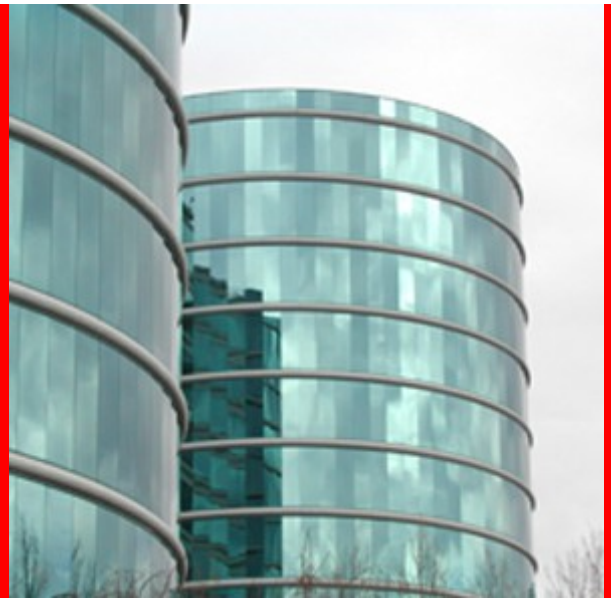


MySQL™

ORACLE®

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

Jonas Oreland

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

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

ftp://ftp.mysql.com:/pub/mysql/download/cluster_telco/mysql-5.1.44-ndb-7.1.3-spj-preview/mysql-cluster-gpl-7.1.3-spj-preview.tar.gz

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

Table of content:

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

Introduction to MySQL Cluster – part II

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)

Introduction to MySQL Cluster – part III

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

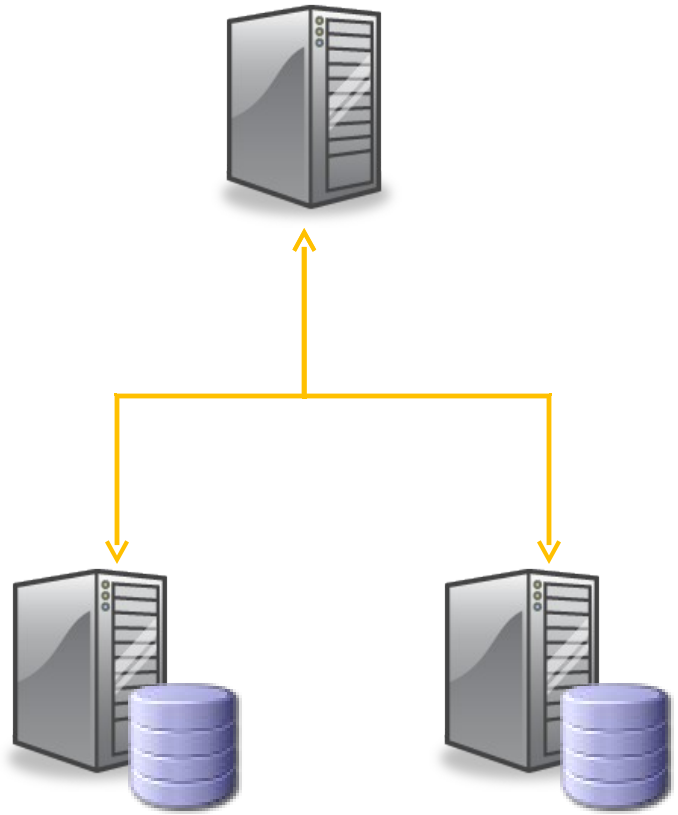
Why joins sometimes are slow with MySQL Cluster – part I

