Performance Tuning Best Practices

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Overview

- Benchmarking and Profiling Concepts
- Sources of Problems
- Schemas and Indexes
- SQL Coding
- Server Parameters

Benchmarking Concepts

- Provides a track record of changes
  - Baseline is the starting point
  - Testing done iteratively
  - Deltas between tests show difference that the change(s) made
- Stress/Load testing of application and/or database
- Harness or framework useful to automate many benchmark tasks

Benchmarking Tips

- Always give yourself a target
- Record *everything*
  - Schema dump
  - my.cnf files
  - hardware/os configuration files as needed
- Isolate the problem
  - Shut down unnecessary programs
  - Stop network traffic to machine
  - Disable the query cache
  - Change one thing at a time

Benchmarking Toolbox

- SysBench
  - http://sysbench.sourceforge.net/
- mysqlslap (5.1+)
  - http://dev.mysql.com/doc/refman/5.1/en/mysqlslap.html
- Apache Bench (ab)
- supersmack
  - http://www.vegan.net/tony/supersmack/
- MyBench
  - http://jeremy.zawodny.com/mysql/mybench/

Profiling Concepts

- Diagnose a running system
- Low hanging fruit
  - Diminishing returns
  - Be careful not to over-optimize
- Identify performance bottlenecks in
  - Memory
  - CPU
  - I/O (Disk)
  - Network and OS

Profiling Toolbox

- SHOW Commands
  - `SHOW PROCESSLIST | STATUS | INNODB STATUS`
  - http://dev.mysql.com/show
- EXPLAIN
  - http://dev.mysql.com/explain
- MyTop
  - http://jeremy.zawodny.com/mysql/mytop/
- Whole host of Linux power tools
  - gprof / oprofile
  - vmstat / ps / top / mpstat / procinfo
- apd for PHP developers
  - http://pecl.php.net/package/apd

Slow Query Log

- Slow Query Log
  - `log_slow_queries=/var/lib/mysql/slow-queries.log`
  - `long_query_time=2`
  - `log_long_format`
  - Use mysqldumpslow to parse the file
  - (5.1+) Can log directly to a table, plus does not require restart of server
    - `SET GLOBAL SLOW_QUERY_LOG = { ON | OFF }`
    - http://dev.mysql.com/doc/refman/5.1/en/log-tables.html

