MySQL Optimization

MySQL User Conference

Jeremy Zawodny

Yahoo!

April 12th, 2003

San Jose, California

http://jeremy.zawodny.com/mysql/

About Me

- Engineer in Y! Search (prev. Y! Finance)
- MySQL user for over 5 years
- Active in MySQL community
- Write about LAMP for Linux Magazine
- MySQL advocacy & support at Yahoo!

Home: Jeremy@Zawodny.com
Work: jzawodn@yahoo-inc.com
http://jeremy.zawodny.com/mysql/

Outline

- Introduction
- Why Optimize?
- Goals
- Database Design
- Application Design
- Writing Fast Queries
- MySQL Server Tuning
- Operating System Tuning
- Hardware Tuning
- Network & Replication
- Where to Learn More
- Questions and Answers

Starting Questions

- What version of MySQL are you using?
- What languages are being used?
- Which operating systems?
- Familiarity with other RDBMS servers?
- Role? DBA? Developer? SysAdmin?
- MySQL dedicated or shared servers?
- How fast is your growth?
  - Transaction rates
  - Data volume

What you Need to Know

- You should ask questions at any time
  - There should be sufficient time
- MySQL usage
  - Basic queries (SELECT, UPDATE, INSERT)
  - Installation or where files are located
- Basic programming concepts
  - Any language will do
- Operating system basics
  - Memory usage, swapping, etc.

MySQL at Yahoo!

- Roughly 200-400 servers world-wide
- FreeBSD and Linux
- Commodity hardware
- Replaces home-grown “database” systems
- Replaces Oracle in a few cases
- Typical install uses between 1-20GB
- Used both “live” and in batch processing
- Replication and load-balancing

Why Optimize?

- You can do more with less
  - MySQL on “normal” hardware scales well
  - A little time can save thousands in hardware
  - The classic story goes…
- As you data grows, you’ll need to
  - Performance will degrade over time
  - You’re probably not monitoring it anyway
- It is easier than re-coding you apps
- Your users will notice if you don’t!

MySQL's Defaults

- Tuned for small and medium data sets
- Uses very little memory even if available
- Suitable for use in a shared environment
- Assumes little about your hardware
- Begins to slow as growth continues
- Uses non-transactional tables (MyISAM)
  - That's what most people need (90%)
  - Very low overhead

Scaling MySQL

- Like Linux, MySQL scales up and down
- Can run many MySQL instances at once
- Can run one very big MySQL instance
- Can run with only a few MB of memory
  - Suitable for small devices
  - Will be disk-bound
- Can embed using libmysqld (MySQL 4.x)
- Can recompile to add/remove features
  - Table types, query cache, etc.

Using Less Hardware

- Hardware is rarely the bottleneck
  - Well-tuned servers are often disk-bound
- MySQL isn't using it aggressively
  - You must configure it
- Modern CPUs are *very* fast
  - What you have is probably sufficient
- Memory is plentiful
  - You're probably not using what you have
- Upgrades do little to solve most problems!

Goals

- Learn to write fast queries and applications
- Learn to design and use the right tables
- Know where to look for bottlenecks
- Predict behavior as load increases
- Understand what to monitor over time
- Understand how MySQL uses system resources
- Learn what settings you can adjust
  - In your operating system
  - In MySQL
  - In your applications
- Know where to learn more…

Database Design

- Normalize your data by default
  - Sometime you need to de-normalize
  - When in doubt, benchmark
    - MySQL super-smack
    - MySQL benchmark suite
    - Home-grown tools
    - Use your real apps!

Database Design

- Select the right column types
  - No bigger than you need
  - MySQL provides a ton of column types
  - Use NOT NULL where it makes sense
  - Use fixed column sizes if you can
    - MyISAM tables with fixed rows are faster
    - Concurrency improvements
  - Store compressed data when possible

See: http://www.mysql.com/doc/S/t/Storage_requirements.html

Database Design

- Select the right table types
  - What locking model do you need?
    - Table (MyISAM)
    - Row (InnoDB)
    - Page (BDB)
  - Consider ratio of reads to writes
  - Foreign key constraints?
  - Do you need transactions?
  - Can you afford to lose records in a crash?
  - Do you know MySQL's table types?

