25x: MySQL Cluster and push-down joins (in pursuit of the holy grail)

Jonas Oreland
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What is your name: Jonas Oreland, Oracle/Sun/MySQL
What is your quest: Making MySQL Cluster superior and affordable to all
What is the air-speed velocity of an unladen swallow: 25x

The knights of Ni: Ole John Aske, Jan Wedvik

25x: MySQL Cluster and push-down joins (in pursuit of the holy grail)

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The buzzwords: An introduction to MySQL Cluster
The benchmarks: Why are joins sometimes slow with MySQL Cluster
The solutions: Distributed push-down joins (and BKA)
The future: Where does push-down joins go next and what about the swallow
Introduction to MySQL Cluster – part I

What is ndb:

- a distributed hash table with a relational model (rows/columns)
- automatic/configurable horizontal partitioning
- built in configurable redundancy (synchronous replication)
- row level locking
- logging/check pointing
- data stored in main-memory or on disk (with page buffer cache)
  (configurable on column level)
- online schema change (add column, create/drop index)
- online repartitioning (adding partitions)
- online adding of nodes
- online backup
What is MySQL Cluster

ndb and set of connectors and add-ons:

- C/C++  ndbapi, native client library
- SQL   MySQL + ha_ndbcluster.cc
- LDAP  OpenLDAP + backndb (using ndbapi)
- Java  ClusterJPA (using ClusterJ via ndbapi)
- MySQL replication with ha_ndbcluster_binlog.cc (geo redundancy)
What are the primitive data access methods supported by ndb

- primary key lookup
- unique key lookup (impl. as 2-way primary key lookup)
- table scan (parallel or pruned) with push down conditions
- index scan (parallel or pruned) with push down (multi) key-ranges and push down conditions
Why joins sometimes are slow with MySQL Cluster – part I

TPC-W getBestSeller
3-way join, subquery, group by, order by

SELECT i_id, i_title, a_fname, a_lname
FROM item, author, order_line
WHERE item.i_id = order_line.ol_i_id
   AND item.i_a_id = author.a_id
   AND order_line.ol_o_id > (SELECT MAX(o_id)-3333
                              FROM orders)
   AND item.i_subject = 'COMPUTERS'
GROUP BY i_id, i_title, a_fname, a_lname
ORDER BY SUM(ol_qty) DESC
LIMIT 50;
Why joins sometimes are slow with MySQL Cluster – part II

- mysql server
  1xDual Intel 5160 3GHz

- gigabit ethernet

- 2 data-nodes
  2xQuad Intel E5450 3GHz
Why joins sometimes are slow with MySQL Cluster – part III

2004 the saga begins
Why joins sometimes are slow with MySQL Cluster – part IV

- Blue is single thread
- Red is 16-threads
- Left is myisam 4.1.14
- Right is ndbd 4.1.14

Horror!
Why joins sometimes are slow with MySQL Cluster – part V

Fast forward to 2009
Why joins sometimes are slow with MySQL Cluster – part VI

- Blue is single thread
- Red is 16-threads
- Left is myisam 4.1.14
- Middle is ndbd 4.1.14
- Right is ndbmtld 7.0.14

Better but still bad!
- No algorithmic changes!
Why joins sometimes are slow with MySQL Cluster – part VII

Nested Loop Join

FOR EACH ROW <a> in TABLE T1 (matching conditions on T1)
    FOR EACH ROW <b> in TABLE T2 (matching condition on T2 given <a>)
        FOR EACH ROW <c> in TABLE T3 (matching conditions on T3 given <b>)

FOR EACH is implemented using one of the 4 primitive data access methods in ndb

NOTICE: Everything is done 1 row at a time. Zero parallelism!
Why joins sometimes are slow with MySQL Cluster – part VIII

Ping time: 100 microseconds

- Latency for 1 primary key operation is 211 microseconds
- Latency for 128 primary key operations is 1548 microseconds

- Time per row for 1 primary key operations is 211 microseconds
- Time per row for 128 primary key operations is 12 microseconds
Why joins sometimes are slow with MySQL Cluster – part IX
Why joins sometimes are slow with MySQL Cluster – part X

mysql> explain SELECT i_id, i_title, a_fname, a_lname FROM item, author, order_line WHERE item.i_id = order_line.ol_i_id AND item.i_a_id = author.a_id AND order_line.ol_o_id > (SELECT MAX(o_id)-3333 FROM orders) AND item.i_subject = 'COMPUTERS' GROUP BY i_id, i_title, a_fname, a_lname ORDER BY SUM(ol_qty) DESC limit 50;