Profiling Tips

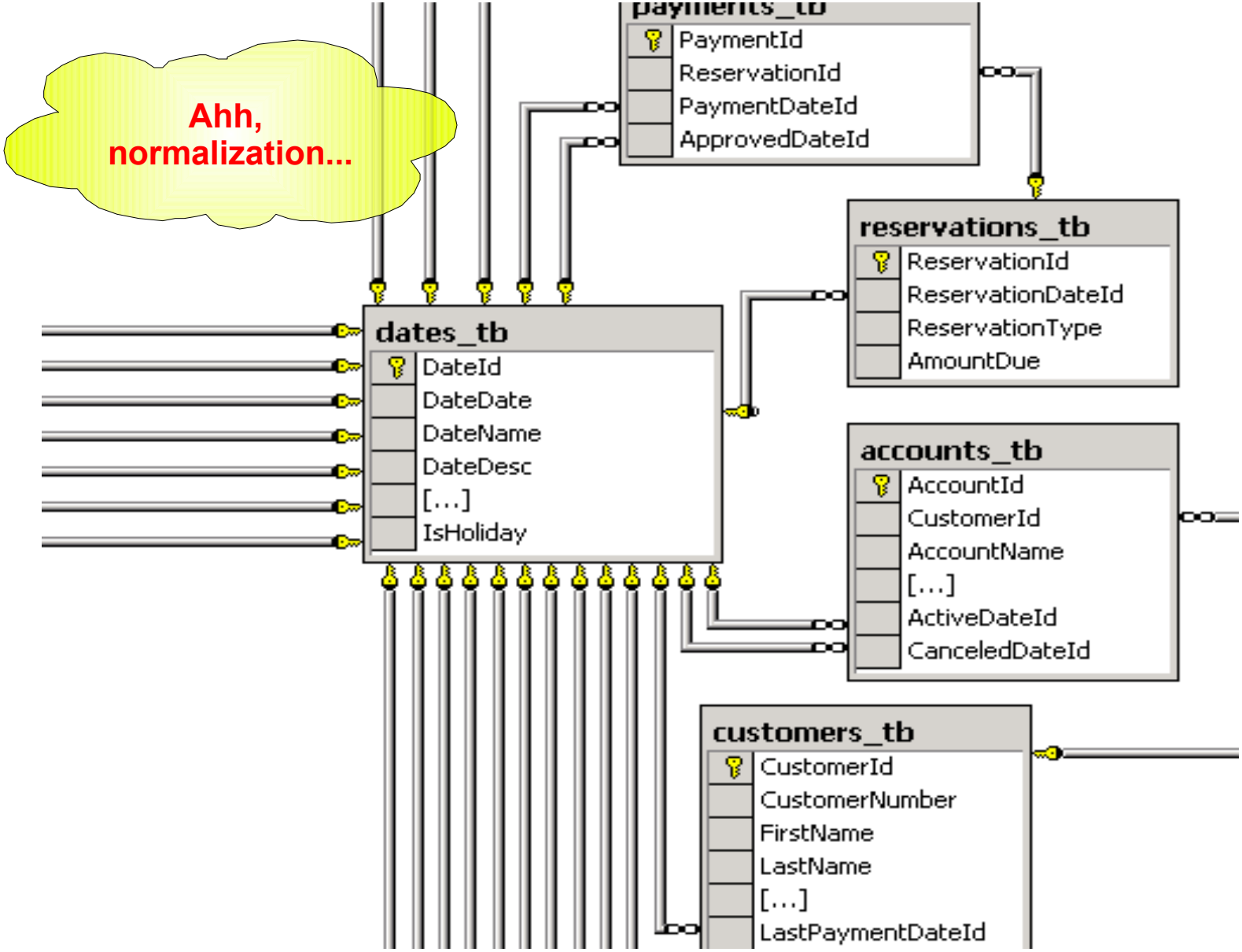
- Get *very* familiar with `EXPLAIN`
  - Access types
  - Learn the `type`, `key`, `ref`, `rows`, `Extra` columns
- Low hanging fruit (diminishing returns)
- Use MyTop to catch locking and long-running queries in real-time

Sources of Problems

- Inefficient or bloated schema design
- Poor or nonexistent indexing
- Bad SQL Coding Practices
- Server variables not tuned properly
- Hardware and/or network bottlenecks

Schema Guidelines

- Inefficient schema a great way to kill performance
- Use the smallest data types necessary
  - Do you really need that `BIGINT`?
- Fewer fields = Narrow rows = More records per block
- Normalize first, denormalize only in extreme cases...



http://thedailywtf.com/forums/thread/75982.aspx

Schema Tips

- Consider horizontally splitting many-columned tables (example ahead)
- Consider vertically partitioning many-rowed tables
  - Merge tables (MyISAM only)
  - Homegrown (email example)
  - Partitioning (5.1+)
- Use AUTO_INCREMENT columns vs. homegrown sequences. Faster and built-in to the database.
- Use “counter” tables to mitigate query cache issues (example ahead)
  - Essential for InnoDB

