MySQL Cluster – Performance Tuning
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General Design Principles

- MySQL Cluster is designed for
  - Short transactions
  - Many parallel transactions
- Utilize Simple access patterns to fetch data
  - Solution that scales!
- Analyze what your most typical use cases are
  - Optimize for those

Overall design goal
Minimize network roundtrips for your most important requests!
General Design Principles

- Application spaces where Cluster is being used heavily
  - Subscriber databases (telecom)
  - Session management
  - Online gaming
  - Finance
  - E-commerce
  - As a Shard catalog in web 2.0 shops
- The key denominator for all these applications are:
  - high throughput, low response times, high-availability, and simple access patterns.
- Reporting is typically performed on a subsystem
  - Replicate to a slave (e.g., MYISAM or INNODB database)
Tuning Options

- **Schema Optimization**
  - De-normalization
  - Optimize data types

- **Query Tuning**
  - Batching
  - Rewrite slow queries
  - Index Tuning

- **Parameter Tuning**
  - Use a good Configuration (affects mostly stability)
  - Mainly MySQL server parameters

- **Network / OS Tuning**
  - Tune Network (TCP) buffers (not the scope of this presentation)
  - Cluster Interconnects

- **Hardware Tuning**
  - Faster CPU/Disk (not the scope of this presentation)
Detecting Problems – PT 101

• Enable the slow query log!
  • set global slow_query_log=1;
  • set global long_query_time=3; //3 seconds
  • set global log_queries_not_using_indexes=1;
  • Slow queries will be written in the slow query log:
    mysql> show global variables like 'slow_query_log_file';
    +---------------------+------------------------------+
    | Variable_name       | Value                        |
    +---------------------+------------------------------+
    | slow_query_log_file | /data1/mysql/mysqld-slow.log |
    +---------------------+------------------------------+
    1 row in set (0.00 sec)

• Slow Queries will be written in plain text.
  • Or use MEM (but MEM cannot monitor data nodes)
1. Start by analyzing the slow query log
   Change long_query_time if needed

2. Use `EXPLAIN` to figure out if the query is
   • Using the correct indexes
   • JOINing the tables in the wrong order
   • so bad it needs to be rewritten.

3. Re-run the optimized typical use cases using `mysqlslap`

4. GOTO BEGIN;

END;

• Other tools such as `mysqlsla` can also be used
• Performance tuning is a never-ending task.
• Never tune unless you can measure and test

Don't optimize unless you have a problem
## Tuning Options

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Schema Optimization - Data Types

• Denormalize tables
  • Tables having the same **PRIMARY KEY** can be denormalized

• Change Data Types
  • Does an EMAIL need to be a TEXT?
Schema Optimization - Denormalization

- Two tables with the same PRIMARY KEY can be denormalized into a single table:

  - USER_SVC_VOIP
  - USER_SVC_BROADBAND

  - Requires two roundtrips to get data

  - Denormalize:
Schema Optimization - Denormalization

- **Normalized:**
  - SELECT * FROM USER_SVC_BROADBAND AS bb, USER_SVC_VOIP AS voip
    WHERE bb.id=voip.id AND bb.id=1;
  - **Total throughput = 12623.09 tps**
  - Average response time=658us

- **Denormalized:**
  - SELECT * FROM USER_SVC_VOIP_BB AS bb_voip
    WHERE bb_voip=1;
  - **Total throughput = 21591.64 tps**
  - Average response time=371us
Schema Optimization – Data Types

• **BLOB/TEXT** columns are stored in an external hidden table.
  • First 255B are stored inline in main table
  • Reading a **BLOB/TEXT** requires two reads
  • Read without lock will be upgraded to shared lock!

• Reading/Writing a **VARCHAR/VARBINARY** is less expensive.

