MySQL 8.0 What's New in the Optimizer

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New Features in 8.0.0

- **Invisible index**
- Descending index
- Common table expressions
- Improved performance of scans
- JSON aggregation
- Hints
- Better IPv6 and UUID support

Invisible Index

```
ALTER TABLE t1 ALTER INDEX idx INVISIBLE;

mysql> SHOW INDEXES FROM t1;
+--------+----------------+-------------------------------------+
| Table  |  Key_name      |  Column_name  | Visible             |
+--------+----------------+---------------------+---------------+
| t1     |  idx           |   a                 |  NO           |
+--------+----------------- +--------------------+--------------+
```

- Maintained by the SE, ignored by the Optimizer
- Primary key cannot be INVISIBLE
- Use case: Check for performance drop BEFORE dropping an index

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Descending Index (lab release 8.0.0 Optimizer)

```
CREATE TABLE t1 (
      a INT,
      b INT,
      INDEX a_b (a DESC, b ASC)
 );
```

- In 5.7: Index in ascending order is created, server scans it backwards
- In 8.0: Index in descending order is created, server scans it forwards
- Works on btree index only

Benefits:

- Forward index scan is faster than backward index scan
- Use indexes instead of filesort for ORDER BY clause with ASC/DESC sort key

Download from http://labs.mysql.com/

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Common Table Expression (8.0.0 optimizer lab release)

```
SELECT … FROM (subquery) AS derived, t1...

WITH derived AS subquery SELECT … FROM derived, t1...;
```

- A derived table is a subquery in the FROM clause
- CTE is just a derived table, but you put its declaration before the outer SELECT instead of in FROM clause.

Common Table Expression VS Derived Table

Advantages over derived table

- Better readability
  - Derived table requires inside out reading
  - SELECT … FROM

    (SELECT … FROM (SELECT … FROM # understand this, go up
- Can be referenced more than once
  - Derived table can't be referenced twice in

    FROM SELECT …

    FROM (subquery) AS derived, derived

Common Table Expression VS Derived Table

Advantages over Derived table

- Better performance
  - SELECT … FROM (subquery) AS derived, (same subquery again) AS derived1
  - Two independent derived tables: if materialization is used, two materializations are done. Performance problem (more space, more time, longer locks)
- Chainable
  - Derived table doesn’t allow chaining
  - SELECT … FROM (subquery) AS derived, (SELECT … FROM derived,...) AS derived1
    Error : Derived table can't refer to previously created derived table

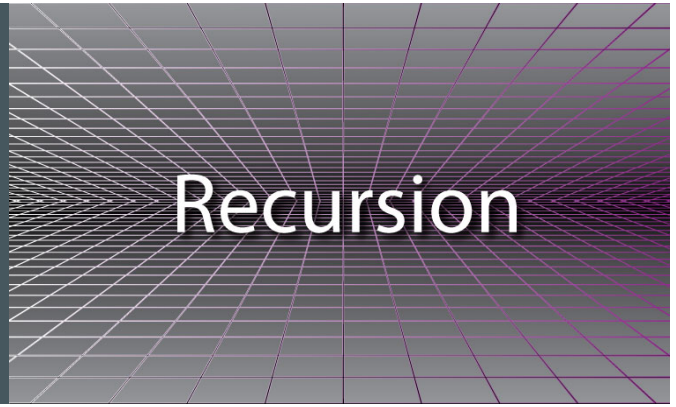
Common Table Expression VS Derived Table

```
WITH cte1(txt)  AS  (SELECT "This "),
        cte2(txt)  AS  (SELECT CONCAT(cte1.txt,"is a ") FROM cte1),
        cte3(txt)  AS  (SELECT "nice query" UNION
                        SELECT "query that rocks" UNION
                        SELECT "query"),
        cte4(txt)  AS  (SELECT concat(cte2.txt, cte3.txt) FROM cte2, cte3)
SELECT MAX(txt), MIN(txt) FROM cte4;
```

```
+----------------------------------+--------------------------+
| MAX(txt)                         | MIN(txt)                 |
+----------------------------------+--------------------------+
| This is a query that rocks       | This is a nice query     |
+----------------------------------+--------------------------+
```