Horizontal Partitioning Example

```
CREATE TABLE Users (
  user_id INT NOT NULL AUTO_INCREMENT
, email VARCHAR(80) NOT NULL
, display_name VARCHAR(50) NOT NULL
, password CHAR(41) NOT NULL
, first_name VARCHAR(25) NOT NULL
, last_name VARCHAR(25) NOT NULL
, address VARCHAR(80) NOT NULL
, city VARCHAR(30) NOT NULL
, province CHAR(2) NOT NULL
, postcode CHAR(7) NOT NULL
, interests TEXT NULL
, bio TEXT NULL
, signature TEXT NULL
, skills TEXT NULL
, company TEXT NULL
, PRIMARY KEY (user_id)
, UNIQUE INDEX (email)
) ENGINE=InnoDB;
```

```
CREATE TABLE Users (
  user_id INT NOT NULL AUTO_INCREMENT
, email VARCHAR(80) NOT NULL
, display_name VARCHAR(50) NOT NULL
, password CHAR(41) NOT NULL
, PRIMARY KEY (user_id)
, UNIQUE INDEX (email)
) ENGINE=InnoDB;

CREATE TABLE UserExtra (
  user_id INT NOT NULL
, first_name VARCHAR(25) NOT NULL
, last_name VARCHAR(25) NOT NULL
, address VARCHAR(80) NOT NULL
, city VARCHAR(30) NOT NULL
, province CHAR(2) NOT NULL
, postcode CHAR(7) NOT NULL
, interests TEXT NULL
, bio TEXT NULL
, signature TEXT NULL
, skills TEXT NULL
, company TEXT NULL
, PRIMARY KEY (user_id)
) ENGINE=InnoDB;
```

Horizontal Partitioning Benefits

- Main table has narrow rows, so...
  - More records fit into a single data page
  - Fewer reads from memory/disk to get same number of records
- Less frequently queried data doesn't take up memory
- More possibilities for indexing and different storage engines
  - Allows targeted multiple MyISAM key caches for hot and cold data (example ahead)

Multiple MyISAM Key Caches

- Method of controlling key cache invalidation
- “Pins” key cache blocks
- Allows you to place frequently accessed table indexes into a hot cache
- Destroyed upon server restart, so use `init_file`
- Preload hot cache with `LOAD INDEX INTO CACHE`
- Control index scan invalidation with division limit

```
// /etc/my.cnf
[mysql.server]
init_file=/path/to/datadir/init.sql
```

```
// init.sql
// Setup the hot cache
SET GLOBAL
hot_cache.key_buffer_size=128K

// Cache the postcode lookup
CACHE INDEX zip_lookup
TO hot_cache;

// Preload the index sequentially
LOAD INDEX INTO CACHE zip_lookup;

// Control cache invalidation
SET GLOBAL
default.key_cache_division_limit=70;
```

Counter Table Example

```
CREATE TABLE Products (
  product_id INT NOT NULL AUTO_INCREMENT
, name VARCHAR(80) NOT NULL
, unit_cost DECIMAL(7,2) NOT NULL
, description TEXT NULL
, image_path TEXT NULL
, num_views INT UNSIGNED NOT NULL
, num_in_stock INT UNSIGNED NOT NULL
, num_on_order INT UNSIGNED NOT NULL
, PRIMARY KEY (product_id)
, INDEX (name(20))
) ENGINE=InnoDB; // Or MyISAM

// Getting a simple COUNT of products
// easy on MyISAM, terrible on InnoDB
SELECT COUNT(*)
FROM Products;
```

```
CREATE TABLE Products (
  product_id INT NOT NULL AUTO_INCREMENT
, name VARCHAR(80) NOT NULL
, unit_cost DECIMAL(7,2) NOT NULL
, description TEXT NULL
, image_path TEXT NULL
, PRIMARY KEY (product_id)
, INDEX (name(20))
) ENGINE=InnoDB; // Or MyISAM

CREATE TABLE ProductCounts (
  product_id INT NOT NULL
, num_views INT UNSIGNED NOT NULL
, num_in_stock INT UNSIGNED NOT NULL
, num_on_order INT UNSIGNED NOT NULL
, PRIMARY KEY (product_id)
) ENGINE=InnoDB;

CREATE TABLE ProductCountSummary (
  total_products INT UNSIGNED NOT NULL
) ENGINE=MEMORY;
```

