ALTER TABLE

Improvements in MARIADB Server

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Generic ALTER TABLE in MariaDB

CREATE TABLE …; INSERT...SELECT; RENAME ...; DROP TABLE …;

- Retroactively named `ALGORITHM=COPY` in MySQL 5.6 and MariaDB 10.0
- Until MariaDB 10.2.13 ([MDEV-11415](https://mariadb.org/mdev-issues/MDEV-11415)), lots of unnecessary undo logging (and the infamous “commit every 10,000 rows” hack to speed up crash recovery).
- Inserting into each index one record at a time (very inefficient).
- No sort buffer is being used inside InnoDB (other than the change buffer)
- Writes a large amount of redo log for the second copy of the table.
History of Native ALTER TABLE in InnoDB

Starting with InnoDB Plugin for MySQL 5.1

• “Fast index creation”: ADD [UNIQUE] INDEX, ADD PRIMARY KEY

• ALGORITHM=INPLACE starting with MySQL 5.6 and MariaDB 10.0
  ○ Misleading name “inplace”; some operations may rebuild the table!
    ■ (ADD|DROP) COLUMN, ADD PRIMARY KEY, CHANGE...[NOT] NULL
  ○ Some operations are instantaneous: rename column, change DEFAULT, …
  ○ Sometimes sloppily called “online” even when no concurrent DML is allowed
ALTER ONLINE TABLE

• InnoDB supports two classes of operations in online ALTER TABLE:
  ○ **ADD [UNIQUE] INDEX**: create indexes without copying the table
  ○ **online table rebuild**: ADD PRIMARY KEY or ADD, DROP, MODIFY columns

• InnoDB refuses ALTER ONLINE TABLE or ALTER TABLE...LOCK=NONE if:
  ○ A **FULLTEXT** or **SPATIAL** index is being created
  ○ The table needs to be rebuilt while FULLTEXT or SPATIAL index are present
Instant ALTER TABLE in InnoDB
Instant ALTER TABLE Operations up to 10.3

- 10.0: Renaming columns, changing DEFAULT value
- 10.2: Extend VARCHAR in some cases: not VARCHAR(255) to VARCHAR(256)
- 10.3: ADD COLUMN (as the last column only), DROP CONSTRAINT
- 10.3.8 (MDEV-16330): Add or remove SYSTEM VERSIONING of a column
- 10.3.10 (MDEV-16328): change page_compression_level
- 10.3.x (MDEV-13301): Rename indexes (by DROP INDEX, ADD INDEX)
10.4: Instant Change of Collation or Charset

Change character set or collation without copying table

- Change the collation only, e.g., `latin1_swedish_ci` to `latin1_german_ci`
- Change `ascii` to almost anything, `utf8mb3` to `utf8mb4`, `ucs2` to `utf16`, ...
  - Unless the collation is compatible, we must drop/add any indexes on the columns.

The table may have to be copied in order to:

- Change a `CHAR` column to variable-length encoding (e.g., `ascii` → `utf8`)
- Change the maximum length from 128 · 255 bytes to more than 255 bytes;
  Example: Change `CHAR(85)` or `VARCHAR(85)` from `utf8mb3` to `utf8mb4`
Instant Column Extension for InnoDB Tables

No change to file formats or data; for any ROW_FORMAT

- 10.2: Any extension of VARCHAR except from ≤255 bytes to >255 bytes
- 10.4: Any extension of VARCHAR from ≤127 bytes or ROW_FORMAT=REDUNDANT
- 10.x: Any extension of CHAR containing UTF-8 (or other variable-length charset), or internally stored as variable-length
- These operations are compatible with old versions of MariaDB or MySQL.

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Instant ALTER TABLE Operations in 10.4

Specific to the original \texttt{ROW\_FORMAT=REDUNDANT}

- Instantly remove \texttt{NOT NULL} attribute, or extend any \texttt{VARCHAR}.

- Cancelled (\textbf{MDEV-18627}): Extend fixed-size columns (treat as variable-size)
  - \texttt{TINYINT}→\texttt{SMALLINT}→\texttt{MEDIUMINT}→\texttt{INT}→\texttt{BIGINT}; \texttt{CHAR}; \texttt{VARCHAR}→\texttt{CHAR}

- Uses 6+$c$ or 6+2$c$ bytes of record header, storing all $c$ columns as variable-length.
  - Later formats (MySQL 5.0.3+): \(5+\lceil\log_2(n+1)\rceil + v\) to \(5+\lceil\log_2(n+1)\rceil + 2v\) bytes \((v\leq c, n\leq c)\); using extra space for variable-length or \texttt{NULL}able columns only. Minimum is 5 bytes.
Short History of InnoDB **ROW_FORMAT**