Database Design

- MyISAM Tables
  - Very efficient
  - Compact storage
  - In-memory key cache for index data
  - Table locking
  - No transactions
  - Good for
    - High volume logging (write)
    - High volume reads
    - Not both
  - Variations: Compressed, RAID, Merge

Database Design

- Compressed MyISAM Tables
  - Read-only
  - Good for CD-ROMs and archives
- MyISAM RAID Tables
  - Break the 2GB/4GB/whatever barrier
- MyISAM Merge Tables
  - Many physically identical MyISAM tables
  - Can treat as a single table (or not)

Database Design

- HEAP Tables
  - Stored in memory
    - They will vanish at server shutdown
  - Very fast hash-based lookups
    - Limited index use
    - Range queries are slower
  - B-Tree available in 4.1
  - Table locking
  - Great for static lookups
  - Size can be limited to prevent disaster

Database Design

- BDB Tables
  - Transactional
  - Automatic recovery
  - Tables grow as needed
  - Page-level locking (8KB page)
    - Single READ-COMMITTED isolation level
  - Uses Berkeley DB under the hood
  - Few users actually use BDB
  - Works well for small - medium transaction rate
  - Locking on the last page can be a problem

Database Design

- InnoDB Tables
  - Modeled after Oracle
    - Row-level locking
    - Non-locking SELECTs
    - Uses pre-allocated tablespace files
  - Multiple isolation levels
    - Easily changed with a SET command
  - Referential integrity - foreign keys
  - High performance
  - Very high concurrency
  - Automatic recovery after crash

Database Design

- Use Indexes wisely
  - Don’t use several indexes when one will do
  - Understand the “leftmost prefix” rule
    - Index on (col1, col2, col3) vs. 3 indexes
  - Don’t index columns until you need to
  - Verify that indexes are used (difficult)
  - Use partial indexes on large (text) fields
  - Index a hash rather than a large value (URL)
    - MD5 is an excellent choice
    - It’s even built-in

Database Design

- Use full-text indexing if you need it
  - MyISAM tables only
  - Very fast
  - Excellent in MySQL 4.x
  - Results are ranked (like a search engine might)
  - Boolean queries
    - Flexible
    - Mostly feature-complete
  - Works on any textual data
    - Other character sets will need 4.1 or 5.0

Full-Text Search

- Use 4.0 if possible
  - Indexing is much faster
  - Stop word list customization
  - Min word size easily changed
    - Remember to rebuild indexes after changing
- In 5.0 we should see
  - Per-table stop word lists
  - Per-table word length options
  - Per-table word characters lists
  - These might be per-index!

Application Design

- Don’t store data you don’t need
  - Compress it
  - Get rid of it
- Don’t store computable data
  - MySQL can do it
  - Your app can do it
- Don’t ask for data you don’t need…
  - Do you really need all fields?
    `SELECT * FROM...`

Application Design

- Use MySQL extensions for speed
  - REPLACE queries
  - Bundled INSERT queries
  - Multi-table deletes
  - User variables
- Use logging to track bottlenecks
- Don’t perform unnecessary queries
  - Cache data (static lookup tables)
  - Use the Query Cache if you must
- Benchmark your application
  - Know where the bottlenecks are
  - Know how a slow db affects your application

Application Design

- Use transactions
  - Prevents data loss
  - Server does less random I/O
  - Performance and reliability
- Keep the clients “near” the server
  - Network latency is a killer
  - Replication can solve geography problems
  - Can also help solve geology problems (quake)
  - Running app and MySQL on same hardware

Application Design

- Think about growth
  - There are size limits that you might hit
  - InnoDB and MyISAM both have them (sort of)
- Keep primary keys short for InnoDB

