MySQL for E-Commerce

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May 2023

About me

- Senior PHP Developer
- Linux, PHP, MySQL since 3.23
- studied at TU München

Three things are important in the database world:

performance, performance and performance

source: sigmod.org/publications/interviews/pdf/p71-column-winslet.pdf

Schema design

- schema probably root cause of “my DB doesn’t scale”
- use smaller data types (don’t store numbers as varchar)
- use decimal instead of float
- avoid UUIDs as primary keys (use uuid_short() or ULIDs)
- use tinyint for bools, enums for fixed-value strings
- select only required columns (avoid select *)
- avoid queries without indexes (full table scan)
- reduce tables and joins with JSON columns
- use utf8mb4 or ascii as character set for varchar
- use default values instead of nullable columns
- don’t use entity-attribute-value model

Type	Storage (Bytes)
TINYINT	1
SMALLINT	2
MEDIUMINT	3
INT	4
BIGINT	8

Data Type	
YEAR	1 byte
DATE	3 bytes
TIME	3 bytes
DATETIME	5 bytes
TIMESTAMP	4 bytes

➔ **write less data, read less data**

➔ **read less rows** (less random IO, less pool buffer lookups)

sources: dev.mysql.com/doc/refman/8.0/en/storage-requirements.html
percona.com/blog/2019/11/22/uuids-are-popular-but-bad-for-performance-lets-discuss/
honeybadger.io/blog/uuids-and-ulids/
static.sched.com/hosted_files/perconaliveonline2020/ab/Boosting%20MySQL%20Performance.pdf
vettabase.com/blog/what-does-null-mean-in-sql/
percona.com/blog/queries-for-finding-poorly-designed-mysql-schemas-and-how-to-fix-them/

Advantages of JSON columns

- less tables, less indexes, less joins
- application code can be written quicker and easier:
  - insert, update, delete with 1 query on 1 table on 1 row (no transaction needed)
  - select only on 1 table
- compared to entity-attribute-value model:
  - less complexity, more consistency, much more performance
- table row count grows linearly instead of exponentially
- JSON elements can be queried, updated or indexed directly within SQL
- JSON data can be created or aggregated on relational data
- attributes can be dynamically added to or removed from JSON columns
- elements in JSON arrays can be pre-sorted
- JSON arrays can be capped to a maximum number of elements
- easy to convert PHP objects and arrays to JSON strings

➔ JSON columns are best to combine relational and non-relational worlds

sources: dev.mysql.com/doc/refman/8.0/en/json.html
dev.mysql.com/doc/refman/8.0/en/json-function-reference.html

Find the best indexes

- reduce number of indexes, reduce number of columns per index
- use smaller data types for index columns (reduce memory usage)
- ideal: all lookups use indexes or primary keys
- analyze, explain, explain, explain, test, test, test
- keep an eye on slow queries (optimizer sometimes chooses wrong indexes, use force index)
- test new mysql versions (performance, deprecations, changes in optimizer)
- having the right index vs. using it correctly:

```
select count(*) from cart_item where created_at > '2022-01-01';
1 row in set (0.127 sec)
select count(*) from cart_item where year(created_at) = '2022';
1 row in set (2.196 sec)

explain select count(*) from cart_item where created_at >= '2022-01-01';
| id | select_type | table     | partitions | type  | possible_keys | key        | key_len | ref  | rows    | filtered | Extra                 |
|  1 | SIMPLE      | cart_item | NULL       | range | created_at    | created_at | 4       | NULL | 2993487 |   100.00 | Using where; Using index |
explain select count(*) from cart_item where year(created_at) = '2022';
| id | select_type | table     | partitions | type  | possible_keys | key        | key_len | ref  | rows    | filtered | Extra                 |
|  1 | SIMPLE      | cart_item | NULL       | index | NULL          | created_at | 4       | NULL | 4987011 |   100.00 | Using where; Using index |
select count(*) from cart_item;
5074069
```

theory: db.in.tum.de/teaching/ws1819/queryopt/slides/chapter3.pdf
index-merge: percona.com/blog/2009/09/19/multi-column-indexes-vs-index-merge/