Counter Table Benefits

- Critical for InnoDB because of complications of MVCC
- Allows query cache to cache specific data set which will be invalidated only infrequently
- Allows you to target `SQL_NO_CACHE` for `SELECT`s against counter tables, freeing query cache
- Allows MEMORY storage engine for summary counters, since stats can be rebuilt

Schema Tips (cont'd)

- Ensure small clustering key (InnoDB)
- Don't use artificial keys when a naturally occurring primary key exists
  - Example of what ***not*** to do:

```
CREATE TABLE Products2Tags (
  record_id INT UNSIGNED NOT NULL AUTO_INCREMENT
, product_id INT UNSIGNED NOT NULL
, tag_id INT UNSIGNED NOT NULL
, PRIMARY KEY (record_id)
, UNIQUE INDEX (product_id, tag_id)
) ENGINE=InnoDB;
```

Indexing Guidelines

- Poor or missing index fastest way to kill a system
- Ensure good selectivity on field (example ahead)
- Look for covering index opportunities (example ahead)
- On multi-column indexes, pay attention to the order of the fields in the index (example ahead)
- As database grows, examine distribution of values within indexed field
- Remove redundant indexes for faster write performance

Selectivity

- The relaive uniqueness of the index values to each other
- S(I) = *d*/*n*
- Multiple columns in an index = multiple levels of selectivity
- So, how do we determine selectivity?

Determining Selectivity

- The hard way:
  - For each table in your schema:

```
SELECT COUNT(DISTINCT field) / COUNT(*)
FROM my_table;

// or...

SHOW INDEX FROM my_table;
```

Determining Selectivity

- The easy way: use `INFORMATION_SCHEMA`

```
SELECT
  t.TABLE_SCHEMA
 , t.TABLE_NAME
 , s.INDEX_NAME
 , s.COLUMN_NAME
 , s.SEQ_IN_INDEX
 , (
   SELECT MAX(SEQ_IN_INDEX)
   FROM INFORMATION_SCHEMA.STATISTICS s2
   WHERE s.TABLE_SCHEMA = s2.TABLE_SCHEMA
   AND s.TABLE_NAME = s2.TABLE_NAME
   AND s.INDEX_NAME = s2.INDEX_NAME
  ) AS "COLS_IN_INDEX"
 , s.CARDINALITY AS "CARD"
 , t.TABLE_ROWS AS "ROWS"
 , ROUND(((s.CARDINALITY / IFNULL(t.TABLE_ROWS, 0.01)) * 100), 2) AS "SEL %"
FROM INFORMATION_SCHEMA.STATISTICS s
 INNER JOIN INFORMATION_SCHEMA.TABLES t
  ON s.TABLE_SCHEMA = t.TABLE_SCHEMA
  AND s.TABLE_NAME = t.TABLE_NAME
WHERE t.TABLE_SCHEMA != 'mysql'
AND t.TABLE_ROWS > 10
AND s.CARDINALITY IS NOT NULL
AND (s.CARDINALITY / IFNULL(t.TABLE_ROWS, 0.01)) < 1.00
ORDER BY t.TABLE_SCHEMA, t.TABLE_NAME, s.INDEX_NAME, "SEL %"
LIMIT 5;
```

Common Index Problem

```
CREATE TABLE Tags (
  tag_id INT NOT NULL AUTO_INCREMENT
, tag_text VARCHAR(50) NOT NULL
, PRIMARY KEY (tag_id)
) ENGINE=MyISAM;

CREATE TABLE Products (
  product_id INT NOT NULL AUTO_INCREMENT
, name VARCHAR(100) NOT NULL
// many more fields...
, PRIMARY KEY (product_id)
) ENGINE=MyISAM;

CREATE TABLE Products2Tags (
  product_id INT NOT NULL
, tag_id INT NOT NULL
, PRIMARY KEY (product_id, tag_id)
) ENGINE=MyISAM;
```

```
// This top query uses the index
// on Products2Tags

SELECT p.name
, COUNT(*) as tags
FROM Products2Tags p2t
INNER JOIN Products p
ON p2t.product_id = p.product_id
GROUP BY p.name;

// This one does not because
// index order prohibits it

SELECT t.tag_text
, COUNT(*) as products
FROM Products2Tags p2t
INNER JOIN Tags t
ON p2t.tag_id = t.tag_id
GROUP BY t.tag_text;
```

