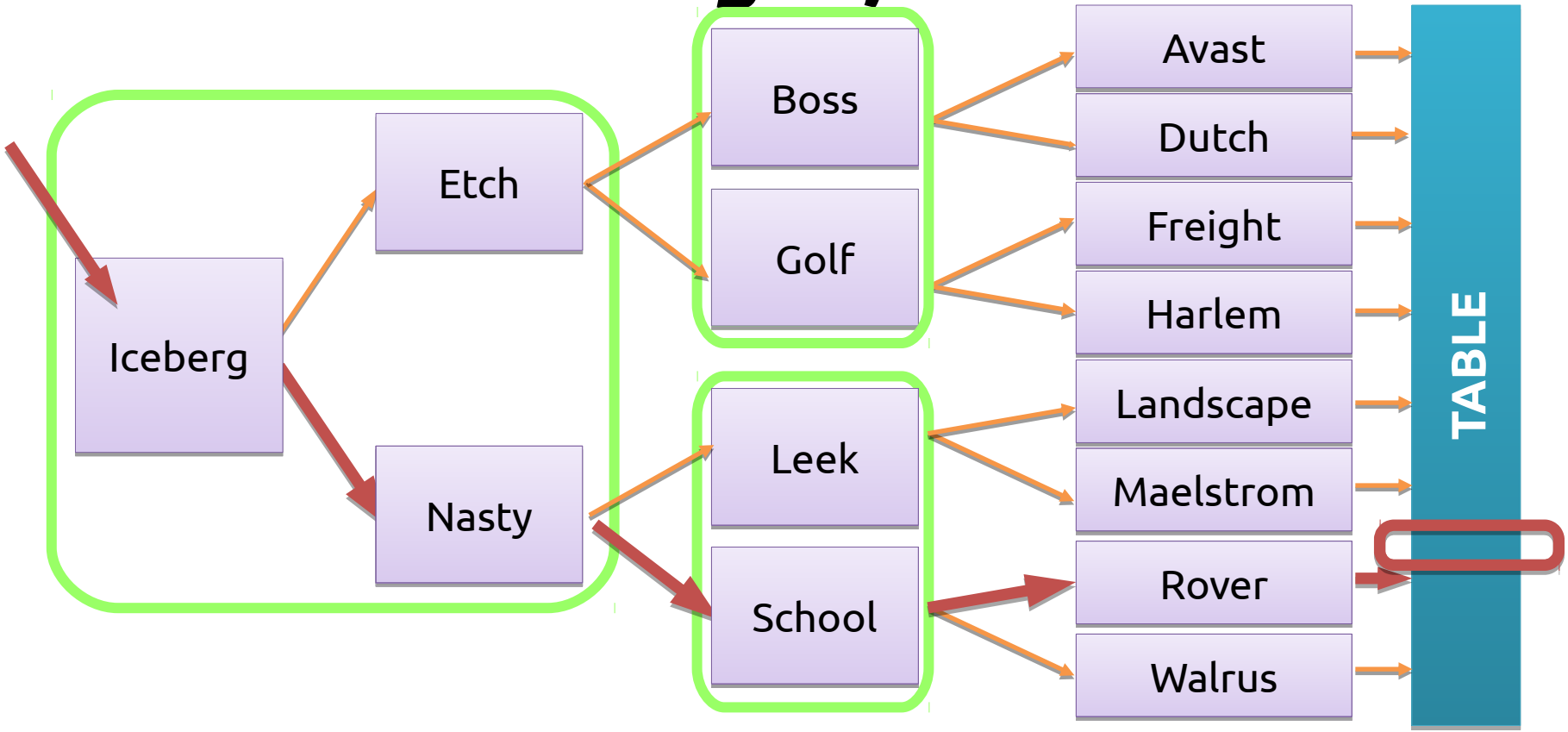
```
SELECT * FROM page WHERE page_title like 'Spa%';
```

It is a range

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title like 'Spa%'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: range
possible_keys: page_title
          key: page_title
      key_len: 257
          ref: NULL
         rows: 94
        Extra: Using index condition
1 row in set (0.00 sec)
```

Despite not being an equality, we can use the index to find the values quickly

BTREE Indexes can be used for ranges, too



Do indexes always work? (2/2)

- What about this other query?

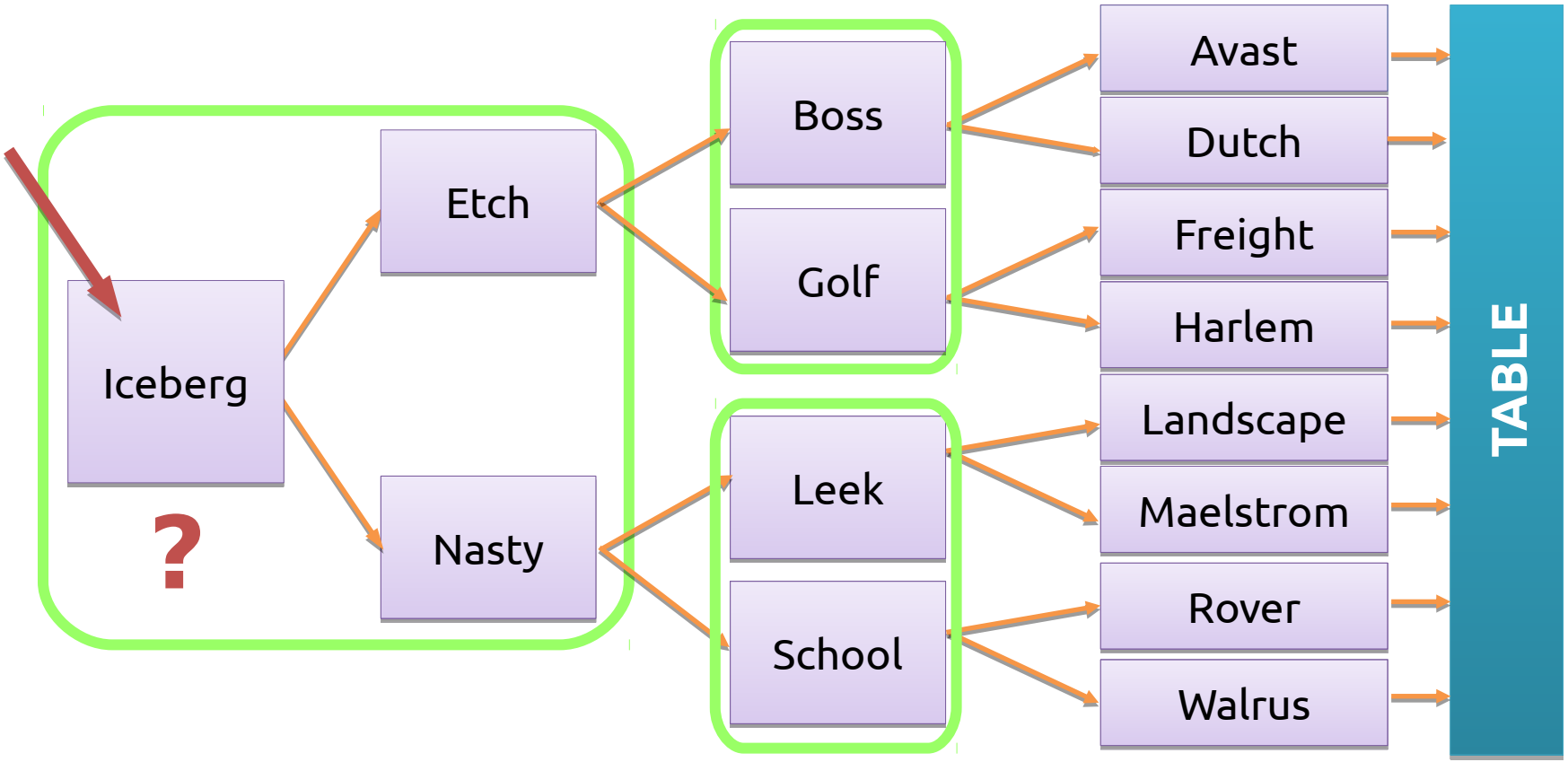
```
SELECT * FROM page WHERE page_title like '%utch';
```

Let's check with EXPLAIN

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title like '%utch'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 93189
        Extra: Using where
1 row in set (0.00 sec)
```

No index can be used for filtering. A full table scan is performed.

BTREE Index



Btree indexes usage

- Filtering
  - Equality (operator '=')
  - Ranges (BETWEEN ... AND, >, <, >=, <=, like 'prefix%')
  - “EXISTS” operators: IN, OR on the same column
- Ordering
  - ORDER BY (indexed columns)
  - GROUP BY (indexed columns)
- Returning values directly from the index
  - Covering index
  - Functions like max(), min(), etc.

type: const

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE
rev_id = 2\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: const
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 4
          ref: const
         rows: 1
        Extra:
1 row in set (0.00 sec)
```

'const' is a special case of 'ref', when the index can assure that only 1 results can be returned (equality + primary key or unique key). It is faster.

type: NULL

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE
rev_id = -1\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: NULL
         type: NULL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra: Impossible WHERE noticed after reading const
tables
1 row in set (0.00 sec)
```

'NULL' is not really a plan, just an optimization that allow discarding immediately impossible conditions

type: ref_or_null

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM user WHERE
user_email_token = '0' OR user_email_token IS NULL\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: user
         type: ref_or_null
possible_keys: user_email_token
          key: user_email_token
      key_len: 33
          ref: const
         rows: 2
        Extra: Using index condition; Using where
1 row in set (0.00 sec)
```

Equivalent to 'ref', but also has into account NULL values

type: range (using IN / OR)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_title IN ('Dutch', 'English', 'Spanish')\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: range
possible_keys: page_title
          key: page_title
      key_len: 257
          ref: NULL
         rows: 4
        Extra: Using index condition
1 row in set (0.00 sec)
```

Despite being a range, its execution is very different from ranges using like, between or inequality operators

Is this a bug? (1/2)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_namespace = 2\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ref
possible_keys: name_title
          key: name_title
      key_len: 4
          ref: const
         rows: 45
        Extra:
1 row in set (0.00 sec)
```

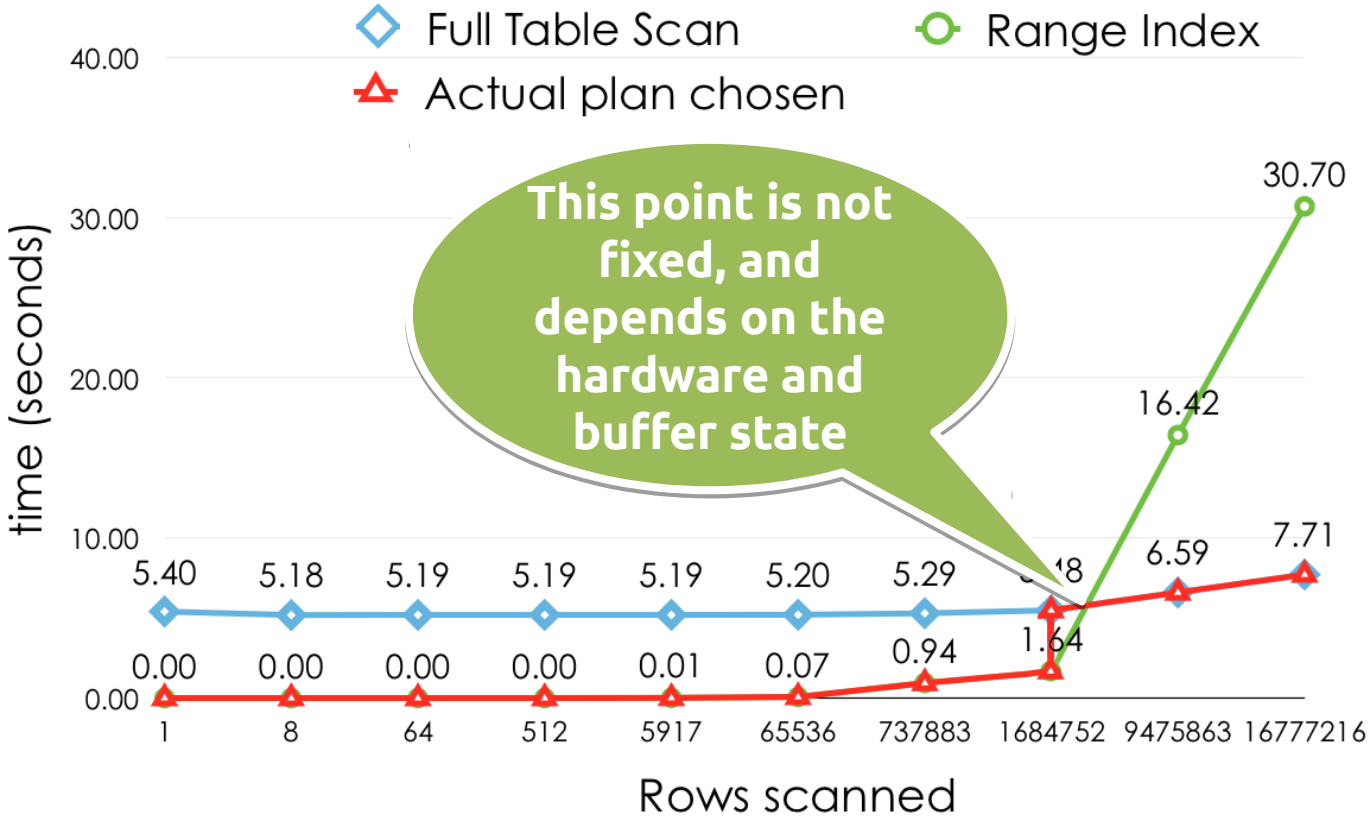
An index is used to return pages with ns=2

Is this a bug? (2/2)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page WHERE
page_namespace = 0\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ALL
possible_keys: name_title
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 7493
        Extra: Using where
1 row in set (0.00 sec)
```

The index is not used with ns=0

Using an index is sometimes suboptimal



What index should we add to make this query faster?

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE
left(rev_timestamp, 6) = '201509'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 163253
        Extra: Using where
1 row in set (0.00 sec)
```

The table has already an index on rev_timestamp

```
MariaDB [nlwiktionary]> SHOW CREATE TABLE revision\G
*************************** 1. row ***************************
       Table: revision
Create Table: CREATE TABLE `revision` (
...
  KEY `rev_timestamp` (`rev_timestamp`),
```

We need to rewrite the query

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE
rev_timestamp >= '201509' and rev_timestamp < '201510'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: range
possible_keys: rev_timestamp
          key: rev_timestamp
      key_len: 14
          ref: NULL
         rows: 7
        Extra: Using index condition
1 row in set (0.00 sec)
```

This transformation is not trivial or even possible in all cases

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE
substr(rev_timestamp, 5, 2) = '09'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         Rows: 173154
        Extra: Using where
1 row in set (0.00 sec)
```

Indexes for Ordering

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page ORDER BY
page_touched DESC LIMIT 10\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 8720
        Extra: Using filesort
1 row in set (0.00 sec)
```

"Using filesort" indicates that an ordering is needed before returning the results

If that is frequent, we can create an index on page_touched...

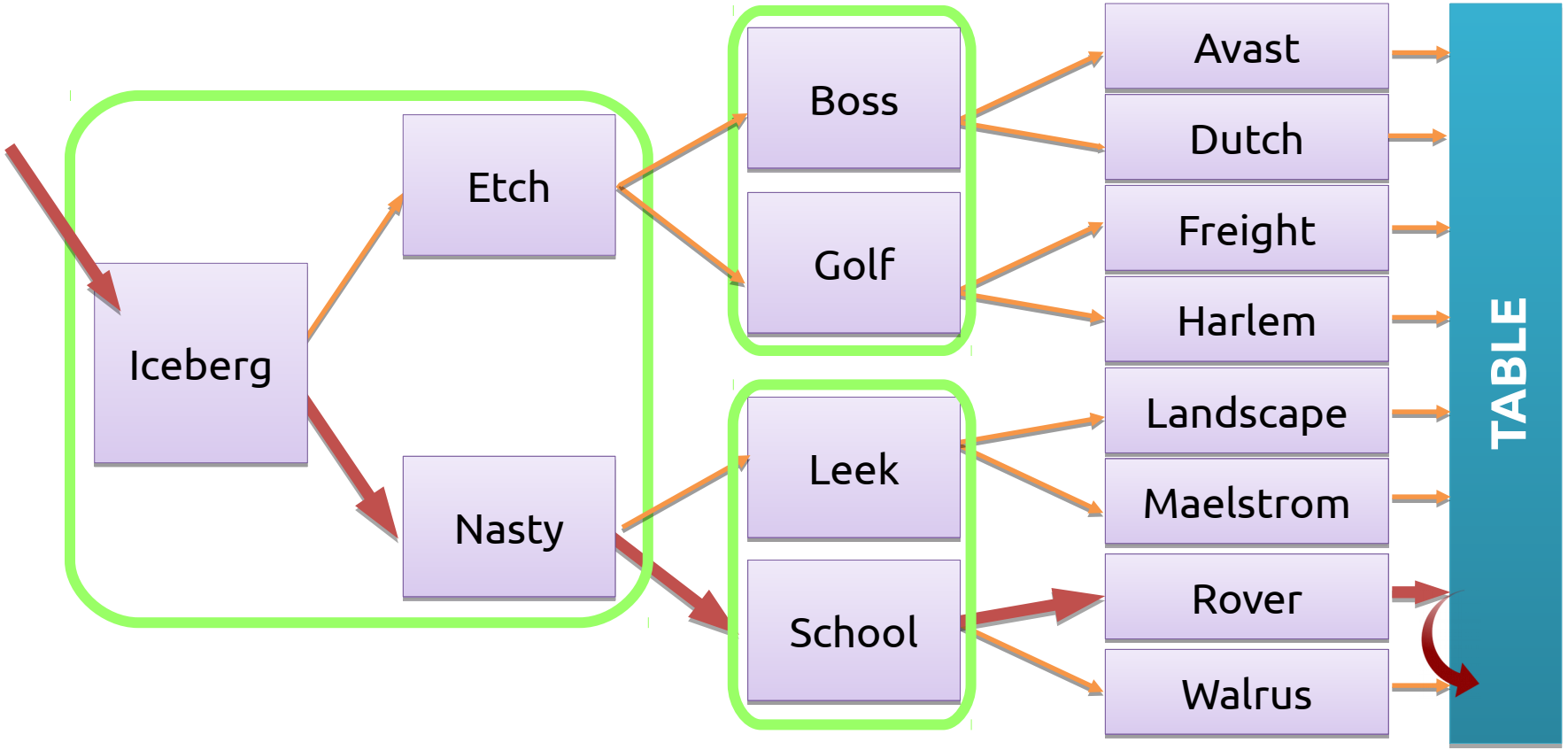
```
[nlwiktionary]> ALTER TABLE page ADD INDEX page_page_touched(page_touched);
Query OK, 0 rows affected (0.30 sec)
Records: 0  Duplicates: 0  Warnings: 0

[nlwiktionary]> EXPLAIN SELECT * FROM page ORDER BY page_touched DESC LIMIT
10\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: page
         type: index
possible_keys: NULL
          key: page_page_touched
      key_len: 14
          ref: NULL
         rows: 10
        Extra:
1 row in set (0.00 sec)
```

The index does not produce any advantage for filtering

However, it is very effective by helping avoiding the sort phase

It can return data in index order faster



Indexes and GROUP BY (no indexes)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT rev_page, count(*) FROM
revision IGNORE INDEX(rev_page_id, page_timestamp,
page_user_timestamp) GROUP BY rev_page\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 201094
        Extra: Using temporary; Using filesort
1 row in set (0.00 sec)
```

Without indexes, a temporary table is created to order results

Trick: ORDER BY NULL avoids filesort

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision GROUP BY substr(rev_timestamp, 5,
2) = '09'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 196824
        Extra: Using temporary; Using filesort
1 row in set (0.00 sec)

MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision GROUP BY substr(rev_timestamp, 5,
2) = '09' ORDER BY NULL\G
*************************** 1. row ***************************
...
         rows: 196871
        Extra: Using temporary
1 row in set (0.00 sec)
```