Max() vs. order by

- similar queries producing the same result can perform differently
- the optimizer can produce unexpected query plans
- with growing tables, query plans can change
- use index hints when necessary

```
explain select max(pkey) from t1 where some_col < 10000;
| id | type  | possible_keys | key      | rows    | filtered | Extra                    |
|  1 | range | some_col      | some_col | 1437473 |   100.00 | Using where; Using index |

select max(pkey) from t1 where some_col < 10000;
1 row in set (0.38 sec)

explain select pkey from t1 where some_col < 10000 order by pkey desc limit 1;
| id | type  | possible_keys | key     | rows | filtered | Extra                              |
|  1 | index | some_col      | PRIMARY |    2 |    50.00 | Using where; Backward index scan |

select pkey from t1 where some_col < 10000 order by pkey desc limit 1;
1 row in set (1.11 sec)

select pkey from t1 use index (some_col) where some_col < 10000 order by pkey desc limit 1;
1 row in set (0.37 sec)
```

Named locks: GET_LOCK(name, timeout_seconds)

- obtains an exclusive global lock with a given name
  - returns 1 on success
  - returns 0 if attempt timed out
  - returns null on error
- can make parallel requests or scripts execute sequentially
- is managed by current MySQL session, independant from transactions
- released on RELEASE_LOCK(name) or disconnect (e.g. if PHP process stops)
- more efficient than row level locking or transactions, avoids deadlocks
- examples:
  - limit a cron job to one instance running at the same time:
    ```
    SELECT GET_LOCK("cron_<cron-job-name>", 1);
    ```
  - process parallel cart requests sequentially:
    ```
    SELECT GET_LOCK("cart_<customer-id>", 10);
    ```
  - limit customers to place exactly one order at the same time:
    ```
    SELECT GET_LOCK("order_<customer-id>", 10);
    ```

source: dev.mysql.com/doc/refman/8.0/en/locking-functions.html#function_get-lock

Connection handling

- maximum number of open connections (sessions) is often the limiting factor for a database server
- open connection late (ideally on the first query)
- close connection early (esp. when waiting for another external service)
- connect with compression to reduce network traffic
- can save additional hardware for mysql proxies
- persistent connections:
  - every PHP process uses its own mysqli pool (php.net/manual/en/mysqli.quickstart.connections.php)
  - can be buggy (e.g. bugs.php.net/bug.php?id=64549)
- Example:

bootstrap.php

```
$db = new PDO('mysql:...;charset=utf8mb4;', ..., [PDO::ATTR_TIMEOUT => 5]);
```

vs.

```
class Repository {
      ...
    public function getTasks(Customer $customer): array {
        $db = $this->app->getDatabase($customer);
        $statement = $db->query('SELECT id, name FROM tasks ...');
        return $statement->fetchAll(PDO::FETCH_CLASS, Tasks::class);
    }
```

Cart updates

- most traffic in a shop goes to product data and cart
- reduce number of columns in cart table
  - e.g. customer_id, sku, quantity with primary key on customer_id, sku
- insert / update cart items with 1 query:

```
INSERT INTO cart_item
   SET customer_id = ?, sku = ?, quantity = ? AS new
    ON DUPLICATE KEY UPDATE quantity = new.quantity;

REPLACE INTO cart_item SET customer_id = ?, sku = ?, quantity = ?;
```

- define maximum number of items allowed in a single cart
  - too many items in the cart slow down browser / apps and increase cart calculation time
- define maximum quantity per sku if logistics requires it
  - e.g. max. 5 crates of water per order

source: dev.mysql.com/doc/refman/8.0/en/insert-on-duplicate.html

Limit resultsets: SELECT … LIMIT

- limit gives quicker response (fetch less data)
- less memory usage for processing less rows
- less data to process in frontend / apps
- page by primary key instead of using OFFSET
  - `SELECT name FROM wishlist LIMIT 100 OFFSET 10000;`

    vs.
  - `SELECT name FROM wishlist WHERE id > 10000 LIMIT 100;`

➔ read less rows, process less rows

source: shopify.engineering/pagination-relative-cursorshttps://shopify.engineering/pagination-relative-cursors