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

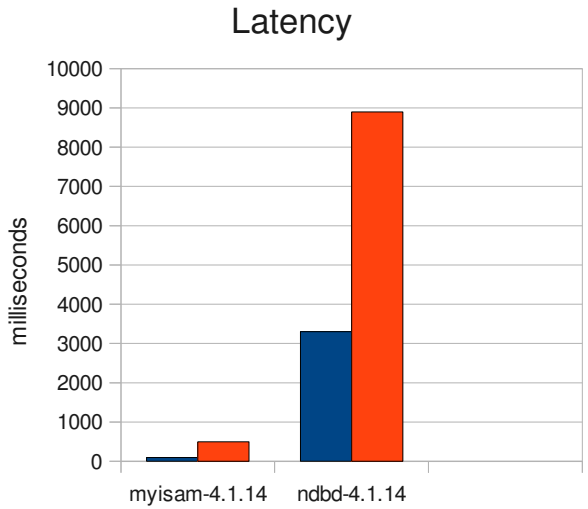


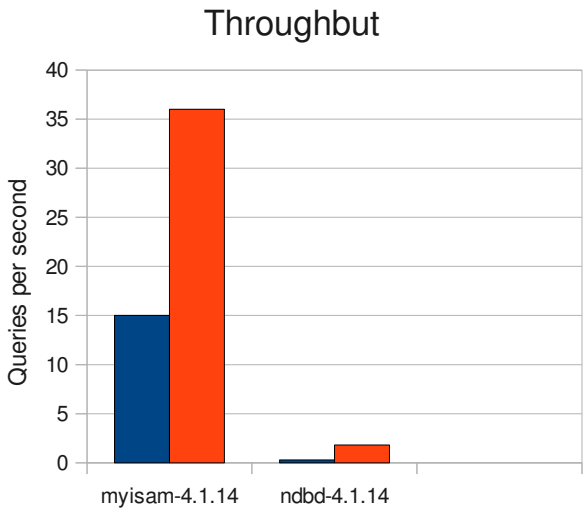
- mysql server
  1xDual Intel 5160 3GHz
- gigabit ethernet
- 2 data-nodes
  2xQuad Intel E5450 3GHz

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

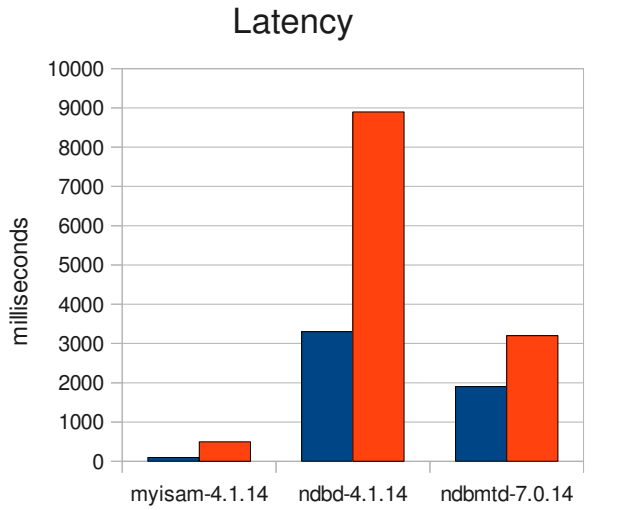
- Left is myisam 4.1.14
- Right is ndbd 4.1.14

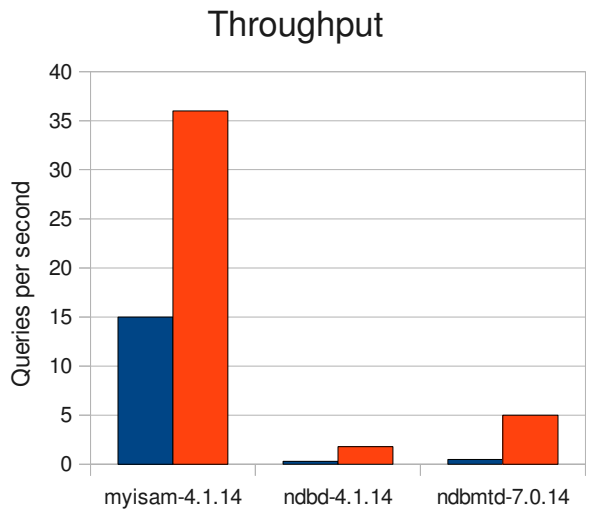
Horror!

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 ndbmtd 7.0.14

- Better but still bad!
- No algorithmic changes!