• Change to **VARBINARY/VARCHAR** if:
  • Your **BLOBs/TEXTs** can fit within an 8052B record (and you need a 4B PK as well)
  • (record size is currently 8052 Bytes)
Schema Optimization – Data Types

- SELECT data1, data2 FROM t1 WHERE id=<rand>
  - sizeof(data1) = 1024B, sizeof(data2) = 1024B.
- 1 App - 8 Threads, 1 MySQLD, 2 Data nodes
- data1 and data2 represented as BLOBs
  - 5844 TPS
- data1 and data2 represented as VARBINARYs
  - 19206 TPS

- **Note 1:** BLOB/TEXT are also more expensive in InnoDB as BLOB/TEXT data is not inlined with the table. Thus, two disk seeks are needed to read a BLOB.
- **Note 2:** We recommend (for any storage engine) to store images, movies etc outside the database on the filesystem.
Schema Optimization - PK selection

- Engineer your schema for the problem you need to solve!
  - Call setup? Locate all friends of a user?
- Very common...
  - Better:
    - Introduce PK <USER_ID, FRIEND_ID>
    - Get rid of column ID
    - Get rid of the UNIQUE (as it is now the PK)

<table>
<thead>
<tr>
<th>ID (auto_inc)</th>
<th>USER_ID</th>
<th>FRIEND_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10001</td>
<td>11000</td>
</tr>
<tr>
<td>2</td>
<td>10001</td>
<td>11001</td>
</tr>
<tr>
<td>3</td>
<td>10001</td>
<td>11002</td>
</tr>
<tr>
<td>4</td>
<td>10002</td>
<td>12022</td>
</tr>
</tbody>
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Simple Access Patterns

- Simple Access Patterns are key to build scalable and high performing solutions (this is not subject to Cluster only)
  - **PRIMARY KEY** lookups are done in constant time \( O(1) \)
  - Fastest way to access data in MySQL Cluster
  - **INDEX** searches are done in \( O(\log n) \) time.
  - **JOINs** are ok if you understand what can make them slow.
    - If your most important requests are 10-way JOINs with huge result sets then Cluster may not be for you.
    - Or use scale out (write to cluster read from innodb): http://johanandersson.blogspot.com/2009/05/ha-mysql-write-scaling-using-cluster-to.html
Operation Cost

- Cost of typical operations (depends on HW/Network)

<table>
<thead>
<tr>
<th>Operation</th>
<th>Avg cost (us)</th>
<th>Min cost (us)</th>
<th>Normalized (scalar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insert 4B + 255B</td>
<td>826</td>
<td>600</td>
<td>2.82</td>
</tr>
<tr>
<td>read 255B</td>
<td>293</td>
<td>174</td>
<td>1</td>
</tr>
<tr>
<td>update 255B</td>
<td>697</td>
<td>505</td>
<td>2.38</td>
</tr>
<tr>
<td>delete</td>
<td>636</td>
<td>202</td>
<td>2.17</td>
</tr>
<tr>
<td>Index/FT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 record (index)</td>
<td>694</td>
<td>400</td>
<td>2.37</td>
</tr>
<tr>
<td>2M FT Scan</td>
<td>4.71(SEC)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- Synchronous replication adds ~2.1x - 2.8x for writes compared to reads
- Index scan takes 2.4x longer than PK read
- Test was with 8 threads connecting to one mysqld
- 'bencher' was used to generate the load. (Xeon 5160 @ 3.00GHz)
Batching

- MySQL Cluster allows batching on
  - INSERT (PK)
  - Most PK UPDATE
  - DELETE (PK)
  - SELECT (PK and some INDEX scans and not in JOINs)

- Batching means
  - One transaction with >1 operation are executed in one round-trip
Batching

• Example – Insert 1M records
  • No batching:
    • INSERT INTO t1(data) VALUES (<data>);
  • Batching (batches of 16):
    • INSERT INTO t1(<columns>) VALUES (<data0>),
      (<data1>)..., (<data15>)
  • 50 seconds to insert 1M records
  • 15 times faster!
Batching