Verify status transitions

- ```
  UPDATE orders SET status = 'processing'
  WHERE order_id = 42;
  ```

  vs

- ```
  UPDATE orders SET status = 'processing', updated_at = now()
  WHERE order_id = 42 AND status = 'new';
  ```

- verify that dataset was changed in the database:

  if ($db->query($query)->**rowCount()** !== 1) {...}

Analytical queries: SELECT ...

- use **read-only replica** whenever possible (reduce traffic on master)
- use **pre-aggregation** of data to read less data
- transaction-isolation = READ COMMITTED
  - REPEATABLE-READ: locks acquired during transaction are held for duration of transaction
  - **READ-COMMITTED**: locks that did not match the scan are released after STATEMENT completes, in READ COMMITTED gap locks are never created
- use a column store database for ad-hoc queries (clickhouse, duckdb, etc.)
  - store data by columns instead of rows ➔ better compression, quicker filtering, aggregation, sorting, etc.
  - vectorized joins, multi-core parallel query execution, S3 storage layer
  - faster sorting (https://duckdb.org/2021/08/27/external-sorting.html)
  - materialized views (https://altinity.com/blog/clickhouse-materialized-views-illuminated-part-1)
  - requires loading data into column store database

➔ gives best performance for analytical queries

sources:
percona.com/blog/2012/08/28/differences-between-read-committed-and-repeatable-read-transaction-isolation-levels/
percona.com/blog/2015/01/14/mysql-performance-implications-of-innodb-isolation-modes/

Read data consistently from replicas

- data is replicated asynchronously to replicas
- replica delay can be monitored with: `show replica status;` // Seconds_Behind_Source
- parallel replication enabled by default with MySQL 8 (before single thread)
- request #1:
  - update data on master

```
-- connect to master
INSERT INTO tasks SET id = 42, name = 'foo';

-- get latest gtid
SELECT @@GLOBAL.gtid_executed;
```

  - store gtid in cookie
- request #2:
  - wait for transaction to be applied on replica

```
-- connect to replica
SELECT WAIT_FOR_EXECUTED_GTID_SET(gtid_from_cookie, 5); -- 0 = success
```

  - read data from replica:

```
SELECT name FROM tasks WHERE id = 42;
```

source: youtube.com/watch?v=9caro2QNcww

Customer data search: low traffic search

MySQL fulltext index

- can be implemented quickly and easily
- can be fast enough for low traffic search
- no extra hardware for search functionality needed
- stays consistent (with index update on transaction commit)

```
CREATE TABLE customer_search (
  customer_id int UNSIGNED NOT NULL PRIMARY KEY,
  search varchar(1024) NOT NULL, -- e.g. “firstname lastname address”
  FULLTEXT (search)
);
```

```
SELECT customer.* FROM customer, customer_search
 WHERE customer.id = customer_search.customer_id
   AND MATCH(customer_search.search) AGAINST (? in boolean mode)
 LIMIT 100;
```

- query example: `"Frank-Walther" Wattstr* +Meier -Franz`
- query input requires sanitizing for “-+<>~*@”

  e.g. "++foo", "**foo" or "foo+" not allowed

source: dev.mysql.com/doc/refman/8.0/en/fulltext-boolean.html

Product data search: high traffic search

- most traffic in a shop goes to product data and cart
- store each product in a JSON document
- use (in-memory) document store as data source
- example products optimized for fulltext search:
  RedisSearch, meilisearch, typesense, lnx-search, Elasticsearch, Algolia
- remember to check licenses and support options
- make vs. buy

Queues

MySQL can be used as a queue:

- for small messages with low volume
- provides transactional safety, example:

```
BEGIN;
  INSERT INTO customer SET id = 42;
  REPLACE INTO queue_crm SET customer_id = 42, num_tries = 0;
COMMIT;
```