Application Design

- Use prepared queries and placeholders
  - MySQL doesn't yet support them
  - Your API may
  - When MySQL does, you benefit!
  - The API may be more efficient anyway
  - MySQL 4.1 and PHP 5.0 benefit

```
SELECT name, address, state, zip
  FROM customers
 WHERE id = ?
```

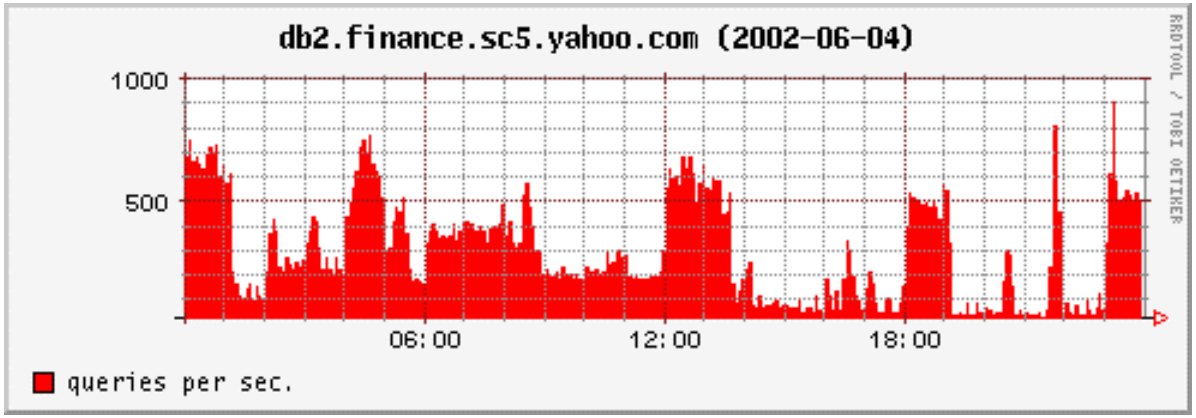
Application Design

- Web apps
  - Use (but don't *over*-use) connection pooling
  - Use middleware to abstract the database
    - May also provide caching and pooling
  - Don't keep everything in the database!
    - Images can live on the file system
    - But you might want to replicate them
  - Pick the fastest driver you can
    - Java has several, Perl has two
    - On Windows, use the "most native"

Break!

Writing Fast Queries

- Use Indexes
- Use `EXPLAIN SELECT`
- Simplify where clause
- Watch Slow query log
- Bundle INSERTs
- UNIONs



Writing Fast Queries

- Understanding how MySQL runs queries
- You need to think like MySQL does
- Some of its goals are…
  - Eliminate as many rows as possible
  - Use indexes where possible
  - Avoid table scans
  - Consider many join orders
  - Avoid hitting the disk
  - Avoid using the data records if the index has it

Writing Fast Queries

- `EXPLAIN SELECT`
  - Tells you what MySQL is thinking
  - Which keys (indexes) can it use
  - Which keys will it use
  - How many rows must it examine (roughly)
    - `ANALYZE TABLE` can help
  - How hard must MySQL work?

