ClickHouse Internals

Qin Liu, Moqi Inc.

qliu@moqi.ai

Most slides are taken from Aleksei Milovidov

ClickHouse use cases

A stream events

- Actions of website visitors (Yandex Metrica)
- Ad impressions
- DNS queries
- E-commerce transactions

We want to save info about these events and then glean some insights from it

ClickHouse philosophy

- Interactive queries on data updated in real time
- Cleaned structured data is needed
- Try hard not to pre-aggregate anything
- Query language: a dialect of SQL + extensions

Sample query in a web analytics system

Top-10 referers for a website for the last week:

```sql
SELECT Referer, count(*) AS count
FROM hits
WHERE CounterID = 111
AND Date BETWEEN '2023-03-13' AND '2023-03-19'
GROUP BY Referer
ORDER BY count DESC
LIMIT 10
```

How to execute a query fast?

Read data fast

- Only needed columns: `CounterID`, `Date`, `Referer`
- Locality of reads (an index is needed!)
- Data compression

Process data fast

- Vectorized execution (block-based processing)
- Parallelize to all available cores and machines
- Specialization and low-level optimizations

Index needed

The principle is the same as with classic DBMSes

- A majority of queries will contain conditions on `CounterID` and (possibly) `Date`

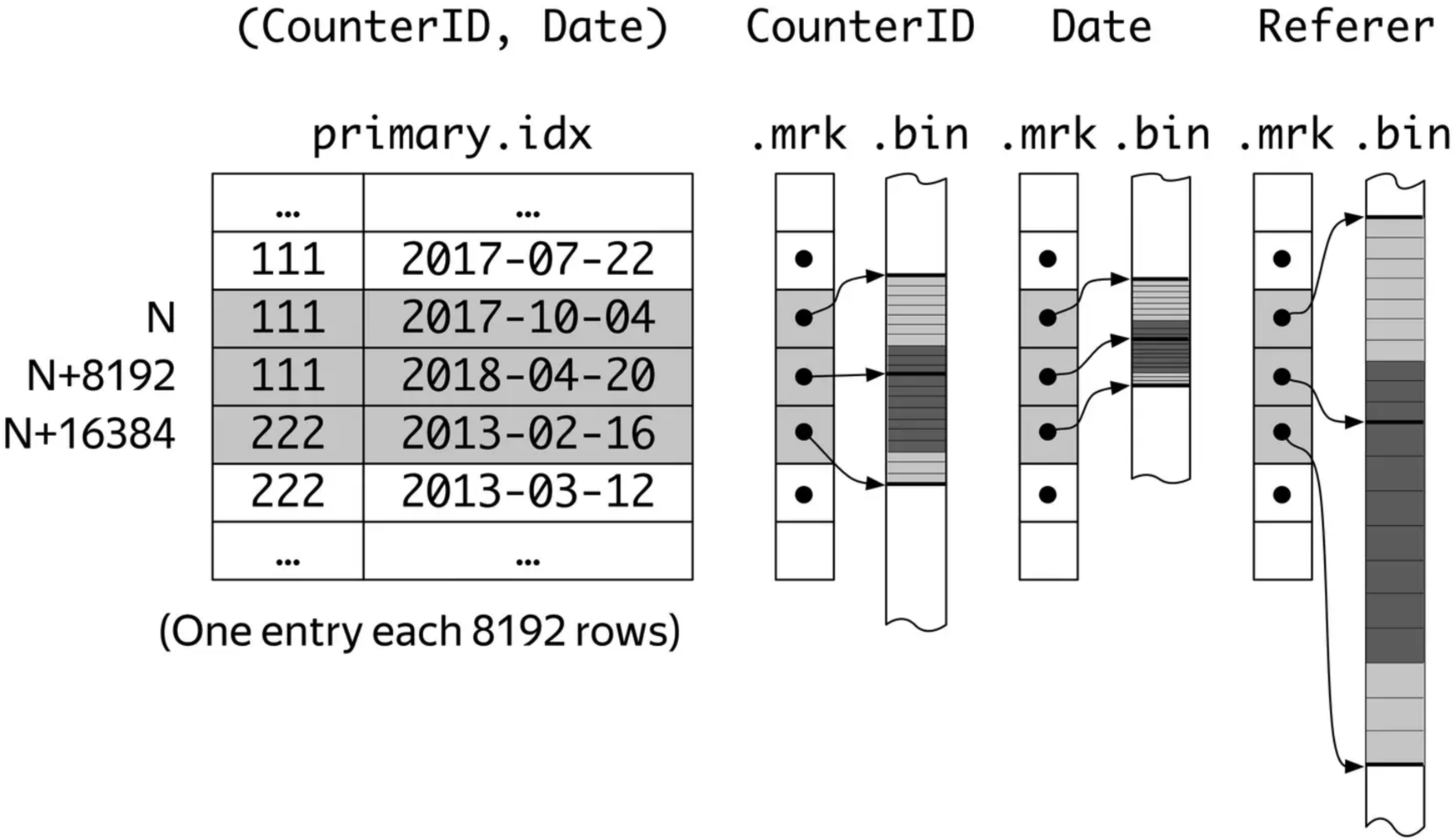
`(CounterID, Date)` fits the bill

- Check this by mentally sorting the table by primary key

Differences

- The table will be physically sorted on disk
- **Is not** a unique constraint

Index Internals



	…	…
	111	2017-07-22
N	111	2017-10-04
N+8192	111	2018-04-20
N+16384	222	2013-02-16
	222	2013-03-12
	…	…

(One entry each 8192 rows)

Things to remember about indexes

Index is sparse

- Must fit into memory
- Default value of granularity (8192) is good enough
- Does not create a unique constraint
- Performance of point queries is not stellar

Table is sorted according to the index

- There can be only one
- Using the index is always beneficial

How to keep the table sorted

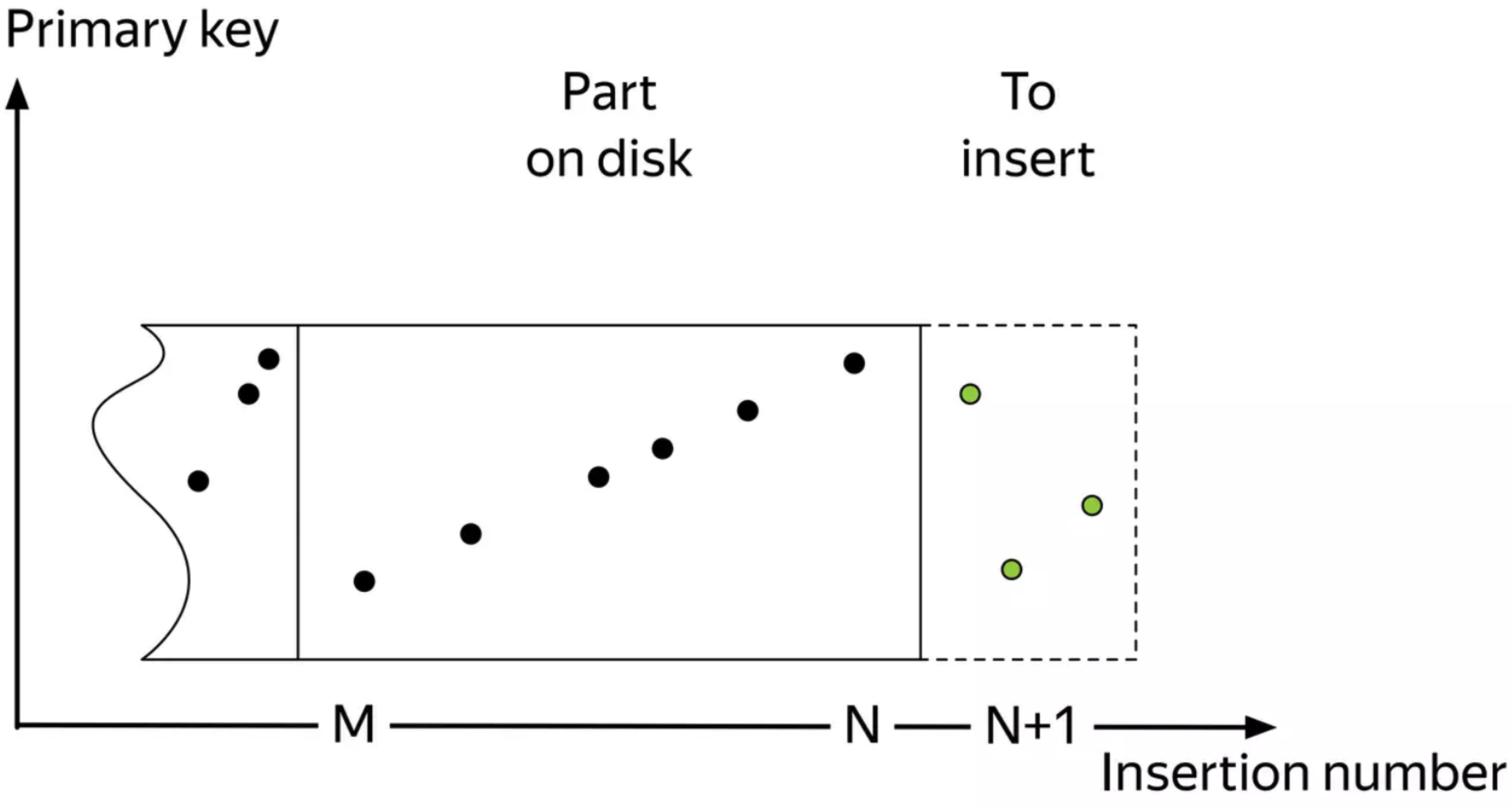
Inserted events are (almost) sorted by time