- can process messages in order or out of order, example for **single** consumer:

```
SELECT GET_LOCK('queue_crm', 1);
SELECT customer_id FROM queue_crm WHERE num_tries < 10 ORDER BY created_at ASC LIMIT 10;
  UPDATE queue_crm SET num_tries = num_tries + 1, last_try = now() WHERE customer_id = 42;
  -- process entry
  DELETE FROM queue_crm WHERE customer_id = 42;
SELECT RELEASE_LOCK('queue_crm');
```

- releases row locks on RELEASE_LOCK() or disconnect (e.g. if PHP process stops)
- makes it easy to re-process failed messages, example:

```
UPDATE queue_crm SET num_tries = 0 WHERE num_tries = 10;
```

Queues #2

MySQL can be used as a queue:

- can process messages in order or out of order, example for **multiple** consumers:

```
BEGIN;
  SELECT customer_id FROM queue_crm WHERE num_tries < 10
   ORDER BY created_at ASC LIMIT 10 FOR UPDATE SKIP LOCKED;
    -- process entry
    -- on success
    DELETE FROM queue_crm WHERE customer_id = 42;
    -- on failure
    UPDATE queue_crm SET num_tries = num_tries + 1, last_try = now() WHERE customer_id = 42;
COMMIT;
```

- releases row locks on COMMIT or disconnect (e.g. if PHP process stops)
- makes it easy to do queue monitoring:

```
  SELECT count(*) FROM queue_crm WHERE num_tries >= 10;
```

source: dev.mysql.com/blog-archive/mysql-8-0-1-using-skip-locked-and-nowait-to-handle-hot-rows/

Log data

- use page compression to reduce read and write IO
- using partitions offers quick deletion by ALTER TABLE log TRUNCATE PARTITION ...
- use JSON columns to store structured logs
- store logs outside of database whenever possible (e.g. datadog, elasticsearch)
- ```
  CREATE TABLE log (
      customer_id int unsigned not null,
      event json not null,
      created_at datetime not null,
      index(customer_id, created_at)
  ) COMPRESSION='lz4' PARTITION BY hash(month(created_at)) PARTITIONS 12;
  ```

- check compression ratio and partition consistency:

```
select name, file_size, allocated_size from information_schema.INNODB_TABLESPACES where name like 'tasks/log%';
+-----------------+------------+----------------+
| name            | file_size  | allocated_size |
+-----------------+------------+----------------+
| tasks/log#p#p0  | 1086324736 |      551456768 |
| tasks/log#p#p1  | 1203765248 |      612634624 |
...
check table log;
```

source: dev.mysql.com/doc/refman/8.0/en/innodb-page-compression.html
```

Data migration (EAV ➔ JSON)

Using SQL to copy data from old schema to new schema (old table(s) to new table):

```
INSERT INTO customers.customer (email, attributes, created)
    SELECT * FROM magento.customer_entity
    LEFT JOIN magento.customer_entity_varchar as firstname on
        firstname.entity_id = customer_entity.entity_id and firstname.attribute_id = 5
    LEFT JOIN magento.customer_entity_varchar as lastname on
        lastname.entity_id = customer_entity.entity_id and lastname.attribute_id = 7
    LEFT JOIN magento.customer_entity_datetime as birthdate on
        birthdate.entity_id = customer_entity.entity_id and birthdate.attribute_id = 11
    SET email = customer_entity.email,
           attributes = json_object(
              'first', firstname.value,
              'last', lastname.value,
              'birth', date(birthdate.value),
              'orders', (select count(*) from magento.sales_flat_order
                           where customer_id = customer_entity.entity_id)
           ),
           created = customer_entity.created_at;
```

Data anonymization

- Use a separate database and views to provide anonymized production data
- Grant permissions to human users only on anonymized data

```
SELECT * FROM customers.customer WHERE id = 1234;
    id: 1234
    email: foo.bar@baz.com
    attributes: {"first": "Thomas", "last": "Bley", "birth": "1930-02-01", "orders": 42}
    created: 2021-05-06 12:41:11