Why joins sometimes are slow with MySQL Cluster – part VII

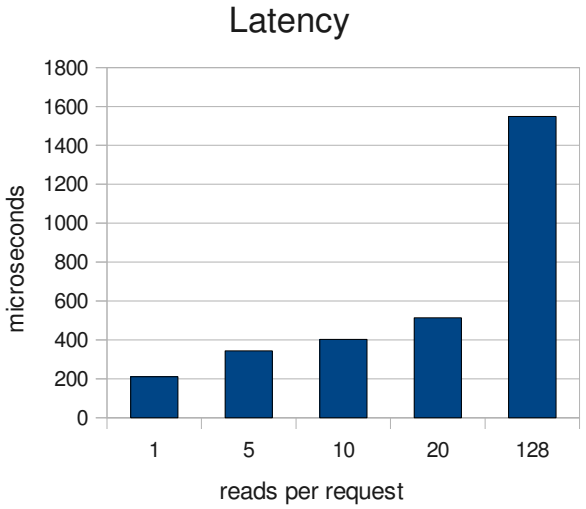
Nested Loop Join

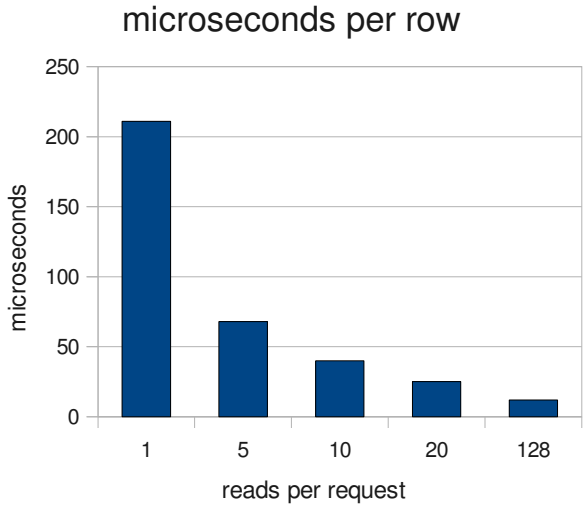
```
FOR EACH ROW <a> in TABLE T1 (matching conditions on T1)
  FOR EACH ROW <b> in TABLE T2 (matching condition on T2 given <a>)
    FOR EACH ROW <c> in TABLE T3 (matching conditions on T3 given <b>)
```

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



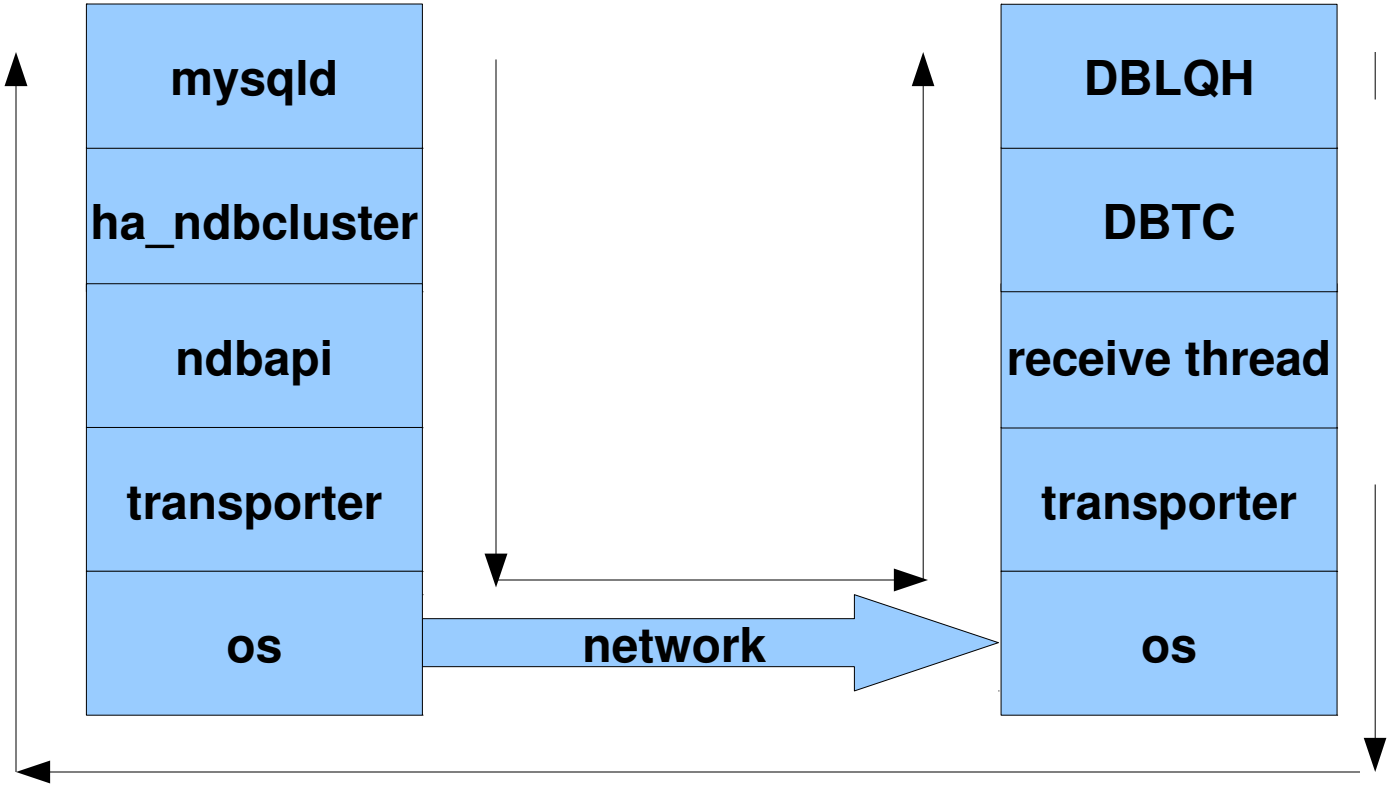


Ping time: 100 microseconds

- 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;
```

select_type	table	type	key	ref	Extra
PRIMARY	**order_line**	**range**	**PRIMARY**	**NULL**	**Using where; Using temporary; Using filesort**
PRIMARY	item	eq_ref	PRIMARY	test.order_line.OL_I_ID	Using where with pushed condition
PRIMARY	author	eq_ref	PRIMARY	test.item.I_A_ID	
SUBQUERY	NULL	NULL	NULL	NULL	Select tables optimized away

```
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**

Why joins sometimes are slow with MySQL Cluster – part IX

So we need to...

cut down the mightiest tree in the forest...with....A HERRING!