+-------------+------------+--------+---------+-------------------------+----------------------------------------------+
<table>
<thead>
<tr>
<th>select_type</th>
<th>table</th>
<th>type</th>
<th>key</th>
<th>ref</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIMARY</td>
<td>order_line</td>
<td>range</td>
<td>PRIMARY</td>
<td>NULL</td>
<td>Using where; Using temporary; Using filesort</td>
</tr>
<tr>
<td>PRIMARY</td>
<td>item</td>
<td>eq_ref</td>
<td>PRIMARY</td>
<td>test.order_line.OL_I_ID</td>
<td>Using where with pushed condition</td>
</tr>
<tr>
<td>PRIMARY</td>
<td>author</td>
<td>eq_ref</td>
<td>PRIMARY</td>
<td>test.item.I_A_ID</td>
<td></td>
</tr>
<tr>
<td>SUBQUERY</td>
<td>NULL</td>
<td>NULL</td>
<td>NULL</td>
<td>NULL</td>
<td>Select tables optimized away</td>
</tr>
</tbody>
</table>
+-------------+------------+--------+---------+-------------------------+----------------------------------------------+

mysql> select count(*) from order_line where order_line.ol_o_id > (SELECT MAX(o_id)-3333 FROM orders);

+----------+
| count(*) |
+----------+
| 10006    |
+----------+
1 row in set (0.04 sec) (41090 us e.g 4 us / row)
Why joins sometimes are slow with MySQL Cluster – part XI

mysql> select count(*) from item, order_line where item.i_subject = 'COMPUTERS' and item.i_id = order_line.ol_i_id and order_line.ol_o_id > (SELECT MAX(o_id)-3333 FROM orders);
+----------+
| count(*) |
+----------+
| 420      |

Latency for 1 primary key operations is 211 microseconds

Query time = 41090 + (10006*211) + (420*211) = 2240976 = 2.2 s
So we need to...
cut down the mightiest tree in the forest...with....A HERRING!
FOR EACH ROW <a> in TABLE T1 (matching conditions on T1)
  Gather <a0...an>
FOR EACH ROW <b> in TABLE T2 (matching condition on T2 given <a0..an>)
  Gather <b0...bn>
FOR EACH ROW <c> in TABLE T3 (matching conditions on T3 given <b0..bn>)

with max n = 128 (as mysql-6.0-bka-preview)
Query time = 41090 + (10006/128)*1548 + (420/128)*1548 = 167179 us = 167 ms

Latency for 128 primary key operations is 1548 microseconds

13x
BKA – part II

- Blue is single thread
- Red is 16-threads

**13x**

- Left is ndbmttd 7.0.14
- Right is BKA
BKA – part III

So what is wrong with BKA?

Nothing!
It's great!!
BKA – part IV

Really, what is “wrong” with BKA?

- it's not released yet

- for low cardinality it does not help at all, as it processes 1 table at a time
  e.g. select from T1, T2 where T1.pk = X and T2.pk = T1.a

- It's “just” a new access method, that can by itself not limit number of rows shipped to mysqld
Distributed push-down joins – part I

What if?
A access method which could combine the existing data access methods, that could evaluate joins or parts of joins without transporting all rows to mysqld...
(e.g a killer rabbit!)
Distributed push-down joins – part III

- Mysql: 250 LOC
- AQP: 700 LOC
- ha_ndbcluster: 400 LOC
- ndbapi: 8k LOC
- transporter
- os

- DBLQH
- DBSPJ: 4k LOC
- DBTC
- receive thread
- transporter
- os

Network connection
Nested Loop Join inside DBSPJ

• Start “thread” scanning local partitions for T1
• On row found in T1
  Start “thread” searching for row in T2
• On row found in T2
  Start “thread” searching for row in T3
• When all threads are finished, report back

NOTICE: Everything is asynchronous, as much as possible is performed in parallel
Distributed push-down joins – part IV

MySQL Integration

1. JOIN::prepare
2. JOIN::optimize

3. handler::make_pushed_join(AQP)

4. JOIN::exec
5. JOIN::cleanup
6. JOIN::reinit

Expose query execution plan after query optimization
Distributed push-down joins – part V