There is no good index in this case

The advantage is not too big, but it avoids the filesort

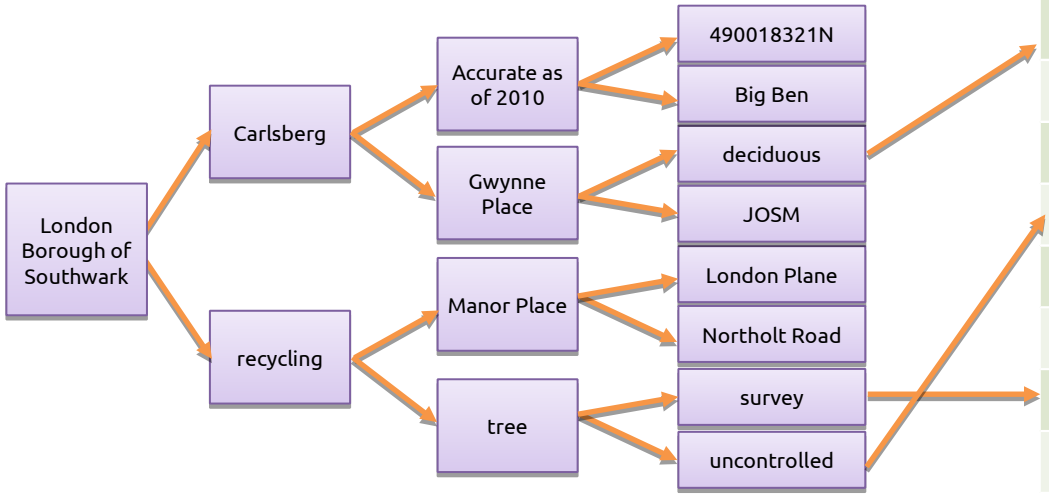
Indexes and GROUP BY (rev_page_id)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT rev_page, count(*) FROM
revision GROUP BY rev_page\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: index
possible_keys: NULL
          key: rev_page_id
      key_len: 8
          ref: NULL
         rows: 192388
        Extra: Using index
1 row in set (0.00 sec)
```

The index does not produce any advantage for filtering (there is no WHERE clause)

However, thanks to it we avoid a sort and a temporary table

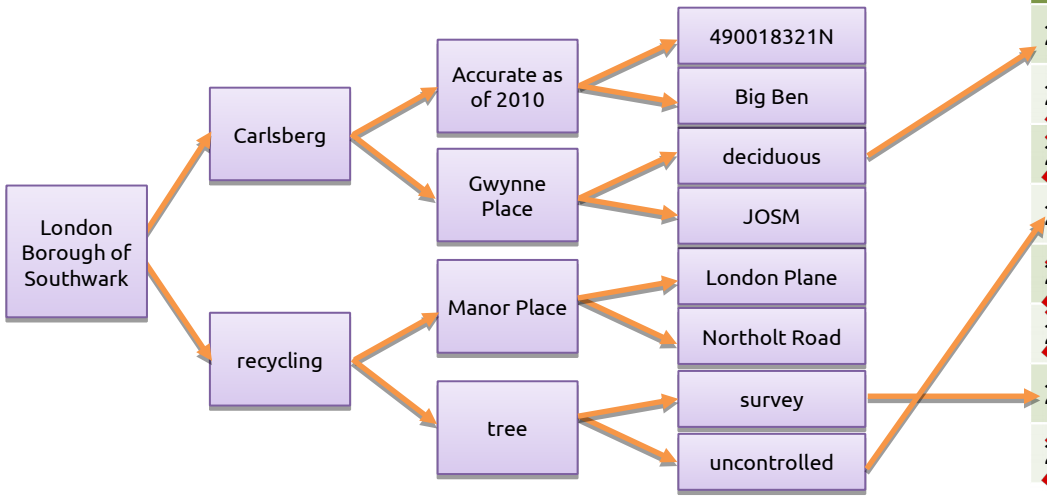
type: index, loose index scan and covering index (1/3)



node_id	version	k	v
234234344545	1	leaves	deciduous
234234344546	3	name	Northolt Road
234234344548	5	gps:latitude	490018321N
234234344549	6	access	uncontrolled
234234344550	1	editor	JOSM
234234344551	9	name	Big Ben
234234344552	1	source	survey
234234344557	1	name	London Plane

With 'type:index', all rows are read in index order (full index scan)

type: index, loose index scan and covering index (2/3)



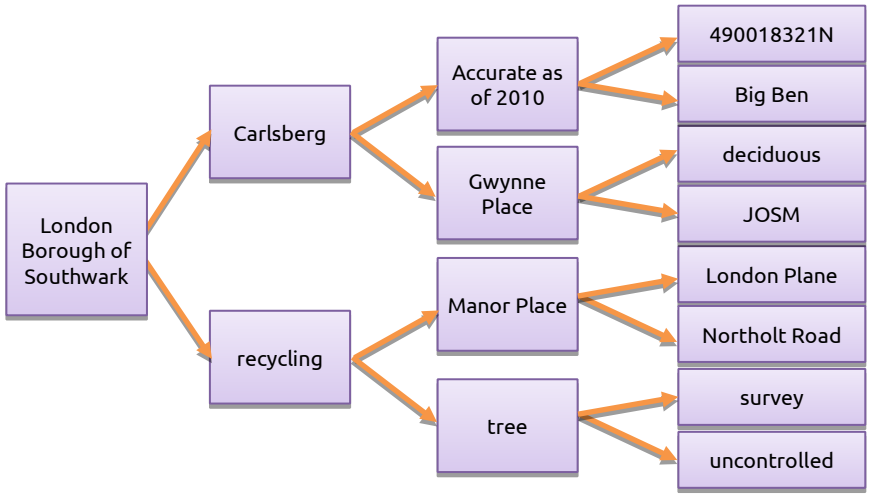
node_id	version	k	v
234234344545	1	leaves	deciduous
2[x]234344546	3	name	Northolt Road
2[x]234344548	5	gps:latitude	490018321N
234234344549	6	access	uncontrolled
2[x]234344550	1	editor	JOSM
2[x]234344551	9	name	Big Ben
234234344552	1	source	survey
2[x]234344557	1	name	London Plane

If we have in addition 'Using index for group-by' we have the loose index scan optimization

Loose Index Scan Example

```
MariaDB [nlwiktionary]> EXPLAIN SELECT rev_page,
max(rev_timestamp) FROM revision GROUP BY rev_page\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: range
possible_keys: NULL
          key: page_timestamp
      key_len: 4
          ref: NULL
         rows: 9769
        Extra: Using index for group-by
1 row in set (0.00 sec)
```

type: index, loose index scan and covering index (3/3)



node	version		v
23423	1		deciduous
234234344			Northolt Road
234234344548		tude	490018321N
234234344549			uncontrolled
234234344			JOSM
234234	9		g Ben
234	1	sourc	survey
23423	1	name	London Plane

If we have in addition 'Using index' we have the covering index optimization

Covering Index Example (1/3)

```
MariaDB [nlwiktionary]> ALTER TABLE revision DROP INDEX rev_page_id, drop index page_timestamp,
drop index page_user_timestamp;
Query OK, 0 rows affected (0.05 sec)
Records: 0  Duplicates: 0  Warnings: 0

MariaDB [nlwiktionary]> EXPLAIN SELECT count(DISTINCT rev_user) FROM revision WHERE rev_page =
790\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 218384
        Extra: Using where
1 row in set (0.00 sec)

MariaDB [nlwiktionary]> SELECT count(DISTINCT rev_user) FROM revision WHERE rev_page = 790\G
*************************** 1. row ***************************
count(DISTINCT rev_user): 1
1 row in set (0.06 sec)
```

Let's start with no indexes

Covering Index Example (2/3)

```
MariaDB [nlwiktionary]> ALTER TABLE revision ADD INDEX revision_rev_page(rev_page);
Query OK, 0 rows affected (0.44 sec)
Records: 0  Duplicates: 0  Warnings: 0


MariaDB [nlwiktionary]> EXPLAIN SELECT count(DISTINCT rev_user) FROM revision WHERE rev_page =
790\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ref
possible_keys: revision_rev_page
          key: revision_rev_page
      key_len: 4
          ref: const
         rows: 4863
        Extra:
1 row in set (0.00 sec)

MariaDB [nlwiktionary]> SELECT count(DISTINCT rev_user) FROM revision WHERE rev_page = 790\G
*************************** 1. row ***************************
count(DISTINCT rev_user): 1
1 row in set (0.01 sec)
```

Adding an index on rev_page increases the speed due to improved filtering

Covering Index Example (3/3)

```
MariaDB [nlwiktionary]> ALTER TABLE revision ADD INDEX revision_rev_page_rev_user(rev_page,
rev_user);
Query OK, 0 rows affected (1.48 sec)
Records: 0  Duplicates: 0  Warnings: 0

MariaDB [nlwiktionary]> EXPLAIN SELECT count(DISTINCT rev_user) FROM revision WHERE rev_page =
790\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ref
possible_keys: revision_rev_page,revision_rev_page_rev_u
          key: revision_rev_page_rev_user
      key_len: 4
          ref: const
         rows: 4863
        Extra: Using index
1 row in set (0.00 sec)

MariaDB [nlwiktionary]> SELECT count(DISTINCT rev_user) FROM revision WHERE rev_page = 790\G
*************************** 1. row ***************************
count(DISTINCT rev_user): 1
1 row in set (0.00 sec)
```

rev_page, rev_user does not increase the index selectiveness, but allow to return results directly from the index

The speed difference can be huge

Query Optimization: From 0 to 10 (and up to 5.7)

MULTI-COLUMN INDEXES

In many cases, conditions are applied on more than one column

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE
rev_page = 790 and rev_timestamp < '2008'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 686822
        Extra: Using where
1 row in set (0.00 sec)
```

Assuming there were no previously created indexes, which would the optimal one be?

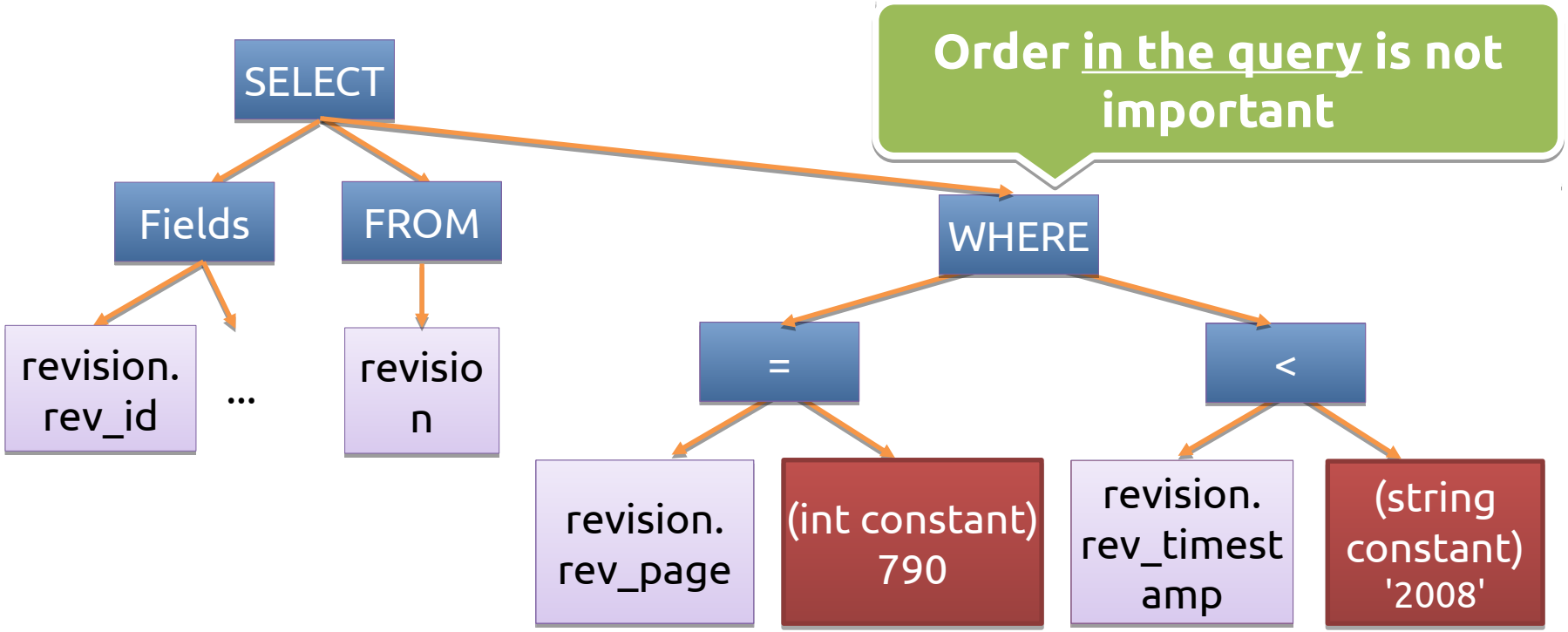
Options for indexes

- 1 index on column (rev_page)
- 1 index on column (rev_timestamp)
- 2 indexes, 1 on (rev_page) and another on (rev_timestamp)
- 1 multi-column index on (rev_page, rev_timestamp)
- 1 multi-column index on (rev_timestamp,rev_page)

Are these last 2 different from each other? Would it depend on the query order?

A brief reminder about query parsing

```
SELECT * FROM revision WHERE rev_page = 790 and rev_timestamp < '2008'
```



Index on (rev_page)

```
MariaDB [nlwiktionary]> ALTER TABLE revision ADD INDEX rev_page (rev_page);
Query OK, 0 rows affected (2.31 sec)
Records: 0  Duplicates: 0  Warnings: 0

MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE rev_page = 790 and
rev_timestamp < '2008'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ref
possible_keys: rev_page
          key: rev_page
      key_len: 4
          ref: const
         rows: 4863
        Extra: Using where
1 row in set (0.00 sec)
```

Query time improves significantly with this index

Less rows are scanned

Adding (rev_timestamp)

```
MariaDB [nlwiktionary]> ALTER TABLE revision ADD INDEX rev_timestamp
(rev_timestamp);
Query OK, 0 rows affected (1.77 sec)
Records: 0  Duplicates: 0  Warnings: 0

MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE rev_page = 790
and rev_timestamp < '2008'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ref
possible_keys: rev_page,rev_timestamp
          key: rev_page
      key_len: 4
          ref: const
         rows: 4863
        Extra: Using where
1 row in set (0.01 sec)
```

In general, only one index can be used per table access

rev_page is preferred over rev_timestamp

Forcing the use of (rev_timestamp)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision FORCE
INDEX(rev_timestamp) WHERE rev_page = 790 and rev_timestamp <
'2008'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: range
possible_keys: rev_timestamp
          key: rev_timestamp
      key_len: 14
          ref: NULL
         rows: 343411
        Extra: Using index condition; Using where
1 row in set (0.00 sec)
```

Forcing the index is worse than type:ALL!

It is a range access

A lot more accessed rows

Adding (rev_page, rev_timestamp)

```
MariaDB [nlwiktionary]> ALTER TABLE revision ADD INDEX
rev_page_rev_timestamp(rev_page, rev_timestamp);
Query OK, 0 rows affected (1.59 sec)
Records: 0  Duplicates: 0  Warnings: 0

MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE rev_page = 790
and rev_timestamp < '2008'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: range
possible_keys: rev_page,rev_timestamp,rev_page_rev_timestamp
          key: rev_page_rev_timestamp
      key_len: 18
          ref: NULL
         rows: 1048
        Extra: Using index condition
1 row in set (0.00 sec)
```

Reduced number of rows scanned

Is (rev_timestamp, rev_page) a better option?

```
MariaDB [nlwiktionary]> ALTER TABLE revision ADD INDEX rev_timestamp_rev_page
(rev_timestamp, rev_page);
Query OK, 0 rows affected (1.76 sec)
Records: 0  Duplicates: 0  Warnings: 0

MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE rev_page = 790 and
rev_timestamp < '2008'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: range
possible_keys: rev_page,rev_timestamp,rev_page_rev_timestamp,rev_timestamp_rev_page
          key: rev_page_rev_timestamp
      key_len: 18
          ref: NULL
         rows: 1048
        Extra: Using index condition
1 row in set (0.00 sec)
```

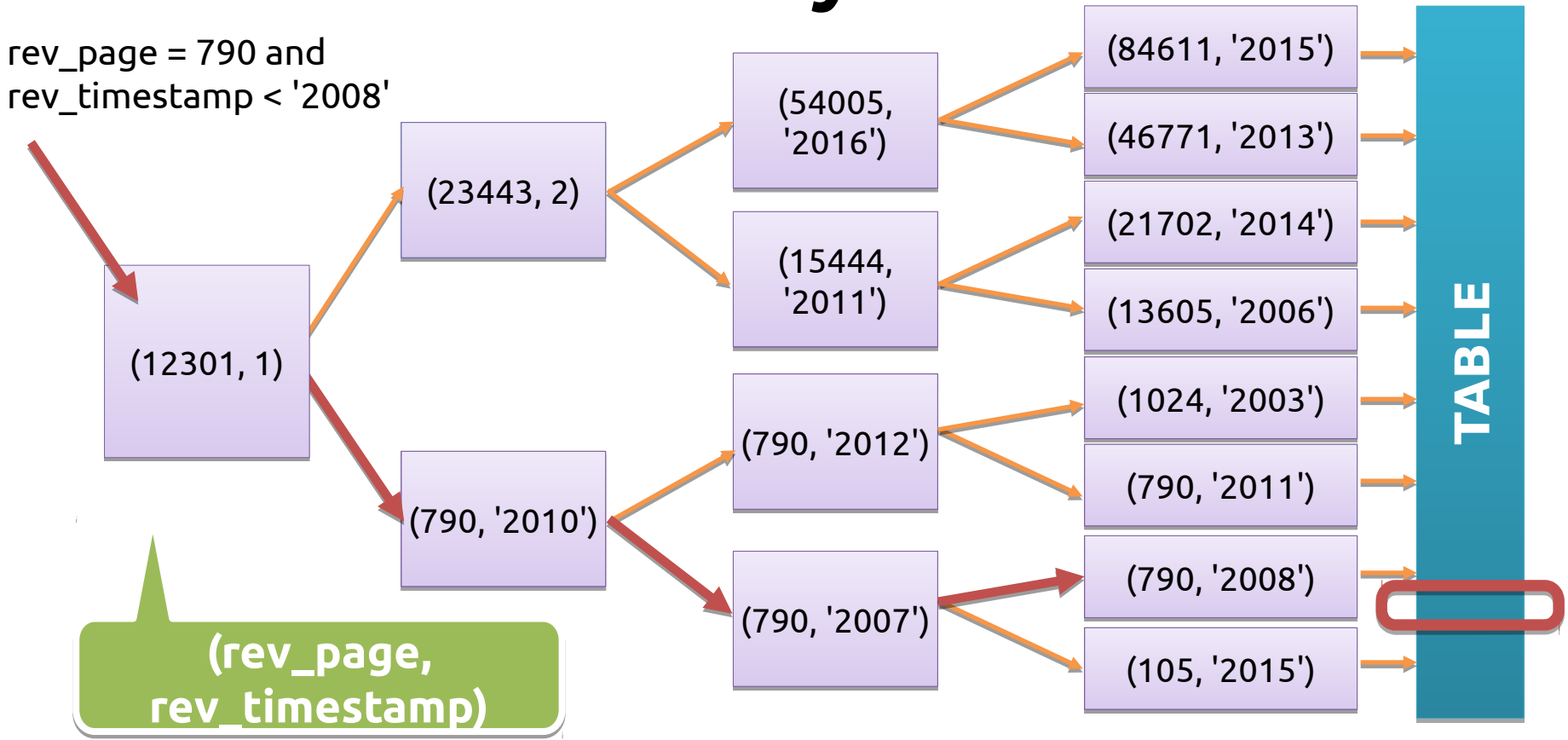
Previous index is still preferred, why?

Forcing (rev_timestamp, rev_page)

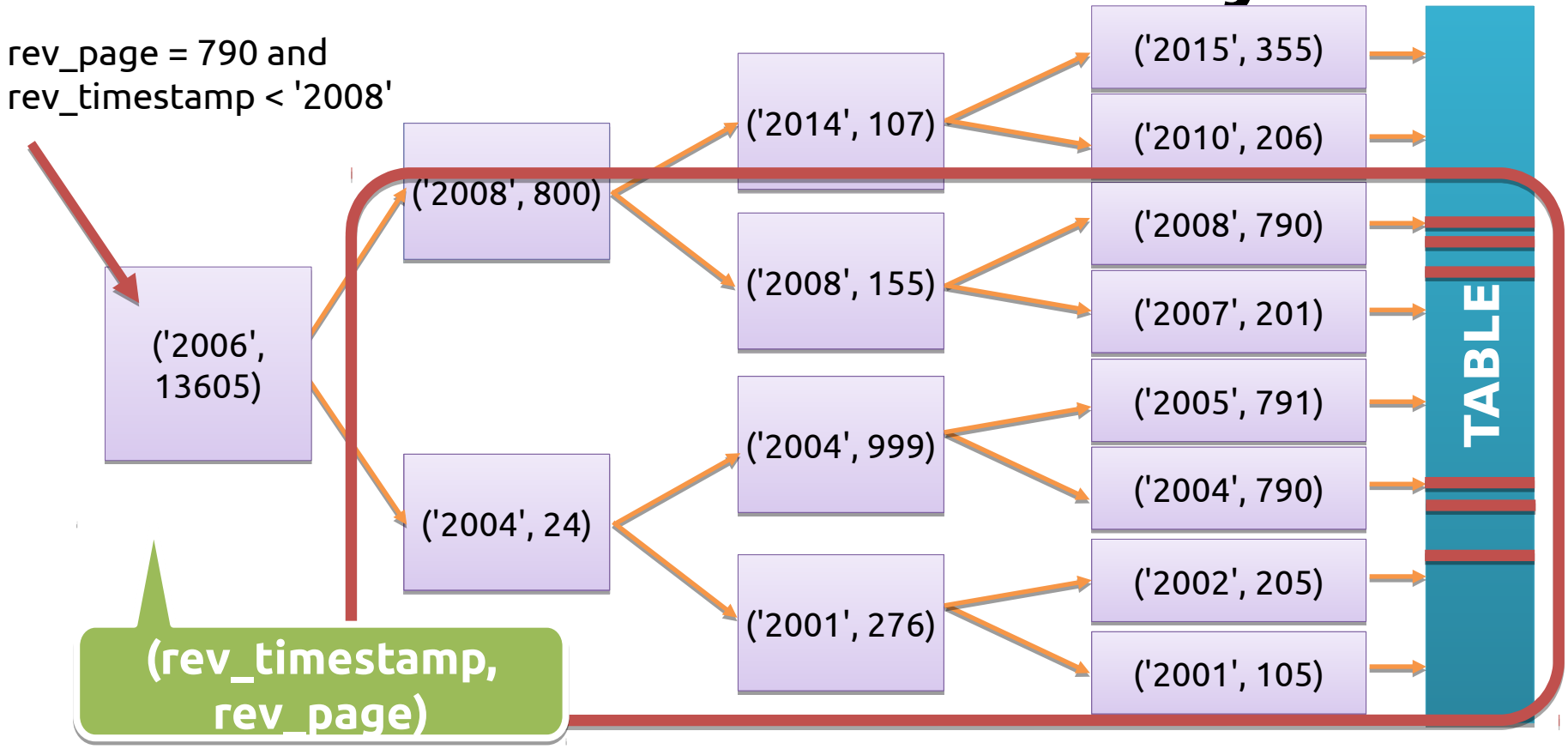
```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision FORCE
INDEX(rev_timestamp_rev_page) WHERE rev_page = 790 and
rev_timestamp < '2008'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: range
possible_keys: rev_timestamp_rev_page
          key: rev_timestamp_rev_page
      key_len: 18
          ref: NULL
         rows: 343411
        Extra: Using index condition
1 row in set (0.00 sec)
```

Only the first column is being used effectively for filtering

A compound index produces a single tree ordered by the 2 values



The alternative index cannot be used in such an effective way



Order and column selection

- Range access using >, <, >=, <=, BETWEEN can only be filtered once effectively, at the end of an index
- When selecting indexes, prefer columns with high cardinality (very selective)
  - The optimal index can depend on the constants used

Use of "Handler_*" statistics

- They are post-execution statistics at row level
  - Unlike EXPLAIN's "rows" column, they are exact, not a guess
  - They allow to compare query execution performance in a deterministic way, independently of the execution time

"Handler" Stats (indexed)