BKA – part I

Batched Key Access

```
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>)
```

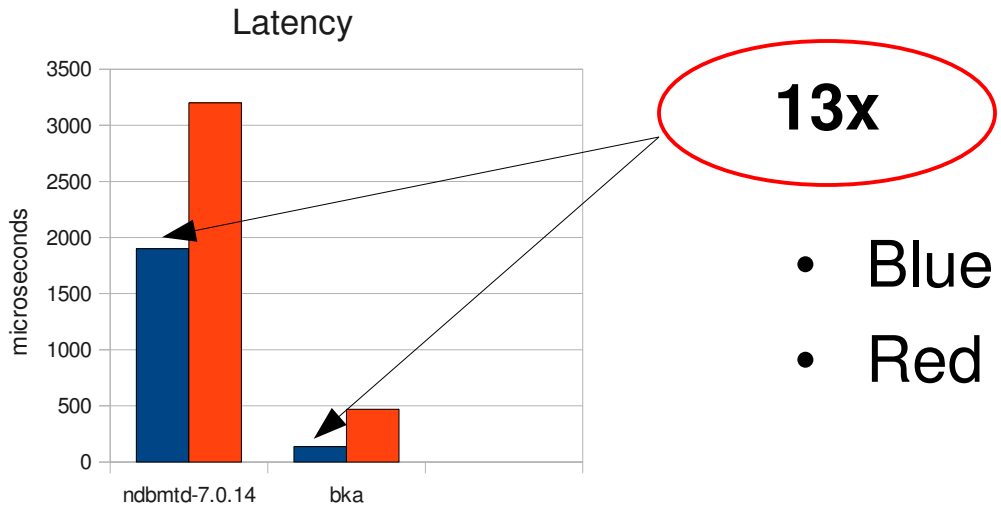
with max n = 128 (as mysql-6.0-bka-preview)

Query time = 41090 + (10006/128)*1548 + (420/128)*1548 = 167179 us = 167 ms

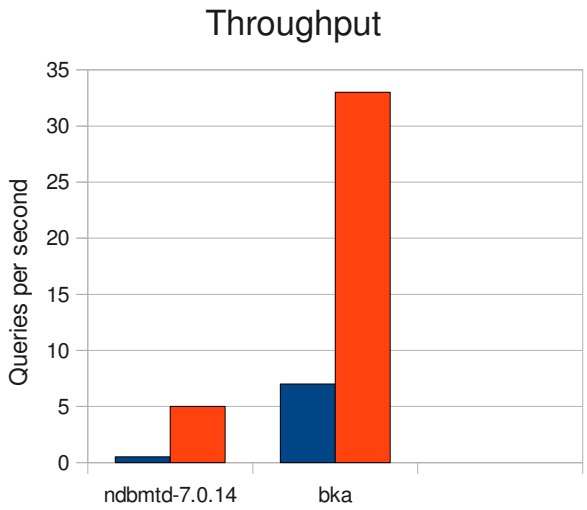
13x

Latency for 128 primary key operations is 1548 microseconds

BKA – part II



- Blue is single thread
- Red is 16-threads



- Left is ndbmtd 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 ?

Distributed push-down joins – part I

What if ?