Recursive CTE

```
WITH RECURSIVE cte AS
( SELECT ... FROM table_name /* "seed" SELECT */
   UNION ALL
   SELECT ... FROM cte, table_name) /* "recursive"  SELECT */
SELECT ... FROM cte;
```



- A recursive CTE refers to itself in a subquery
- The “seed” SELECT is executed once to create the initial data subset, the recursive SELECT is repeatedly executed to return subsets of data until the complete result set is obtained.
- Useful to dig in hierarchies (parent/child, part/subpart)
- Similar to Oracle's CONNECT BY

Recursive CTE – Simple Example

Print 1 to 10 :

```
WITH RECURSIVE qn AS
  ( SELECT 1 AS a
    UNION ALL
    SELECT 1+a FROM qn WHERE a<10
  )
SELECT * FROM qn;
```

```
a
1
2
3
4
5
6
7
8
9
10
```

Recursive CTE – Example Fibonacci Numbers

Fibonacci numbers:

```
WITH RECURSIVE qn AS
  (  SELECT 1 AS n, 1 AS un, 1 AS unp1
     UNION ALL
    SELECT 1+n, unp1, un+unp1
        FROM qn WHERE n<10)
SELECT * FROM qn;
```

n	un	unp1
1	1	1
2	1	2
3	2	3
4	3	5
5	5	8
6	8	13
7	13	21
8	21	34
9	34	55
10	55	89

Recursive CTE – Example Hierarchy Traversal

```
CEATE TABLE EMPLOYEES (
        ID INT PRIMARY KEY,
        NAME VARCHAR(100),
        MANAGER_ID INT,
        INDEX (MANAGER_ID),
        FOREIGN KEY (MANAGER_ID) REFERENCES EMPLOYEES(ID) );
```

```
INSERT INTO EMPLOYEES VALUES
(333,   “Yasmina",   NULL), #  CEO , Manager ID = NULL
(198,   "John",       333), # John is 198 reports to 333, Yasmina
(692,   "Tarek",      333),
(29,    "Pedro",      198),  # Pedro is 29, reports to 198, John
(4610,  "Sarah",      29),
(72,    "Pierre",     29),
(123,   "Adil",       692);
```

Recursive CTE – Example Hierarchy Traversal

Print all employees and their management chain:

```
WITH RECURSIVE EMPLOYEES_EXTENDED (ID, NAME, PATH) AS (
  SELECT ID, NAME, CAST(ID AS CHAR(200))
  FROM EMPLOYEES  WHERE MANAGER_ID IS NULL
  UNION ALL
  SELECT S.ID, S.NAME, CONCAT(M.PATH, ",", S.ID)
  FROM EMPLOYEES_EXTENDED M JOIN   EMPLOYEES S ON M.ID=S.MANAGER_ID )
SELECT * FROM EMPLOYEES_EXTENDED ORDER BY PATH;
```

ID	NAME	PATH
333	Yasmina	333
198	John	333,198
29	Pedro	333,198,29
4610	Sarah	333,198,29,4610 # Sarah->Pedro->John->Yasmina
72	Pierre	333,198,29,72
692	Tarek	333,692
123	Adil	333,692,123

