MySQL Indexing

Best Practices

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You've Made a Great Choice !

- Understanding indexing is crucial both for Developers and DBAs
- Poor index choices are responsible for large portion of production problems
- Indexing is not a rocket science

MySQL Indexing: Agenda

- Understanding Indexing
- Setting up best indexes for your applications
- Working around common MySQL limitations

Indexing in the Nutshell

- What are indexes for ?
  - Speed up access in the database
  - Help to enforce constraints (**UNIQUE**, **FOREIGN KEY**)
  - Queries can be ran without any indexes
    - But it can take a really long time

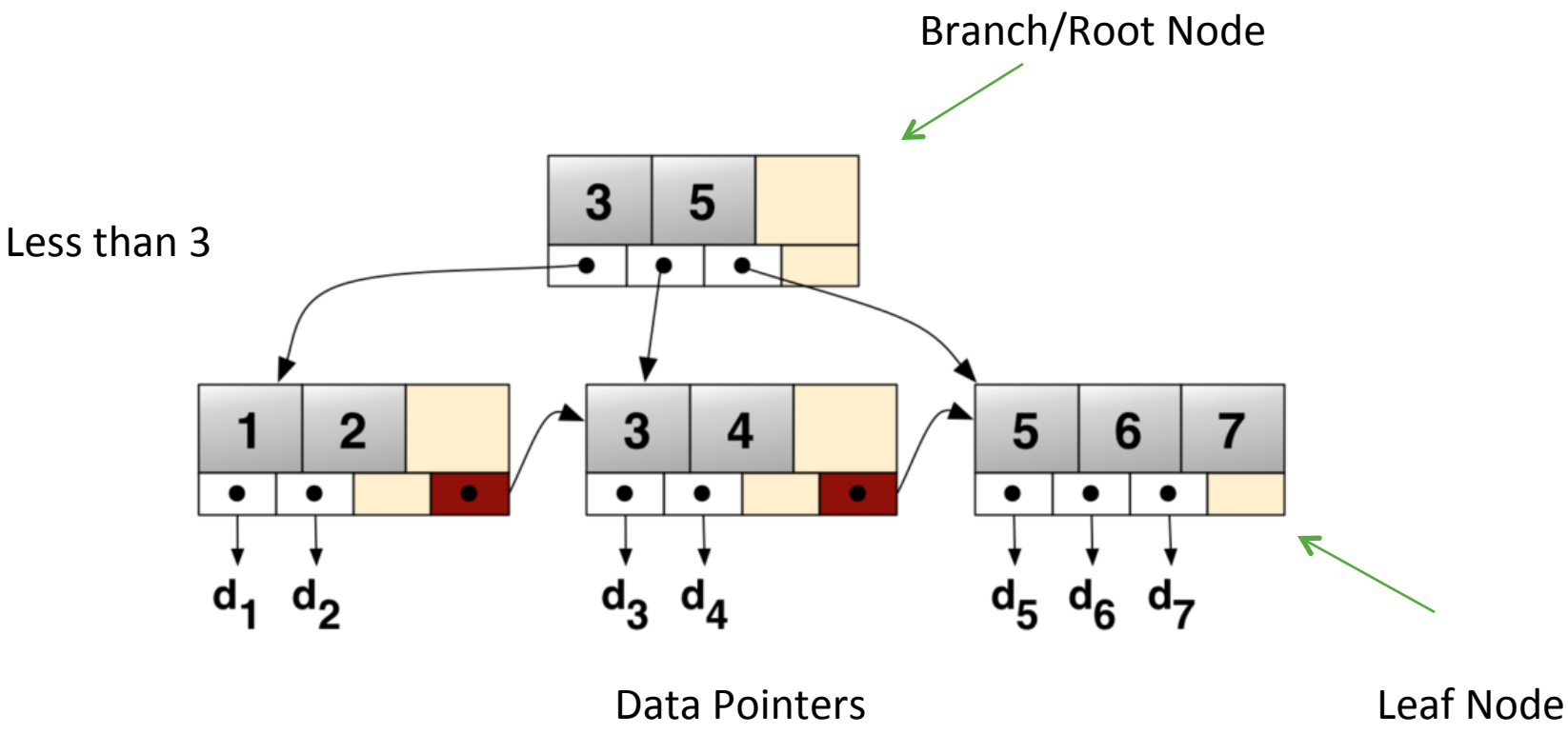
Types of Indexes you might heard about

- **BTREE** Indexes
  - Majority of indexes you deal in MySQL is this type
- **RTREE** Indexes
  - MyISAM only, for GIS
- **HASH** Indexes
  - MEMORY, NDB
- **BITMAP** Indexes
  - Not Supported by MySQL
- **FULLTEXT** Indexes
  - MyISAM, Innodb planned in MySQL 5.6