Abstract Query Plan

MySQL server

Storage Engine
Distributed push-down joins – part VI

mysql> show variables like 'ndb_join_pushdown';
+---------------------------------+-------+
| Variable_name                    | Value |
+---------------------------------+-------+
| ndb_join_pushdown                | ON    |
+---------------------------------+-------+
1 row in set (0.00 sec)
Distributed push-down joins – part VII

```
mysql> explain SELECT i_id, i_title, a_fname, a_lname FROM item, author, order_line WHERE item.i_id = order_line.ol_i_id AND item.i_a_id = author.a_id AND order_line.ol_o_id > (SELECT MAX(o_id)-3333 FROM orders) AND item.i_subject = 'COMPUTERS' GROUP BY i_id, i_title, a_fname, a_lname ORDER BY SUM(ol_qty) DESC limit 50;
+----------+------------+--------+--------------------+-------------------------------------------------------------------------+
| type     | table      | type   | ref                | Extra                                                                   |
| PRIMARY  | order_line | range  | NULL               | Parent of 3 pushed join@1; Using where; Using temporary; Using filesort |
| PRIMARY  | item       | eq_ref | order_line.OL_I_ID | Child of pushed join@1; Using where with pushed condition               |
| PRIMARY  | author     | eq_ref | item.I_A_ID        | Child of pushed join@1                                                  |
| SUBQUERY | NULL       | NULL   | NULL               | Select tables optimized away                                           |
+----------+------------+--------+--------------------+-------------------------------------------------------------------------+
4 rows in set (0.00 sec)
```
Distributed push-down joins – part VIII

**SHOW STATUS LIKE 'NDB_PUSHED%';**

mysql> show status like 'ndb_pushed%';

<table>
<thead>
<tr>
<th>Variable_name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ndb_pushed_queries_defined</td>
<td>1</td>
</tr>
<tr>
<td>Ndb_pushed_queries_executed</td>
<td>1</td>
</tr>
<tr>
<td>Ndb_pushed_reads</td>
<td>10426</td>
</tr>
<tr>
<td>Ndb_pushed_queries_dropped</td>
<td>0</td>
</tr>
</tbody>
</table>

4 rows in set (0.00 sec)
Distributed push-down joins – part IX

New ndbinfo counters

mysql> select node_id,counter_name,sum(val) from ndbinfo.counters where block_name='DBSPJ' group by node_id, counter_name;

+---------+------------------------+------+
| node_id | counter_name           | val  |
+---------+------------------------+------+
|       1 | READS_RECEIVED         |    0 |
|       1 | LOCAL_READS_SENT       | 5216 |
|       1 | REMOTE_READS_SENT      | 4874 |
|       1 | TABLE_SCANS_RECEIVED   |    0 |
|       1 | LOCAL_TABLE_SCANS_SENT |    0 |
|       1 | RANGE_SCANS_RECEIVED   |    4 |
|       1 | LOCAL_RANGE_SCANS_SENT |    4 |
|       2 | READS_RECEIVED         |    0 |
|       2 | LOCAL_READS_SENT       | 4754 |
|       2 | REMOTE_READS_SENT      | 5168 |
|       2 | TABLE_SCANS_RECEIVED   |    0 |
|       2 | LOCAL_TABLE_SCANS_SENT |    0 |
|       2 | RANGE_SCANS_RECEIVED   |    4 |
|       2 | LOCAL_RANGE_SCANS_SENT |    4 |
+---------+------------------------+------+
14 rows in set (0.13 sec)

• LOCAL_”X”_SENT
  #”X” sent to local node

• REMOTE_”X”_SENT
  #”X” sent to remote node

• READS
• TABLE_SCANS
• RANGE_SCANS
Distributed push-down joins – part X

- Blue is single thread
- Red is 16-threads
- Left is ndbmtd 7.0.14
- Middle is BKA
- Right is SPJ-7.0.14

Latency

Throughput

Queries per second
Distributed push-down joins – part XI

Limitations - functionality

• No datatype conversions
• No blobs
• No locks
• Only supports eq_ref and const as access method for child tables

Limitations - performance

• Only supports eq_ref and const as access method for child tables
• Only implemented left outer join inside ndb(mt)d, mysqld implements inner join
• Only supports pushed filters on “root” table
• Not multi-threaded (works in ndbmttd, but executed in single thread)
Distributed push-down joins – part XII

