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Dive into ClickHouse Storage System

Alexander Sapin, Software Engineer

ClickHouse Storages

External Table Engines:

- File on FS
- S3
- HDFS
- MySQL
- ...

Internal Table Engines:

- Memory
- Log
- StripeLog
- MergeTree family

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Advantages:

- Inserts are atomic
- Selects are blazing fast
- Primary and secondary indexes
- Data modification!
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Features:

- Infrequent INSERTs required (work in progress)
- Background operations on records with the same keys
- Primary key is NOT unique

Write

Create Table and Fill Some Data

Create Table:

```
CREATE TABLE mt (
    EventDate Date,
    OrderID Int32,
    BannerID UInt64,
    GoalNum Int8
) ENGINE = MergeTree()
PARTITION BY toYYYYMM(EventDate) ORDER BY (OrderID, BannerID)
```

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) ENGINE = MergeTree()
PARTITION BY toYYYYMM(EventDate) ORDER BY (OrderID, BannerID)
```

Fill Data (twice):

```
INSERT INTO mt SELECT toDate('2018-09-26'),
    number, number + 10000, number % 128 from numbers(1000000);
INSERT INTO mt SELECT toDate('2018-10-15'),
    number, number + 10000, number % 128 from numbers(1000000, 1000000);
```

Table on Disk

metadata:

```
$ ls /var/lib/clickhouse/metadata/default/
mt.sql
```

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data:

```
$ ls /var/lib/clickhouse/data/default/mt
201809_2_2_0  201809_3_3_0  201810_1_1_0  201810_4_4_0 201810_1_4_1
detached  format_version.txt
```

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$ ls /var/lib/clickhouse/metadata/default/
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$ ls /var/lib/clickhouse/data/default/mt
201809_2_2_0  201809_3_3_0  201810_1_1_0  201810_4_4_0 201810_1_4_1
detached  format_version.txt
```

Contents:

- Format file `format_version.txt`
- Directories with parts
- Directory for detached parts

Parts: Details

- Part of the data in PK order
- Contain interval of insert numbers
- Created for each `INSERT`
- Cannot be changed (immutable)

Parts: Why?

PK ordering is needed for efficient OLAP queries

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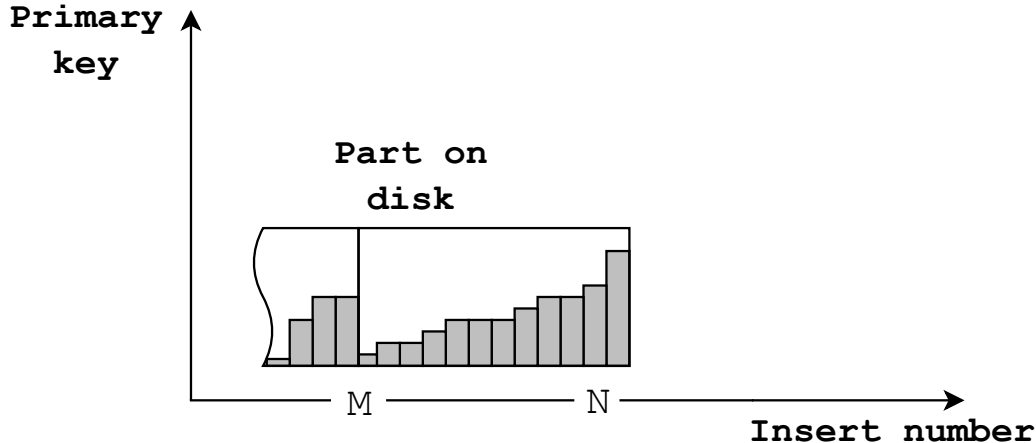
- But the data comes in order of time
  - By `EventDate`
- Re-sorting all the data is expensive
  - ClickHouse handle hundreds of terabytes
- **Solution:** Store data in a set of ordered parts!