```
mysql> SHOW SESSION STATUS like 'Hand%';
+----------------------------+----------+
| Variable_name              | Value    |
+----------------------------+----------+
| Handler_commit             | 80       |
| Handler_delete             | 0        |
| Handler_discover           | 0        |
| Handler_external_lock      | 166      |
| Handler_mrr_init           | 0        |
| Handler_prepare            | 0        |
| Handler_read_first         | 23       |
| Handler_read_key           | 736212   |
| Handler_read_last          | 0        |
| Handler_read_next          | 22208001 |
| Handler_read_prev          | 0        |
| Handler_read_rnd           | 665215   |
| Handler_read_rnd_next      | 14223297 |
| Handler_rollback           | 0        |
| Handler_savepoint          | 0        |
| Handler_savepoint_rollback | 0        |
| Handler_update             | 66970    |
| Handler_write              | 2869409  |
+----------------------------+----------+
18 rows in set (0.00 sec)
```

Number of times that the first entry of an index was read. It may indicate the number of full index scans

Number of time a row has been retrieved using an index

Next row has been requested in index order (typical for index scans or ranges)

"Handler" Stats (unindexed)

```
mysql> SHOW SESSION STATUS like 'Hand%';
+----------------------------+----------+
| Variable_name              | Value    |
+----------------------------+----------+
| Handler_commit             | 80       |
| Handler_delete             | 0        |
| Handler_discover           | 0        |
| Handler_external_lock      | 166      |
| Handler_mrr_init           | 0        |
| Handler_prepare            | 0        |
| Handler_read_first         | 23       |
| Handler_read_key           | 736212   |
| Handler_read_last          | 0        |
| Handler_read_next          | 22208001 |
| Handler_read_prev          | 0        |
| Handler_read_rnd           | 665215   |
| Handler_read_rnd_next      | 14223297 |
| Handler_rollback           | 0        |
| Handler_savepoint          | 0        |
| Handler_savepoint_rollback | 0        |
| Handler_update             | 66970    |
| Handler_write              | 2869409  |
+----------------------------+----------+
18 rows in set (0.00 sec)
```

A row has been requested in a specific position (typical for joins or order by without indexes)

Request tp read the next row in “table order” (typical for full table scans)

Insertions in SELECTS may indicate temporary tables

Comparing statistics of the previous indexes (no indexes)

```
MariaDB [nlwiktionary]> FLUSH STATUS;
Query OK, 0 rows affected (0.00 sec)

MariaDB [nlwiktionary]> SELECT * FROM revision IGNORE INDEX(rev_page, rev_timestamp, rev_page_rev_timestamp,
rev_timestamp_rev_page) WHERE rev_page = 790 and rev_timestamp < '2008';
1049 rows in set (0.58 sec)

MariaDB [nlwiktionary]> SHOW STATUS like 'Hand%';
+----------------------------+--------+
| Variable_name              | Value  |
+----------------------------+--------+
| Handler_commit             | 1      |
| Handler_delete             | 0      |
…
| Handler_read_first         | 0      |
| Handler_read_key           | 0      |
| Handler_read_last          | 0      |
| Handler_read_next          | 0      |
| Handler_read_prev          | 0      |
| Handler_read_rnd           | 0      |
| Handler_read_rnd_deleted   | 0      |
| Handler_read_rnd_next      | 8[illegible]
| Handler_rollback           | 0      |
…
| Handler_update             | 0      |
| Handler_write              | 0      |
+----------------------------+--------+
25 rows in set (0.00 sec)
```

Typical result for a full table scan

Index on (rev_page)

```
MariaDB [nlwiktionary]> SHOW STATUS like 'Hand%';
+----------------------------+-------+
| Variable_name              | Value |
+----------------------------+-------+
| Handler_commit             | 1     |
| Handler_delete             | 0     |
…
| Handler_read_first         | 0     |
| Handler_read_key           | 1     |
| Handler_read_last          | 0     |
| Handler_read_next          | 4864  |
| Handler_read_prev          | 0     |
| Handler_read_rnd           | 0     |
| Handler_read_rnd_deleted   | 0     |
| Handler_read_rnd_next      | 0     |
| Handler_rollback           | 0     |
…
| Handler_update             | 0     |
| Handler_write              | 0     |
+----------------------------+-------+
25 rows in set (0.01 sec)
```

Using the index, request the first row with rev_page=790

Then, scan them one by one in index order

Index on (rev_timestamp)

```
MariaDB [nlwiktionary]> SHOW STATUS like 'Hand%';
+----------------------------+---------+
| Variable_name              | Value   |
+----------------------------+---------+
| Handler_commit             | 1       |
| Handler_delete             | 0       |
…
| Handler_read_first         | 0       |
| Handler_read_key           | 1       |
| Handler_read_last          | 0       |
| Handler_read_next          | 199155  |
| Handler_read_prev          | 0       |
| Handler_read_rnd           | 0       |
| Handler_read_rnd_deleted   | 0       |
| Handler_read_rnd_next      | 0       |
| Handler_rollback           | 0       |
…
| Handler_update             | 0       |
| Handler_write              | 0       |
+----------------------------+---------+
25 rows in set (0.00 sec)
```

Let's ignore ICP for now

Using the index, request the first row where rev_timestamp<2008

Then, scan them one by one in index order (more are matched)

Index on (rev_page, rev_timestamp)

```
MariaDB [nlwiktionary]> SHOW STATUS like 'Hand%';
+----------------------------+-------+
| Variable_name              | Value |
+----------------------------+-------+
| Handler_commit             | 1     |
| Handler_delete             | 0     |
…
| Handler_read_first         | 0     |
| Handler_read_key           | 1     |
| Handler_read_last          | 0     |
| Handler_read_next          | 1045  |
| Handler_read_prev          | 0     |
| Handler_read_rnd           | 0     |
| Handler_read_rnd_deleted   | 0     |
| Handler_read_rnd_next      | 0     |
| Handler_rollback           | 0     |
…
| Handler_update             | 0     |
| Handler_write              | 0     |
+----------------------------+-------+
25 rows in set (0.00 sec)
```

With both conditions covered, we can find the actual first row that matches the condition using the index

Rows scanned == Rows returned

Index on (rev_timestamp, rev_page), no ICP

```
MariaDB [nlwiktionary]> SHOW STATUS like 'Hand%';
+----------------------------+---------+
| Variable_name              | Value   |
+----------------------------+---------+
| Handler_commit             | 1       |
| Handler_delete             | 0       |
…
| Handler_read_first         | 0       |
| Handler_read_key           | 1       |
| Handler_read_last          | 0       |
| Handler_read_next          | 199155  |
| Handler_read_prev          | 0       |
| Handler_read_rnd           | 0       |
| Handler_read_rnd_deleted   | 0       |
| Handler_read_rnd_next      | 0       |
| Handler_rollback           | 0       |
…
| Handler_update             | 0       |
| Handler_write              | 0       |
+----------------------------+---------+
25 rows in set (0.00 sec)
```

Assuming no ICP, exact same results than with (rev_timestamp). The extra column does not help. Also, EXPLAIN's row count was very off.

Redundant Indexes

- Creating all 4 previous indexes in production is not a great idea
  - "Left-most index prefix" allows, for example (rev_page, rev_timestamp) doing everything you can do with (rev_page)
  - If two indexes have equal selectivity, MySQL chooses the shortest one

"Left-most index" Example

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision FORCE
INDEX(rev_page_rev_timestamp) WHERE rev_page = 790\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ref
possible_keys: rev_page_rev_timestamp
          key: rev_page_rev_time
      key_len: 4
          ref: const
         rows: 4863
        Extra:
1 row in set (0.00 sec)
```

Duplicate Indexes

- It is very easy to create indexes with the same exact definition (same columns and ordering)
  - Set a convention for index naming (e.g `tablename_column1_column2_idx`) – MySQL does not allow 2 indexes with the same identifier
  - Since MySQL 5.6, an warning is thrown if a duplicate index is created

pt-duplicate-index-checker

```
$ pt-duplicate-key-checker h=127.0.0.1,P=5621,u=msandbox,p=msandbox
[…]
# rev_timestamp is a left-prefix of rev_timestamp_rev_page
# Key definitions:
#   KEY `rev_timestamp` (`rev_timestamp`),
#   KEY `rev_timestamp_rev_page` (`rev_timestamp`,`rev_page`)
# Column types:
#    `rev_timestamp` binary(14) not null default '\0\0\0\0\0\0\0\0\0
#    `rev_page` int(10) unsigned not null
# To remove this duplicate index, execute:
ALTER TABLE `nlwiktionary`.`revision` DROP INDEX `rev_timestamp`;

# rev_page is a left-prefix of rev_page_rev_timestamp
# Key definitions:
#   KEY `rev_page` (`rev_page`),
#   KEY `rev_page_rev_timestamp` (`rev_page`,`rev_timestamp`),
# Column types:
#    `rev_page` int(10) unsigned not null
#    `rev_timestamp` binary(14) not null default '\0\0\0\0\0\0\0\0\0\0\0\0\0\0'
# To remove this duplicate index, execute:
ALTER TABLE `nlwiktionary`.`revision` DROP INDEX `rev_page`;

#  ########################################################## Summary of indexes
########################################
# Size Duplicate Indexes   15478317
# Total Duplicate Indexes  4
# Total Indexes            285
```

Simple tool to check redundant and duplicate indexes

"OR"-style conditions over the same column

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE
rev_page = 790 OR rev_page = 795 OR rev_page = 1024\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: range
possible_keys: rev_page,rev_page_rev_timestamp
          key: rev_page
      key_len: 4
          ref: NULL
         rows: 4890
        Extra: Using index condition; Using where
1 row in set (0.01 sec)
```

Equivalent to:
SELECT * FROM revision WHERE rev_page IN (790, 795, 1024)

Handlers on "IN" / "OR" conditions over the same column

```
+----------------------------+-------+
| Variable_name              | Value |
+----------------------------+-------+
| Handler_commit             | 1     |
| Handler_delete             | 0     |
…
| Handler_prepare            | 0     |
| Handler_read_first         | 0     |
| Handler_read_key           | 3     |
| Handler_read_last          | 0     |
| Handler_read_next          | 4891  |
| Handler_read_prev          | 0     |
| Handler_read_rnd           | 0     |
| Handler_read_rnd_deleted   | 0     |
| Handler_read_rnd_next      | 0     |
| Handler_rollback           | 0     |
…
| Handler_update             | 0     |
| Handler_write              | 0     |
+----------------------------+-------+
25 rows in set (0.00 sec)
```

Despite identifying themselves as “range”s, the execution is slightly different, one index dive (similar to a ref) is done per value. This can be an issue in conditions with thousands of items.

"OR"-style conditions over different columns

- We cannot use a single index efficiently for both conditions
  - We can scan both conditions separatelly and mix the results, discarding duplicates
  - Or use an index for one condition and not for the other
  - Index merge allows to use two indexes for a single table access simultaneously

Index Merge Example

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE
rev_page = 790 or rev_timestamp < '2004'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: index_merge
possible_keys: rev_page,rev_timestamp,rev_page_rev_timestamp,
rev_timestamp_rev_page
          key: rev_page,rev_timesta
      key_len: 4,14
          ref: NULL
         rows: 4871
        Extra: Using sort_union(rev_page,rev_timestamp); Using
where
1 row in set (0.00 sec)
```

Both indexes are used, then combined using the "union" operation

INDEX_MERGE Issues

- Sometimes it is faster to to execute the sentence using UNION:
  - This is specially true with (UNION ALL) since MySQL 5.7, if you do not care about duplicates
- There are also interseccion merges, but multi-column indexes are preferred

Disabling optimizer features (I)

- The optimizer_switch variable allows enabling and disablig globally or per session many query optimizer features:

```
MariaDB [nlwiktionary]> SHOW VARIABLES like 'optimizer_switch'\G
*************************** 1. row ***************************
Variable_name: optimizer_switch
        Value:
index_merge=on,index_merge_union=on,index_merge_sort_union=on,index_merge_intersect
ion=on,index_merge_sort_intersection=off,engine_condition_pushdown=off,index_condit
ion_pushdown=on,derived_merge=on,derived_with_keys=on,firstmatch=on,loosescan=on,ma
terialization=on,in_to_exists=on,semijoin=on,partial_match_rowid_merge=on,partial_m
atch_table_scan=on,subquery_cache=on,mrr=off,mrr_cost_based=off,mrr_sort_keys=off,o
uter_join_with_cache=on,semijoin_with_cache=on,join_cache_incremental=on,join_cache
_hashed=on,join_cache_bka=on,optimize_join_buffer_size=off,table_elimination=on,ext
ended_keys=on,exists_to_in=on
1 row in set (0.00 sec)
```

Deshabilitar características del optimizador (II)

```
MariaDB [nlwiktionary]> SET optimizer_switch='index_merge_sort_union=off';
Query OK, 0 rows affected (0.00 sec)

MariaDB [nlwiktionary]> EXPLAIN SELECT * F
790 or rev_timestamp < '2004'\G
*************************** 1. row *******
           id: 1
  select_type: SIMPLE
        table: revision
         type: ALL
possible_keys:
rev_page,rev_timestamp,rev_page_rev_timestamp,rev_timestamp_rev_page
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 686822
        Extra: Using where
1 row in set (0.00 sec)
```

This will only have effect for the current session.

What happens if we have two ranges?

- As seen previously, we cannot use efficiently two range types on the same table access. Alternatives:
  - Use only one index for the most selective column
  - Use index condition pushdown to get an advantage
  - Change one of the two ranges into a discrete "IN" comparison/bucketize with a new column
  - Use quadtrees or R-TREEs (spatial indexing)

Example of Bucketizing (I)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT count(*) FROM revision
WHERE rev_timestamp < '2008' AND rev_len > 5500\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ALL
possible_keys: rev_timestamp,rev_timestamp_rev_page
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 686822
        Extra: Using where
1 row in set (0.00 sec)
```

Looks like only an index on (rev_timestamp) or (rev_len) would be useful as we have 2 ranges.

Example of Bucketizing (II)

```
MariaDB [nlwiktionary]> ALTER TABLE revision ADD COLUMN
rev_len_cat int;
Query OK, 0 rows affected (38.28 sec)
Records: 0  Duplicates: 0  Warnings: 0

MariaDB [nlwiktionary]> UPDATE revision set rev_len_cat =
IF(rev_len < 10000, rev_len div 1000, 10);
Query OK, 820308 rows affected (15.19 sec)
Rows matched: 820308  Changed: 820308  Warnings: 0

MariaDB [nlwiktionary]> ALTER TABLE revision ADD INDEX
rev_len_cat_rev_timestamp (rev_len_cat, rev_timestamp);
Query OK, 0 rows affected (2.11 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

Example of Bucketizing (III)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT count(*) FROM revision WHERE
rev_timestamp < '2008' AND rev_len > 5500 AND rev_len_cat IN (5, 6,
7, 8, 9, 10)\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: range
possible_keys:
rev_timestamp,rev_timestamp_rev_page,rev_len_cat_rev_timestamp
          key: rev_len_cat_rev_timestamp
      key_len: 19
          ref: NULL
         rows: 4442
        Extra: Using where
1 row in set (0.00 sec)
```

We did some transformations to both the structure and the query.

Example of Index Condition Pushdown

```
MariaDB [nlwiktionary]> ALTER TABLE revision ADD INDEX
rev_len_rev_timestamp(rev_len, rev_timestamp);
Query OK, 0 rows affected (1.77 sec)
Records: 0  Duplicates: 0  Warnings: 0

MariaDB [nlwiktionary]> SET optimizer_switch='index_condition_pushdown=on'; EXPLAIN
SELECT * FROM revision WHERE rev_timestamp < '2008' AND rev_len > 5500\G
Query OK, 0 rows affected (0.00 sec)
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: range
possible_keys: rev_timestamp,rev_timestamp_
          key: rev_len_rev_timestamp
      key_len: 5
          ref: NULL
         rows: 38744
        Extra: Using index condition
1 row in set (0.00 sec)
```

Index condition pushdown (ICP) eanbles the engines to use extra parts of the index while avoiding costly row movements to and from the SQL layer

ICP Issues

- Differences in execution time is more significative when the extra column condition is very selective (getting 5x the original performance)
- ICP is ignored when using covering Index, making the performance worse

Does LIMIT improve the performance? (I)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page ORDER BY page_touched\G
*************************** 1. row ***************************
           type: ALL
possible_keys: NULL
            key: NULL
        key_len: NULL
            ref: NULL
           rows: 90956
          Extra: Using filesort

MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page ORDER BY page_touched LIMIT 10\G
*************************** 1. row ***************************
           type: index
possible_keys: NULL
            key: page_page_touched
        key_len: 14
            ref: NULL
           rows: 10
          Extra:
1 row in set (0.00 sec)
```

In some cases it can be essential to allow effective usage of the indexes

Does LIMIT improve the performance? (II)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision ORDER BY rev_comment\G
*************************** 1. row ***************************
[...]    type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 817636
        Extra: Using filesort
1 row in set (0.00 sec)

MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision ORDER BY rev_comment LIMIT 10\G
*************************** 1. row ***************************
[…]     table: revision
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 817636
        Extra: Using filesort
1 row in set (0.00 sec)
```

In other cases, it has no effect on the scanned rows (just on the returned ones)

Does LIMIT improve the performance? (I)

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page ORDER BY page_title LIMIT 100\G
*************************** 1. row ***************************
           type: index
possible_keys: NULL
            key: page_title
        key_len: 257
            ref: NULL
           rows: 100
          Extra:
1 row in set (0.00 sec)

MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM page ORDER BY page_title LIMIT 10000,
100\G
*************************** 1. row ***************************
           type: ALL
possible_keys: NULL
            key: NULL
        key_len: NULL
            ref: NULL
           rows: 90956
          Extra: Using filesort
1 row in set (0.00 sec)
```

In this case, performance will vary depending on the offset (not ideal)

Can we filter and sort at the same time using indexes?

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE
rev_comment='' ORDER BY rev_timestamp ASC\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revisic
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 817636
        Extra: Using where; Using filesort
1 row in set (0.00 sec)
```

This query is slow because a) the full table scan

b) Required sort after filtering

Adding and index on (rev_comment, rev_timestamp)

```
MariaDB [nlwiktionary]> ALTER TABLE revision ADD INDEX
rev_comment_rev_timestamp (rev_comment, rev_timestamp);
Query OK, 0 rows affected (3.19 sec)
Records: 0  Duplicates: 0  Warnings: 0

MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE rev_comment=''
ORDER BY rev_timestamp ASC\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ref
possible_keys: rev_comment_rev_timest
          key: rev_comment_rev_timesta
      key_len: 769
          ref: const
         rows: 266462
        Extra: Using index condition; Using where
1 row in set (0.00 sec)
```

Both type: ALL and filesort have disappeared

This is not always possible

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE
rev_len > 5500 ORDER BY rev_timestamp ASC\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: range
possible_keys: rev_len_rev_timest
          key: rev_len_rev_timest
      key_len: 5
          ref: NULL
         rows: 38744
        Extra: Using index condition; Using filesort
1 row in set (0.00 sec)
```

The range makes impossible to use the index optimally for the the ORDER BY: either we filter (rev_len) or sort (rev_timestamp)

A Strange Game. The Only Winning Move is Not to Play

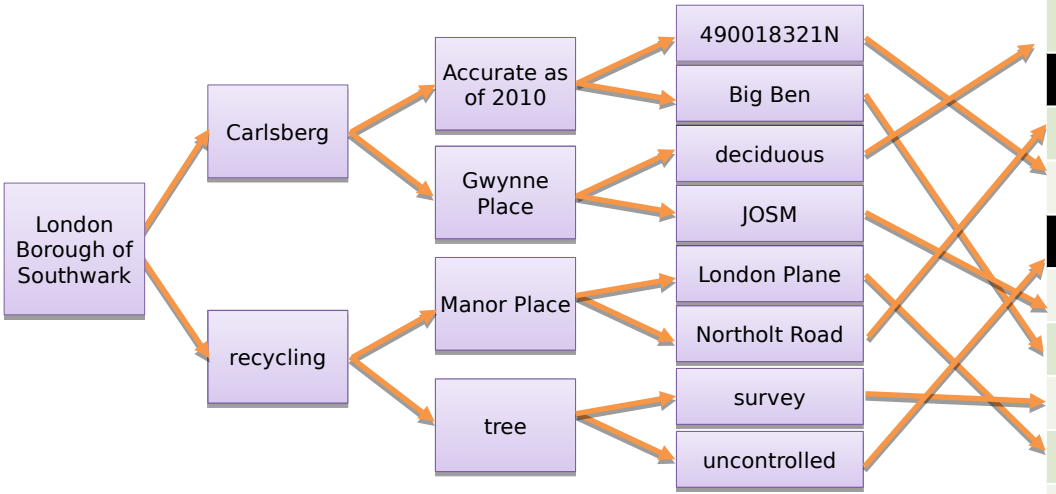
```
mysql-5.6.21 (osm) > SELECT * FROM nodes FORCE
INDEX(version_idx) WHERE version < 15 ORDER BY changeset_id;
/* type: range, Using filesort */
2859673 rows in set (30.58 sec)

mysql-5.6.21 (osm) > SELECT * FROM nodes FORCE
INDEX(changeset_id_idx) WHERE version < 15 ORDER BY
changeset_id;
/* type: index */
2859673 rows in set (30.92 sec)

mysql-5.6.21 (osm) > SELECT * FROM nodes WHERE version < 15
ORDER BY changeset_id;
/* type: ALL, Using filesort */
2859673 rows in set (16.54 sec)
```