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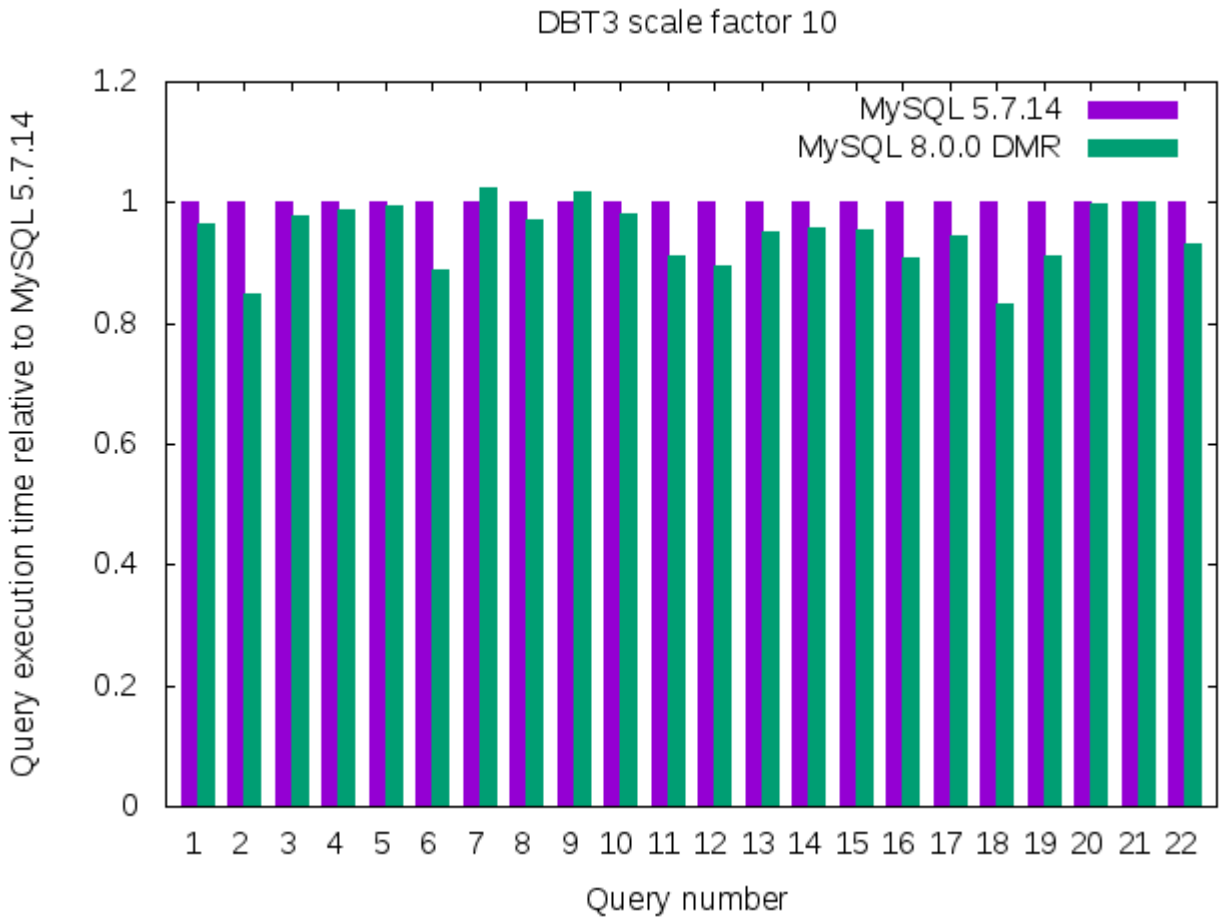
- **Improved performance of scans**
- JSON aggregation
- Hints
- Better UUID and IPv6support

Improved Performance of Scans

- Motivation:
  - InnoDB already uses an internal buffer to fetch records in batches
  - Optimizer knows the operation and the estimated number of records to read
  - Why cannot optimizer tell InnoDB how much to read??
- 8.0 extends the handler API: provides a buffer for each table or index where optimizer expects more than one row
  - So far only InnoDB uses this API
- Queries with improved performance:

```
SELECT * FROM t;
SELECT * FROM t WHERE pk BETWEEN 1000 and  10 000;
SELECT * FROM t1, t2 WHERE t1.pk = t2.pk;  /* buffer for the outer table, no need for inner table which is accessed using eq_ref)
```

Improved Performance of Scans - DBT3



- 18 out of 22 queries got improved performance
- 4 queries have more than 10% improvement, 2 queries more than 15% improvements

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- **JSON Aggregation**
- Hint
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JSON Support

- 5.7:
  - JSON datatype
  - JSON functions
  - Indexing of JSON through virtual column
- 8.0:
  - Add more functions
  - Improve performance

JSON Aggregation (8.0.0 optimizer lab release)