Family of BTREE like Indexes

- A lot of different implementations
  - Share same properties in what operations they can speed up
  - Memory vs Disk is life changer
- B+ Trees are typically used for Disk storage
  - Data stored in leaf nodes

B+Tree Example



Indexes in MyISAM vs Innodb

- In MyISAM data pointers point to physical offset in the data file
  - All indexes are essentially equivalent
- In Innodb
  - PRIMARY KEY (Explicit or Implicit) - stores data in the leaf pages of the index, not pointer
  - Secondary Indexes – store primary key as data pointer

What Operations can BTREE Index do ?

- Find all rows with KEY=5 (point lookup)
- Find all rows with KEY>5 (open range)
- Find all rows with 5<KEY<10 (closed range)
- NOT find all rows with last digit of the KEY is Zero
  - This can't be defined as a "range" operation

String Indexes

- There is no difference… really
  - Sort order is defined for strings (collation)
    - “AAAA” < “AAAB”
- Prefix LIKE is a special type of Range
  - LIKE “ABC%” means
    - “ABC[LOWEST]”<KEY<“ABC[HIGHEST]”
  - LIKE “%ABC” can’t be optimized by use of the index

Multiple Column Indexes

- Sort Order is defined, comparing leading column, then second etc
  - KEY(col1,col2,col3)
  - (1,2,3) < (1,3,1)
- It is still one BTREE Index; not a separate BTREE index for each level

Overhead of The Indexing

- Indexes are costly; Do not add more than you need
  - In most cases extending index is better than adding new one
- **Writes** - Updating indexes is often major cost of database writes
- **Reads** - Wasted space on disk and in memory; additional overhead during query optimization

Impact on Cost of Indexing

- Long **PRIMARY KEY** for Innodb
  - Make all Secondary keys longer and slower
- "Random" **PRIMARY KEY** for Innodb
  - Insertion causes a lot of page splits
- Longer indexes are generally slower
- Index with insertion in random order
  - SHA1('password')
- Low selectivity index cheap for insert
  - Index on gender
- Correlated indexes are less expensive
  - insert_time is correlated with auto_increment id

Indexing Innodb Tables

- Data is clustered by Primary Key
  - Pick **PRIMARY KEY** what suites you best
  - For comments – **(POST_ID,COMMENT_ID)** can be good **PRIMARY KEY** storing all comments for single post close together
    - Alternatively “pack” to single **BIGINT**
- **PRIMARY KEY** is implicitly appended to all indexes
  - **KEY (A)** is really **KEY (A,ID)** internally
  - Useful for sorting, Covering Index.

How MySQL Uses Indexes

- Data Lookups
- Sorting
- Avoiding reading “data”
- Special Optimizations

Using Indexes for Data Lookups

- **SELECT * FROM EMPLOYEES WHERE LAST_NAME="Smith"**
  - The classical use of index on (LAST_NAME)
- Can use Multiple column indexes
  - **SELECT * FROM EMPLOYEES WHERE LAST_NAME="Smith" AND DEPT="Accounting"**
  - Will use index on (DEPT,LAST_NAME)

It Gets Tricky With Multiple Columns

- Index (A,B,C) - order of columns matters
- Will use Index for lookup (all listed keyparts)
  - **A>5**
  - **A=5 AND B>6**
  - **A=5 AND B=6 AND C=7**
  - **A=5 AND B IN (2,3) AND C>5**
- Will NOT use Index
  - **B>5** – Leading column is not referenced
  - **B=6 AND C=7** - Leading column is not referenced
- Will use Part of the index
  - **A>5 AND B=2** - range on first column; only use this key part
  - **A=5 AND B>6 AND C=2** - range on second column, use 2 parts

The First Rule of MySQL Optimizer

- MySQL will stop using key parts in multi part index as soon as it met the real range (<,>, BETWEEN), it however is able to continue using key parts further to the right if IN(…) range is used