MyISAM Internals

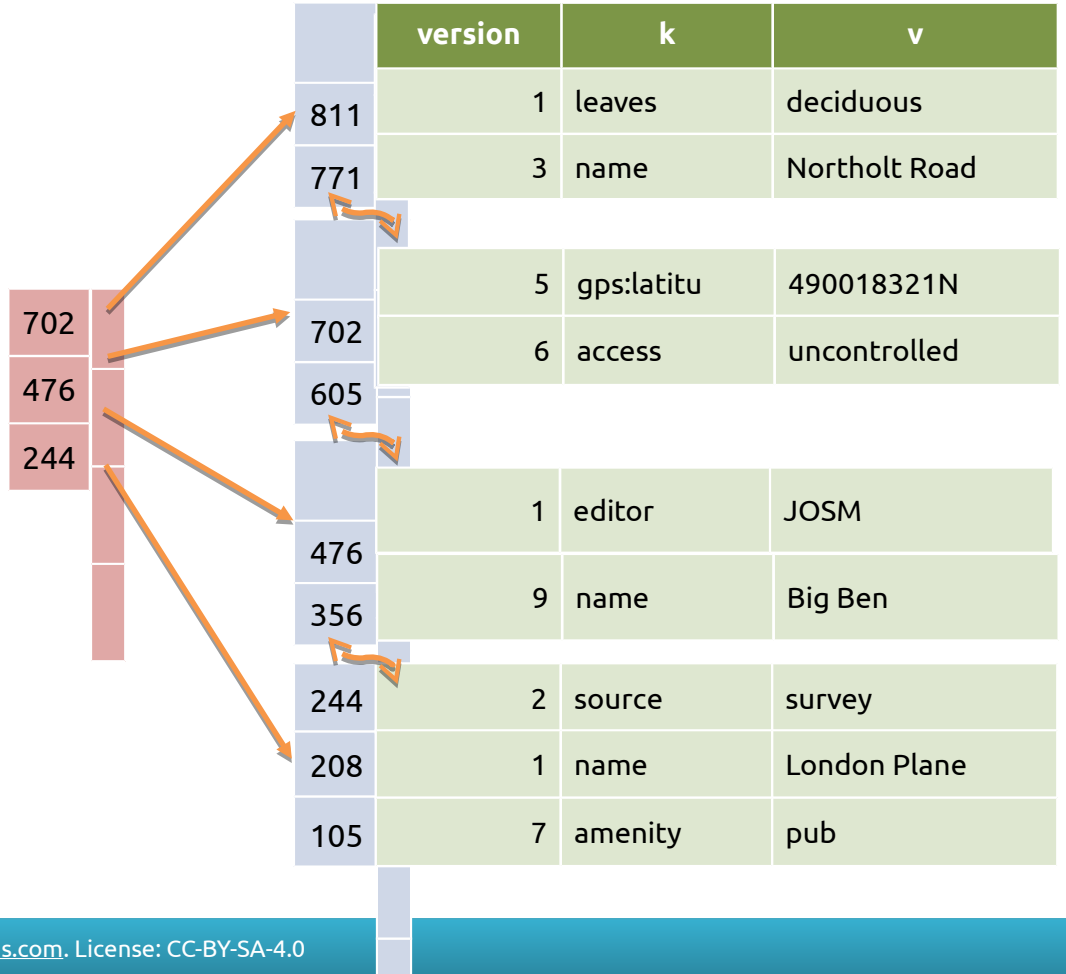
Index (part of revision.MYI)



Data (revision.MYD)

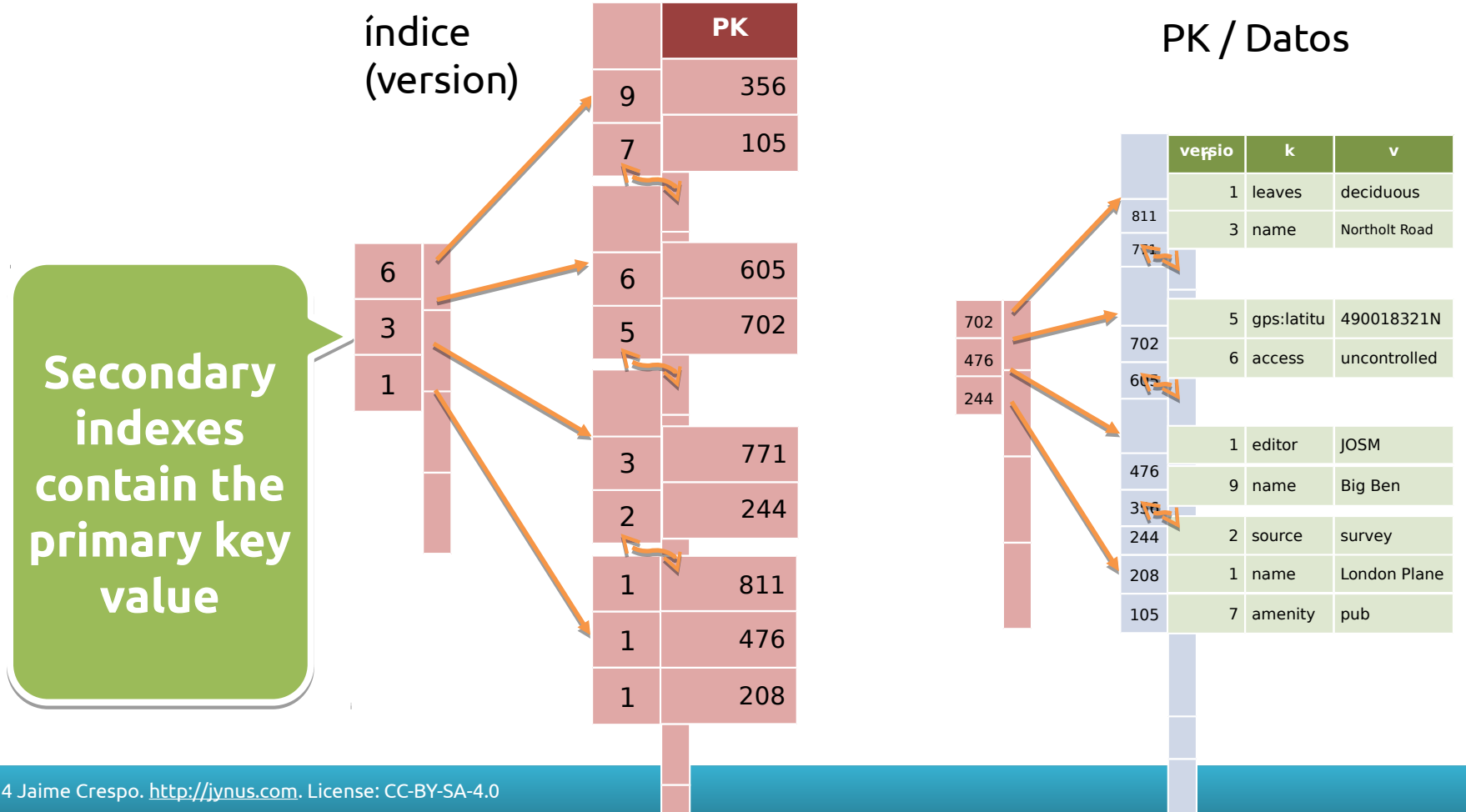
node_id	versio	k	v
234234344545	1	leaves	deciduous
(empty row)			
234234344548	5	gps:latitude	490018321N
234234344549	6	access	uncontrolled
(empty row)			
234234344551	9	name	Big Ben
234234344552	1	source	survey
234234344557	1	name	London Plane
234234344552	2	source	survey
234234344557	2	name	London Plane

InnoDB Internals (PRIMARY)



Data clustered always using the primary key

InnoDB Internals (Secondary)



Consequences of using InnoDB (I)

- Every table should have a primary key
  - If one is not defined, MySQL will choose an available NOT NULL unique key
  - If that is not possible, an internal 6-byte row identifier will be generated (not user-accesible)

Consequences of using InnoDB (II)

- Inserting in primary key order is much faster
  - Less fragmentation/page-split
  - Usage of "batch" mode, improving insert speed
- Using auto-increment keys as primary keys can be a good idea for InnoDB

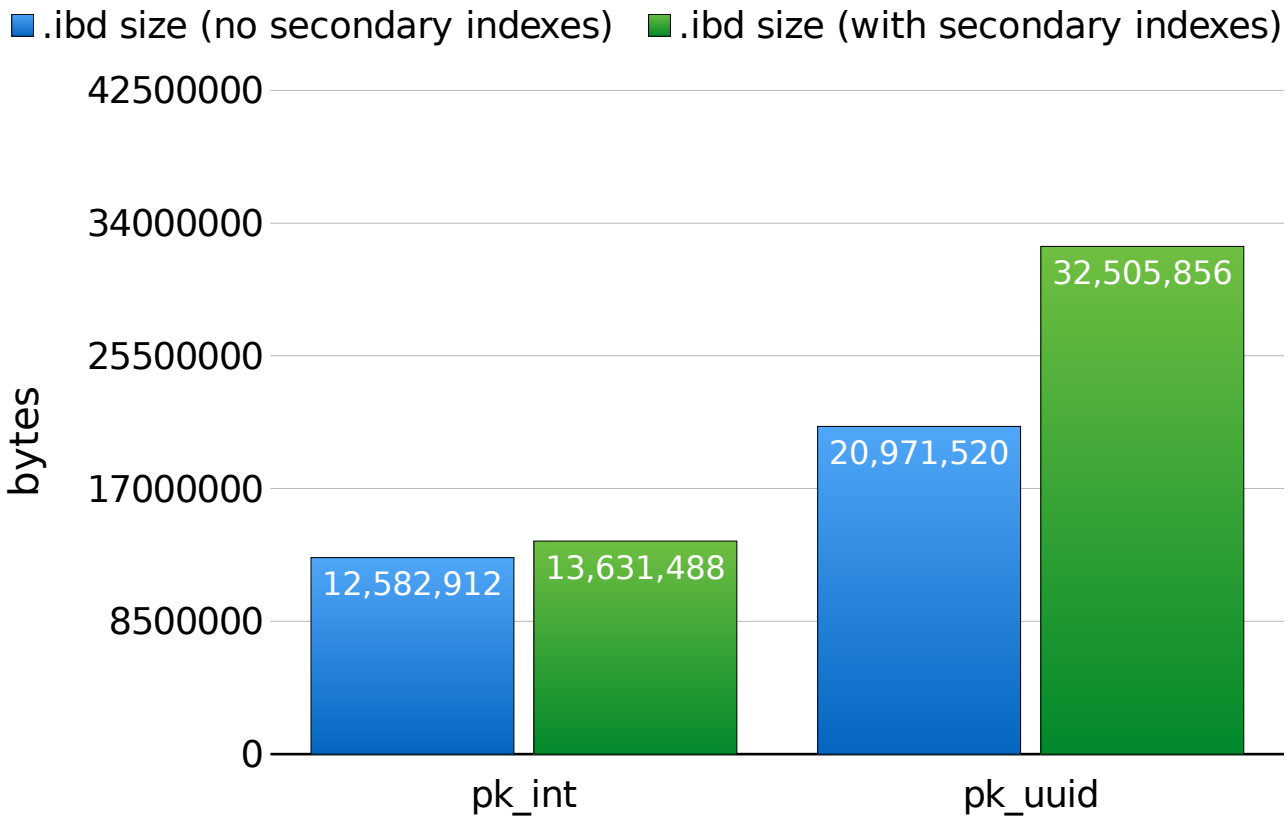
Consequences of using InnoDB (III)

- A very long primary key may increment substantially the size of secondary keys
  - Int or bigint types are recommended instead of UUIDs or other long strings

Differences in size

```
mysql-5.6.21 (osm) > CREATE
TABLE pk_int (id int
PRIMARY KEY auto_increment,
a int,
b int,
c int,
d int);
Query OK, 0 rows affected
(0.16 sec)

mysql-5.6.21 (osm) > CREATE
TABLE pk_uuid (id char(36)
PRIMARY KEY,
a int,
b int,
c int,
d int);
Query OK, 0 rows affected
(0.04 sec)
```



Extended primary key optimization

- As the primary key is part of all seconady keys, this can be used “for free”:
  - For row filtering (since MySQL 5.6)
  - To return results in primary key order
  - To avoid reading data from the table (covering index)

Extended Primary Key Example

```
mysql-5.6.21 (osm) > EXPLAIN SELECT node_id FROM nodes WHERE
changeset_id = 24284 and node_id <> 146472942\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: nodes
         type: range
possible_keys: PRIMARY,changeset_id_idx
          key: changeset_id_idx
      key_len: 16
          ref: NULL
         rows: 50
        Extra: Using where; Using index
1 row in set (0.07 sec)
```

Query Optimization: From 0 to 10 (and up to 5.7)

FULLTEXT SEARCH

Fuzzy Search of “gloucester/Gloucester’s/etc”

- “Typical” way to solve this:

```
mysql-5.7.5 (osm) >
SELECT way_id as id, v
FROM way_tags
WHERE v like '%gloucester%';
425 rows in set (0.46 sec)
```

Let's Add an Index

```
mysql-5.7.5 (osm) > ALTER TABLE way_tags ADD INDEX(v);
Query OK, 0 rows affected (6.44 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql-5.7.5 (osm) > SELECT ...;
425 rows in set (0.38 sec)
```


```
mysql-5.7.5 (osm) > EXPLAIN SELECT way as type, way_id as
id, v FROM way_tags WHERE v like '%gloucester%';
+----+.+-------+--------------+-----+---------+-----+---------+----------+-------------------------+
| id |.| type  | possible_keys | key | key_len | ref | rows    | filtered | Extra                   |
+----+.+-------+--------------+-----+---------+-----+---------+----------+-------------------------+
|  1 |.| index | NULL         | v_2 | 767     | NULL | 1333338 |    11.11 | Using where; Using index |
+----+.+-------+--------------+-----+---------+-----+---------+----------+-------------------------+
1 row in set, 1 warning (0.01 sec)
```

Fulltext Index

```
mysql-5.7.5 (osm) > ALTER TABLE way_tags add FULLTEXT index(v);
Query OK, 0 rows affected (3.20 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql-5.7.5 (osm) > SELECT ...;
425 rows in set (0.00 sec)

mysql-5.7.5 (osm) > EXPLAIN SELECT 'way' as type, way_id as id, v
FROM way_tags WHERE MATCH(v) AGAINST ('+gloucester*' IN BOOLEAN
MODE);
```

```
+----+.+----------+---------------+------+---------+-------+------+----------+----------------------------------+
| id |.| type     | possible_keys | key  | key_len | ref   | rows | filtered | Extra                            |
+----+.+----------+---------------+------+---------+-------+------+----------+----------------------------------+
|  1 |.| fulltext | v             | v    | 0       | const |    1 |   100.00 | Using where; Ft_hints: no_ranking |
+----+.+----------+---------------+------+---------+-------+------+----------+----------------------------------+
1 row in set, 1 warning (0.00 sec)
```

Newer Fulltext Optimizations

```
mysql-5.5.40 (osm) > EXPLAIN SELECT count(*) FROM way_tags_myisam WHERE MATCH(v) AGAINST('gloucester');
+----+-------------+----------------+----------+---------------+------+---------+------+------+-------------+
| id | select_type | table          | type     | possible_keys | key  | key_len | ref  | rows | Extra       |
+----+-------------+----------------+----------+---------------+------+---------+------+------+-------------+
|  1 | SIMPLE      | way_tags_myisam | fulltext | v             | v    | 0       |      |    1 | Using where |
+----+-------------+----------------+----------+---------------+------+---------+------+------+-------------+
1 row in set (0.00 sec)

mysql-5.5.40 (osm) > SHOW STATUS like 'Hand%';
+----------------------------+-------+
| Variable_name              | Value |
+----------------------------+-------+
| Handler_commit             | 0     |
| Handler_delete             | 0     |
...
| Handler_read_first         | 0     |
| Handler_read_key           | 0     |
| Handler_read_last          | 0     |
| Handler_read_next          | 425   |
| Handler_read_prev          | 0     |
| Handler_read_rnd           | 0     |
| Handler_read_rnd_next      | 0     |
...
| Handler_update             | 0     |
| Handler_write              | 0     |
+----------------------------+-------+
16 rows in set (0.00 sec)
```

Newer Fulltext Optimizations (cont.)

```
mysql-5.7.5 (osm) > EXPLAIN SELECT count(*) FROM way_tags WHERE MATCH(v) AGAINST('gloucester');
+----+-------------+-------+------------+------+---------------+------+---------+------+------+----------+--------------------------+
| id | select_type | table | partitions | type | possible_keys | key  | key_len | ref  | rows | filtered | Extra                    |
+----+-------------+-------+------------+------+---------------+------+---------+------+------+----------+--------------------------+
|  1 | SIMPLE      | NULL  | NULL       | NULL | NULL          | NULL | NULL    | NULL | NULL |     NULL | Select tables optimized away |
+----+-------------+-------+------------+------+---------------+------+---------+------+------+----------+--------------------------+
1 row in set, 1 warning (0.00 sec)

mysql-5.7.5 (osm) > SHOW STATUS like 'Hand%';
+----------------------------+-------+
| Variable_name              | Value |
+----------------------------+-------+
| Handler_commit             | 1     |
| Handler_delete             | 0     |
...
| Handler_read_first         | 0     |
| Handler_read_key           | 0     |
| Handler_read_last          | 0     |
| Handler_read_next          | 0     |
| Handler_read_prev          | 0     |
| Handler_read_rnd           | 0     |
| Handler_read_rnd_next      | 0     |
...
| Handler_update             | 0     |
| Handler_write              | 0     |
+----------------------------+-------+
18 rows in set (0.00 sec)
```

Open Issues and Limitations

- No postfix support (wildcards)
- Simple Ranking (and different from MyISAM)
- No stemming support
- Some multi-language limitations

More on FULLTEXT InnoDB support:
http://www.drdobbs.com/database/full-text-search-with-innodb/231902587

Alternatives

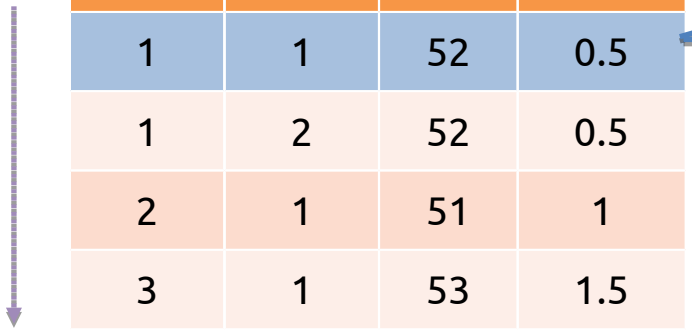
- Apache Lucene
  - Solr
  - Elasticsearch
- Sphinx
  - SphinxSE

Query Optimization: From 0 to 10 (and up to 5.7)

JOINS

(Block) Nested Loop Join

- Until MySQL 5.5 there was only one algorithm to execute a JOIN:



node_id	version	lat	lon
1	1	52	0.5
1	2	52	0.5
2	1	51	1
3	1	53	1.5

node_id	version	k	v
1	1	name	Big Benn
1	1	tourism	attraction
1	2	name	Big Ben
1	2	tourism	attraction
3	1	name	London Eye

Extra Access type: eq_ref

```
mysql-5.6.21 (osm) > EXPLAIN SELECT * FROM nodes JOIN node_tags
                     USING(node_id, version) WHERE node_tags.v= 'Big Ben'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: node_tags
         type: ref
possible_keys: PRIMARY,v_idx
          key: v_idx
      key_len: 767
          ref: const
         rows: 1
        Extra: Using where; Using index
*************************** 2. row ***********************
           id: 1
  select_type: SIMPLE
        table: nodes
         type: eq_ref
possible_keys: PRIMARY,version_idx
          key: PRIMARY
      key_len: 16
          ref: osm.node_tags.node_id,osm.node_tags.version
         rows: 1
        Extra: NULL
2 rows in set (0.00 sec)
```

eq_ref is similar to ref, but allows faster JOINS because, by using a unique key, it only has to search one row for each previous result

JOIN Optimization

- Two main goals:
  - Perform an effective filtering on each table access, if possible using indexes
  - Perform the access in the most efficient table order
- When joining 3 or more tables in a star schema, the "covering index" strategy can have a huge impact

Example: optimize this JOIN (I)

```
SELECT n.node_id, n.latitude, n.longitude
  FROM way_nodes w_n
  JOIN way_tags w_t
    ON w_n.way_id = w_t.way_id and
       w_n.version = w_t.version
  JOIN nodes n
    ON w_n.node_id = n.node_id
  JOIN node_tags n_t
    ON n.node_id = n_t.node_id and
       n.version = n_t.version
 WHERE w_t.k = 'building' and
       n_t.k = 'entrance' and
       n_t.v = 'main';
```

We start without secondary indexes

Example: optimize this JOIN (II)

```
*********************** 1. row ***********************
           id: 1
  select_type: SIMPLE
        table: w_t
         type: index
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 783
          ref: NULL
         rows: 1335702
        Extra: Using where; Using index
*********************** 2. row ***********************
           id: 1
  select_type: SIMPLE
        table: w_n
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 16
          ref: osm.w_t.way_id,osm.w_t.version
         rows: 3
        Extra: NULL
*********************** 3. row ***********************
           id: 1
  select_type: SIMPLE
        table: n_t
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 8
          ref: osm.w_n.node_id
         rows: 1
        Extra: Using where
*********************** 4. row ***********************
           id: 1
  select_type: SIMPLE
        table: n
         type: eq_ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 16
          ref: osm.w_n.node_id,osm.n_t.version
         rows: 1
        Extra: Using index
4 rows in set (0.01 sec)

mysql-5.6.21 (osm) > SELECT …
858 rows in set (9.00 sec)
```

Example: optimize this JOIN (III)

```
mysql-5.6.21 (osm) > ALTER TABLE way_tags ADD
INDEX k_idx(k);
Query OK, 0 rows affected (4.80 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

Example: optimize this JOIN (IV)

```
********************** 1. row **********************
           id: 1
  select_type: SIMPLE
        table: w_t
         type: ref
possible_keys: PRIMARY,k_idx
          key: k_idx
      key_len: 767
          ref: const
         rows: 452274
        Extra: Using where; Using index
********************** 2. row **********************
           id: 1
  select_type: SIMPLE
        table: w_n
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 16
          ref: osm.w_t.way_id,osm.w_t.version
         rows: 3
        Extra: NULL

mysql-5.6.21 (osm) > SELECT …
858 rows in set (8.58 sec)
```

```
********************** 3. row **********************
           id: 1
  select_type: SIMPLE
        table: n_t
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 8
          ref: osm.w_n.node_id
         rows: 1
        Extra: Using where
********************** 4. row **********************
           id: 1
  select_type: SIMPLE
        table: n
         type: eq_ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 16
          ref: osm.w_n.node_id,osm.n_t.version
         rows: 1
        Extra: NULL
4 rows in set (0.00 sec)
```

Example: optimize this JOIN (V)

```
mysql-5.6.21 (osm) > ALTER TABLE node_tags ADD
INDEX k_idx(k);
Query OK, 0 rows affected (2.82 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

The order does not seem to be adequate, let's try adding an index to start by accessing node_tags