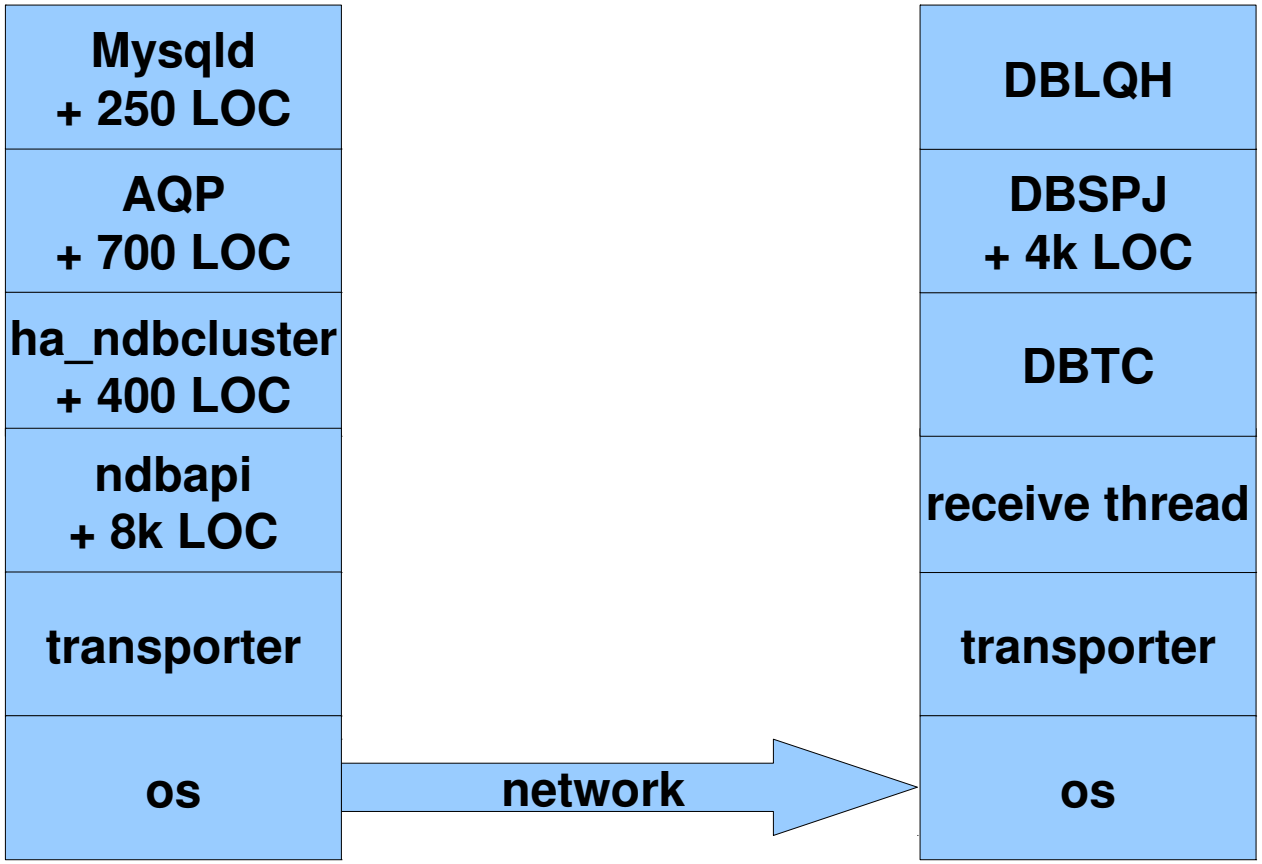
A access method which could combine the existing data access methods,

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



Distributed push-down joins – part II

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

EXPLAIN!

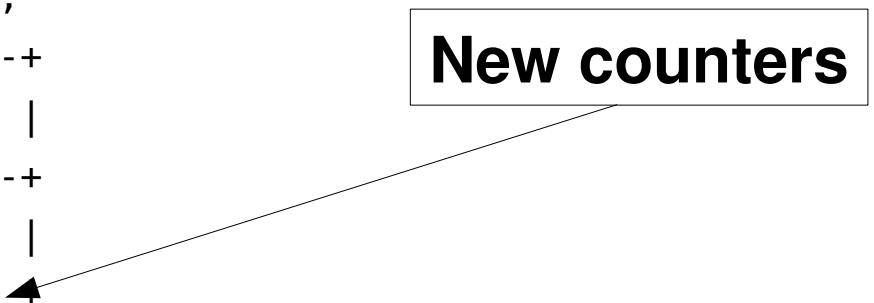
```
mysql> explain SELECT i_id, i_title, a_fname, a_lname FROM item, author, order_line WHERE item.i_id = order_line.ol_i_id AND
item.i_a_id = author.a_id AND order_line.ol_o_id > (SELECT MAX(o_id)-3333 FROM orders) AND item.i_subject = 'COMPUTERS' GROUP BY
i_id, i_title, a_fname, a_lname ORDER BY SUM(ol_qty)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

New keywords

Distributed push-down joins – part VIII

SHOW STATUS LIKE 'NDB_PUSHED%';