• Read 10 records services for a user:
  • PK is <userid, friend_id>

• Batching (batches of 10):
  • SELECT * FROM t1 WHERE user_id=1 AND friend_id IN (1,2,3,4,5,7,8,9,10);
    • 0.001s

• No batching:
  • 10 x SELECT * FROM t1 WHERE user_id=1 AND friend_id={ id };
    • 0.006s
Batching

• Another way – batching on different tables

```
SET transaction_allow_batching=1; /set on the connection
BEGIN;
INSERT INTO user(uid, fname, lname, email) VALUES ( ... );
10 x INSERT INTO service(uid, sid, data ) VALUES ( ... );
COMMIT;
```

• The above will be executed in one batch (one roundtrip)

  • `transaction_allow_batching=0`: 1223 TPS
  • `transaction_allow_batching=1`: 2204 TPS (80% faster)

• Batching using `transaction_allow_batching` does not work with

  • UPDATE .. SET X=X+1 .. , JOINs, REPLACE
Efficient Scanning – Partition Pruning

• Scanning only one partition is *sometimes* better than scanning all partitions (all nodes).
  – By default, all index scans hit all data nodes – good if big result set.
  – User-defined partitioning can help to improve equality index scans on part of a primary key.
  – `CREATE TABLE user_friends (user_id, friend_id, data, PRIMARY KEY(user_id, friend_id)) PARTITION BY KEY(user_id);`

• All data belonging to a particular `user_id` will be on the same partition.
  – `SELECT * FROM user_friends WHERE user_id=1;`

• Only one data node will be scanned (no matter how many nodes you have)
Efficient Scanning – Partition Pruning

- You can verify if you got it correct checking the `Ndb_pruned_scan_count` status variable
- Increases when a pruned scan occurs

```sql
mysql> select * from user_friend where user_id=1;

mysql> show global status like 'ndb_pruned_scan_count';
+---------------------------------+-------+
| Ndb_pruned_scan_count | 1     |
+---------------------------------+-------+
1 row in set (0.00 sec)
```
Efficient Scanning – Partition Pruning

• Partition Pruning is better up to a certain point
  – Depends on number of data nodes and records retrieved
Query Optimization – JOINs

- JOINs are executed in the MySQL server.
- The OPTIMIZER in MYSQL only knows one algorithm
  - Nested Loop Join
  - This algorithm is not brilliant in its effectiveness
- If we have the following query:

```sql
SELECT fname, lname, title
FROM a,b
WHERE b.id=a.id AND a.country='France';
```
Query Optimization - JOINs

- SELECT fname, lname, title FROM a,b WHERE b.id=a.id AND a.country='France';

1. Index scan left table to find matches.
2. For each match in 'a', find matches in 'b'
   - In this an index scan on the right table on b.id for each matching record in 'a'
   - This could be very expensive if there are many records matching a.country='France'
Query Optimization - JOIN

• The main performance limiter for JOINs are
  – Number of tables in JOIN
  – Number of Records matching the JOIN criteria

• In general
  – JOINs are limiting scalability even for INNODB/MYISAM
    • It is a complex access pattern
  – JOINs should be as simple as possible
    • WHERE – conditions should be as limiting as possible
    • Consider this:
      • **Every inspected record costs about 200us for a PK join**
        • A join hitting 2000 (2000 x 200 us) records → 0.4 seconds
        • A join hitting 2 000 000 records → 40 seconds
  – Using SCI/DX can help a lot as JOINs are subject to network latency that is problematic.
Query Optimization - JOIN

- Make sure the tables are joined in the correct order
  - Check with `EXPLAIN`!
  - Sometime the order is screwed up
  - Make sure you have the necessary indexes
  - Make sure tables are JOINed with the table having the best/most conditions comes first in the JOIN.
  - Preferably take the smallest table first in the JOIN
  - `STRAIGHT_JOIN` can help a lot
Query Optimization - SUB-SELECT

- Rewrite SUB-SELECTS as JOINs
  - SELECT x FROM t1 WHERE t1.id IN
    (SELECT t2.id FROM t2 WHERE t2.y>10
  Becomes
  - SELECT x FROM t1,t2 WHERE t1.id=t2.id AND t2.y>10;
Indexes

• Don't trust the OPTIMIZER!
  • Statistics gathering is very bad
  • Optimizer thinks there are only 10 rows to examine in each table!