Writing Fast Queries

- EXPLAIN SELECT

```
mysql> EXPLAIN SELECT * FROM Headlines H, S2H S WHERE S.Symbol = 'YHOO' and H.Id = S.HeadlineId;
+-------+--------+-------------------+---------+---------+--------------+------+-------------------------+
| table | type   | possible_keys     | key     | key_len | ref          | rows | Extra                   |
+-------+--------+-------------------+---------+---------+--------------+------+-------------------------+
| S     | ref    | HeadlineId,Symbol | Symbol  |      75 | const        |  383 | where used; Using index |
| H     | eq_ref | PRIMARY           | PRIMARY |       4 | S.HeadlineId |    1 | where used              |
+-------+--------+-------------------+---------+---------+--------------+------+-------------------------+
2 rows in set (0.00 sec)

mysql> EXPLAIN SELECT * FROM Headlines H, S2H S WHERE S.Symbol = 'YHOO' and H.Id = S.HeadlineId ORDER BY Time DESC;
+-------+--------+-------------------+---------+---------+--------------+------+-----------------------------------------+
| table | type   | possible_keys     | key     | key_len | ref          | rows | Extra                                   |
+-------+--------+-------------------+---------+---------+--------------+------+-----------------------------------------+
| S     | ref    | HeadlineId,Symbol | Symbol  |      75 | const        |  383 | where used; Using index; Using temporary;
                                                                                  Using filesort
| H     | eq_ref | PRIMARY           | PRIMARY |       4 | S.HeadlineId |    1 | where used                              |
+-------+--------+-------------------+---------+---------+--------------+------+-----------------------------------------+
```

Writing Fast Queries

- EXPLAIN SELECT
  - Table
    - Order is significant
    - Aliases appear
  - Type
    - System
      - Table has one row
      - Easily optimized
    - Const
      - Only a single row matches
      - Read once

Writing Fast Queries

- EXPLAIN SELECT (continued)
  - Type (continued)
    - eq_ref
      - One row matches per combination
      - Unique index match
    - ref
      - Several matching rows per combination
      - Non-unique index
    - range
      - A range of rows will be retrieved
    - index
      - Index will be scanned for matches
      - Like a table scan, but faster
    - all
      - Full table scan
      - Worst case

Writing Fast Queries

- EXPLAIN SELECT (continued)
  - Possible keys
    - What MySQL had to choose from
  - Key
    - What it decided to use
  - Key length
    - Length (in bytes) of the longest key
  - Ref
    - Which column it will match with
  - Rows
    - Approximately how many rows must be examined

Writing Fast Queries

- EXPLAIN SELECT (continued)
  - Extra information
    - Using filesort
      - An extra pass is required to sort the records
      - This can be slow at times
    - Using index
      - Data will come from the index rather than rows
      - This can speed things up
    - Using temporary
      - MySQL will create a temporary table
      - It’ll be a disk-based table if it’s too large
    - Where used
      - The where clause will be applied to this table

Writing Fast Queries

- Optimizer tips and tricks
  - It's smart, but not perfect
  - Only one index per table per query
    - You *may* need to de-normalize to get performance
    - You *may* need to write two queries instead of one
  - Don't compute in the WHERE
    - MySQL doesn't know how to optimize constant expressions

```
SELECT * FROM Headlines
WHERE Time > SUBDATE(NOW(), INTERVAL 7 DAY);
```

Insert Speed

- In 4.1 and beyond, use prepared statements
- In older versions
  - Single inserts are the slowest
  - Multi-rows inserts are faster
  - Bulk-loading (LOAD DATA or *mysqlimport*) are very, very, very fast
- Using InnoDB, use transactions wisely
  - Many inserts in AUTOCOMMIT mode are very, very slow

Query Cache

- Part of MySQL 4.0
- Can seriously boost performance
- Might save legacy apps you can't change
- Use query cache selectively if you have lots of writes
  - SELECT SQL_CACHE …
- Use *mytop* to watch query cache stats
  - Version 1.3 and 1.4 will have more stats

MySQL Server Tuning

- Watching performance
- Benchmarking
- Tunable Parameters
  - Most bang, least effort
  - Incremental gains
- Methodology
  - Iterative testing
  - Long-term monitoring