Example: optimize this JOIN (VI)

```
********************** 1. row **********************
           id: 1
  select_type: SIMPLE
        table: w_t
         type: ref
possible_keys: PRIMARY,k_idx
          key: k_idx
      key_len: 767
          ref: const
         rows: 452274
        Extra: Using where; Using index
********************** 2. row **********************
           id: 1
  select_type: SIMPLE
        table: w_n
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 16
          ref: osm.w_t.way_id,osm.w_t.version
         rows: 3
        Extra: NULL

mysql-5.6.21 (osm) > SELECT …
858 rows in set (7.33 sec)
```

```
********************** 3. row *******
           id: 1
  select_type: SIMPLE
        table: n_t
         type: ref
possible_keys: PRIMARY,k_idx
          key: PRIMARY
      key_len: 8
          ref: osm.w_n.node_id
         rows: 1
        Extra: Using where
********************** 4. row *******
           id: 1
  select_type: SIMPLE
        table: n
         type: eq_ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 16
          ref: osm.w_n.node_id,osm.n_t.version
         rows: 1
        Extra: NULL
4 rows in set (0.00 sec)
```

It keeps using the wrong order, even if we delete the w_t.k_idx index

Example: optimize this JOIN (VII)

```
SELECT STRAIGHT_JOIN n.node_id, n.latitude, n.longitude
  FROM node_tags n_t
  JOIN nodes n
    ON n.node_id = n_t.node_id and
       n.version = n_t.version
  JOIN way_nodes w_n
    ON w_n.node_id = n.node_id
  JOIN way_tags w_t
    ON w_n.way_id = w_t.way_id and
       w_n.version = w_t.version
 WHERE w_t.k = 'building' and
       n_t.k = 'entrance' and
       n_t.v = 'main';
```

Let's see why rewriting it into this query

Example: optimize this JOIN (VIII)

```
*********************** 1. row ***********************
           id: 1
  select_type: SIMPLE
        table: n_t
         type: ref
possible_keys: PRIMARY,k_idx
          key: k_idx
      key_len: 767
          ref: const
         rows: 2390
        Extra: Using index condition; Using where
*********************** 2. row ***********************
           id: 1
  select_type: SIMPLE
        table: n
         type: eq_ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 16
          ref: osm.n_t.node_id,osm.n_t.version
         rows: 1
        Extra: NULL
*********************** 3. row ***********************
           id: 1
  select_type: SIMPLE
        table: w_n
         type: ALL
possible_keys: PRIMARY
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 3597858
        Extra: Using where; Using join buffer (Block
Nested Loop)
*********************** 4. row ***********************
           id: 1
  select_type: SIMPLE
        table: w_t
         type: eq_ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 783
          ref: osm.w_n.way_id,osm.w_n.version,const
         rows: 1
        Extra: Using where; Using index
4 rows in set (0.00 sec)
```

There is no index on w_n that would allow efficient access

Example: optimize this JOIN (IX)

```
mysql-5.6.21 (osm) > ALTER TABLE way_nodes ADD
INDEX node_id_idx(node_id);
Query OK, 0 rows affected (17.77 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

Example: optimize this JOIN (X)

```
*********************** 1. row ***********************
           id: 1
  select_type: SIMPLE
        table: n_t
         type: ref
possible_keys: PRIMARY,k_idx
          key: k_idx
      key_len: 767
          ref: const
         rows: 2390
        Extra: Using index condition; Using where
*********************** 2. row ***********************
           id: 1
  select_type: SIMPLE
        table: n
         type: eq_ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 16
          ref: osm.n_t.node_id,osm.n_t.version
         rows: 1
        Extra: NULL
```

Now it starts by the right table (without STRAIGHT_JOIN)

```
*********************** 3. row ***********************
           id: 1
  select_type: SIMPLE
        table: w_n
         type: ref
possible_keys: PRIMARY,node_id_idx
          key: node_id_idx
      key_len: 8
          ref: osm.n_t.node_id
         rows: 1
        Extra: Using index
*********************** 4. row ***********************
           id: 1
  select_type: SIMPLE
        table: w_t
         type: eq_ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 783
          ref: osm.w_n.way_id,osm.w_n.version,const
         rows: 1
        Extra: Using where; Using index
4 rows in set (0.04 sec)
```

```
mysql-5.6.21 (osm) > SELECT …
858 rows in set (0.73 sec)
```

Example: optimize this JOIN (XI)

```
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: n_t
         type: ref
possible_keys: PRIMARY,k_idx,k_v_i
          key: k_v_idx
      key_len: 1534
          ref: const,const
         rows: 900
        Extra: Using where; Using index
*************************** 2. row ***************************
           id: 1
  select_type: SIMPLE
        table: n
         type: eq_ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 16
          ref: osm.n_t.node_id,osm.n_t.version
         rows: 1
        Extra: NULL

mysql-5.6.21 (osm) > SELECT ...
858 rows in set (0.02 sec)
```

An index on (k,v) is even better

```
*************************** 3. row ***************************
           id: 1
  select_type: SIMPLE
        table: w_n
         type: ref
possible_keys: PRIMARY,node_id_idx
          key: node_id_idx
      key_len: 8
          ref: osm.n_t.node_id
         rows: 1
        Extra: Using index
*************************** 4. row ***************************
           id: 1
  select_type: SIMPLE
        table: w_t
         type: eq_ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 783
          ref: osm.w_n.way_id,osm.w_n.version,const
         rows: 1
        Extra: Using where; Using index
4 rows in set (0.00 sec)
```

“New” JOIN methods

- MySQL 5.6 added:
  - Batch Key Access
- MariaDB has since 5.3:
  - Batch Key Access
  - Hash Joins
  - Slightly modified versions of the above ones (with “incremental” buffers to join 3 or more tables)

Multi-range read

- This optimization orders results obtained from a secondary key in primary key/physical order before accessing the rows
  - It may help exection time of queries when disk-bound
  - It requires tunning of the read_rnd_buffer_size (size of the buffer used for ordering the results)
- BKA JOINs are based on the mrr optimization

MRR Example (I)

```
mysql-5.6.21 (osm) > EXPLAIN SELECT * FROM nodes WHERE timestamp >=
'2013-07-01 00:00:00' AND timestamp < '2014-01-01 00:00:00'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: nodes
         type: range
possible_keys: nodes_timestamp_idx
          key: nodes_timestamp_idx
      key_len: 5
          ref: NULL
         rows: 429684
        Extra: Using index condition; Using MRR
1 row in set (0.02 sec)
```

MRR example (II)

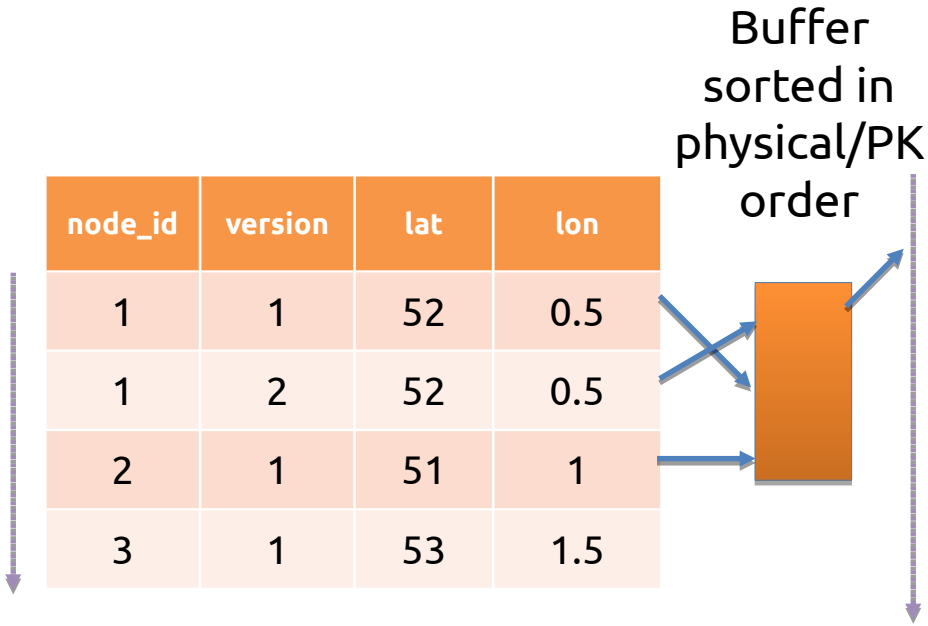
```
[restart]
mysql> SET optimizer_switch='mrr=off';
mysql> SELECT * FROM nodes WHERE timestamp >= '2013-07-01 00:00:00' AND timestamp <
'2014-01-01 00:00:00';
205617 rows in set (5.16 sec)
mysql> SELECT * FROM nodes WHERE timestamp >= '2013-07-01 00:00:00' AND timestamp <
'2014-01-01 00:00:00';
205617 rows in set (0.60 sec)

[restart]
mysql> SET read_rnd_buffer_size=50 * 1024 * 1024;
mysql> SELECT * FROM nodes WHERE timestamp >= '2013-07-01 00:00:00' AND timestamp <
'2014-01-01 00:00:00';
205617 rows in set (2.39 sec)
mysql> SELECT * FROM nodes WHERE timestamp >= '2013-07
'2014-01-01 00:00:00';
205617 rows in set (0.73 sec)
```

"Cold" results are significantly better with mrr (but it can impact negatively, too)

Batch Key Access

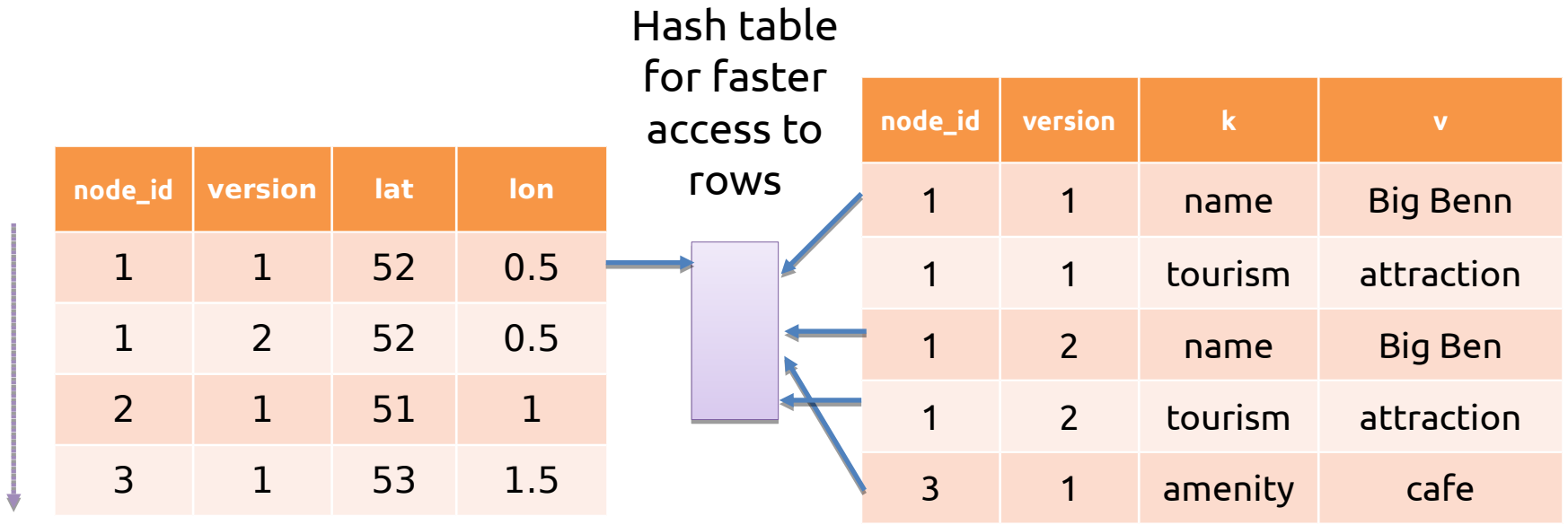
node_id	version	lat	lon
1	1	52	0.5
1	2	52	0.5
2	1	51	1
3	1	53	1.5



node_id	version	k	v
1	1	name	Big Benn
1	1	tourism	attraction
1	2	name	Big Ben
1	2	tourism	attraction
3	1	amenity	cafe

Hash Joins

- Only work for equi-joins



MySQL Configuration

- BKA requires changes of default optimizer configuration:

```
mysql-5.7.5 (osm) > SET optimizer_switch= 'mrr=on';
mysql-5.7.5 (osm) > SET optimizer_switch= 'mrr_cost_based=off';
mysql-5.7.5 (osm) > SET optimizer_switch= 'batch_key_access=on';
```

  - Additionally, configuring the join_buffer_size adequately

MariaDB configuration

```
mariadb-10.0.14 (osm) > SET optimizer_switch = 'join_cache_incremental=on';
mariadb-10.0.14 (osm) > SET optimizer_switch = 'join_cache_hashed=on';
mariadb-10.0.14 (osm) > SET optimizer_switch = 'join_cache_bka=on';
```

- Enabled by default

```
mariadb-10.0.14 (osm) > SET join_cache_level = 3 (for hash joins)
mariadb-10.0.14 (osm) > SET join_cache_level = 5 (for BKA)
```

- Also, configure join_buffer_size appropriately.
- Hash joins, like BKA, are highly dependent on disk-bound DBs to be effective due to the extra overhead

Nested Loop Join (cold buffers buffer_pool=100MB, join_buffer=4M)

```
mariadb-10.0.14 (osm) > EXPLAIN SELECT
changeset_id, count(*) FROM changesets JOIN nodes
on changesets.id = nodes.changeset_id GROUP BY
visible\G
******************** 1. row ********************
           id: 1
  select_type: SIMPLE
        table: changesets
         type: index
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 8
          ref: NULL
         rows: 69115
        Extra: Using index; Using temporary; Using
filesort
******************** 2. row ********************
           id: 1
  select_type: SIMPLE
        table: nodes
         type: ref
possible_keys: changeset_id
          key: changeset_id
      key_len: 8
          ref: osm.changesets.id
         rows: 19
        Extra:
2 rows in set (0.00 sec)

mariadb-10.0.14 (osm) > SELECT visible, count(*)
FROM changesets JOIN nodes on changesets.id =
nodes.changeset_id GROUP BY visible;
+---------+----------+
| visible | count(*) |
+---------+----------+
|       1 |  2865312 |
+---------+----------+
1 row in set (32.86 sec)
```

Hash Join (cold buffers, buffer_pool=100M, join_buffer=4M)

```
mariadb-10.0.14 (osm) > EXPLAIN SELECT
changeset_id, count(*) FROM changesets JOIN
nodes on changesets.id = nodes.changeset_id
GROUP BY visible\G
******************** 1. row
********************
           id: 1
  select_type: SIMPLE
        table: changesets
         type: index
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 8
          ref: NULL
         rows: 69115
        Extra: Using index; Using temporary;
Using filesort
******************** 2. row ********************
           id: 1
  select_type: SIMPLE
        table: nodes
         type: hash_ALL
possible_keys: changeset_id
          key: #hash#changeset_id
      key_len: 8
          ref: osm.changesets.id
         rows: 2781732
        Extra: Using join buffer (flat, BNLH join)
2 rows in set (0.00 sec)

mariadb-10.0.14 (osm) > SELECT visible, count(*)
FROM changesets JOIN nodes on changesets.id =
nodes.changeset_id GROUP BY visible;
+---------+----------+
| visible | count(*) |
+---------+----------+
|       1 |  2865312 |
+---------+----------+
1 row in set (6.66 sec)
```

Query Optimization: From 0 to 10 (and up to 5.7)

SUBQUERIES

Access types: unique_subquery/index_subquery

```
mysql-5.6.21 (osm) > EXPLAIN SELECT
* FROM node_tags WHERE v = 'Big Ben'
and node_id NOT IN (SELECT node_id
FROM nodes WHERE tile < 100000000)\G
*************** 1. row ***************
           id: 1
  select_type: PRIMARY
        table: node_tags
         type: ref
possible_keys: v_idx
          key: v_idx
      key_len: 767
          ref: const
         rows: 1
        Extra: Using where; Using
index
*************** 2. row ***************
           id: 2
  select_type: DEPENDENT SUBQUERY
        table: nodes
         type: index_subquery
possible_keys: PRIMARY,nodes_tile_idx
          key: PRIMARY
      key_len: 8
          ref: func
         rows: 1
        Extra: Using where
2 rows in set (0.00 sec)
```

Unique subquery is similar, but using a unique or primary key

Subqueries in MySQL

- MySQL versions traditionally had very bad press regarding subquries
  - It was common to recommend rewriting them (when possible) into JOINS
- Since MySQL 5.6, its query execution plans have improved significantly

Lazy Materialization of derived tables

- Option available since MySQL 5.6
  - Improves the execution time of EXPLAIN (it no longer needs to execute subqueries)
  - Derived tables can be indexed automatically at execution time to improve its performance

Derived Table Example

```
mysql-5.5.40 (osm) > EXPLAIN SELECT count(*) FROM (SELECT * FROM nodes WHERE VISIBLE = 1) n JOIN changesets ON
n.changeset_id = changesets.id;
+----+-------------+------------+--------+---------------+---------+---------+---------------+---------+-------------+
| id | select_type | table      | type   | possible_keys | key     | key_len | ref           | rows    | Extra       |
+----+-------------+------------+--------+---------------+---------+---------+---------------+---------+-------------+
|  1 | PRIMARY     | <derived2> | ALL    | NULL          | NULL    | NULL    | NULL          | 2865312 |             |
|  1 | PRIMARY     | changesets | eq_ref | PRIMARY       | PRIMARY | 8       | n.changeset_id |       1 | Using index |
|  2 | DERIVED     | nodes      | ALL    | NULL          | NULL    | NULL    | NULL          | 2865521 | Using where |
+----+-------------+------------+--------+---------------+---------+---------+---------------+---------+-------------+
3 rows in set (1.42 sec)

mysql-5.6.21 (osm) > EXPLAIN SELECT count(*) FROM (SELECT * FROM nodes WHERE VISIBLE = 1) n JOIN changesets ON
n.changeset_id = changesets.id;
+----+-------------+------------+-------+---------------+-------------+---------+-----------------+---------
+-------------+
| id | select_type | table      | type  | possible_keys | key         | key_len | ref             | rows    | Extra
    |
+----+-------------+------------+-------+---------------+-------------+---------+-----------------+---------
+-------------+
|  1 | PRIMARY     | changesets | index | PRIMARY       | PRIMARY     | 8       | NULL            |   70917 | Using
index |
|  1 | PRIMARY     | <derive                                  to_key0> |                 .id |      40 | NULL
    |
|  2 | DERIVED     | nodes                                                                    | 2853846 | Using
where |
+----+-------------+---------                                                                 ---+---------
+-------------+
3 rows in set (0.00 sec)
```

Subquery is not executed

Auto-generated index

A Common 5.5 Performance Problem

```
mysql-5.5.40 (osm) > EXPLAIN SELECT * FROM nodes
                       WHERE nodes.changeset_id IN (
                         SELECT changesets.id
                          FROM changesets
                          JOIN users
                            ON changesets.user_id = users.id and users.display_name = 'Steve');
+----+--------------------+------------+--------+--------------------------------+---------------------+---------+-------+---------+-------------+
| id | select_type        | table      | type   | possible_keys                  | key                 | key_len | ref   | rows    | Extra       |
+----+--------------------+------------+--------+--------------------------------+---------------------+---------+-------+---------+-------------+
|  1 | PRIMARY            | nodes      | ALL    | NULL                           | NULL                | NULL    | NULL  | 2865521 | Using where |
|  2 | DEPENDENT SUBQUERY | users      | cons   | PRIMARY,users_display_name_idx | users_display_name_idx | 767  | const |       1 | Using index |
|  2 | DEPENDENT SUBQUERY | changesets | eq_ref |                                | PRIMARY             | 8       | func  |       1 | Using where |
+----+--------------------+------------+--------+--------------------------------+---------------------+---------+-------+---------+-------------+
3 rows in set (0.00 sec)

mysql-5.5.40 (osm) > SELECT ...;
+-----------+-----------+-----------+--------------+-------
| node_id   | latitude  | longitude | changeset_id | visi
+-----------+-----------+-----------+--------------+-------
|     99890 | 515276425 |  -1497621 |          552 |
|    109174 | 515364532 |  -1457329 |         1875 |
|    276538 | 515324296 |  -2094688 |          810 |       1 |
|    442987 | 515449207 |  -1275650 |         1941 |       1 | 20                                            1 |
|    442988 | 515449741 |  -1272860 |         1941 |       1 | 2006-01                                       1 |
|    498803 | 515438432 |  -1269436 |         2171 |       1 | 2006-02-03 21:55:17 | 2062268628 |         1 |
| 138212838 | 513010180 |  -1699929 |      7757299 |       1 | 2011-04-03 18:14:14 | 2062220563 |         6 |
+-----------+-----------+-----------+--------------+---------+---------------------+------------+-----------+
7 rows in set (2.60 sec)
```

This means that the subquery is executed almost 3 million times

Semijoin Optimization

- The only way to execute certain IN subqueries was to execute them with poor strategy
  - This forced to rewrite certain queries into JOINS or scalar subqueries, when possible
- There are now several additional automatic options:
  - Convert to a JOIN
  - Materialization (including index creation)
  - FirstMatch
  - LooseScan
  - Duplicate Weedout

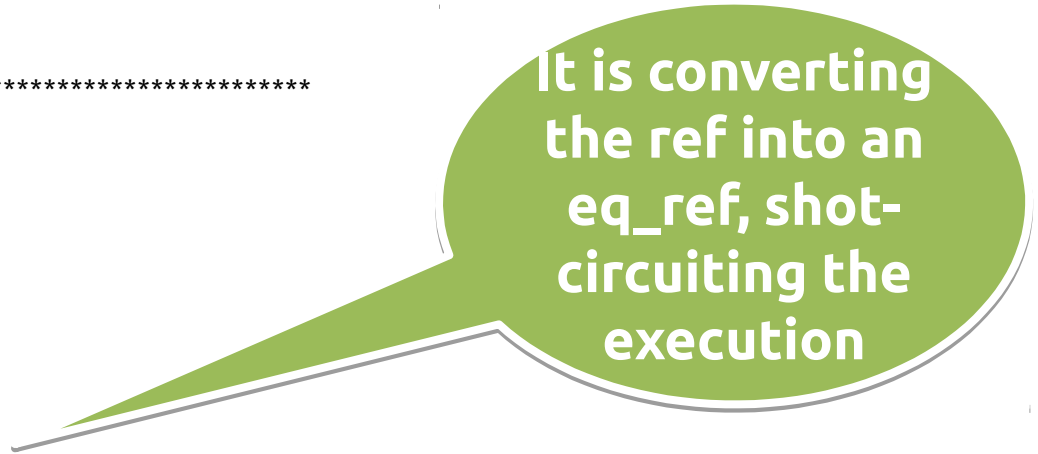
The Previous Query is Not a Problem in 5.6/5.7/MariaDB 5.3+