• If you have two similar indexes on a table
  • `index(a)`
  • `index(a,ts)`

• Use `FORCE INDEX` to use the correct index
  • Don’t use `USE INDEX`

• Check with `EXPLAIN`!
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Parameter Tuning – ndb_cluster_connection_pool

- **Problem:**
  - A mutex on the connection from the mysqld to the data nodes prevents scalability.
  - Many threads → contention on the mutex
  - Must have many mysqld processes running...

- **Solution:**
  - `Ndb_cluster_connection_pool` (in `my.cnf`) creates more connections from one mysqld to the data nodes
    - One free `[mysqld]` slot is required in `config.ini` for each connection.
    - Threads load balance on the connections → less contention on mutex → increased scalability
Parameter Tuning – Ndb_cluster_connection_pool

- >70% better perf
- `Ndb_cluster_connection_pool=2x<CPU cores>` is a good starting point.
- [www.severalnines.com/config](http://www.severalnines.com/config) allows you to specify this
Parameter Tuning – auto_increments

- A range of `auto_increments` are cached in the MySQL Server
  - ServerA gets 1..1024, serverB gets 1025-2048
  - When out of values in range → go to data nodes, lock, fetch next range, unlock → serialization!
  - `ndb_autoincrement_prefetch_sz=1` (default - too small)
  - Must fetch new ranges all the time from data nodes! Round-trip!

- **16 BATCHED INSERTS / 8 THREADS / 1 APP**
  Default=1: 1211.91TPS
  256: 3471.71TPS
  1024 : 3659.52TPS

- Increase `ndb_auto_increment_prefetch_sz` depending on INSERT load.
Parameter Tuning - Misc

• Don't forget to set:
  • thread_cache_size = <max_connections>
  • table_open_cache=512

• Use SHOW GLOBAL STATUS;
  • If Threads_created increases -> increase thread_cache_size!
  • If Opened_tables increases -> increase table_open_cache!

• Please note that www.severalnines.com/config sets great default values! (the best in the industry actually)
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Network – Cluster Interconnects

- Cluster Interconnects
  - Instead of spending $$$ on application tuning/development
  - Also great for DRBD!

- DX (SCI) is a Cluster Interconnect offering:
  - High Bandwidth (20 Gb/sec full duplex), Low latency (<2us)
  - Offers a socket interface – any socket based application benefits from it
  - 10 Gig-E form factor on cabling
  - Seamless fallback to Gig-E
  - >2x more performance just plugging it in.
  - DXH510 PCI Express Host Adapter (600USD list price Oct 2008)
  - DXS410 DX 10 Port Switch (4200USD list price Oct 2008)

- Read more at http://www.dolphinics.com
Other things

• Make sure you **never**:
  • Run in SWAP – the data nodes will be sub-performing and you will have an unstable system.

• Make sure you **do**:
  • Lock data nodes threads to CPUs not handling interrupts for ETH.
  • Vm.swappiness=0
  • Mount with noatime
  • On SUN CMT (T5240 etc) it is very important to create processor sets and bind interrupt handling to particular Core (HW Thread)
Tools

- Third party tools at www.severalnines.com
  - Configurator
    - Uses best practices for setting up a good config.ini and my.cnf
    - Scripts to control cluster from one single location.
  - CMON – Cluster Monitor
    - Monitor X number of Clusters (and mysqld statistics) from a single web interface
  - Sizer – Capacity Planning
  - Sandbox – Development package (localhost) for Cluster
Questions?

THANK YOU!

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