MySQL Server Tuning

Watching Performance

```
MySQL on db.finance (3.23.47-max-log)                up 79+08:23:44 [15:37:21]
 Queries Total: 2,068,312,373  Avg/Sec: 301.69  Now/Sec: 242.04  Slow: 798
 Threads Total: 45       Active: 5     Cached: 0
 Key Efficiency: 99.85%  Bytes in: 3,713,492,213  Bytes out: 1,006,022,300

     Id      User      Host          DB   Time    Cmd Query or State
     --      ----      ----          --   ----    --- ----------
5827598     yahoo     proc2         IDX      0  Sleep
5779323      fred     feed1        Fred      0  Sleep
5779350      fred     feed1        Fred      0  Query select a.id as id, a.feed_
5829250     yahoo   museful       mysql      0  Query show full processlist
5825442     yahoo     proc2         IDX      0  Sleep
5826226     yahoo     proc3         IDX      0  Query SELECT * FROM Headlines H,
5825441     yahoo     proc4         IDX      1  Sleep
5829234      root localhost MySQL_Admin      1  Sleep
5779354      fred     feed1        Fred      9  Sleep
4303469     yahoo     proc2         IDX     11  Sleep
4286987     yahoo      biz5         IDX     14  Sleep
5829245     yahoo     proc3         IDX     19  Sleep
5829242    locker     proc4     Finance     19  Sleep
5829246     yahoo     proc4         IDX     19  Sleep
5829244    locker     proc3     Finance     19  Sleep
5829240    locker     proc4     Finance     20  Sleep
-- paused, press any key to resume --
```

MySQL Server Tuning

- Key Performance Numbers
  - Queries per second
    - Min, Max, Short-term, Long-Term
  - Bytes per second
    - Inbound vs. Outbound
  - New connections per second
  - Idle vs. Active clients
  - Key cache efficiency
  - Query cache efficiency

MySQL Server Tuning

- How MySQL uses memory
  - Main Global Caches and Buffers
    - Query cache
    - Key buffer
    - Table cache
    - InnoDB buffer pool
    - InnoDB log buffer
  - Main Thread-specific Caches and Buffers
    - Record buffer
    - Sort buffer
    - Join buffer

MySQL Server Tuning

- SHOW STAUTS
  - Created_tmp_disk_tables
    - If large, increase temp table size
  - Handler_*
    - Determine key buffer effectiveness
  - Com_*
    - Find the commands that are most often run
  - Questions and Uptime
    - Compute queries/second
  - Select_*
    - How many types of each SELECT are executed
  - Qcache_*
    - Query cache performance

On-the-Fly Tuning

- Use MySQL's SET syntax to change parameters on the fly (new in 4.0)
  - max_connections
  - wait_timeout
  - thread_cache
  - key_buffer_size
  - table_cache
- Don't change too much at once
- Persistent connections aren't always fast!
- Changes may take time to notice

MySQL Server Tuning

- SHOW STATUS
  - Table_locks_*
    - How many times are queries waiting for locks?
    - Concurrency problems show up here
  - Bytes_*
    - How much data are you pumping out
    - Compare with inbound traffic
  - Qcache_*
    - Query cache performance
    - Memory usage

MySQL Server Tuning

- my.cnf file parameters
  - key_buffer
  - tmp_table_size
  - Table_cache
  - Max_connections
  - Max_user_connections
  - Long_query_time
  - Thread_concurrency

MySQL Server Tuning

- my.cnf file parameters
  - innodb_buffer_pool_size
  - innodb_log_file_size
  - innodb_file_io_threads
  - innodb_flush_log_at_trx_commit
  - innodb_log_buffer_size
  - innodb_flush_method
    - fdatasync
    - O_DSYNC

InnoDB Performance

- Transaction log flushing has three options
  - (1) Flush on commit
  - (0) Never flush
  - (2) Flush once per second

MySQL Server Tuning

- Fileysystem Issues
  - Spread data among disks
    - Put heavily used and lightly used databases together
    - RAID-5 or RAID-10 for data (w/batter-backed cache)
    - RAID-1 for logs
    - New CREATE TABLE makes this easier
  - Logs separate from data
    - Logs are mostly serialized writes
    - Tables are updated and used in *mostly* random fashion
  - If you have *a lot* of tables in a database
    - Use a filesystem designed to handle it
    - ResiserFS is a good choice
  - A journaling filesystem
    - Makes crash recovery faster
    - Better utilizes disk I/O (usually)