Combine JSON documents in multiple rows into a JSON array

```
CREATE TABLE t1(id INT, grp INT, jsoncol JSON);

 INSERT INTO t1 VALUES(1, 1,
'{"key1":"value1","key2":"value2"}');

INSERT INTO t1 VALUES(2, 1,
'{"keyA":"valueA","keyB":"valueB"}');

INSERT INTO t1 VALUES(3, 2,
'{"keyX":"valueX","keyY":"valueY"}');
```

```
SELECT JSON_ARRAYAGG(jsoncol) AS
json FROM t1;


[{"key1":"value1","key2":"value2"},
{"keyA":"valueA","keyB":"valueB"},
{"keyX":"valueX","keyY":"valueY"}]
```

JSON Aggregation (8.0.0 optimizer lab release)

Combine JSON documents in multiple rows into a JSON object

```
CREATE TABLE t1(id INT, grp INT,
jsoncol JSON);

 INSERT INTO t1 VALUES(1, 1,
'{"key1":"value1","key2":"value2"}');

INSERT INTO t1 VALUES(2, 1,
'{"keyA":"valueA","keyB":"valueB"}');

INSERT INTO t1 VALUES(3, 2,
'{"keyX":"valueX","keyY":"valueY"}');
```

```
SELECT JSON_OBJECTAGG(id, jsoncol) AS json
FROM t1 GROUP BY grp;


1 | {"1":{"key1":"value1","key2":"value2"},
"2":{"keyA":"valueA","keyB":"valueB"}}
2 | {"3":{"keyX":"valueX","keyY":"valueY"}}
```

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Improved HINTs

- 5.7: Introduced new hint syntax /*+ ...*/
  - Flexibility over optimizer switch, effect individual statement only
  - Hints within statement take precedence over optimizer switch
  - Hints apply at different scope levels: global, query block, table, index
- 8.0: Add more hints, gradually replace the old hint syntax

Hint: Join Order (8.0.0 optimizer lab Release)

- Hints to control table order for join execution
- 5.7: STRAIGHT_JOIN to force the listed order in FROM clause
- 8.0:
  - JOIN_FIXED_ORDER /* replacement for STRAIGHT_JOIN*/
  - JOIN_ORDER /* use specified order */
  - JOIN_PREFIX /* use specified order for first tables */
  - JOIN_SUFFIX /* use specified order for last tables */

Join Order Hints

Original query

```
EXPLAIN SELECT *
FROM customer JOIN orders ON c_custkey = o_custkey
WHERE c_acctbal < -1000 AND o_orderdate < '1993-01-01';
```

id	select type	table	type	possible keys	key	key len	ref	rows	filtered	extra
1	SIMPLE	orders	ALL	i_o_orderdate, i_o_custkey	NULL	NULL	NULL	15000000	31.19	Using where
1	SIMPLE	customer	eq_ref	PRIMARY	PRIMARY	4	dbt3.orders.o_custkey	1	33.33	Using where

Join Order Hints

Change join order with hint

EXPLAIN SELECT /*+ JOIN_ORDER(customer, orders) */ *
FROM customer JOIN orders ON c_custkey = o_custkey
WHERE c_acctbal < -1000 AND o_orderdate < '1993-01-01';

id	select type	table	type	possible keys	key	key len	ref	rows	filtered	extra
1	SIMPLE	customer	ALL	PRIMARY	NULL	NULL	NULL	1500000	31.19	Using where
1	SIMPLE	orders	ref	i_o_orderdate, i_o_custkey	i_o_custkey	5	dbt3. customer. c_custkey	15	33.33	Using where

Alternatives with same effect for this query:

JOIN_PREFIX(customer) JOIN_SUFFIX(orders) JOIN_FIXED_ORDER()

Hint: Merge/Materialize Derived Table

```
SELECT /*+ NO_MERGE(dt) */ *
FROM t1 JOIN (SELECT x, y FROM t2) dt ON  t1.x = dt.x;
```

- Derived table is subquery in a FROM clause
- 5.6: Always materialize
- 5.7: Merged into outer queries in most cases, materialized in some cases
- 8.0: Users can override default behavior with hints
  - /*+ MERGE() */
  - /*+ NO_MERGE() */