```
mysql-5.6.21 (osm) > EXPLAIN SELECT * FROM nodes
                               WHERE nodes.changeset_id IN (
                                 SELECT changesets.id
                                   FROM change sets
                                   JOIN users
                                     ON changesets.user_id = users.id and users.display_name = 'Steve');
+----+-------------+-----------+-------+-------------------------------+-----------------------+---------+------------------+-------+-------------+
| id | select_type | table     | type  | possible_keys                 | key                   | key_len | ref              | rows  | Extra       |
+----+-------------+-----------+-------+-------------------------------+-----------------------+---------+------------------+-------+-------------+
|  1 | SIMPLE      | users     | const | PRIMARY,users_display_name_idx | users_display_name_idx | 767     | const            |     1 | Using index |
|  1 | SIMPLE      | changesets | ALL   | PRIMARY                       | NULL                  | NULL    | NULL             | 70917 | Using where |
|  1 | SIMPLE      | nodes     | ref   | changeset_id                  | changeset_id          | 8       | osm.changesets.id |    21 | NULL        |
+----+-------------+-----------+-------+-------------------------------+-----------------------+---------+------------------+-------+-------------+
3 rows in set (0.00 sec)

mysql-5.6.21 (osm) > SELECT ...;
+-----------+-----------+-----------+-------------+---------+---------------------+-----------+---------+
| node_id   | latitude  | longitude | changeset_id | visible | timestamp           | tile      | version |
+-----------+-----------+-----------+-------------+---------+---------------------+-----------+---------+
|     99890 | 515276425 |  -1497621 |          552 |       1 | 2005-10-25 00:35:24 | 2062268512 |       1 |
...
| 138212838 | 513010180 |  -1699929 |      7757299 |       1 | 2011-04-03 18:14:14 | 2062220563 |       6 |
+-----------+-----------+-----------+-------------+---------+---------------------+-----------+---------+
7 rows in set (0.02 sec)
```

First Match Strategy

```
mysql-5.7.5 (osm) > EXPLAIN SELECT * FROM changesets WHERE id IN (SELECT changeset_id FROM nodes)\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: changesets
   partitions: NULL
         type: ALL
possible_keys: PRIMARY
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 70917
     filtered: 100.00
        Extra: NULL
*************************** 2. row ***************************
           id: 1
  select_type: SIMPLE
        table: nodes
   partitions: NULL
         type: ref
possible_keys: changeset_id
          key: changeset_id
      key_len: 8
          ref: osm.changesets.id
         rows: 33
     filtered: 100.00
        Extra: Using index; FirstMatch(changesets)
2 rows in set, 1 warning (0.00 sec)
```



Enabling and disabling materialization, semijoin, etc

```
mysql-5.7.8 (osm) > SHOW VARIABLES like 'optimizer_switch'\G
*************************** 1. row ***************************
Variable_name: optimizer_switch
        Value:
index_merge=on,index_merge_union=on,index_merge_sort_union=on,index_merge_in
tersection=on,engine_condition_pushdown=on,index_condition_pushdown=on,mrr=o
n,mrr_cost_based=on,block_nested_loop=on,batched_key_access=off,materializat
ion=on,semijoin=on,loosescan=on,firstmatch=on,duplicateweedout=on,subquery_m
aterialization_cost_based=on,use_index_extensions=on,condition_fanout_filter
=on,derived_merge=on
1 row in set (0.00 sec)
```

Query Optimization: From 0 to 10 (and up to 5.7)

QUERY PROFILING

Which Queries Should I Optimize First?

- My two favorite methods:
  - pt-query-digest
  - PERFORMANCE_SCHEMA
- I prefer pt-query-digest for long-term reports, PERFORMANCE_SCHEMA for more real-time evaluation and fine-tuning
  - Also, PERFORMANCE_SCHEMA was not “ready” until MySQL 5.6

pt-query-digest

- It is a 3rd party tool written in Perl, originally created by Baron Schwartz
- It requires activation of the slow log:
  - `SET GLOBAL slow_query_log = 1;`
  - `SET long_query_time = 0;`
- In Percona Server and MariaDB it can provide extra information:
  - `SHOW GLOBAL VARIABLES like 'log_slow_verbosity';`

pt-query-digest Execution (I)

```
# 1094.7s user time, 9.4s system time, 141.22M rss, 205.21M vsz
# Current date: Wed Jul  1 07:32:28 2015
# Hostname: db1018
# Files: STDIN
# Overall: 4.66M total, 640 unique, 53.47 QPS, 0.02x concurrency _________
# Time range: 2015-06-30 07:00:10 to 2015-07-01 07:11:37
# Attribute          total     min     max     avg     95%  stddev  median
# ============     ======= ======= ======= ======= ======= ======= =======
# Exec time          1320s     1us      3s   283us   332us     3ms   152us
# Lock time           238s       0    13ms    51us    93us    39us    52us
# Rows sent          5.02M       0   4.16k    1.13    1.96    8.69    0.99
# Rows examine       9.50M       0 232.93k    2.14    3.89  261.15    0.99
# Merge passes           0       0       0       0       0       0       0
# Query size         1.06G      17  67.89k  243.89  511.45  368.99  192.76
# Boolean:
# Filesort        8% yes,  91% no
# Full scan      94% yes,   5% no
# Priority que    3% yes,  96% no
# Tmp table      29% yes,  70% no
# Tmp table on    1% yes,  98% no
```

Actual execution on Wikipedia production servers

pt-query-digest Execution (II)

```
# Profile
# Rank Query ID           Response time  Calls   R/Call V/M   Item
# ==== ================== ============== ======= ====== ===== ============
#    1 0xSANITIZED        242.2765 18.4%  691005 0.0004  0.00 SELECT revision page user
#    2 0xSANITIZED        204.7052 15.5%   80863 0.0025  0.01 SELECT revision page user
#    3 0xSANITIZED        162.8476 12.3% 1025179 0.0002  0.00 SELECT page
#    4 0xSANITIZED         68.1164  5.2%   93928 0.0007  0.01 SELECT revision page user
#    5 0xSANITIZED         66.8302  5.1%  354562 0.0002  0.00 SELECT page revision
#    6 0xSANITIZED         57.0374  4.3%  211631 0.0003  0.00 SELECT page revision
#    7 0xSANITIZED         44.0751  3.3%    6925 0.0064  0.07 SELECT page categorylinks
category
#    8 0xSANITIZED         35.0655  2.7%    9689 0.0036  0.00 SELECT text
#    9 0xSANITIZED         29.4363  2.2%  152259 0.0002  0.00 SELECT page
#   10 0xSANITIZED         24.1864  1.8%  176927 0.0001  0.00 SELECT msg_resource
#   11 0xSANITIZED         23.7016  1.8%  144807 0.0002  0.00 SELECT page_restrictions
#   12 0xSANITIZED         16.6547  1.3%   10135 0.0016  0.03 SELECT revision
#   13 0xSANITIZED         15.0564  1.1%  263809 0.0001  0.00 SET
```

pt-query-digest Execution (III)

```
# Query 1: 7.93 QPS, 0.00x concurrency, ID 0xSANITIZED at byte 1553864032
# This item is included in the report because it matches -limit.
# Scores: V/M = 0.00
# Time range: 2015-06-30 07:00:10 to 2015-07-01 07:11:37
# Attribute    pct   total     min     max     avg     95%  stddev  median
# ============ === ======= ======= ======= ======= ======= ======= =======
# Count         14  691005
# Exec time     18    242s   163us    91ms   350us   348us   563us   301us
# Lock time     26     63s    47us     7ms    91us   103us    14us    84us
# Rows sent     12 657.18k       0       1    0.97    0.99    0.16    0.99
# Rows examine   6 657.18k       0       1    0.97    0.99    0.16    0.99
# Query size    31 345.42M     501     749  524.16  537.02    9.22  511.45
# String:
# Databases    itwiki (225976/32%), enwiktiona... (219461/31%)... 15 more
# Hosts
# Users        wikiuser
# Query_time distribution
#   1us
#  10us
# 100us  ################################################################
#   1ms  #
#  10ms  #
# 100ms
#    1s
#  10s+
# Tables
#    SHOW TABLE STATUS FROM `enwiktionary` LIKE 'revision'\G
#    SHOW CREATE TABLE `enwiktionary`.`revision`\G
#    SHOW TABLE STATUS FROM `enwiktionary` LIKE 'page'\G
#    SHOW CREATE TABLE `enwiktionary`.`page`\G
#    SHOW TABLE STATUS FROM `enwiktionary` LIKE 'user'\G
#    SHOW CREATE TABLE `enwiktionary`.`user`\G
# EXPLAIN /*!50100 PARTITIONS*/
SELECT /* Revision::fetchFromConds SANITIZED */ * FROM `revision`
INNER JOIN `page` ON ((page_id = rev_page)) LEFT JOIN `user` ON
((rev_user != 0) AND (user_id = rev_user))  WHERE page_namespace = '0' AND
page_title = 'SANITIZED' AND (rev_id=page_latest)  LIMIT 1\G
```

PERFORMANCE_SCHEMA

- Monitoring schema (engine) enabled by default since MySQL 5.6
  - performance_schema = 1 (it is not dynamic)
- Deprecates the old query profiling
- It is way more user-friendly when combined with the SYS schema/ps_helper (a set of views and stored procedures created by Mark Leith)
  - Included by default since 5.7.7

Installation of the SYS Schema for 5.6/MariaDB

```
$ git clone https://github.com/MarkLeith/mysql-sys.git
Cloning into 'mysql-sys'...
remote: Counting objects: 926, done.
remote: Compressing objects: 100% (73/73), done.
remote: Total 926 (delta 35), reused 6 (delta 2)
Receiving objects: 100% (926/926), 452.19 KiB | 225.00
KiB/s, done.
Resolving deltas: 100% (584/584), done.
$ cd mysql-sys/
$ ~/sandboxes/msb_5_6_24/use < sys_56.sql
```

Example Usage: Discovering Unused Indexes

```
mysql-5.7.8 (osm) > SELECT * FROM sys.schema_unused_indexes LIMIT 5;
+---------------+-------------------+--------------------------------+
| object_schema | object_name       | index_name                     |
+---------------+-------------------+--------------------------------+
| osm           | acls              | acls_k_idx                     |
| osm           | changeset_tags    | changeset_tags_id_idx          |
| osm           | current_nodes     | current_nodes_timestamp_idx    |
| osm           | current_nodes     | current_nodes_tile_idx         |
| osm           | current_relations | current_relations_timestamp_idx |
+---------------+-------------------+--------------------------------+
5 rows in set (0.04 sec)

mysql-5.7.8 (osm) > SELECT * FROM current_nodes WHERE tile = 100;
...

mysql-5.7.8 (osm) > SELECT * FROM sys.schema_unused_indexes LIMIT 5;
+---------------+-------------------+--------------------------------+
| object_schema | object_name       | index_name                     |
+---------------+-------------------+--------------------------------+
| osm           | acls              | acls_k_idx                     |
| osm           | changeset_tags    | changeset_tags_id_idx          |
| osm           | current_nodes     | current_nodes_timestamp_idx    |
| osm           | current_relations | current_relations_timestamp_idx |
| osm           | current_relations | changeset_id                   |
+---------------+-------------------+--------------------------------+
5 rows in set (0.03 sec)
```

Example Usage: Slow Queries (ordered by server time)

```
mysql-5.7.8 (osm) > SELECT * FROM sys.statement_analysis LIMIT 10\G
*************** 1. row ***************
           query: SELECT `way_id` AS
`id` , `v` FROM `way_tags` WHERE `v` LIKE ?
              db: osm
       full_scan: *
      exec_count: 15
       err_count: 0
      warn_count: 0
   total_latency: 7.83 s
     max_latency: 1.33 s
     avg_latency: 521.84 ms
    lock_latency: 17.94 ms
       rows_sent: 6779
   rows_sent_avg: 452
   rows_examined: 20152155
rows_examined_avg: 1343477
   rows_affected: 0
rows_affected_avg: 0
      tmp_tables: 0
 tmp_disk_tables: 0
     rows_sorted: 0
sort_merge_passes: 0
          digest:
21f90695b1ebf20a5f4d4c1e5e860f58
      first_seen: 2014-11-01 17:04:51
       last_seen: 2014-11-01 17:05:22
```

Example Usage: Top Queries Creating Temporary Tables

```
mysql-5.7.8 (osm) > SELECT * FROM
sys.statements_with_temp_tables WHERE db = 'osm' LIMIT 10\G
*************************** 1. row ***************************
                   query: SELECT ? AS TYPE , `node_id` A ... gs` WHERE `k` = ? AND `v` = ?
                      db: osm
              exec_count: 11
           total_latency: 7.57 s
       memory_tmp_tables: 11
         disk_tmp_tables: 0
avg_tmp_tables_per_query: 1
  tmp_tables_to_disk_pct: 0
              first_seen: 2014-11-01 17:33:55
               last_seen: 2014-11-01 17:34:45
                  digest: 5e6e82799b7c7c0e5c57cfe63eb98d5d
```

Example Usage: Top Queries Creating Temporary Tables (cont.)

```
mysql-5.7.8 (osm) > SELECT DIGEST_TEXT FROM performance_schema.events_statements_summary_by_digest
WHERE digest = '5e6e82799b7c7c0e5c57cfe63eb98d5d'\G
*************************** 1. row ***************************
DIGEST_TEXT: SELECT ? AS TYPE , `node_id` AS `id` FROM `node_tags` WHERE `k` = ? AND `v` = ? UNION
SELECT ? AS TYPE , `way_id` AS `id` FROM `way_tags` WHERE `k` = ? AND `v` = ? UNION SELECT ? AS
TYPE , `relation_id` AS `id` FROM `relation_tags` WHERE `k` = ? AND `v` = ?
1 row in set (0.00 sec)

mysql-5.7.8 (osm) > EXPLAIN SELECT 'node' as type, node_id as id FROM node_tags WHERE k='amenity'
and v='cafe' UNION SELECT 'way' as type, way_id as id FROM way_tags WHERE k='amenity' and v='cafe'
UNION SELECT 'relation' as type, relation_id as id FROM relation_tags WHERE k='amenity' and
v='cafe';
+----+--------------+---------------+------------+------+---------------+------+---------+------+---------+----------+-----------------+
| id | select_type  | table         | partitions | type | possible_keys | key  | key_len | ref  | rows    | filtered | Extra           |
+----+--------------+---------------+------------+------+---------------+------+---------+------+---------+----------+-----------------+
|  1 | PRIMARY      | node_tags     | NULL       | ALL  | NULL          | NULL | NULL    | NULL |  851339 |     0.00 | Using where     |
|  2 | UNION        | way_tags      | NULL       | ALL  | NULL          | NULL | NULL    | NULL | 1331016 |     0.00 | Using where     |
|  3 | UNION        | relation_tags | NULL       | ALL  | NULL          | NULL | NULL    | NULL |   63201 |     0.00 | Using where     |
| NULL | UNION RESULT | <union1,2,3>  | NULL       | ALL  | NULL          | NULL | NULL    | NULL |    NULL |     NULL | Using temporary |
+----+--------------+---------------+------------+------+---------------+------+---------+------+---------+----------+-----------------+
4 rows in set, 1 warning (0.01 sec)
```

Query Optimization: From 0 to 10 (and up to 5.7)

GENERAL OPTIMIZER IMPROVEMENTS

EXPLAIN FOR CONNECTION (SHOW EXPLAIN FOR)

```
mysql 5.7.8 > SHOW PROCESSLIST;
+----+----------+-----------+-------------+---------+------+----------
+-------------------------------------------------------------------------------------------------------------------+
| Id | User     | Host      | db          | Command | Time | State    | Info
                                                                                                                    |
+----+----------+-----------+-------------+---------+------+----------
+-------------------------------------------------------------------------------------------------------------------+
|  4 | msandbox | localhost | NULL        | Query   |    1 | starting | SHOW PROCESSLIST
                                                                                                                    |
|  8 | msandbox | localhost | nlwiktionary | Query   |    6 | update   | INSERT INTO `pagel
(74239,0,0,'WikiWoordenboek:Genus'),(74240,0,0,'WikiWoordenboek:Genus |
+----+----------+-----------+-------------+---------+------+----------
+-------------------------------------------------------------------------------------------------------------------+
2 rows in set (0.14 sec)

mysql 5.7.8 > EXPLAIN FOR CONNECTION 8;
+----+-------------+-----------+------------+------+---------------+------+---------+------+------+----------+-------+
| id | select_type | table     | partitions | type | possible_keys | key  | key_len | ref  | rows | filtered | Extra |
+----+-------------+-----------+------------+------+---------------+------+---------+------+------+----------+-------+
|  1 | INSERT      | pagelinks | NULL       | ALL  | NULL          | NULL | NULL    | NULL | NULL |     NULL | NULL  |
+----+-------------+-----------+------------+------+---------------+------+---------+------+------+----------+-------+
1 row in set (0.03 sec)
```

Use “SHOW EXPLAIN FOR #” with MariaDB 10

MySQL 5.7 Optimizer Tweaks

```
mysql-5.5.40 (osm) > SELECT *
                       FROM nodes
                       JOIN node_tags
                         ON node_tags.node_id = nodes.node_id
                      WHERE nodes.latitude
                            BETWEEN 517000000 and 520000000\G
59 rows in set (1.37 sec)
mysql-5.5.40 (osm) > SELECT STRAIGHT_JOIN *
                       FROM nodes
                       JOIN node_tags
                         ON node_tags.node_id =
                      WHERE nodes.latitude
                            BETWEEN 517000000 and 52
59 rows in set (0.86 sec)
```

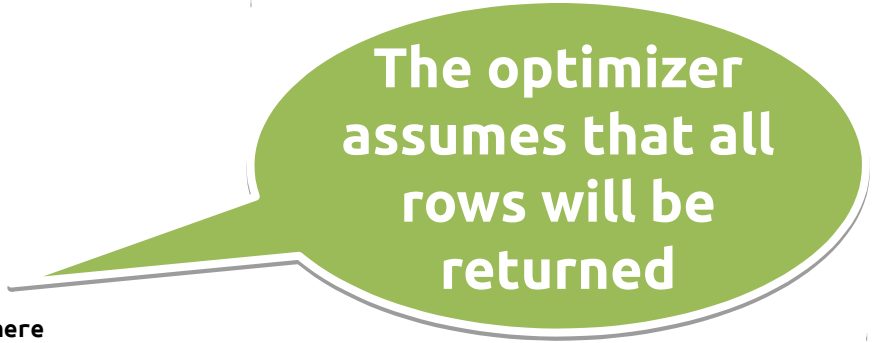
This condition is very selective, but there is no index available

Why does it take the wrong table order?

```
mysql-5.5.40 (osm) > EXPLAIN EXTENDED SELECT * FROM nodes JOIN node_tags ON node_tags.node_id = nodes.node_id WHERE
nodes.latitude BETWEEN 517000000 and 520000000\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: node_tags
         type: ALL
possible_keys: PRIMARY
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 839031
     filtered: 100.00
        Extra:
*************************** 2. row ***************************
           id: 1
  select_type: SIMPLE
        table: nodes
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 8
          ref: osm.node_tags.node_id
         rows: 1
     filtered: 100.00
        Extra: Using where
2 rows in set, 1 warning (0.00 sec)
```

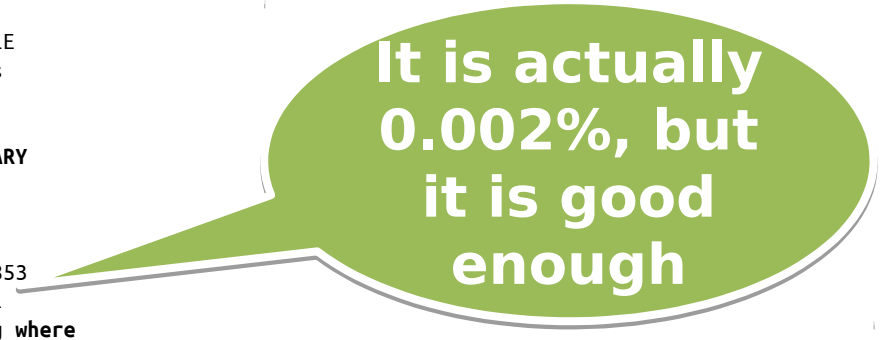
Unindexed Columns Are not Accounted

```
mysql-5.5.40 (osm) > EXPLAIN EXTENDED SELECT STRAIGHT_JOIN * FROM nodes JOIN node_tags ON node_tags.node_id = nodes.node_id
WHERE nodes.latitude BETWEEN 517000000 and 520000000\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: nodes
         type: ALL
possible_keys: PRIMARY
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 2865521
     filtered: 100.00
        Extra: Using where
*************************** 2. row ***************************
           id: 1
  select_type: SIMPLE
        table: node_tags
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 8
          ref: osm.nodes.node_id
         rows: 1
     filtered: 100.00
        Extra:
2 rows in set, 1 warning (0.00 sec)
```



What's new in 5.7?