```
mysql> show status like 'ndb_pushed%';
+-----------------------------+-------+
| Variable_name               | Value |
+-----------------------------+-------+
| Ndb_pushed_queries_defined  | 1     |
| Ndb_pushed_queries_executed | 1     |
| Ndb_pushed_reads            | 10426 |
| Ndb_pushed_queries_dropped  | 0     |
+-----------------------------+-------+
4 rows in set (0.00 sec)
```



Distributed push-down joins – part IX

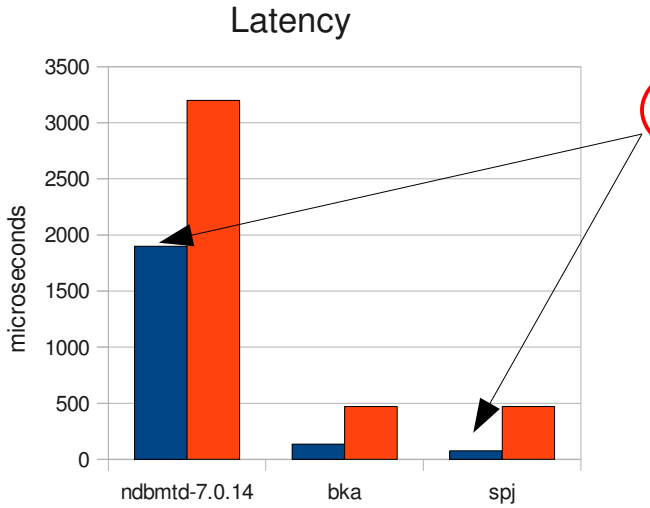
New ndbinfo counters

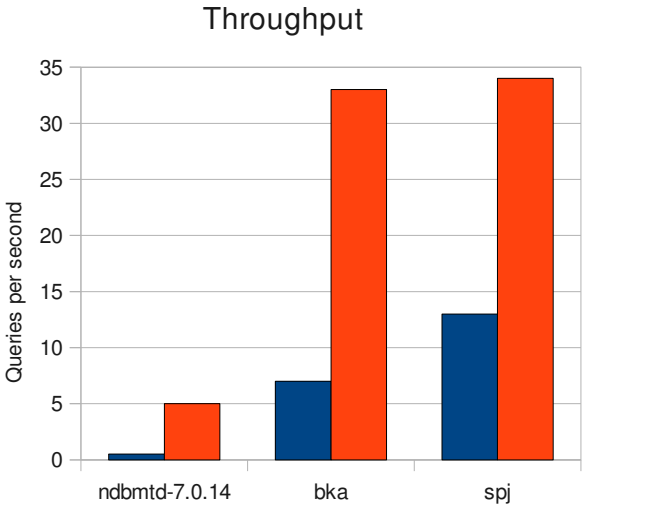
```
mysql> select node_id,counter_name,sum(val) from
ndbinfo.counters where block_name='DBSPJ' group
by node_id, counter_name;
+---------+-----------------------+------+
| node_id | counter_name          | val  |
+---------+-----------------------+------+
|       1 | READS_RECEIVED        |    0 |
|       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

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

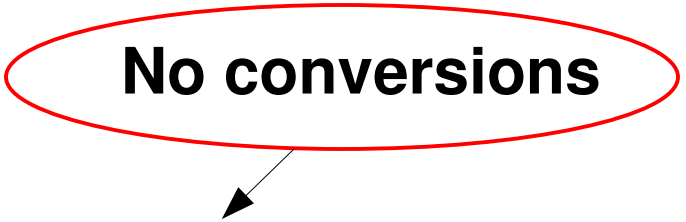
- Only supports `eq_ref` and `const` as access method for child tables
- Only implemented left outer join inside ndb(mt)d, mysqld implements inner join
- Only supports pushed filters on “root” table
- Not multi-threaded (works in ndbmtd, but executed in single thread)

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)
```

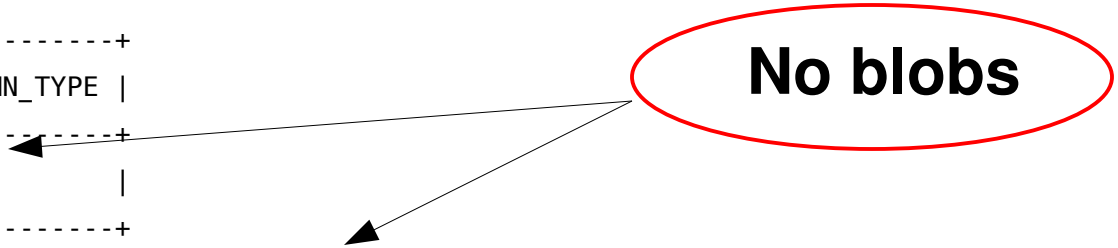
Distributed push-down joins – part XIII

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 |       |
+-------------+--------+--------+---------+---------+-----------------+------+-------+
```



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 | 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> 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**