Limitations – no datatype conversion

mysql> explain SELECT i_title, a_fname FROM item,author WHERE item.i_a_id = author.a_id AND i_id = 9;
+-------------+--------+--------+---------+---------+------------------+------+---------------------------+
| select_type | table  | type   | key     | key_len | ref              | rows | Extra                     |
|-------------+--------+--------+---------+---------+------------------+------+---------------------------+
| SIMPLE      | item   | const  | PRIMARY | 4       | const            |    1 |                           |
|             |        |        |         |         | Parent of 2 pushed join@1 |      |                          |
| SIMPLE      | author | eq_ref | PRIMARY | 4       | test.item.I_A_ID |    1 | Child of pushed join@1   |
+-------------+--------+--------+---------+---------+------------------+------+---------------------------+
2 rows in set (0.00 sec)

mysql> alter table author modify column A_ID bigint;
Query OK, 2500 rows affected (2.59 sec)
Records: 2500  Duplicates: 0  Warnings: 0

mysql> explain SELECT i_title, a_fname FROM item,author WHERE item.i_a_id = author.a_id AND i_id = 9;
+-------------+--------+--------+---------+---------+------------------+------+---------------------------+
| select_type | table  | type   | key     | key_len | ref              | rows | Extra                     |
|-------------+--------+--------+---------+---------+------------------+------+---------------------------+
| SIMPLE      | item   | const  | PRIMARY | 4       | const            |    1 |                           |
| SIMPLE      | author | eq_ref | PRIMARY | 8       | test.item.I_A_ID |    1 | Using where              |
+-------------+--------+--------+---------+---------+------------------+------+---------------------------+
2 rows in set (0.00 sec)
Distributed push-down joins – part XIII

Limitations – no blobs

mysql> explain SELECT i_title, a_fname FROM item,author WHERE item.i_a_id = author.a_id AND i_id = 9;
+-------------+--------+--------+---------+---------+------------------+------+---------------------------+
| select_type | table  | type   | key     | key_len | ref              | rows | Extra                     |
+-------------+--------+--------+---------+---------+------------------+------+---------------------------+
| SIMPLE      | item   | const  | PRIMARY | 4       | const            |    1 | Parent of 2 pushed join@1 |
| SIMPLE      | author | eq_ref | PRIMARY | 4       | test.item.I_A_ID |    1 | Child of pushed join@1    |
+-------------+--------+--------+---------+---------+------------------+------+---------------------------+

mysql> select COLUMN_NAME, COLUMN_TYPE from INFORMATION_SCHEMA.COLUMNS where TABLE_NAME='author' and COLUMN_NAME='A_BIO';
+-------------+-------------+
| COLUMN_NAME | COLUMN_TYPE |
+-------------+-------------+
| A_BIO       | blob        |
+-------------+-------------+

mysql> explain SELECT i_title, a_fname, a_bio FROM item,author WHERE item.i_a_id = author.a_id AND i_id = 9;
+-------------+--------+--------+---------+---------+------------------+------+-------+
| select_type | table  | type   | key     | key_len | ref              | rows | Extra |
+-------------+--------+--------+---------+---------+------------------+------+-------+
| SIMPLE      | item   | const  | PRIMARY | 4       | const            |    1 |       |
| SIMPLE      | author | eq_ref | PRIMARY | 4       | test.item.I_A_ID |    1 |       |
+-------------+--------+--------+---------+---------+------------------+------+-------+

No blobs
Distributed push-down joins – part XIV

Limitations – no locks

mysql> explain SELECT i_title, a_fname FROM item,author WHERE item.i_a_id = author.a_id  AND i_id = 9;
+-------------+--------+--------+---------+---------+------------------+------+---------------------------+
| select_type | table  | type   | key     | key_len | ref              | rows | Extra                     |
+-------------+--------+--------+---------+---------+------------------+------+---------------------------+
| SIMPLE      | item   | const  | PRIMARY | 4       | const            |    1 |                           |
+-------------+--------+--------+---------+---------+------------------+------+---------------------------+
| SIMPLE      | author | eq_ref | PRIMARY | 4       | test.item.I_A_ID |    1 |                           |
+-------------+--------+--------+---------+---------+------------------+------+---------------------------+
2 rows in set (0.00 sec)

mysql> explain SELECT i_title, a_fname FROM item,author WHERE item.i_a_id = author.a_id  AND i_id = 9 FOR UPDATE;
+-------------+--------+-------+---------+---------+-------+------+-------+
| select_type | table  | type  | key     | key_len | ref   | rows | Extra |
+-------------+--------+-------+---------+---------+-------+------+-------+
| SIMPLE      | item   | const | PRIMARY | 4       | const |    1 |       |
+-------------+--------+-------+---------+---------+-------+------+-------+
| SIMPLE      | author | const | PRIMARY | 4       | const |    1 |       |
+-------------+--------+-------+---------+---------+-------+------+-------+
2 rows in set (0.00 sec)
Distributed push-down joins – part XV