```
mysql-5.7.5 (osm) > EXPLAIN SELECT * FROM nodes JOIN node_tags ON node_tags.node_id = nodes.node_id WHERE nodes.latitude BETWEEN 517000000 and
520000000\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: nodes
   partitions: NULL
         type: ALL
possible_keys: PRIMARY
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 2773853
     filtered: 11.11
        Extra: Using where
*************************** 2. row ***************************
           id: 1
  select_type: SIMPLE
        table: node_tags
   partitions: NULL
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 8
          ref: osm.nodes.node_id
         rows: 3
     filtered: 100.00
        Extra: NULL
2 rows in set, 1 warning (0.00 sec)
```



If things go wrong -our Friend optimizer_switch

```
mysql-5.7.8 (osm) > SET optimizer_switch='condition_fanout_filter=off';
Query OK, 0 rows affected (0.00 sec)
```

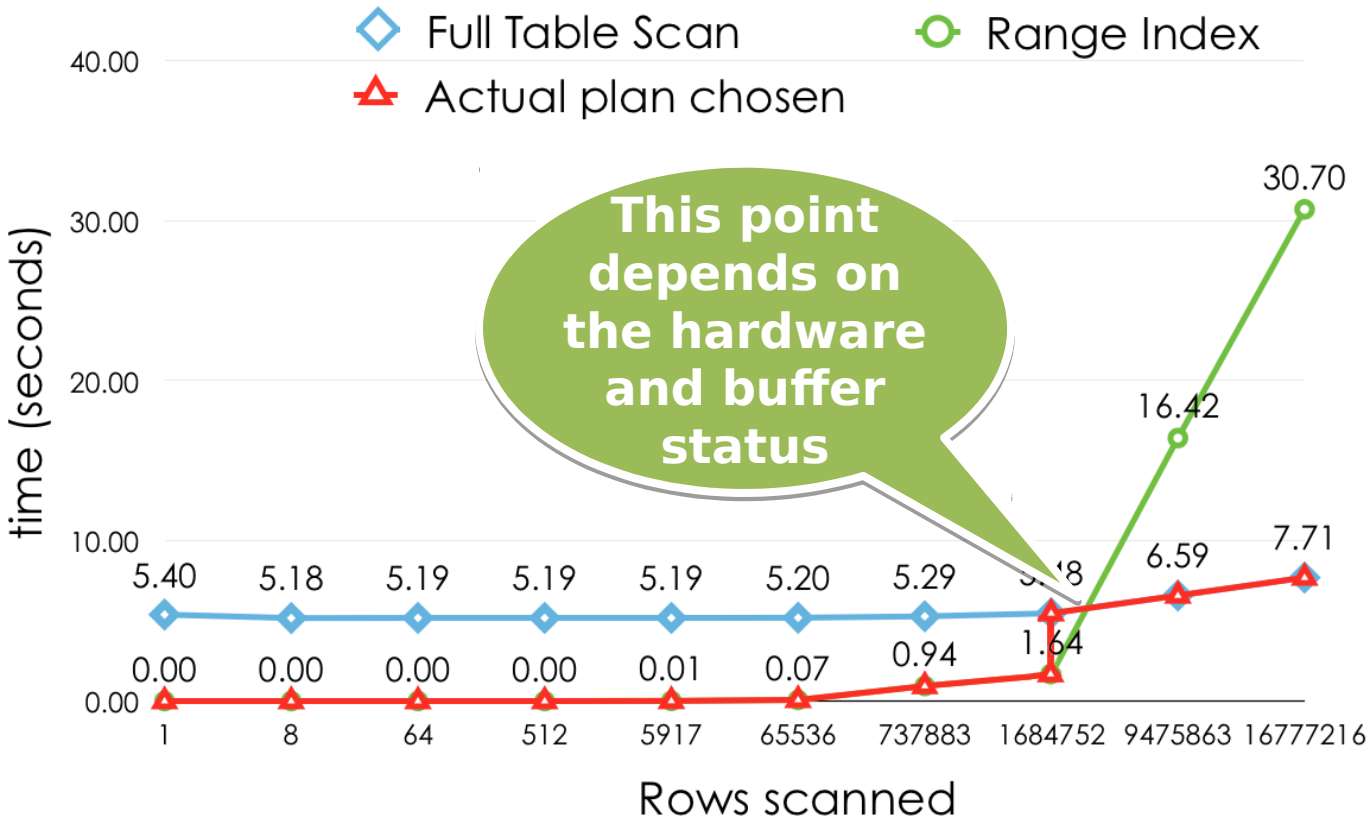
Improved EXPLAIN FORMAT=JSON

```
"nested_loop": [
      {
        "table": {
          "table_name": "nodes",
          "access_type": "ALL",
          "possible_keys": [
            "PRIMARY"
          ],
          "rows_examined_per_scan": 2773853,
          "rows_produced_per_join": 308175,
          "filtered": 11.11,
          "cost_info": {
            "read_cost": "512783.58",
            "eval_cost": "61635.01",
            "prefix_cost": "574418.60",
            "data_read_per_join": "21M"
          },
```

Cost information is now included

Engine statistics are now floats for improved precision

Optimizer Cost Tuning



Configurable Costs

```
mysql 5.7.8> SELECT * FROM mysql.server_cost;
+------------------------------+------------+---------------------+---------+
| cost_name                    | cost_value | last_update         | comment |
+------------------------------+------------+---------------------+---------+
| disk_temptable_create_cost   |       NULL | 2015-09-20 20:48:10 | NULL    |
| disk_temptable_row_cost      |       NULL | 2015-09-20 20:48:10 | NULL    |
| key_compare_cost             |       NULL | 2015-09-20 20:48:10 | NULL    |
| memory_temptable_create_cost |       NULL | 2015-09-20 20:48:10 | NULL    |
| memory_temptable_row_cost    |       NULL | 2015-09-20 20:48:10 | NULL    |
| row_evaluate_cost            |       NULL | 2015-09-20 20:48:10 | NULL    |
+------------------------------+------------+---------------------+---------+
6 rows in set (0.00 sec)
```

The unit is "read of a random data page"

```
mysql 5.7.8> SELECT * FROM mysql.engine_cost;
+-------------+-------------+------------------------+------------+---------------------+---------+
| engine_name | device_type | cost_name              | cost_value | last_update         | comment |
+-------------+-------------+------------------------+------------+---------------------+---------+
| default     |           0 | io_block_read_cost     |       NULL | 2015-09-20 20:48:10 | NULL    |
| default     |           0 | memory_block_read_cost |       NULL | 2015-09-20 20:48:10 | NULL    |
+-------------+-------------+------------------------+------------+---------------------+---------+
2 rows in set (0.00 sec)
```

Changing Costs Example

```
mysql-5.7.5 (osm) > EXPLAIN FORMAT=JSON SELECT 'node' as type, node_id as id FROM
node_tags WHERE k='amenity' and v='cafe' UNION SELECT 'way' as type, way_id as id FROM
way_tags WHERE k='amenity' and v='cafe' UNION SELECT 'relation' as type, relation_id as
id FROM relation_tags WHERE k='amenity' and v='cafe'\G
            "cost_info": {
              "query_cost": "22567.80"
1 row in set, 1 warning (0.00 sec)
mysql-5.7.5 (osm) > UPDATE mysql.server_cost SET cost_value = 10;
mysql-5.7.5 (osm) > FLUSH OPTIMIZER_COSTS;
<session restart>
mysql-5.7.5 (osm) > EXPLAIN ...\G
            "cost_info": {
              "query_cost": "661371.00"
1 row in set, 1 warning (0.00 sec)
```

More info on usage in the manual: http://dev.mysql.com/doc/refman/5.7/en/cost-model.html

Still waiting for...

- Utility to analyze the underlying technology (HD, SSD, memory) and filling up the tables automatically
- Buffer “hotness”-aware statistics
- Statistics for non-indexed columns/histograms
  - MariaDB has histograms since 10

Engine-Independent Statistics/Histograms in MariaDB 10

```
mariadb-10.0.14 (osm) > SET histogram_size = 255;
Query OK, 0 rows affected (0.00 sec)

mariadb-10.0.14 (osm) > SET use_stat_tables = 2;
Query OK, 0 rows affected (0.01 sec)

mariadb-10.0.14 (osm) > ANALYZE TABLE node_tags;
+---------------+---------+----------+----------------------------------------+
| Table         | Op      | Msg_type | Msg_text                               |
+---------------+---------+----------+----------------------------------------+
| osm.node_tags | analyze | status   | Engine-independent statistics collected |
| osm.node_tags | analyze | status   | OK                                     |
+---------------+---------+----------+----------------------------------------+
2 rows in set (3.01 sec)

mariadb-10.0.14 (osm) > ANALYZE TABLE nodes;
+-----------+---------+----------+----------------------------------------+
| Table     | Op      | Msg_type | Msg_text                               |
+-----------+---------+----------+----------------------------------------+
| osm.nodes | analyze | status   | Engine-independent statistics collected |
| osm.nodes | analyze | status   | OK                                     |
+-----------+---------+----------+----------------------------------------+
2 rows in set (32.52 sec)

mariadb-10.0.14 (osm) > SET optimizer_use_condition_selectivity = 3; (or 4 for histograms)
Query OK, 0 rows affected (0.00 sec)
```

Better Stats!

```
mariadb-10.0.14 (osm) > EXPLAIN EXTENDED SELECT * FROM nodes JOIN node_tags ON node_tags.node_id = nodes.node_id WHERE
nodes.latitude BETWEEN 517000000 and 520000000\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: nodes
         type: ALL
possible_keys: PRIMARY
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 2865312
     filtered: 0.39
        Extra: Using where
*************************** 2. row ***************************
           id: 1
  select_type: SIMPLE
        table: node_tags
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 8
          ref: osm.nodes.node_id
         rows: 3
     filtered: 100.00
        Extra:
2 rows in set, 1 warning (0.01 sec)
```

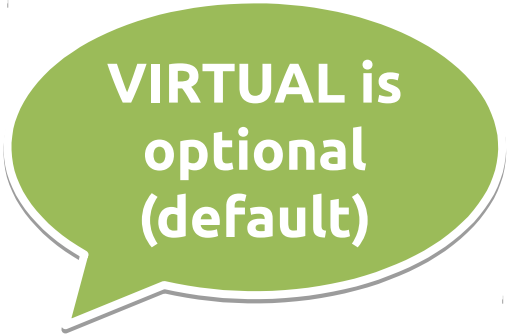
Other Changes/Bugs Fixed

- UNION ALL does not create temporary tables, returns tables faster
- (a, b) IN ((1, 2), (2, 3)) can use index ranges
- EXPLAIN EXTENDED is now the default behavior
- I.C. Pushdown support for partitioned tables
- IGNORE clause meaning has been standardized between sentence types
- Increased default for optimizer_search_depth

Query Optimization: From 0 to 10 (and up to 5.7)

COMPUTED/VIRTUAL COLUMNS

Syntax




```
ALTER TABLE nodes
  ADD COLUMN lon DECIMAL (10, 7)
    as (longitude/10000000) VIRTUAL,
  ADD COLUMN lat DECIMAL (9, 7)
    as (latitude/10000000) VIRTUAL;
```

- They can be used to simplify SELECTS, calculating values on the fly
- Non accessed rows are not calculated

Functional Indexes

- Before 5.7.8:

```
mysql-5.7.5 (osm) > ALTER TABLE nodes add index(lon);
ERROR 1951 (HY000): Key/Index cannot be defined on a non-
stored virtual column.
```

- Now:

```
mysql-5.7.8 (osm) > ALTER TABLE nodes add index(lon);
Query OK, 0 rows affected (16.54 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

  - This effectively is an implementation of functional indexes, allowing to solve previous query optimization issues without the overhead of an extra column

Do you remember this query?

```
MariaDB [nlwiktionary]> EXPLAIN SELECT * FROM revision WHERE
substr(rev_timestamp, 5, 2) = '09'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         Rows: 173154
        Extra: Using where
1 row in set (0.00 sec)
```

Now we can solve it like this

```
mysql-5.7.8> ALTER TABLE revision ADD COLUMN rev_month tinyint AS
(substr(rev_timestamp, 5, 2)) VIRTUAL, ADD INDEX rev_month (rev_month);
Query OK, 820308 rows affected (3 min 29.48 sec)
Records: 820308  Duplicates: 0  Warnings: 0

mysql-5.7.8> EXPLAIN SELECT * FROM revision WHERE rev_month = 9\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
   partitions: NULL
         type: ref
possible_keys: rev_month
          key: rev_month
      key_len: 2
          ref: const
         rows: 104112
     filtered: 100.00
        Extra: NULL
1 row in set, 1 warning (0.01 sec)
```

Stored Columns

```
mysql-5.7.8 (osm) > ALTER TABLE nodes CHANGE lat lat DECIMAL (9, 7) as
(latitude/10000000) STORED;
ERROR 1954 (HY000): 'Changing the STORED status' is not supported for virtual
columns.
```

They dropped the 'yet' :-)

```
mysql-5.7.8 (osm) > ALTER TABLE nodes DROP COLUMN lat, ADD COLUMN lat DECIMAL
(9, 7) as (latitude/10000000) STORED;
Query OK, 2865312 rows affected (4 min 51.05 sec)
Records: 2865312 Duplicates: 0 Warnings: 0
```

MariaDB uses the 'PERMANENT' keyword

Features and Limitations

- ~~Virtual “non-stored” columns cannot be indexed~~
- “Stored columns” can be PRIMARY, UNIQUE, FOREIGN and MULTI keys
- It cannot contain subqueries or other tables or rows references
- It cannot contain used-defined stored functions
- It can contain server and user-defined variables
- It can be computed based on other virtual columns

Query Optimization: From 0 to 10 (and up to 5.7)

QUERY REWRITE PLUGINS

New APIs for Query Rewriting

- One for pre-parsing rewriting
- Another for post-parsing rewriting

Example Plugin Installation

```
$ ~/sandboxes/msb_5_7_8/my sql <
./share/install_rewriter.sql
```

More on this: http://mysqlserverteam.com/the-query-rewrite-plugins/

Query Rewriting Setup

```
mysql-5.7.8 > INSERT INTO query_rewrite.rewrite_rules (pattern, replacement) VALUES ('SELECT ?', 'SELECT ?
+ 1');
Query OK, 1 row affected (0.01 sec)

mysql-5.7.8 > CALL query_rewrite.flush_rewrite_rules();
Query OK, 0 rows affected (0.01 sec)

mysql-5.7.8 > SELECT 1;
+-------+
| 1 + 1 |
+-------+
|     2 |
+-------+
1 row in set, 1 warning (0.00 sec)

mysql-5.7.8 > SHOW WARNINGS;
+-------+------+-----------------------------------------------------------------------+
| Level | Code | Message                                                               |
+-------+------+-----------------------------------------------------------------------+
| Note  | 1105 | Query 'SELECT 1' rewritten to 'SELECT 1 + 1' by a query rewrite plugin |
+-------+------+-----------------------------------------------------------------------+
1 row in set (0.00 sec)
```

Considerations

- It cannot correct malformed queries- pattern and replacement must be syntactically correct
- Useful for query optimizations for 3rd party applications
- User is notified that a rewrite happened with a note-level message
- Low overhead (5%); specially for untouched queries
- You can do stupid things like:

```
mysql-5.7.5 ((none)) > INSERT INTO
query_rewrite.rewrite_rules( pattern, replacement ) VALUES
( 'SELECT 1', 'DROP TABLE test.test' );
Query OK, 1 row affected (0.01 sec)
```

Query Optimization: From 0 to 10 (and up to 5.7)

OPTIMIZER HINTS

New functionality since 5.7.7

- MySQL accepts hints for query execution with the syntax /*+... */:

```
mysql-5.7.8> EXPLAIN SELECT /*+ NO_ICP(revision)*/ * FROM revision WHERE rev_comment like
'jaime%' AND rev_timestamp > '2008'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: revision
   partitions: NULL
         type: range
possible_keys:
rev_timestamp,rev_timestamp_rev_page,rev_timestamp_2,rev_comment_rev_timestamp
          key: rev_comment_rev_timestamp
      key_len: 783
          ref: NULL
         rows: 1
     filtered: 50.00
        Extra: Using where
1 row in set, 1 warning (0.00 sec)
```

More info on this feature:
https://www.percona.com/blog/2015/04/30/optimizer-hints-mysql-5-7-7-missed-manual/

Syntax

- The syntax is identical to the one Oracle Database uses, but does not deprecate yet the old hint syntax (USE INDEX, STRAIGHT_JOIN, ...)
  - “planned”
- It has some overlap with optimizer_switch
  - Although it has lower granularity (table instead of statement)

Max Query Execution

- Indicate it in miliseconds:

```
mysql-5.7.8 > SELECT /*+ MAX_EXECUTION_TIME(1784)*/ SLEEP(10)\G
*************************** 1. row ***************************
SLEEP(2000): 1
1 row in set (1.78 sec)
```

- `max_statement_time` syntax and variable seems to have been removed since 5.7.8

Other hints

- BKA / NO_BKA
- BNL / NO_BNL
- MRR / NO_MRR
- NO_ICP
- NO_RANGE_OPTIMIZATION
- QB_NAME (controlls the query block where to apply the hint to)

Query Optimization: From 0 to 10 (and up to 5.7)

SQL MODE CHANGES

Default SQL Mode Changes

- MySQL 5.5 and earlier
  - `''`
- MySQL 5.6 (from 5.6.6):
  - **`'NO_ENGINE_SUBSTITUTION'`** is the default
  - `NO_ENGINE_SUBSTITUTION` and `STRICT_TRANS_TABLES` were suggested in upstream default my.cnf
- MySQL 5.7 (from 5.7.5):
  - **`'ONLY_FULL_GROUP_BY,STRICT_TRANS_TABLES,NO_ENGINE_SUBSTITUTION'`** is the new default

More on this: http://www.tocker.ca/2014/01/14/making-strict-sql_mode-the-default.html

Stricter Defaults

```
mysql> CREATE TABLE `test` (
  `id` int(11) NOT NULL,
  `type` enum('movie','album','videogame') NOT NULL,
  `date` datetime NOT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB;

mysql> INSERT INTO test (type, date) VALUES ('tv show', -1);
```

MySQL 5.5/5.6 with default settings

```
mysql> INSERT INTO test (type, date) VALUES ('tv show', -1);
Query OK, 1 row affected, 3 warnings (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+-----------------------------------------------+
| Level   | Code | Message                                       |
+---------+------+-----------------------------------------------+
| Warning | 1364 | Field 'id' doesn't have a default value       |
| Warning | 1265 | Data truncated for column 'type' at row 1     |
| Warning | 1264 | Out of range value for column 'date' at row 1 |
+---------+------+-----------------------------------------------+
3 rows in set (0.00 sec)

mysql> SELECT * FROM test;
+----+------+---------------------+
| id | type | date                |
+----+------+---------------------+
|  0 |      | 0000-00-00 00:00:00 |
+----+------+---------------------+
1 row in set (0.00 sec)
```

MySQL 5.7

```
mysql> INSERT INTO test (type, date) VALUES ('tv show', -1);
ERROR 1265 (01000): Data truncated for column 'type' at row 1

mysql> INSERT INTO test (type, date) VALUES ('videogame', -1);
ERROR 1292 (22007): Incorrect datetime value: '-1' for column 'date' at row
1

mysql> INSERT INTO test (type, date) VALUES ('movie', now());
ERROR 1364 (HY000): Field 'id' doesn't have a default value

mysql> INSERT INTO test (id, type, date) VALUES (1, 'videogame', now());
Query OK, 1 row affected (0.01 sec)
```

GROUP BY Behavior Changes

```
mysql-5.6.21 (osm) > SELECT way_id, count(*), node_id
                     FROM way_nodes
                     GROUP BY way_id
                     ORDER BY count(*) DESC
                     LIMIT 10;
+-----------+----------+------------+
| way_id    | count(*) | node_id    |
+-----------+----------+------------+
| 155339744 |     1187 | 1558095871 |
| 243986064 |     1156 | 2604713337 |
|  87136668 |     1128 | 1013304944 |
| 148812873 |      852 | 1618837453 |
| 149200774 |      835 |   34921158 |
| 183618216 |      826 | 1940223096 |
| 273858696 |      824 | 1267549776 |
| 261584374 |      770 | 2669122104 |
| 227880171 |      704 | 2240011804 |
| 193564006 |      684 | 1808872763 |
+-----------+----------+------------+
10 rows in set (1.24 sec)
```

With ONLY_FULL_GROUP_BY (default in 5.7)

```
mysql-5.7.5 (osm) > SELECT way_id, count(*), node_id
                    FROM way_nodes
                    GROUP BY way_id
                    ORDER BY count(*) DESC
                    LIMIT 10;
ERROR 1055 (42000): Expression #3 of SELECT list is not in GROUP
BY clause and contains nonaggregated column
'osm.way_nodes.node_id' which is not functionally dependent on
columns in GROUP BY clause; this is incompatible with
sql_mode=only_full_group_by
```

Problem with ONLY_FULL_GROUP_BY in MySQL <= 5.6

```
mysql-5.6.21 (osm) > SET SQL_mode='ONLY_FULL_GROUP_BY';
Query OK, 0 rows affected (0.00 sec)

mysql-5.6.21 (osm) > SELECT
                         u.id as `user id`,
                         u.display_name as `user name`,
                         count(*) as `# changesets`
                     FROM users u
                     JOIN changesets c
                       ON u.id = c.user_id
                     GROUP BY u.id
                     ORDER BY count(*) DESC
                     LIMIT 10;
ERROR 1055 (42000): 'osm.u.display_name' isn't in GROUP BY
```

More on this: http://rpbouman.blogspot.com/2014/09/mysql-575-group-by-respects-functional.html

5.7 Aims for SQL99 Compliance

```
mysql-5.7.5 (osm) > SELECT u.id as `user id`, u.display_name as `user
name`, count(*) as `# changesets` FROM users u JOIN changesets c ON u.id =
c.user_id GROUP BY u.id ORDER BY count(*) DESC LIMIT 10;
+---------+---------------+--------------+
| user id | user name     | # changesets |
+---------+---------------+--------------+
|   31257 | Ed Avis       |         4333 |
|     508 | Welshie       |         2696 |
| 1016290 | Amaroussi     |         2351 |
|  352985 | ecatmur       |         1450 |
|  142807 | SDavies       |         1342 |
|     736 | Steve Chilton |         1182 |
|     346 | Tom Chance    |         1175 |
|   38784 | Tom Morris    |         1165 |
|   88718 | UrbanRambler  |         1151 |
|    1611 | Harry Wood    |         1091 |
+---------+---------------+--------------+
10 rows in set (0.09 sec)
```

Backward Compatibility

- Some ORMs and frameworks change the default SQL Mode:
  - Ruby on Rails 4+ sets STRICT_ALL_TABLES
  - Drupal 7+ sets TRADITIONAL
  - Mediawiki will set TRADITIONAL, ONLY_FULL_GROUP_BY
- Other applications do not work in standard-compliance modes:
  - Wordpress used to not work in strict mode (fixed): http://www.xaprb.com/blog/2013/03/15/wordpress-and-mysqls-strict-mode/
  - Cacti does not work with ONLY_FULL_GROUP_BY,NO_ZERO_DATE

Deprecated Modes

- `ERROR_FOR_DIVISION_BY_ZERO`, `NO_ZERO_DATE`, and `NO_ZERO_IN_DATE` are deprecated and do nothing
  - Use `STRICT_TRANS_TABLES` or `STRICT_ALL_TABLES`, which include those modes and produce an error

Query Optimization: From 0 to 10 (and up to 5.7)

GIS IMPROVEMENTS & JSON TYPES

Find the Closest Starbucks

```
mysql-5.7.5 (osm) > SET @lat:=51.49353; SET @lon:=-0.18340;
mysql-5.7.5 (osm) > SELECT n.node_id,
                          n.longitude/10000000 as longitude,
                          n.latitude/10000000 as latitude,
                          sqrt(pow((latitude/10000000 - @lat) * 111257.67, 2
                               pow((longitude/10000000 - @lon) * 69450.32, 2)
                          as `distance in metres`
                    FROM nodes n
                    JOIN node_tags n_t1
                      ON n.node_id = n_t1.node_id
                    JOIN node_tags n_t2
                      ON n.node_id = n_t2.node_id
                   WHERE
                          n_t1.k = 'amenity' and
                          n_t1.v = 'cafe' and
                          n_t2.k = 'name' and
                          n_t2.v = 'Starbucks'
                ORDER BY `distance in metres` ASC
                   LIMIT 1;
+-----------+-----------+----------+--------------------+
| node_id   | longitude | latitude | distance in metres |
+-----------+-----------+----------+--------------------+
| 699693936 |   -0.1823 |  51.4945 |  130.9792513096838 |
+-----------+-----------+----------+--------------------+
1 row in set (0.20 sec)
```

This Query is Slow

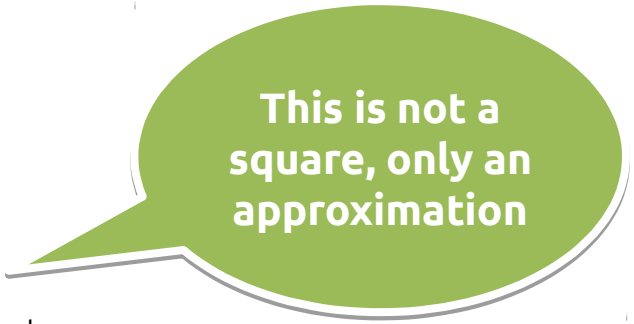
```
mysql-5.7.5 (osm) > EXPLAIN SELECT n.node_id,
n.longitude/10000000 as longitude,
n.latitude/10000000 as latitude,
sqrt(pow((latitude/10000000-@lat)*111257.67, 2) +
pow((longitude/10000000-@lon)*69450.32, 2)) as
`distance in metres` FROM nodes n JOIN node_tags n_t1
ON n.node_id = n_t1.node_id JOIN node_tags n_t2 ON
n.node_id = n_t2.node_id  WHERE n_t1.k = 'amenity'
and n_t1.v = 'cafe' and n_t2.k = 'name' and n_t2.v =
'Starbucks' ORDER BY `distance in metres` ASC LIMIT
1\G
*********************** 1. row ***********************
           id: 1
  select_type: SIMPLE
        table: n_t1
   partitions: NULL
         type: ALL
possible_keys: PRIMARY
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 832040
     filtered: 0.00
        Extra: Using where; Using temporary; Using
file sort
*********************** 2. row ***********************
           id: 1
  select_type: SIMPLE
        table: n_t2
   partitions: NULL
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 8
          ref: osm.n_t1.node_id
         rows: 3
     filtered: 1.41
        extra: Using where
*********************** 3. row ***********************
           id: 1
  select_type: SIMPLE
        table: n
   partitions: NULL
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 8
          ref: osm.n_t1.node_id
         rows: 1
     filtered: 100.00
        Extra: NULL
3 rows in set, 1 warning (0.00 sec)
```

Can We Optimize it?