Common Index Problem Solved

```
CREATE TABLE Tags (
  tag_id INT NOT NULL AUTO_INCREMENT
, tag_text VARCHAR(50) NOT NULL
, PRIMARY KEY (tag_id)
) ENGINE=MyISAM;

CREATE TABLE Products (
  product_id INT NOT NULL AUTO_INCREMENT
, name VARCHAR(100) NOT NULL
// many more fields...
, PRIMARY KEY (product_id)
) ENGINE=MyISAM;

CREATE TABLE Products2Tags (
  product_id INT NOT NULL
, tag_id INT NOT NULL
, PRIMARY KEY (product_id, tag_id)
) ENGINE=MyISAM;
```

```
CREATE INDEX ix_tag
ON Products2Tags (tag_id);

// or... create a covering index:

CREATE INDEX ix_tag_prod
ON Products2Tags (tag_id, product_id);

// But, only if not InnoDB... why?
```

SQL Coding Topics

- Change the way you think about SQL programming
- Coding guidelines
- Common Pitfalls
- Bulk loading performance
- The DELETE statement

Thinking In Terms of Sets

- SQL programming != procedural programming
- Break an English-language request into a group of sets, either intersecting or joining
  - Example: “Show the maximum price that each product was sold, along with the product description for each product”
  - We're dealing with two sets of data:
    - Set of product descriptions
    - Set of maximum sold prices
  - **NOT**:
    - *for each*...

Coding Guidelines

- Use “chunky” coding habits (KISS)
- Use stored procedures for a performance boost (5.0+)
- Isolate indexed fields on one side of equation (example ahead)
- Use calculated fields if necessary (example ahead)
- Learn to use joins (!)
  - Eliminate correlated subqueries using standard joins (examples ahead)
- Don't try to outthink the optimizer
  - Sergey, Timour and Igor are really, really smart...

Correlated Subquery Conversion Example

- Task: convert a correlated subquery in the `SELECT` clause to a standard join

```
// Bad practice
SELECT p.name
,   (SELECT MAX(price)
     FROM OrderItems
     WHERE product_id = p.product_id)
AS max_sold_price
FROM Products p;
```

```
// Good practice
SELECT p.name
, MAX(oi.price) AS max_sold_price
FROM Products p
 INNER JOIN OrderItems oi
  ON p.product_id = oi.product_id
GROUP BY p.name;
```

Derived Table Example

- Task: convert a correlated subquery in the `WHERE` clause to a standard join on a derived table

```
// Bad performance
SELECT
c.company
, o.*                                   FROM
Customers c
 INNER JOIN Orders o
  ON c.customer_id = o.customer_id
WHERE order_date = (
 SELECT MAX(order_date)
 FROM Orders
 WHERE customer = o.customer
)
GROUP BY c.company;
```

```
// Good performance
SELECT
c.company
, o.*                                   FROM
Customers c
 INNER JOIN (
  SELECT
     customer_id
   , MAX(order_date) as max_order
  FROM Orders
  GROUP BY customer_id
 ) AS m
  ON c.customer_id = m.customer_id
 INNER JOIN Orders o
  ON c.customer_id = o.customer_id
  AND o.order_date = m.max_order
GROUP BY c.company;
```

Demonstration :)

- What did I show earlier that used a correlated subquery?
- Do you think we can rewrite it to use a better performing block of SQL code?
- Cool. Let's do it.