MySQL Server Tuning

- Upgrade once in a while
  - New versions are often faster
  - Better optimizations in query parser
  - New and enhanced caching
- Convert older tables to newer format
  - ISAM to MyISAM
  - BDB to InnoDB (or not)
  - `ALTER TABLE my_table TYPE=InnoDB`
- Don’t flush the transaction logs on commit

Upgrade Testing

- It’s often a good idea to keep up-to-date
- Performance tweaks and optimizations are introduced during the maintenance process
- Be sure to test your critical queries carefully
- Always use a real load test or read the EXPLAIN output
- Without load, “slow” queries are often fast

Operating System Tuning

- Virtual Memory Use
  - FreeBSD - excellent
  - Linux - varies wildly
    - 2.4.9 good
    - >= 2.4.16 good
    - Others not good
- Per-process limits on:
  - Memory
  - File descriptors
- Network duplex settings
- Competing processes on the machine?

Operating System Tuning

- Key Metrics
  - Memory used/free/cache/buffer
    - Swapping is very bad
    - You might even disable swap
  - Paging and page faults
    - Make sure there's no memory pressure
    - Server variables might be wrong if many page faults
  - Disk I/O
    - Make sure the I/O is where you expect
    - Disk I/O tuning (see your OS docs)
  - Processes running, sleeping, blocked/waiting
  - Actual CPU usage (might be too low)

Operating System Tuning

- Useful Unix Tools
  - top, ps, vmstat
  - iostat, sar
  - mrtg, rrdtool
- Windows Tools
  - Performance Monitor (perfmeter)
  - Task Manager
  - Others I don’t know (not a Windows guy)

Hardware Tuning

- CPU Issues
  - Speed
  - Single vs. Dual
- RAM Issues
- Disks
  - IDE vs. SCSI
  - RAID (hardware or software)
  - Battery-backed cache on controller is best

Hardware Tuning

- Network
  - The faster the better (watch latency)
  - Duplex settings
- I/O Channels
  - The more the merrier
  - Most PC motherboards suck
  - Server-class boards are better
  - High-end hardware (IBM, Sun) are best
  - You'll be lucky to have this problem!

Network & Replication

- Put clients near servers
- Redundancy is very good
- Put slaves near master(s)
  - Unless that's stupid
- Use load-balancing technology
  - High(er) availability MySQL
  - Easy scaling of traffic
- Pick the correct replication topology
- Backup slaves instead of the master

Network & Replication

- Replication is quite flexible
- Can build a topology to solve most problems
- Only a few nagging issues
  - Auto-increment fields
  - Automatic Fail-over
  - Need to build health checks
    - Performance/Latency
    - Slave stopped?
- Come to my replication talk to learn more!

Stupid Query Tricks

- Use SQL_CALC_ROWS and FOUND_ROWS() rather than double-queries:
  - SELECT ... LIMIT N, M
  - SELECT COUNT(*)
- Instead:
  - SELECT ... LIMIT N, M
  - SELECT FOUND_ROWS()
- Requires far less overhead on MySQL

Stupid Query Tricks

- Use a UNION to re-write a slow OR query

```
SELECT * FROM mytable
WHERE col1 = ‘foo’ OR col2 = ‘bar’
```

```
(SELECT * FROM mytable
WHERE col1 = ‘foo’)
UNION
(SELECT * FROM mytable
WHERE col2 = ‘bar’)
```

Stupid Query Tricks

- Ordering, limiting, and ordering again

```
(SELECT * FROM mytable
WHERE col1 = ‘foo’
ORDER BY col2 LIMIT 50)
ORDER BY col3
```

Final Advice

- Read
- Learn
- Test
- Ask
- Monitor
- Benchmark

For More Info…

- MySQL mailing lists
  - Visit lists.mysql.com
- Books
  - MySQL Manual
  - MySQL (Paul's Book)
  - Managing & Using MySQL
- Web searching

Questions and Answers