- We could add a bounding box:

```
mysql-5.7.5 (osm) > ALTER TABLE nodes add index(latitude, longitude);

mysql-5.7.5 (osm) >
       SELECT n.node_id,
       n.longitude/10000000 as longitude,
       n.latitude/10000000 as latitude,
       sqrt(pow((latitude/10000000 - @lat) * 111257.67, 2) +
            pow((longitude/10000000 - @lon) * 69450.32, 2))
            as `distance in metres`
       FROM nodes n
       JOIN node_tags n_t1
           ON n.node_id = n_t1.node_id
       JOIN node_tags n_t2
           ON n.node_id = n_t2.node_id
       WHERE
           n_t1.k = 'amenity' and
           n_t1.v = 'cafe' and
           n_t2.k = 'name' and
           n_t2.v = 'Starbucks' and
           n.latitude BETWEEN ((@lat - 1000/111257.67) * 10000000)
                          AND ((@lat + 1000/111257.67) * 10000000) and
           n.longitude BETWEEN ((@lon - 1000/69450.32) * 10000000)
                          AND ((@lon + 1000/69450.32) * 10000000)
       ORDER BY `distance in metres` ASC
       LIMIT 1;
```



We Create an Index... and Force It

```
mysql-5.7.5 (osm) > EXPLAIN SELECT ...;
+----+-------------+-------+------------+------+----------+-----
| id | select_type | table | partitions | type | possible | k
|    |             |       |            |      | _keys    |
+----+-------------+-------+------------+------+----------+-----
|  1 | SIMPLE      | n_t1  | NULL       | ALL  | PRIMARY  | NUL
|  1 | SIMPLE      | n     | NULL       | ref  | PRIMARY, | PRIMARY | 8    | osm.n_t1.node_id |      1 |     5.00 | Using where      |
|    |             |       |            |      | latitude |         |      |                  |        |          |                  |
|  1 | SIMPLE      | n_t2  | NULL       | ref  | PRIMARY  | PRIMARY | 8    | osm.n_t1.node_id |      3 |     1.41 | Using where      |
+----+-------------+-------+------------+------+----------+---------+------+------------------+--------+----------+------------------+
3 rows in set, 1 warning (0.00 sec)

mysql-5.7.5 (osm) > EXPLAIN SELECT ... FROM nodes n FORCE INDEX(latitude) ...;
+----+-------------+-------+------------+-------+----------+----------+------+--------------+--------+----------+------------------+
| id | select_type | table | partitions | type  | possible | key      | key_ | ref          | rows   | filtered | Extra            |
|    |             |       |            |       | _keys    |          | len  |              |        |          |                  |
+----+-------------+-------+------------+-------+----------+----------+------+--------------+--------+----------+------------------+
|  1 | SIMPLE      | n     | NULL       | range | latitude | latitude | 8    | NULL         | 493666 |    11.11 | Using where;     |
|    |             |       |            |       |          |          |      |              |        |          | Using index;     |
|    |             |       |            |       |          |          |      |              |        |          | Using filesort   |
|  1 | SIMPLE      | n_t1  | NULL       | ref   | PRIMARY  | PRIMARY  | 8    | osm.n.node_id |      3 |     1.41 | Using where      |
|  1 | SIMPLE      | n_t2  | NULL       | ref   | PRIMARY  | PRIMARY  | 8    | osm.n.node_id |      3 |     1.41 | Using where      |
+----+-------------+-------+------------+-------+----------+----------+------+--------------+--------+----------+------------------+
3 rows in set, 1 warning (0.00 sec)

mysql-5.7.5 (osm) > SELECT ... FROM n
+-----------+-----------+----------
| node_id   | longitude | latitude
+-----------+-----------+----------
| 699693936 |   -0.1823 |  51.4
+-----------+-----------+----------
1 row in set (0.09 sec)
```

MySQL ignores the newly created index, why?

Performance improvement is not great

Still many rows are examined

Most of the gain comes from the covering index, not the filtering

Multiple Range Scans Cannot Be Optimized with BTREE Indexes

- We need quadtrees or R-TREE Indexes for indexing in multiple dimensions
  - The later are implemented in MySQL with the name “SPATIAL indexes”, as they only apply to GIS types
- Spatial indexing is available for the first time for InnoDB tables on MySQL 5.7.5

Creating a Spatial Index

```
mysql-5.7.5 (osm) > ALTER TABLE nodes
                    ADD COLUMN coord GEOMETRY NOT NULL;
Query OK, 0 rows affected (21.80 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql-5.7.5 (osm) > UPDATE nodes
                    SET coord = point(longitude/10000000,
                                      latitude/10000000);
Query OK, 2865312 rows affected (34.66 sec)
Rows matched: 2865312  Changed: 2865312  Warnings: 0

mysql-5.7.5 (osm) > ALTER TABLE nodes add SPATIAL
index(coord);
Query OK, 0 rows affected (1 min 50.00 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

New Query

```
mysql> SET @area := envelope(linestring(POINT(@lon - 500/69450.32, @lat - 500/111257.67), POINT(@lon +
500/69450.32, @lat + 500/111257.67)));
```

```
mysql> SELECT n.node_id,
              x(n.coord) as longitude,
              y(n.coord) as latitude,
              st_distance(POINT(@lon, @lat), coord) as distance
       FROM nodes n
       JOIN node_tags n_t1
           ON n.node_id = n_t1.node_id
       JOIN node_tags n_t2
           ON n.node_id = n_t2.node_id
       WHERE
           n_t1.k = 'amenity' and
           n_t1.v = 'cafe' and
           n_t2.k = 'name' and
           n_t2.v = 'Starbucks' and
           st_within(coord, @area)
       ORDER BY st_distance(POINT(@lon, @lat), coord) ASC
       LIMIT 1;
```

Better Performance

mysql-5.7.5 (osm) > SELECT ...;

```
+-----------+------------+------------+-----------------------+
| node_id   | longitude  | latitude   | distance              |
+-----------+------------+------------+-----------------------+
| 699693936 | -0.1822879 | 51.4944808 | 0.0014631428672541478 |
+-----------+------------+------------+-----------------------+
1 row in set (0.02 sec)
```

This field is almost useless

mysql-5.7.5 (osm) > EXPLAIN SELECT ...;

```
+----+--------+-------+-------+-------+----------+---------+------+---------+------+----------+----------------+
| id | select | table | parti | type  | possible | key     | key  | ref     | rows | filtered | Extra          |
|    | _type  |       | tions |       | _keys    |         | _len |         |      |          |                |
+----+--------+-------+-------+-------+----------+---------+------+---------+------+----------+----------------+
|  1 | SIMPLE | n     | NULL  | range | PRIMARY  | coord   | 34   | NULL    |    2 |   100.00 | Using where;   |
|    |        |       |       |       | ,coord   |         |      |         |      |          | Using filesort |
|  1 | SIMPLE | n_t1  | NULL  | ref   | PRIMARY  | PRIMARY | 8    | osm.n.  |    3 |     1.41 | Using where    |
|    |        |       |       |       |          |         |      | node_id |      |          |                |
|  1 | SIMPLE | n_t2  | NULL  | ref   | PRIMARY  | PRIMARY | 8    | osm.n.  |    3 |     1.41 | Using where    |
|    |        |       |       |       |          |         |      | node_id |      |          |                |
+----+--------+-------+-------+-------+----------+---------+------+---------+------+----------+----------------+
3 rows in set, 1 warning (0.00 sec)
```

Better Filtering

mysql-5.7.5 (osm) > SHOW STATUS LIKE 'Hand%';

Not using the index:

Variable_name	Value
Handler_commit	1
Handler_delete	0
Handler_discover	0
Handler_external_lock	6
Handler_mrr_init	0
Handler_prepare	0
Handler_read_first	1
Handler_read_key	1914
Handler_read_last	0
Handler_read_next	1954
Handler_read_prev	0
Handler_read_rnd	1
Handler_read_rnd_next	833426
Handler_rollback	0
Handler_savepoint	0
Handler_savepoint_rollback	0
Handler_update	0
Handler_write	1

18 rows in set (0.00 sec)

Using the BTREE index:

Variable_name	Value
Handler_commit	1
Handler_delete	0
Handler_discover	0
Handler_external_lock	6
Handler_mrr_init	0
Handler_prepare	0
Handler_read_first	0
Handler_read_key	274
Handler_read_last	0
Handler_read_next	**246540**
Handler_read_prev	0
Handler_read_rnd	0
Handler_read_rnd_next	**0**
Handler_rollback	0
Handler_savepoint	0
Handler_savepoint_rollback	0
Handler_update	0
Handler_write	0

18 rows in set (0.00 sec)

Using the SPATIAL index:

Variable_name	Value
Handler_commit	1
Handler_delete	0
Handler_discover	0
Handler_external_lock	6
Handler_mrr_init	0
Handler_prepare	0
Handler_read_first	0
Handler_read_key	522
Handler_read_last	0
Handler_read_next	**5254**
Handler_read_prev	0
Handler_read_rnd	259
Handler_read_rnd_next	**0**
Handler_rollback	0
Handler_savepoint	0
Handler_savepoint_rollback	0
Handler_update	0
Handler_write	0

18 rows in set (0.00 sec)

Geohash Functions

```
mysql-5.7.5 (osm) > SELECT ST_GeoHash(@lon, @lat, 10);
+----------------------------+
| ST_GeoHash(@lon, @lat, 10) |
+----------------------------+
| gcpugy47w3                 |
+----------------------------+
1 row in set (0.00 sec)
```

- Useful to index coordinates with a BTREE
  - It could be specially useful combined with indexed STORED columns (emulating quadtrees)

More on Geohashing: http://mysqlserverteam.com/geohash-functions/

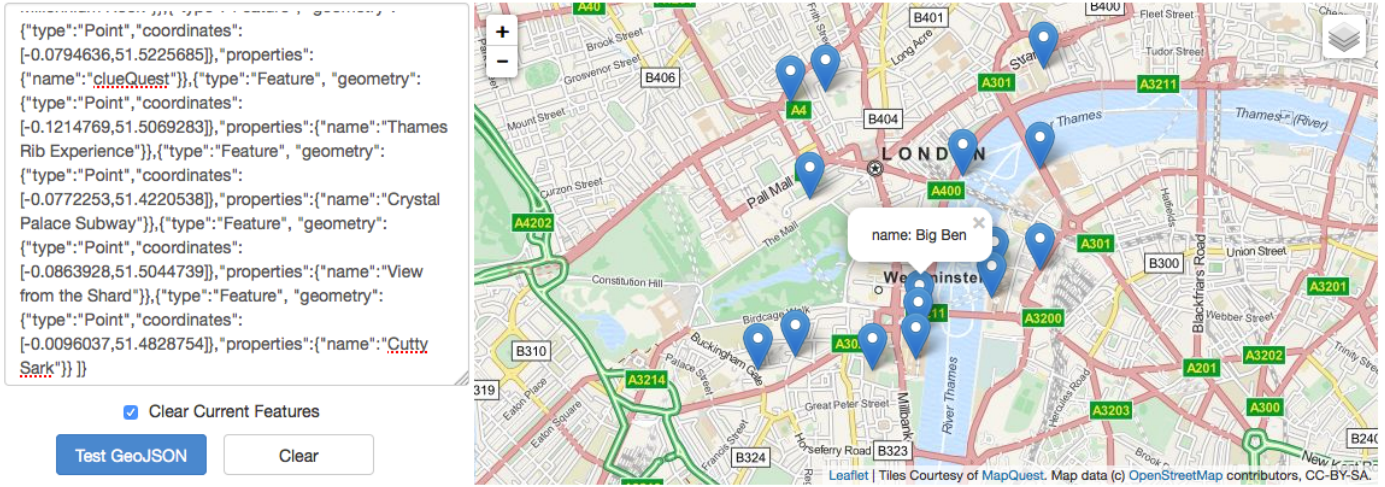
GeoJSON Functions

```
mysql-5.7.5 (osm) > SELECT nm.v, ST_AsGeoJson(n.coord)
                      FROM node_tags n_t
                      JOIN nodes n USING (node_id, version)
                      JOIN node_tags nm USING (node_id, version)
                     WHERE n_t.k='tourism' AND
                           n_t.v='attraction' AND
                           nm.k='name';
+---------------------------+-------------------------------------------------------+
| v                         | ST_AsGeoJson(n.coord)                                 |
+---------------------------+-------------------------------------------------------+
| BedZED                    | {"type":"Point","coordinates":[-0.1560632,51.3821745]} |
| Blewcoat School           | {"type":"Point","coordinates":[-0.1360484,51.4983179]} |
| Camden / Buck Street Market | {"type":"Point","coordinates":[-0.143193,51.5400398]}  |
| Camden Lock Village       | {"type":"Point","coordinates":[-0.1447181,51.5416552]} |
| Wimbledon Windmill        | {"type":"Point","coordinates":[-0.2315468,51.4376583]} |
.
.
.
```

GeoJSON Functions (cont.)

```
$ ./sandboxes/msb_5_7_5/use osm -B -e "SET SESSION group_concat_max_len = 10000; SELECT
CONCAT('{\"type\":\"FeatureCollection\", \"features\":[ ',
GROUP_CONCAT(CONCAT('{\"type\":\"Feature\", \"geometry\":', ST_AsGeoJson(n.coord),
',\"properties\":{\"name\":\"',nm.v,'\"}}')), ' ]}') FROM node_tags n_t JOIN nodes n USING
(node_id, version) JOIN node_tags nm USING (node_id, version) WHERE n_t.k='tourism' and
n_t.v='attraction' AND nm.k='name'"
```

http://geojsonlint.com/



Open Issues

- The SRID can be set and retrieved, but all operations are done in squared euclidean coordinates:

```
mysql-5.7.5 (osm) > SET @p1 := GeomFromText('POINT(-1 51)',
4326);
Query OK, 0 rows affected (0.00 sec)

mysql-5.7.5 (osm) > SET @p2 := GeomFromText('POINT(0 51)', 4326);
Query OK, 0 rows affected (0.00 sec)

mysql-5.7.5 (osm) > SET @p3 := GeomFromText('POINT(-1 52)',
4326);
Query OK, 0 rows affected (0.00 sec)

mysql-5.7.5 (osm) > SELECT srid(@p1);
+-----------+
| srid(@p1) |
+-----------+
|      4326 |
+-----------+
1 row in set (0.00 sec)
```

```
mysql-5.7.5 (osm) > SELECT st_distance(@p1, @p2);
+-----------------------+
| st_distance(@p1, @p2) |
+-----------------------+
|                     1 |
+-----------------------+
1 row in set (0.00 sec)

mysql-5.7.5 (osm) > SELECT st_distance(@p1, @p3);
+-----------------------+
| st_distance(@p1, @p3) |
+-----------------------+
|                     1 |
+-----------------------+
1 row in set (0.00 sec)
```

New JSON Native Data Type

- Since 5.7.8, MySQL allows columns defined with the JSON data type:

```
mysql-5.7.8 > CREATE TABLE json_test(id int PRIMARY KEY
auto_increment, content JSON);
Query OK, 0 rows affected (0.03 sec)

mysql-5.7.8 > INSERT INTO json_test (content) VALUES ('{"type":
"correct_json"}');
Query OK, 1 row affected (0.00 sec)

mysql-5.7.8 > INSERT INTO json_test (content) VALUES ('{"type":
"incorrect_json}');
ERROR 3140 (22032): Invalid JSON text: "Missing a closing quotation
mark in string." at position 24 in value (or column) '{"type":
"incorrect_json}'.
```

JSON functions

- MySQL includes almost all functions to manipulate JSON that you may think of:
  - Validation test: `JSON_TYPE`
  - Object creation: `JSON_ARRAY, JSON_MERGE, ...`
  - Searching: `JSON_EXTRACT`
  - Modifying: `JSON_SET, JSON_INSERT, ...`

Indexing JSON

- JSON Columns cannot be indexed:

```
mysql [localhost] {msandbox} (test) > ALTER TABLE
json_test ADD INDEX(content);
ERROR 3152 (42000): JSON column 'content' cannot be
used in key specification.
```

- However, they can be compared with regular fields and use indexes thanks to virtual columns

Query Optimization: From 0 to 10 (and up to 5.7)

CONCLUSIONS

5.7/10.1 About to be released

- Both are currently in Release Candidate
- Unless you are desperate for a feature, skip the first releases (or backport it to your current version)

MySQL 5.7 New Features

- MySQL 5.6 seemed Percona Server-inspired
- MySQL 5.7 seems MariaDB/Galera-inspired
  - Competition is always good for consumer

Many Optimizer Advantages Have to Be Manually Enabled

- Modifying on a per-query basis:

```
SET optimizer_switch='batched_key_access=on';
SET join_cache_level=8; # for MariaDB
```

  in order to take advantage of them make the features useless unless you are fine-tuning
  - I expect that to change in the future

I Herby Declare MyISAM as Dead

- All major MyISAM-only features are now on MySQL 5.7
  - FULLTEXT
  - GIS
  - Transportable tables
- There are still reasons to use MyISAM
  - MyISAM is still required for the mysql schema and non-durable temporary tables (WIP)

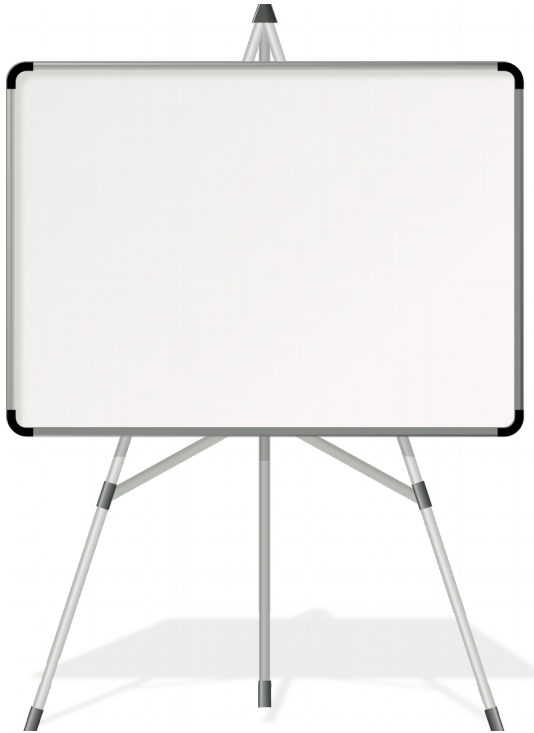
Benchmarks

- Do not trust first party benchmarks
  - In fact, do not trust 3rd party benchmarks either
- Only care about the performance of your application running on your hardware

Q&A

Not to Miss

- Official track:
  MySQL at Wikipedia: How we do relational data at the Wikimedia Foundation
- Do you want to do query optimization for a website with 20 Billion views per month?
  http://grnh.se/0y4pxm



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- Special thanks to in order by rand() to: Morgan Tocker, Sean Pringle, David Hildebrandt, Bill Karwin, Domas Mituzas, Mark Callaghan, Shlomi Noach, Mark Bergsma, Valerii Kravchuk, Miguel Ángel Nieto, Dimitri Kravtchuk, Olav Sandstå and the whole Wikimedia Team, and all people at the MariaDB, Percona and MySQL/Oracle teams, and the Percona Live Organization and Sponsors