CREATE or REPLACE VIEW customers_anonymized.customer AS
    SELECT id,
        concat('invalid_', id, '@bringmeister.de') AS email, -- invalid_1234@bringmeister.de
        json_object(
            'first', concat('first_', id),    -- first_1234
            'last', concat('last_', id),      -- last_1234
            'birth', '1980-01-02',
            'orders', attributes->>"$.orders" -- 1980-01-02, 42
        ) AS attributes,
        created
    FROM customers.customer;
```

Pseudo random order ID generation

Order IDs should be increasing, but increasing with some “randomness”:

- generate Order ID before saving the order
- increment Order ID sequence with random values
- LAST_INSERT_ID(): returns automatically generated value
- RAND(): Returns a random float value in the range 0 <= value < 1.0
- can be an alternative to UUID / ULID

```
CREATE TABLE order_sequence (order_id int unsigned not null);
INSERT INTO order_sequence SET order_id = 1; // start with Order ID 1

-- update order_id = order_id + rand(5, 10) returning order_id
UPDATE order_sequence SET order_id = LAST_INSERT_ID(order_id + FLOOR((RAND() * 6) + 5));
SELECT LAST_INSERT_ID();
```

➔ generates an randomly increasing Order ID sequence

e.g. 6, 16, 25, 39, 46, 56, 65, 73, 78, 85, 90, ...

source: dev.mysql.com/doc/refman/8.0/en/information-functions.html#function_last-insert-id

Foreign keys, triggers and procedures

skip foreign keys

- require additional indexes
- require additional locking and lookups on related tables for insert, update or delete, can cause deadlocks, slow for data imports
- cascading logic might be different from required business logic
- not supported by some tools (e.g. gh-ost), only work inside a single db server
- can have bugs (itw01.com/8Q76OEZ.html)
- locked data types, cascaded write not in binary log (code.openark.org/blog/mysql/things-that-dont-work-well-with-mysqls-foreign-key-implementation)
- only working inside a single server (not for sharding)

skip triggers and procedures

- logic is limited to SQL functionality
- cannot connect to external systems (e.g. send an email)
- difficult to update atomically
- often cause unwanted side effects, e.g. cyclic execution

➔ better to keep application logic inside application code, use MySQL only as storage

Legacy code and rewrites

- identify and optimize **20% of slowest queries**
- verify backups
- remove unused indexes (make invisible first), create better indexes
- remove unused columns and tables
- **remove historic data** if possible (GDPR)
- optimize database schema (reduce joins with JSON columns)
- analyze data quality to avoid bugs (esp. historic data)
- use character set utf8mb4
- enable MySQL access log for local development
- use caching when data changes rarely
- fill caches in the background or use random expiries

Integration tests

- start tests with **empty** tables
- wrap tests inside a **transaction**
- verify that **data** is written **correctly** to the database
- Use a real database with same configuration (esp. sql_mode)
- example:

```php
class ExampleRepositoryTest extends TestCase
{
    protected function setUp(): void
    {
        $this->app->getDatabase()->beginTransaction();
    }

    protected function tearDown(): void
    {
        $this->app->getDatabase()->rollBack();
    }

    public function testCreateExample(): void
    {
        // insert into ...
        // select from ...
        // assert ...
    }
}
```

Mass delete data

Mass delete data can be much quicker by copying data to a second table:

```
DELETE FROM sometable WHERE created_at <= date_sub(now(), INTERVAL 3 MONTH);

vs.