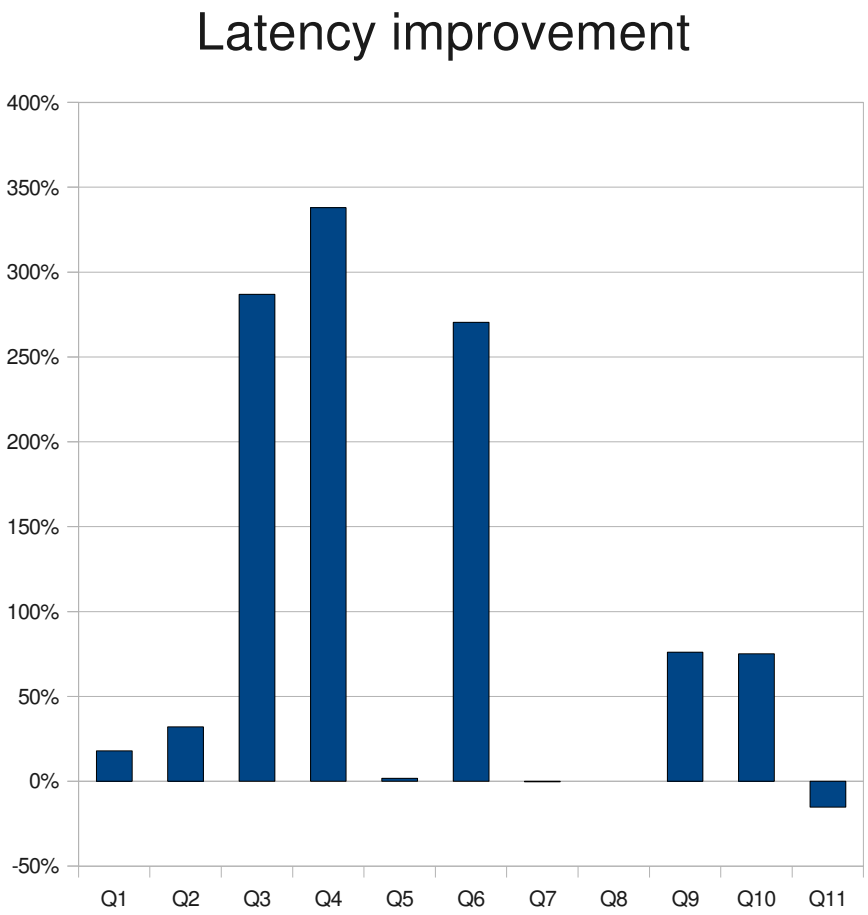
No push :-(

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 noticable 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 unrealisticly 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

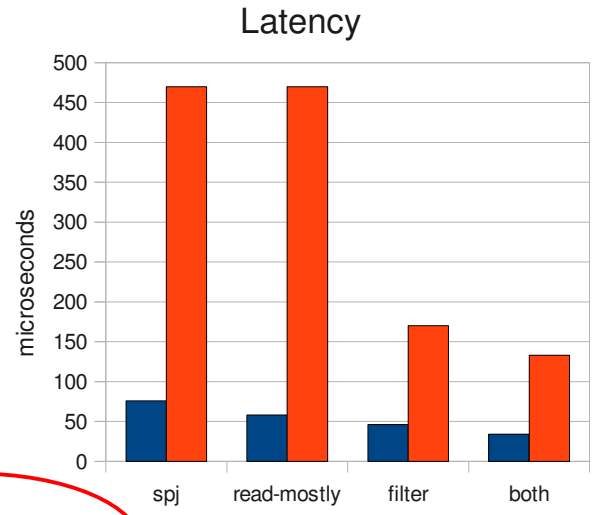
Medium hanging fruit

- “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)