- Originally, InnoDB had a record header of 6+c or 6+2c bytes.
  - Basically, each column was encoded as variable-length and allowing NULL.
- MySQL 5.0.3 retroactively named the original format `ROW_FORMAT=REDUNDANT` and introduced a new default `ROW_FORMAT=COMPACT`:
  - 5-byte fixed header, “is null” bitmap (except for NOT NULL columns), encode the lengths of variable-length fields only (using 1 or 2 bytes per field)
  - `CHAR(n)` on UTF-8 is encoded like `VARCHAR(n to 3n or 4n bytes)`
  - Must copy table to remove NOT NULL or to extend fixed-length columns.
- InnoDB Plugin for MySQL 5.1 introduced **DYNAMIC** and (dead end) **COMPRESSED**:
  - Based on COMPACT, but not storing 768-byte prefix of off-page columns.
- `innodb_default_row_format=DYNAMIC` since MariaDB 10.2
File Format Changes to Avoid Rebuild for Instant ALTER TABLE
**ALTER TABLE Improvements in MariaDB 10.3**

- **MDEV-13134** introduced syntax to avoid “surprise rebuilds”:
  \[
  \text{ALGORITHM=} (\text{INSTANT}|\text{NOCOPY}) \text{ and SET alter\_algorithm=} (\text{instant}|\text{nocopy})
  \]

- **MDEV-11369** introduced instant **ADD COLUMN**, limited to appending last
  - Both Alibaba and Tencent had developed something similar based on MySQL 5.6.
  - MariaDB supports also **DEFAULT** value expressions, with values stored in one place, in a hidden *metadata record* at the start of the clustered index.
  - Does not support **ROW\_FORMAT=COMPRESSED**.
Example of Instant ADD COLUMN

CREATE TABLE t(id INT PRIMARY KEY, u INT UNIQUE) ENGINE=InnoDB;
INSERT INTO t(id,u) VALUES(1,1),(2,2),(3,3);
ALTER TABLE t ADD COLUMN
d DATETIME DEFAULT current_timestamp(),
t TEXT CHARSET utf8 DEFAULT 'The quick brown fox',
p POINT NOT NULL DEFAULT ST_GeomFromText('POINT(0 0)');
UPDATE t SET t=NULL WHERE id=3;

<table>
<thead>
<tr>
<th>id</th>
<th>u</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
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<tr>
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<th>d</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2017-11-10 12:14:00</td>
<td>'The quick brown fox'</td>
<td>POINT(0 0)</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
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</tr>
<tr>
<td>3</td>
<td>3</td>
<td>2017-11-10 12:14:00</td>
<td>NULL</td>
<td>POINT(0 0)</td>
</tr>
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</table>

MariaDB
10.4: DROP, (ADD|MODIFY)...(FIRST|AFTER...) Extends the 10.3 Instant ADD COLUMN metadata record with a BLOB

- Keeps the user record format unchanged; adds metadata for column mapping.
  - Physically, do ADD COLUMN last in the clustered index records.
  - DROP COLUMN will leave garbage in old records; new records will write NULL, empty strings, or dummy fixed-length values.

- The format of secondary indexes remains completely unchanged.

- Replacing PRIMARY KEY (a, b) with PRIMARY KEY (b, a) must copy the table.
Basic Usage of Instant ALTER TABLE

- By default, `ALTER TABLE` is instantaneous when possible.
- Use the `FORCE` keyword for the old-fashioned table rebuild, with the old-fashioned (additional) limitations with regard to `FULLTEXT INDEX` and `SPATIAL INDEX`.
- `FULLTEXT INDEX` limits the ability to `ADD`, `DROP` columns or change their order.
- To monitor the number of avoided table rebuilds via using the metadata record:
  ```sql
  SELECT variable_value
  FROM information_schema.global_status
  WHERE variable_name = 'innodb_instant_alter_column';
  ```
- See also [https://mariadb.com/resources/blog/instant-add-column-innodb](https://mariadb.com/resources/blog/instant-add-column-innodb)
Record Changes for Instant **ADD COLUMN**

- An InnoDB table is a collection of indexes:
  - Clustered index (ordered by `PRIMARY KEY` or similar); index-organized table
  - Optional secondary indexes, pointing to clustered index keys
- In the clustered index leaf page records, we **ADD COLUMN** last:
  - `(PRIMARY KEY, DB_TRX_ID, DB_ROLL_PTR, non-virtual columns, added columns)`
- How to tell if added columns are present?
  - `ROW_FORMAT=REDUNDANT` explicitly stores the number of index fields.
  - `ROW_FORMAT=COMPACT, ROW_FORMAT=DYNAMIC` will require bigger changes:
    - Record header flag and optional field for “number of added columns”.
    - Must store the original number of fields or columns somewhere.
Page Changes for Instant ALTER TABLE

- **Root page:** FIL_PAGE_TYPE_INSTANT; PAGE_INSTANT stores the original (smaller, or with DROP COLUMN, bigger) number of clustered index fields.