- But we need to sort by primary key!

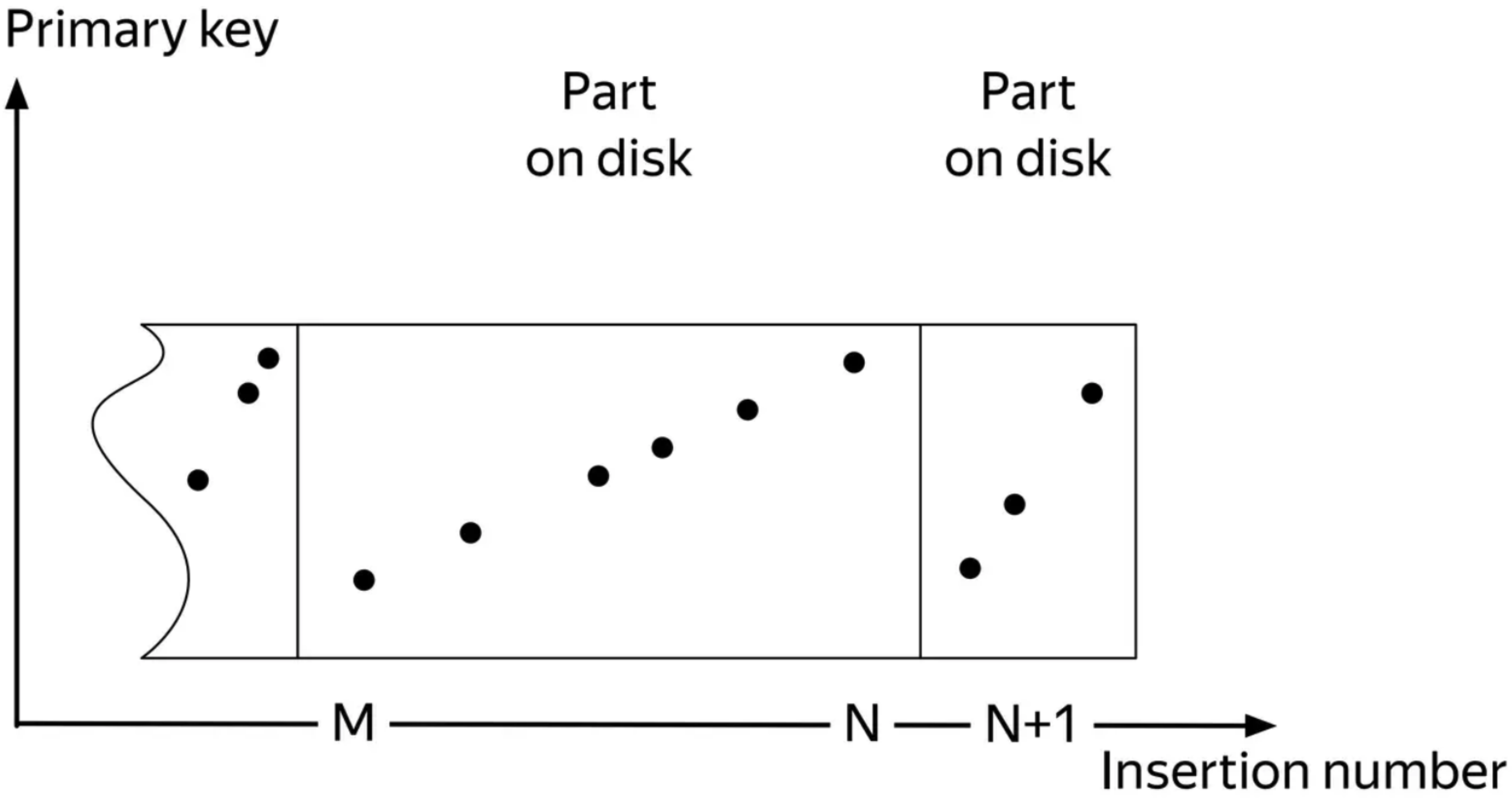
MergeTree: maintain a small set of sorted parts