Avoiding Common Pitfalls

- Isolate indexed fields on one side of equation (example ahead)
- Use calculated fields if necessary (example ahead)
- Problems with non-deterministic functions (example ahead)
- Retrieving random records in a scalable way (example ahead)

Isolating Indexed Fields Example

- Task: get the Order ID, date of order, and Customer ID for all orders in the last 7 days

```
// Bad idea
SELECT *
FROM Orders
WHERE
TO_DAYS(order_created) –
TO_DAYS(CURRENT_DATE()) >= 7;
```

```
// Better idea
SELECT *
FROM Orders
WHERE
order_created >= CURRENT_DATE() – INTERVAL 7 DAY;
```

Calculated Fields Example

- Task: search for top-level domain in email addresses

```
// Initial schema
CREATE TABLE Customers (
  customer_id INT NOT NULL
, email VARCHAR(80) NOT NULL
// more fields
, PRIMARY KEY (customer_id)
, INDEX (email(40))
) ENGINE=InnoDB;

// Bad idea, can't use index
// on email field
SELECT *
FROM Customers
WHERE email LIKE '%.com';
```

```
// So, we enable fast searching on a reversed field
// value by inserting a calculated field
ALTER TABLE Customers
ADD COLUMN rv_email VARCHAR(80) NOT NULL;

// Now, we update the existing table values
UPDATE Customers SET rv_email = REVERSE(email);

// Then, we create an index on the new field
CREATE INDEX ix_rv_email ON Customers (rv_email);

// Then, we make a trigger to keep our data in sync
DELIMITER ;;
CREATE TRIGGER trg_bi_cust
BEFORE INSERT ON Customers
FOR EACH ROW BEGIN
 SET NEW.rv_email = REVERSE(NEW.email);
END ;;

// same trigger for BEFORE UPDATE...
// Then SELECT on the new field...
WHERE rv_email LIKE CONCAT(REVERSE('.com'), '%');
```

Non Deterministic Function Dilemma

- A non-deterministic function does not return the same data given the same parameters
- So, what's the problem here?

```
// Bad idea
SELECT *
FROM Orders
WHERE
TO_DAYS(order_created) –
TO_DAYS(CURRENT_DATE()) >= 7;

// Better idea
SELECT *
FROM Orders
WHERE
order_created >= CURRENT_DATE()
– INTERVAL 7 DAY;
```

```
// Best idea is to factor out the CURRENT_DATE
// non-deterministic function in your application
// code and replace the function with a constant.

// For instance, in your PHP code, you would
// simply insert date('Y-m-d') in the query
// instead of CURRENT_DATE()

// Now, query cache can actually cache the query!
SELECT order_id, order_created, customer_id
FROM Orders
WHERE order_created >= '2006-05-24' – INTERVAL 7 DAY;
```

Dealing With Random Records

- Task: Retrieve a single random banner ad from our table of ads

```
// Bad idea... why?
SELECT *
FROM Ads
ORDER BY RAND()
LIMIT 1
```

```
// The query on the left forces MySQL to do a full
// table scan on the entire table.  NOT GOOD!

// Instead, issue the following, which allows
// MySQL to quickly use indexes in order to
// grab the desired row

SELECT @row_id := COUNT(*) FROM Ads;
SELECT @row_id := FLOOR(RAND() * @row_id) + 1;
SELECT * FROM Ads WHERE ad_id = @row_id;

// Pop quiz: what should the above look like
// if the Ads table is an InnoDB table? :)
```

Bulk Loading Performance

- Always use multi-record `INSERT` for mass bulk loading
- Use `ALTER TABLE ... DISABLE KEYS`
- If possible, use `LOAD DATA INFILE` or use the CSV storage engine, and `ALTER TABLE`
- If inserting into an InnoDB table:
  - First, insert into MyISAM table, then do: `INSERT INTO innodb_table SELECT * FROM myisam_table`
- Add or drop multiple indexes in one go using `ALTER TABLE` vs many `CREATE` or `DROP INDEX` statements