Using Index for Sorting

- **SELECT * FROM PLAYERS ORDER BY SCORE DESC LIMIT 10**
  - Will use index on SCORE column
  - Without index MySQL will do “filesort” (external sort) which is very expensive
- Often Combined with using Index for lookup
  - **SELECT * FROM PLAYERS WHERE COUNTRY=“US” ORDER BY SCORE DESC LIMIT 10**
    - Best served by Index on **(COUNTRY,SCORE)**

Multi Column indexes for efficient sorting

- It becomes even more restricted!
- KEY(A,B)
- Will use Index for Sorting
  - **ORDER BY A** - sorting by leading column
  - **A=5 ORDER BY B** - EQ filtering by 1st and sorting by 2nd
  - **ORDER BY A DESC, B DESC** - Sorting by 2 columns in same order
  - **A>5 ORDER BY A** - Range on the column, sorting on the same
- Will NOT use Index for Sorting
  - **ORDER BY B** - Sorting by second column in the index
  - **A>5 ORDER BY B** – Range on first column, sorting by second
  - **A IN(1,2) ORDER BY B** - In-Range on first column
  - **ORDER BY A ASC, B DESC** - Sorting in the different order

MySQL Using Index for Sorting Rules

- You can’t sort in different order by 2 columns
- You can only have Equality comparison (=) for columns which are not part of ORDER BY
  - Not even IN() works in this case

Avoiding Reading The data

- "Covering Index"
  - Applies to index use for specific query, not type of index.
- Reading Index ONLY and not accessing the "data"
- **SELECT STATUS FROM ORDERS WHERE CUSTOMER_ID=123**
  - **KEY(CUSTOMER_ID,STATUS)**
- Index is typically smaller than data
- Access is a lot more sequential
  - Access through data pointers is often quite "random"

Min/Max Optimizations

- Index help **MIN()/MAX()** aggregate functions
  - But only these
- **SELECT MAX(ID) FROM TBL;**
- **SELECT MAX(SALARY) FROM EMPLOYEE GROUP BY DEPT_ID**
  - Will benefit from **(DEPT_ID,SALARY)** index
  - “Using index for group-by”

Indexes and Joins

- MySQL Performs Joins as “Nested Loops”
  - **SELECT * FROM POSTS,COMMENTS WHERE AUTHOR=“Peter” AND COMMENTS.POST_ID=POSTS.ID**
    - Scan table **POSTS** finding all posts which have Peter as an Author
    - For every such post go to **COMMENTS** table to fetch all comments
- Very important to have all JOINs Indexed
- Index is only needed on table which is being looked up
  - The index on **POSTS.ID** is not needed for this query performance
- Re-Design JOIN queries which can’t be well indexed

Using Multiple Indexes for the table

- MySQL Can use More than one index
  - "Index Merge"
- **SELECT * FROM TBL WHERE A=5 AND B=6**
  - Can often use Indexes on **(A)** and **(B)** separately
  - Index on **(A,B)** is much better
- **SELECT * FROM TBL WHERE A=5 OR B=6**
  - 2 separate indexes is as good as it gets
  - Index **(A,B)** can't be used for this query

Prefix Indexes

- You can build Index on the leftmost prefix of the column
  - ALTER TABLE TITLE ADD KEY(TITLE(20));
  - Needed to index BLOB/TEXT columns
  - Can be significantly smaller
  - Can't be used as covering index
  - Choosing prefix length becomes the question

Choosing Prefix Length

- Prefix should be “Selective enough”
  - Check number of distinct prefixes vs number of total distinct values

```
mysql> select count(distinct(title)) total, count
(distinct(left(title,10))) p10, count(distinct(left
(title,20))) p20 from title;
+--------+--------+--------+
| total  | p10    | p20    |
+--------+--------+--------+
| 998335 | 624949 | 960894 |
+--------+--------+--------+
1 row in set (44.19 sec)
```

Choosing Prefix Length

- Check for Outliers
  - Ensure there are not too many rows sharing the same prefix

Most common Titles

```
mysql> select count(*) cnt, title tl
from title group by tl order by cnt desc
limit 3;
+-----+-----------------+
| cnt | tl              |
+-----+-----------------+
| 136 | The Wedding     |
| 129 | Lost and Found  |
| 112 | Horror Marathon |
+-----+-----------------+
3 rows in set (27.49 sec)
```

Most Common Title Prefixes

```
mysql> select count(*) cnt, left(title,20) tl
from title group by tl order by cnt desc
limit 3;
+-----+----------------------+
| cnt | tl                   |
+-----+----------------------+
| 184 | Wetten, dass..? aus  |
| 136 | The Wedding          |
| 129 | Lost and Found       |
+-----+----------------------+
3 rows in set (33.23 sec)
```

How MySQL Picks which Index to Use ?