- At the start of the clustered index, store a metadata record with REC_INFO_MIN_REC_FLAG and the optional “added columns” header:
  - The number of fields must match the current table definition.
  - Values of “added columns” are the values of “missing columns” in user records.
  - For DROP COLUMN, some original metadata is stored in a metadata BLOB.
Better ALTER TABLE for Replication and all Storage Engines
Problems with Online Table Rebuild

Why are tools like GH-OST still used instead of `ALTER ONLINE TABLE`?

- Replication slave will only start after commit→huge lag (to be fixed in [MDEV-11675](#))
- The `online_log` needs to be buffered (in memory or temporary files)
  - The size depends on the concurrent DML workload; hard to predict!
  - Written before commit; DML duplicate key errors make also `ALTER TABLE` fail

Watch out for [MDEV-16329](#) Cross-Engine `ALTER ONLINE TABLE`

- Keep engine-native for `ADD [UNIQUE] INDEX` or `ALGORITHM=INSTANT`
Speeding up Bulk Operations in InnoDB

Needed for MDEV-16329 Cross-Engine ALTER ONLINE TABLE

MDEV-515: InnoDB bulk insert into empty table or partition

- Speeds up `mysqldump` and many `INSERT, REPLACE, LOAD DATA`
- Works also for generic `ALTER TABLE...ALGORITHM=COPY`
- For recovery, just write 1 undo log record “truncate on rollback”
- Avoid or reduce redo logging; build indexes pre-sorted, page by page
  - Similar to `CREATE INDEX` in MariaDB 10.2+

MariaDB Server 10.5?
Theoretical Limits of Avoiding Copying in ALTER TABLE
Format Tagging for Lazy Conversions

Avoid rebuilding or copying the table when changing data encodings

- Format changes can be instantaneous if they relax constraints:
  - Change virtually anything to utf8 or utf16; e.g.: \_latin1 0xe4 ≡ \_utf8 0xc3a4
  - Change INT UNSIGNED to BIGINT (unsigned to wider signed integer)

- These could be implemented with a per-record or per-page “format version tag” and by converting records to the newest version whenever the data is being read.

- Affected secondary indexes must be rebuilt.
File Format Changes for Format Tagging

User data records (or pages) must indicate their physical format

- “Format version number” that points to something in the hidden metadata record?

- A prototype with “dual-format” clustered index leaf pages was implemented and rejected due to the **ROW_FORMAT=REDUNDANT** storage overhead

- For any **ROW_FORMAT**, we need additional metadata to indicate how to convert data when reading or searching: e.g., `latin1` to `utf8`, `INT` to `BIGINT`

- **Do we want this?** Could add significant memory and time overhead to DML!

Speculation
**ALGORITHM=NOCOPY with Validation (1/2)**

Avoid copying the table even if the data could be incompatible

- Perform a **locking table scan** to validate the data.
  - Example: `i` BIGINT NULL to INT UNSIGNED NOT NULL is OK if `i`\(\geq 0\)
  - `ALTER ONLINE TABLE` actually conflicts with `ALGORITHM=NOCOPY` in this case!
  - `ALTER IGNORE TABLE` would involve `UPDATE` of offending data.

- Affected **secondary indexes must be rebuilt** if the physical format changes
  - `ADD CONSTRAINT ... (CHECK|FOREIGN KEY)` does not change format!
ALGORITHM=NOCOPY with Validation (2/2)

The Lifetime of an ALTER TABLE Transaction

1. Check constraints for each row, e.g., MODIFY i INT UNSIGNED:
   - ALTER IGNORE would UPDATE offending data, e.g.: SET i=NULL WHERE i<0

2. DROP INDEX and ADD INDEX of affected indexes, or user-specified ones

3. Any additional operations that are part of the ALTER (say, instant DROP COLUMN)

4. Update the data dictionary
Summary

- MariaDB 10.3 and 10.4 changed the InnoDB data format to allow instantaneous (ADD|MODIFY) COLUMN...(FIRST|AFTER...), DROP. You can still FORCE a rebuild.

- MariaDB 10.4 supports instant ALTER TABLE whenever it is technically possible without changing the storage format further.

- Future MariaDB versions might support instant ALTER TABLE or avoid copying whenever technically possible. The current metadata format is extensible.

- Use ALGORITHM=INSTANT or ALGORITHM=NOCOPY (or SET alter_algorithm) to get errors instead of unexpected DoS via excessive I/O.