DELETE and UPDATE

- The `UPDATE` statement
  - Use the `ON DUPLICATE KEY UPDATE` clause of the `INSERT` statement for a performance gain
- The `DELETE` statement
  - Do you really need to delete the row?
  - Properly segment data that should be deleted using vertical partitioning so that you can use `TRUNCATE TABLE` instead
  - Or, `INSERT` the record id into a separate table, then:

```
DELETE main_table FROM main_table
LEFT JOIN deleted_records
ON main_table.id = deleted_records.id
WHERE deleted_records.id IS NOT NULL;
```

Server Variable Guidelines

- Be aware of what is global vs per thread
- Make small changes, then test
- Often provide a quick solution, but temporary
- Query Cache is not a panacea
- `key_buffer_size != innodb_buffer_size`
  - Also, remember `mysql` system database is MyISAM
- Memory is cheapest, fastest, easiest way to increase performance

Tuning Server Variable Topics

- Use SHOW VARIABLES to see current settings
- Use SHOW STATUS to see server counters
- Global vs Per Connection
- Storage engine-specific variables
  - Critial MyISAM variables
  - Critical InnoDB variables

Critical MyISAM Server Variables

- **`key_buffer_size`** >> Main MyISAM key cache
  - Blocks of size 1024 (1K)
  - Examine **`Key_reads`** VS **`Key_read_requests`**
  - Watch for **`Key_blocks_unused`** approaching 0
- **`table_cache`** (InnoDB too…)
  - Number of simultaneously open file descriptors
  - < 5.1 contains meta data about tables and file descriptor
    - >= 5.1 Split into **`table_open_cache`**
- **`myisam_sort_buffer_size`**
  - Building indexes, set this as high as possible

Critical MyISAM Connection Variables

- **`read_buffer_size`** >> For table scans
  - No block size like key_cache
  - Pop quiz: what cache is used for MyISAM data records?
  - Increase within session if you know you will be doing a large table scan
  - Examine **`Handler_read_rnd_next/Handler_read_rnd`** for average size of table scans
- **`sort_buffer_size`** >> Cache for **`GROUP BY/ORDER BY`**
  - If you see **`Created_tmp_disk_table`** increasing dramatically, increase this as well as check the **`tmp_table_size`** variable

Critical InnoDB Server Variables

- **`innodb_buffer_pool_size`** >> Both data and index pages
  - Blocks of size 16K
  - If you have InnoDB-only system, set to 60-80% of total memory
  - Examine **`Innodb_buffer_pool_reads`** vs **`Innodb_buffer_pool_read_requests`**
  - Watch for **`Innodb_buffer_pool_pages_free`** approaching 0
- **`innodb_log_file_size`**
  - Size of the actual log file
  - Set to 40-50% of **`innodb_buffer_pool_size`**

Critical InnoDB Server Variables (cont'd)

- **`innodb_log_buffer_size`** >> Size of double-write log buffer
  - Set < 16M (recommend 1M to 8M)
- **`innodb_flush_method`**
  - Determines how InnoDB flushes data and logs
  - defaults to fsync()
  - If getting lots of **`Innodb_data_pending_fsyncs`**
    - Consider **`O_DIRECT`** (Linux only)
  - Other ideas
    - Get a battery-backed disk controller with a write-back cache
    - Set **`innodb_flush_log_at_trx_commit=2`** (Risky)

Recommended Resources

- http://www.mysqlperformanceblog.com/
  - Peter Zaitsev's blog – Excellent material
- *Optimizing Linux Performance*
  - Philip Ezolt (HP Press)
- http://dev.mysql.com/tech-resources/articles/pro-mysql-ch6.pdf
  - *Pro MySQL* (Apress) chapter on profiling (`EXPLAIN`)
- *Advanced PHP Programming*
  - George Schlossnagle (Developer's Library)

Final Thoughts

- The road ahead
  - More storage engines
    - Falcon, SolidDB, PBXT, more
  - Online Backup API
  - Foreign Key support for more engines
  - Subquery optimization
- MySQL Forge
- http://jpipes.com
- jay@mysql.com