CREATE TABLE sometable_new LIKE sometable;
LOCK TABLE sometable write, sometable_new WRITE;
INSERT INTO sometable_new SELECT * FROM sometable
    WHERE created_at > date_sub(now(), INTERVAL 3 MONTH);
RENAME TABLE sometable TO sometable_old, sometable_new TO sometable;
UNLOCK TABLES;
DROP TABLE sometable_old;
```

Schema changes

- table writes are blocked by alter table operations
- use tools like gh-ost for background table changes
  (requires double the disk space for a table, does not support foreign keys)
- example:

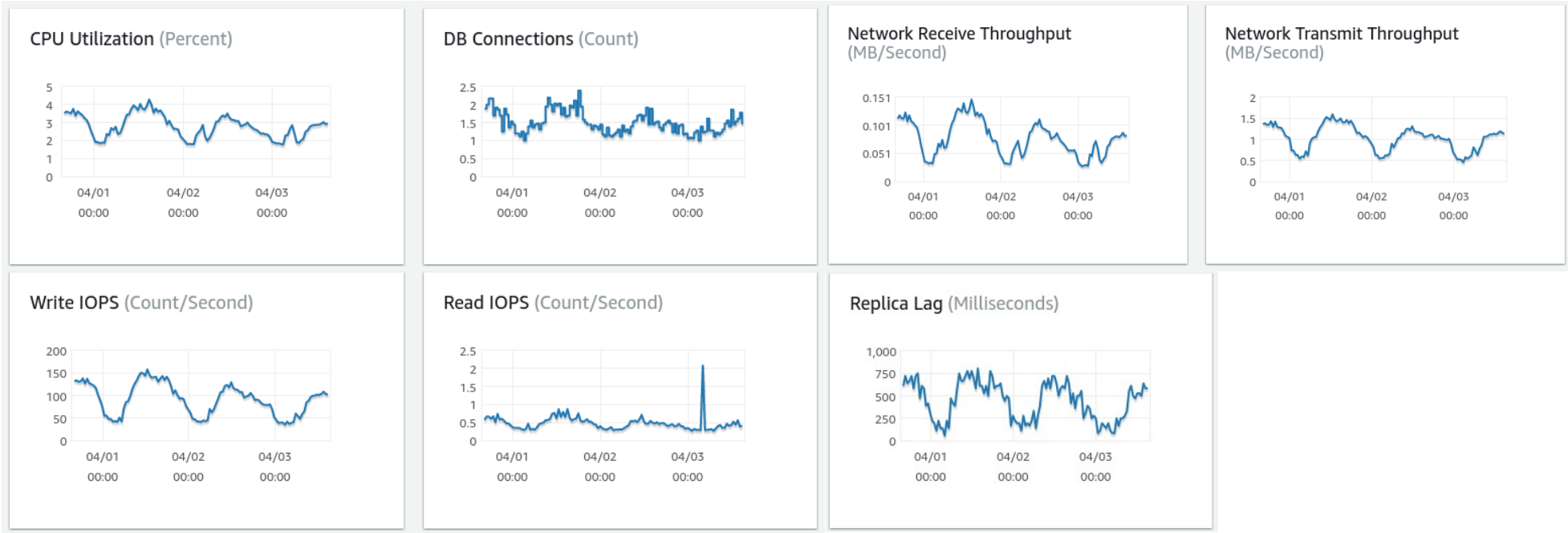
```
optimize table customers.customer;
-- can be written as
alter table customers.customer engine=innodb;
-- and becomes

gh-ost \
  --max-load=Threads_running=25 --critical-load=Threads_running=1000 \
  --host=<host> --port=<port> --user="root" --password="<pw>" \
  --chunk-size=100000 --dml-batch-size 10 \
  --initially-drop-ghost-table --initially-drop-old-table \
  --ok-to-drop-table --allow-on-master --execute \
  --database="customers" --table="customer" -alter="engine=innodb"
```

source: github.com/github/gh-ost

Monitoring

- log slow queries (server side, slow query log, show processlist)
- log failed queries (application side)
- analyze deadlocks: `show engine innodb status;`
- monitor replica status: `show replica status;`
  (Replica_IO_Running, Replica_SQL_Running, Seconds_Behind_Source)
- monitor performance metrics:



sources: percona.com/blog/2006/07/17/show-innodb-status-walk-through/
percona.com/blog/2014/10/28/how-to-deal-with-mysql-deadlocks/

Monitor auto_increment overflows