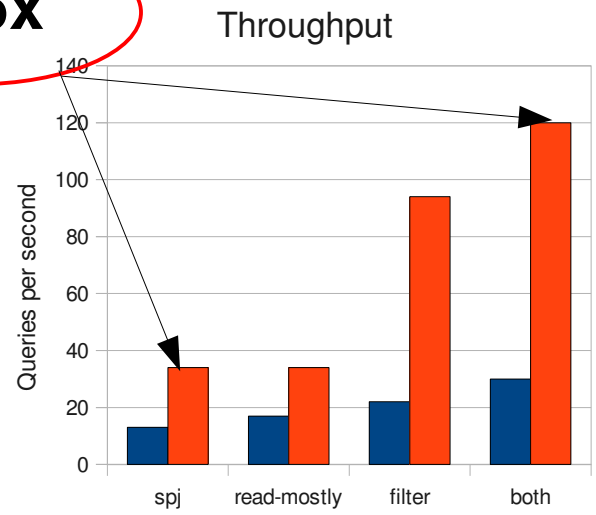
Low hanging fruit

- pushed filters also on child operations
- multi threaded DBSPJ

The future! - part II



3.5x



- 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

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)
```

UC'08 BKA presentation

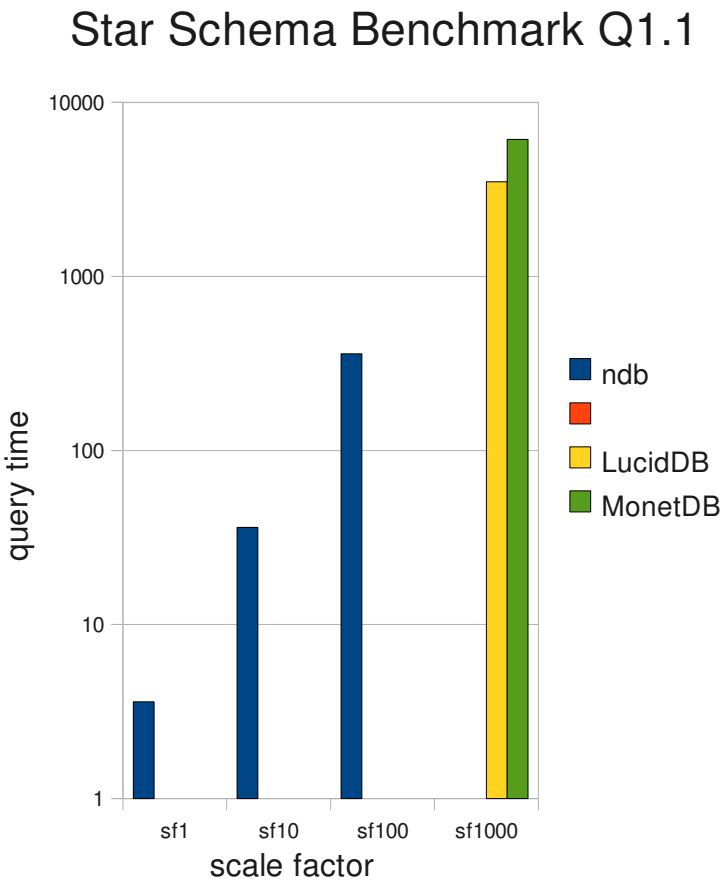
Based on TPC-H

44 times improvement!

```
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)

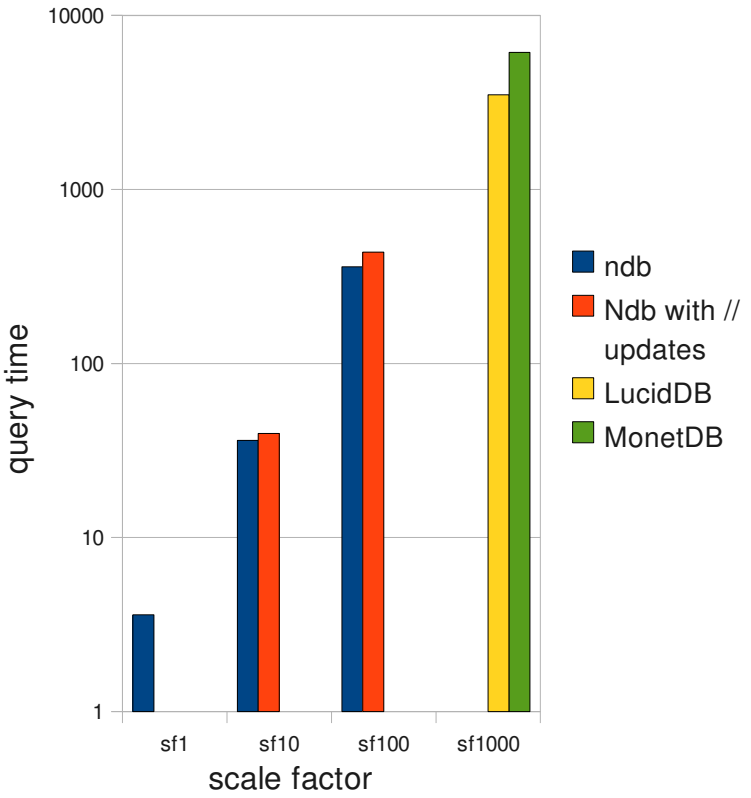


- Star Schema Benchmark is a modified TPC-H
- sf100 = 61Gb
- sf1000 = 610Gb
- LucidDB/MonetDB numbers come from http://www.percona.com/docs/wiki/b

  (using different hardware)

The future – part III (what about that swallow)

Star Schema Benchmark Q1.1



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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Any resemblance to reality is purely coincidental

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 therefor not be put into production

ftp://ftp.mysql.com:/pub/mysql/download/cluster_telco/mysql-5.1.44-ndb-7.1.3-spj-preview/mysql-cluster-gpl-7.1.3-spj-preview.tar.gz