Limitations – only eq_ref and const children

mysql> explain SELECT i_title, a_fname FROM author, item WHERE author.a_lname = 'KING ARTHUR' AND item.i_a_id = author.a_id;

```
+-------------+--------+-------+----------------+------------------+------+-----------------------------------+
| select_type | table  | type  | key            | ref              | rows | Extra                             |
+-------------+--------+-------+----------------+------------------+------+-----------------------------------+
| SIMPLE      | author | range | author_a_lname | NULL             |   10 | Using where with pushed condition |
| SIMPLE      | item   | ref   | item_i_a_id    | test.author.A_ID |    1 | Using where                       |
+-------------+--------+-------+----------------+------------------+------+-----------------------------------+
```

Possible types

- const
- eq_ref
- system
- ref
- ref_or_null
- index_merge
- unique_subquery
- index_subquery
- range
- index
- ALL

No push:

- 1 to many
- Many to many

“to many”
Distributed push-down joins – part XVI
Test of all TPC-W queries (except getBestSellers)

Summary

- 7 noticeable improvement
- 3 queries no change ("to many")
- 1 query 15% slower

So what does this mean?
- Hard to say

My **guess** is that TPC-W is unrealistically push-friendly
Distributed push-down joins – part XVII

So what is wrong with SPJ?

Nothing!
It's great!!
Distributed push-down joins – part XVIII

Really, what is wrong with SPJ?

• it's not released yet

• only supporting eq_ref and const as child access types will most likely significantly limit pushability
The future! - part I

High hanging fruit

• Pushed aggregates
• More join algorithms

Medium hanging fruit

• “to many” (the holy handgrenade!)
• not only left outer join (in ndb(mt)d)
• “connect by” (not considering SQL)
• 2-way traveling JOIN
• read-mostly tables (fully replicated)

Low hanging fruit

• pushed filters also on child operations
• multi threaded DBSPJ
The future! - part II

- Blue is single thread
- Red is 16-threads

Graphs show (left to right)
- SPJ as previously
- + w/ emulated read-mostly tables
- + w/ emulated filters on child operations
- + w/ both emulations

3.5x
The future – part III
(what about that swallow)

mysql> SELECT COUNT(*) FROM part, lineitem WHERE l_partkey=p_partkey AND p_retailprice>2050 and l_discount > 0.04;
+----------+
| COUNT(*) |
+----------+
|    20132 |
+----------+
1 row in set (13.47 sec)

mysql> set ndb_join_pushdown=off;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT COUNT(*) FROM part, lineitem WHERE l_partkey=p_partkey AND p_retailprice>2050 and l_discount > 0.04;
+----------+
| COUNT(*) |
+----------+
|    20132 |
+----------+
1 row in set (9 min 53.03 sec)
The future – part III
(what about that swallow)

Star Schema Benchmark Q1.1

- Star Schema Benchmark is a modified TPC-H
  - sf100 = 61Gb
  - sf1000 = 610Gb
- LucidDB/MonetDB numbers come from http://www.percona.com/docs/wiki/ssb:start (using different hardware)
The future – part III
(what about that swallow)

Jonas dreaming!

- MySQL Cluster will never be as fast for DSS as specialized RDBMS:es
- But! Being moderately slower and supporting 50k updates/sec in parallel can make a unique combination!
25x: MySQL Cluster and push-down joins (in pursuit of the holy grail)

Summary:

The buzzwords: MyCluster is reasonably buzz-word compliant!
The benchmarks: Joins can be slow, but it's unavoidable with current algorithms
The solutions: SPJ and BKA both shows great potential
The future: Time will tell!
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25x: MySQL Cluster and push-down joins (in pursuit of the holy grail)

We want you to test!

Caveat: code is known to contain bugs related to node failure handling and should therefore not be put into production