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Improved Support for UUID

```
mysql> select uuid();
+--------------------------------------+
| uuid()                               |
+--------------------------------------+
| aab5d5fd-70c1-11e5-a4fb-b026b977eb28 |
+--------------------------------------+
```

- Five “-” separated hexadecimal numbers
- MySQL uses version 1, The first three numbers are generated from the low, middle, and high parts of a timestamp.
- 36 characters, inefficient for storage

➡ Convert to BINARY(16) datatype, only 16 bytes

Improved Support for UUID

```
IS_UUID ()  /* Check validity */

UUID_TO_BIN (arg1)   /* Convert UUID formatted text to binary(16) */
UUID_TO_BIN (arg1, arg2) /* If arg2 = true, shuffle  low and high time parts)

BIN_TO_UUID  (arg1)  /* Convert binary(16) to UUID formatted text */
BIN_TO_UUID  (arg1, arg2) /* If arg2 = true, shuffle  low and high time parts)
```

- Ease of use!
- More efficient indexing
  - Low part of timestamp being first makes index inserts slow
  - Shuffling low part with high part improves index efficiency

IPv4 vs IPv6

Getting all the networks that contain the given IP address

```
SELECT inet_ntoa(network) AS network, inet_ntoa(netmask) AS netmask
FROM network_table
WHERE (inet_aton('192.168.0.30') & netmask) = network;

SELECT inet6_ntoa(network) AS network, inet6_ntoa(netmask) AS netmask
FROM network_table
WHERE (inet6_aton('2001:0db8:85a3:0000:0000:8a2e:0370:7334') & netmask) = network;
```

- IPv4 address commonly stored as INT
- IPv6 address 128 bit, commonly stored as BINARY(16)
- The secondary query would give wrong results in 5.7, because & operator converts both operands from VARBINARY to BIGINT

Bitwise Operations on Binary Data Types

Bit operators and functions:

& | ^ ~ << >>

BIT_COUNT

Aggregate bit functions:

BIT_AND

BIT_XOR

BIT_OR

- Prior to 8.0, bitwise operations only worked on integer, truncation beyond 64 bits
- 8.0: Extends bit-wise operations to work with BINARY/BLOB
- 8.0: More functions to be added ...

Improved Support for IPv6

Use BINARY[16] and Bitwise-operations

```
SET @cidr = '2606:b400:85c:1040::1/64';

# Extract network length
SET @net_len = SUBSTRING_INDEX(@cidr, '/', -1 );
SELECT @net_len;
->  64

# Netmask
SET @net_mask= ~INET6_ATON('::') << (128 - @net_len);
SELECT INET6_NTOA(@net_mask);
->  ffff:ffff:ffff:ffff::

SET @network = INET6_ATON(SUBSTRING_INDEX(@cidr, '/', 1 )) & @net_mask;
# Print it in human-readable format
SELECT INET6_NTOA(@network);
-> 2606:b400:85c:1040::
```

Improved Support for IPv6

```
#host mask
SET @host_mask= ~INET6_ATON('::') >> @net_len;
SELECT INET6_NTOA(@host_mask);
-> ::ffff:ffff:ffff:ffff

# Generate network range IPv6 address.
SET @range_start = @network & @net_mask;
SELECT INET6_NTOA(@range_start);
-> 2606:b400:85c:1040::

SET @range_to = @network | @host_mask;
SELECT INET6_NTOA(@range_to);
-> 2606:b400:85c:1040:ffff:ffff:ffff:ffff

#Check if address in the range
SET @address1 = INET6_ATON('2606:b400:85c:1040:c5e4:2bb8:cc09:c4e2‘;)
SELECT @address1 between @range_start and @range_to:
-> 1
```

What is on Our Roadmap?

- Advanced JSON functions
- Cost model improvements: histogram, data in memory vs disk
- Advanced SQL features e.g WINDOWING functions
- Improve prepared statement/cache query plan
- Optimization for GIS operations

Hardware and Software
Engineered to Work Together