- Similar idea to an LSM tree

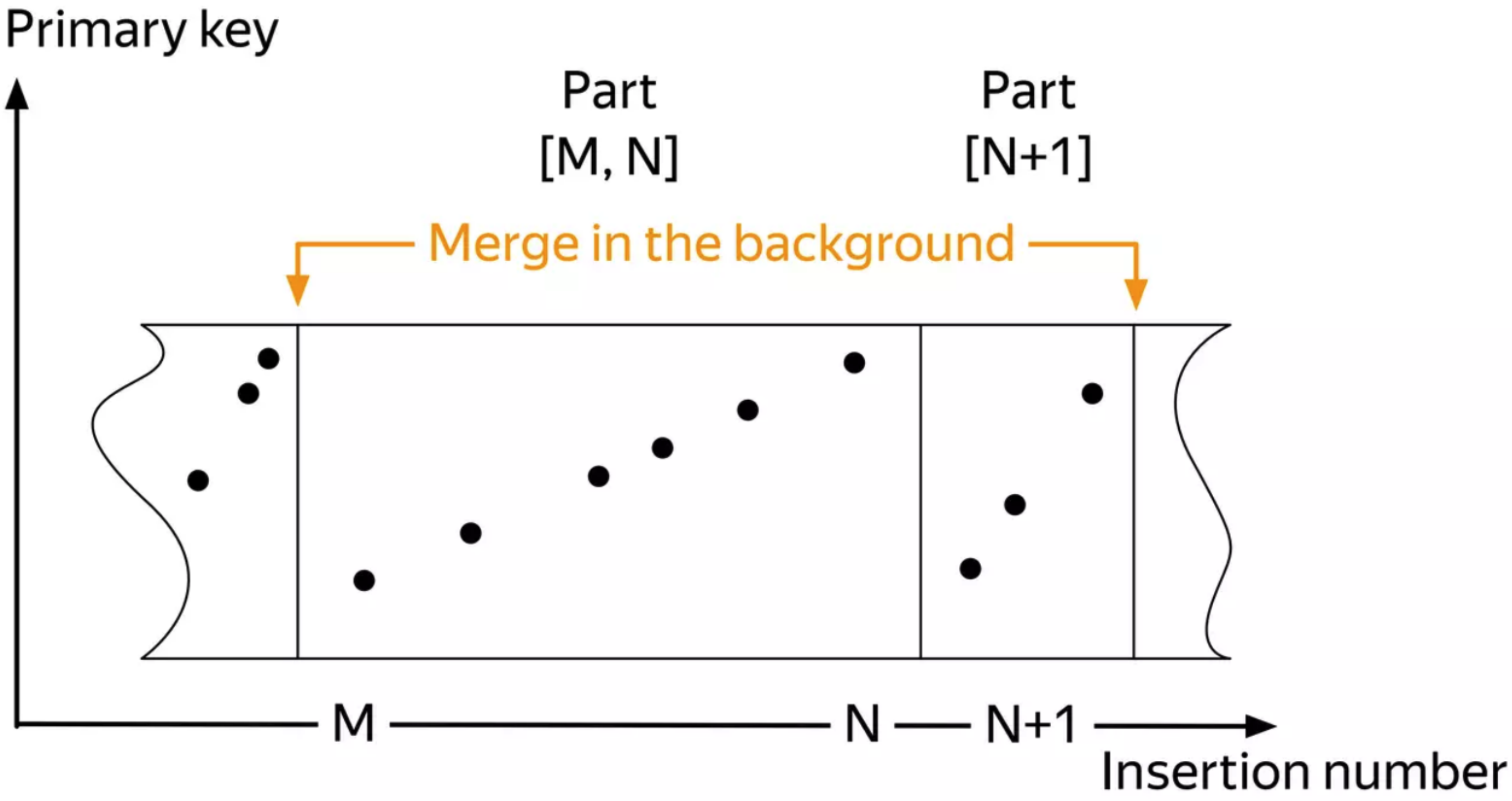
How to keep the table sorted



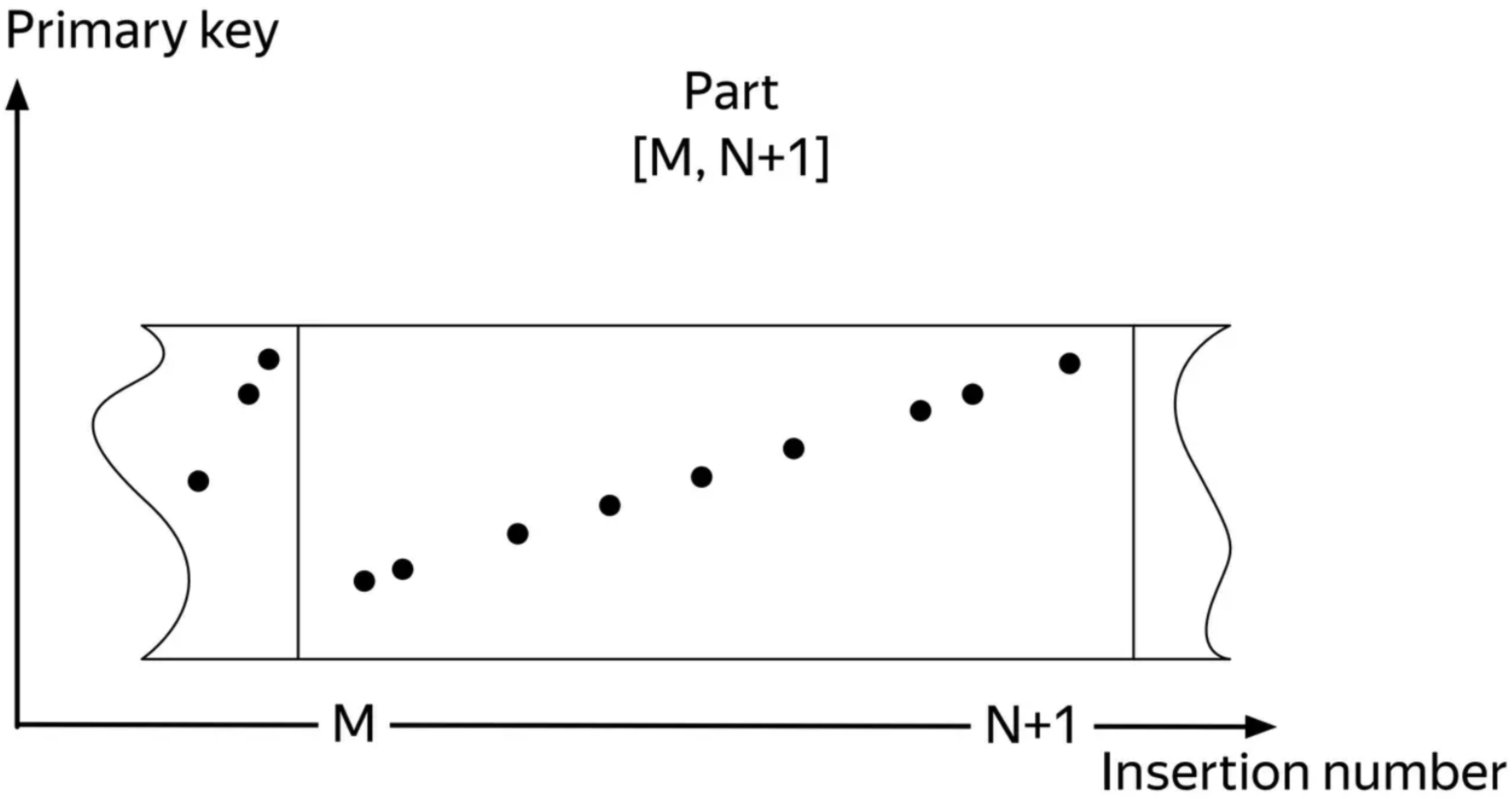
How to keep the table sorted



How to keep the table sorted



How to keep the table sorted



Things to do while merging

Replace/update records

- ReplacingMergeTree
- CollapsingMergeTree

Pre-aggregate data

- AggregatingMergeTree

Metrics rollup

- GraphiteMergeTree

MergeTree partitioning

```
ENGINE = MergeTree ... PARTITION BY toYYYYMM(Date)
```