```
ANALYZE TABLE <table_name>, <table_name>, ...; // update information_schema

SELECT
    t.TABLE_SCHEMA, t.TABLE_NAME, c.COLUMN_NAME, t.AUTO_INCREMENT, c.DATA_TYPE,
    t.AUTO_INCREMENT / (
        CASE DATA_TYPE
          WHEN 'tinyint' THEN IF(COLUMN_TYPE LIKE '%unsigned', 255, 127)
          WHEN 'smallint' THEN IF(COLUMN_TYPE LIKE '%unsigned', 65535, 32767)
          WHEN 'mediumint' THEN IF(COLUMN_TYPE LIKE '%unsigned', 16777215, 8388607)
          WHEN 'int' THEN IF(COLUMN_TYPE LIKE '%unsigned', 4294967295, 2147483647)
          WHEN 'bigint' THEN IF(COLUMN_TYPE LIKE '%unsigned', 18446744073709551615,
                                                              9223372036854775807)
        END / 100) AS used
   FROM information_schema.TABLES t NATURAL JOIN information_schema.COLUMNS c
  WHERE t.AUTO_INCREMENT IS NOT NULL AND c.DATA_TYPE LIKE '%int'
    AND c.COLUMN_KEY = 'PRI' AND t.TABLE_SCHEMA != 'mysql'
 HAVING used > 0.8;

| TABLE_SCHEMA | TABLE_NAME | COLUMN_NAME | AUTO_INCREMENT | DATA_TYPE | used    |
| orders       | order      | id          |     3435973836 | int       | 85.0000 |
```

source: superuser.com/questions/729004/nagios-monitor-mysql-auto-increment-overflow

Server configuration

- innodb_dedicated_server: on
- innodb_buffer_pool_size: 75-80% of system memory
  (best case: active workset fits into pool buffer)
- innodb_flush_method: O_DIRECT_NO_FSYNC (skip kernel file system cache)
- innodb_use_fdatasync: on (skip flushing metadata)
- innodb_flush_log_at_trx_commit: 2 (default 1, less durability)
- sync_binlog: 0 or 1 (keeps binlog/replicas consistent)
- innodb_adaptive_hash_index: off (faster for many concurrent joins)
- max_heap_table_size / tmp_table_size: 128M (used for joins, sorting, subqueries)
- gtid-mode: on, enforce_gtid_consistency: on
- wait_timeout: 120 (4x max_execution_time)
- event_scheduler: off (when you don't need it)
- performance_schema: off (when you don't need it)

sources: percona.com/blog/2016/04/12/is-adaptive-hash-index-in-innodb-right-for-my-workload/
dev.mysql.com/doc/refman/8.0/en/internal-temporary-tables.html
dev.mysql.com/doc/refman/8.0/en/innodb-parameters.html
percona.com/blog/mysql-zfs-performance-update/
dev.mysql.com/doc/refman/8.0/en/innodb-dedicated-server.html

Additional resources

- InnoDB Performance Optimization: youtube.com/watch?v=qMmSwhSlnX0
- Introduction into MySQL Query Tuning: youtube.com/watch?v=1pxcOgzb6aU
- Tuning InnoDB Primary Keys: percona.com/blog/2018/07/26/tuning-innodb-primary-keys/
- MySQL 8.0 – locking details: lefred.be/content/mysql-8-0-locking-details/
- Why joins take so much performance? de.wikipedia.org/wiki/Joinalgorithmen
- Backup Performance Comparison
  percona.com/blog/dump-performance-comparison-mysqldump-vs-mysql-shell-utilities-vs-mydumper/
- Linux OS Tuning for MySQL Database Performance
  percona.com/blog/2018/07/03/linux-os-tuning-for-mysql-database-performance/
- Millions of Queries per Second
  percona.com/blog/2017/01/06/millions-queries-per-second-postgresql-and-mysql-peaceful-battle-at-modern-demanding-workloads/

Thanks for listening!

Questions?

download slides:
github.com/thomasbley/talks

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