- Performs dynamic picking for every query execution
  - The constants in query texts matter a lot
- Estimates number of rows it needs to access for given index by doing “dive” in the table
- Uses “Cardinality” statistics if impossible
  - This is what **ANALYZE TABLE** updates

More on Picking the Index

- Not Just minimizing number of scanned rows
- Lots of other heuristics and hacks
  - PRIMARY Key is special for Innodb
  - Covering Index benefits
  - Full table scan is faster, all being equal
  - Can we also use index for Sorting
- Things to know
  - Verify plan MySQL is actually using
  - Note it can change dynamically based on constants and data

Use EXPLAIN

- EXPLAIN is a great tool to see how MySQL plans to execute the query
  - http://dev.mysql.com/doc/refman/5.5/en/using-explain.html
  - Remember real execution might be different

```
mysql> explain select max(season_nr) from title group by production_year;
+----+-------------+-------+-------+---------------+-----------------+---------+------+------+----------------------------+
| id | select_type | table | type  | possible_keys | key             | key_len | ref  | rows | Extra                      |
+----+-------------+-------+-------+---------------+-----------------+---------+------+------+----------------------------+
|  1 | SIMPLE      | title | range | NULL          | production_year | 5       | NULL |  201 | Using index for group-by |
+----+-------------+-------+-------+---------------+-----------------+---------+------+------+----------------------------+
1 row in set (0.01 sec)
```

MySQL Explain 101

- Look at the “type” sorted from “good” to “bad”
  - **system,const,eq_ref,ref,range,index,ALL**
- Note “**rows**” – higher numbers mean slower query
- Check “**key_len**” – shows how many parts of the key are really used
- Watch for **Extra**.
  - **Using Index** - Good
  - **Using Filesort**, **Using Temporary** - Bad

Indexing Strategy

- Build indexes for set of your performance critical queries
  - Look at them together not just one by one
- Best if all **WHERE** clause and **JOIN** clauses are using indexes for lookups
  - At least most selective parts are
- Generally extend index if you can, instead of creating new indexes
- Validate performance impact as you're doing changes

Indexing Strategy Example

- Build Index order which benefits more queries
  - **SELECT * FROM TBL WHERE A=5 AND B=6**
  - **SELECT * FROM TBL WHERE A>5 AND B=6**
  - **KEY (B,A)** Is better for such query mix
- All being equal put more selective key part first
- Do not add indexes for non performance critical queries
  - Many indexes slow system down

Trick #1: Enumerating Ranges

- **KEY (A,B)**
- **SELECT * FROM TBL WHERE A BETWEEN 2 AND 4 AND B=5**
  - Will only use first key part of the index
- **SELECT * FROM TBL WHERE A IN (2,3,4) AND B=5**
  - Will use both key parts

Trick #2: Adding Fake Filter

- **KEY (GENDER,CITY)**
- **SELECT * FROM PEOPLE WHERE CITY="NEW YORK"**
  - Will not be able to use the index at all
- **SELECT * FROM PEOPLE WHERE GENDER IN ("M","F") AND CITY="NEW YORK"**
  - Will be able to use the index
- The trick works best with low selectivity columns.
  - Gender, Status, Boolean Types etc

Trick #3: Unionizing Filesort

- **KEY(A,B)**
- **SELECT * FROM TBL WHERE A IN (1,2) ORDER BY B LIMIT 5;**
  - Will not be able to use index for SORTING
- **(SELECT * FROM TBL WHERE A=1 ORDER BY B LIMIT 5) UNION ALL (SELECT * FROM TBL WHERE A=2 ORDER BY B LIMIT 5) ORDER BY B LIMIT 5;**
  - Will use the index for Sorting. "filesort" will be needed only to sort over 10 rows.

Thank You !

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