- Table can be partitioned by any expression (default: by month)
- Parts from different partitions are not merged
- Easy manipulation of partitions

  ```
  ALTER TABLE DROP PARTITION
  ALTER TABLE DETACH/ATTACH PARTITION
  ```

- MinMax index by partition columns

Things to remember about MergeTree

Merging runs in the background

- Even when there are no queries!

Control total number of parts

- Rate of INSERTs
- `MaxPartsCountForPartition` and `DelayedInserts` metrics are your friends

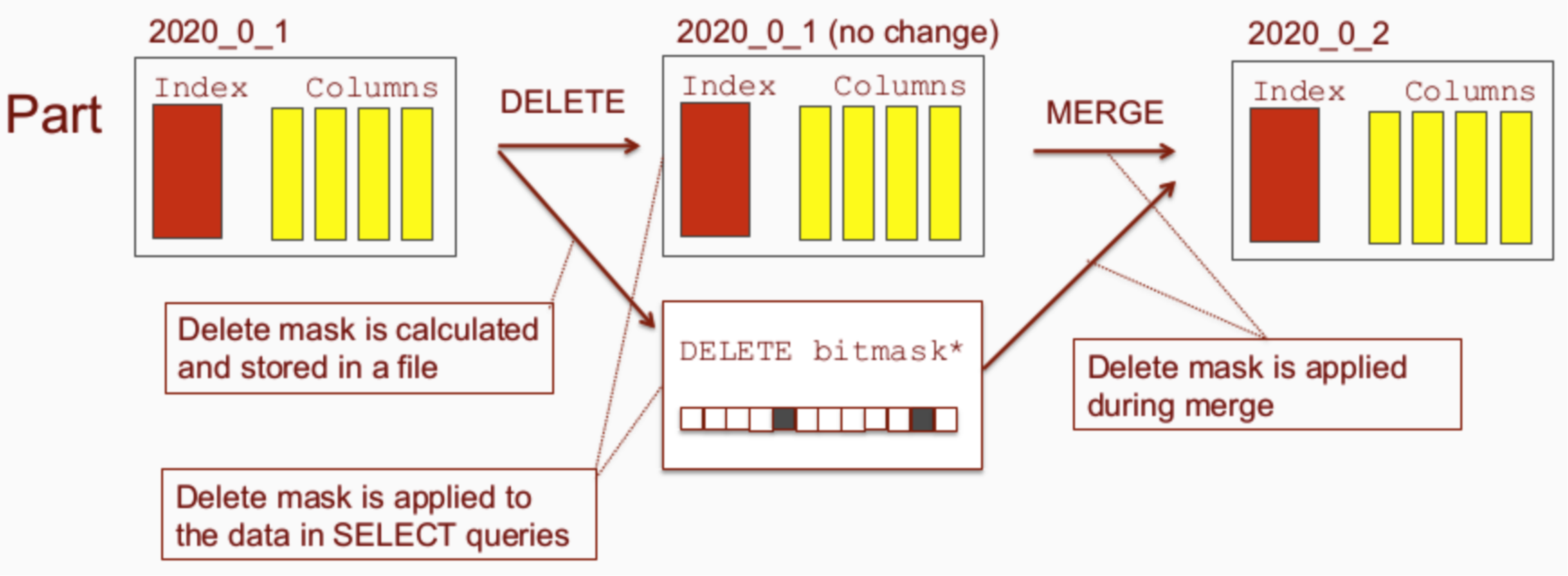
Delete and update

Delete and update are very expensive

- The entire part that contains the deleted/updated rows must be updated
- Parts can be quite large after merging

Lightweight delete

Added by Jianmei Zhang from Moqi, #37893



Delete mask is calculated and stored in a file

Delete mask is applied to the data in SELECT queries

Delete mask is applied during merge