Parts: Main Idea



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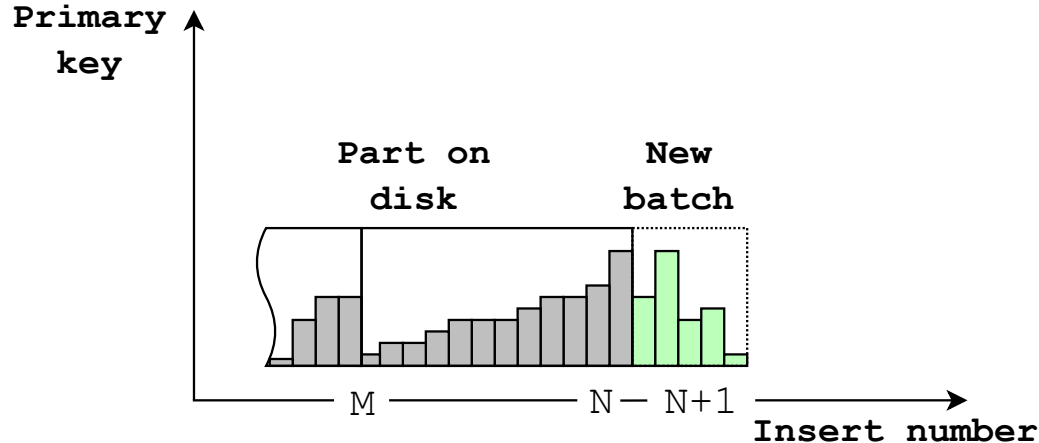

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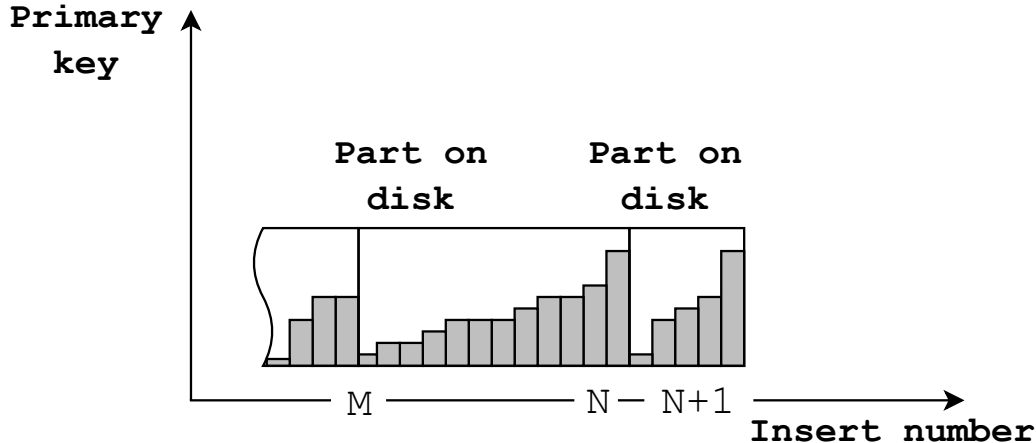
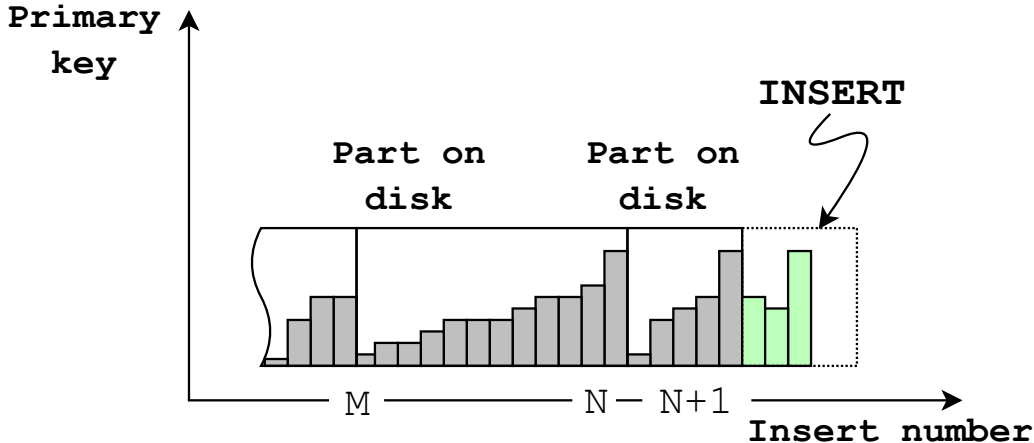


Parts: Atomic insert



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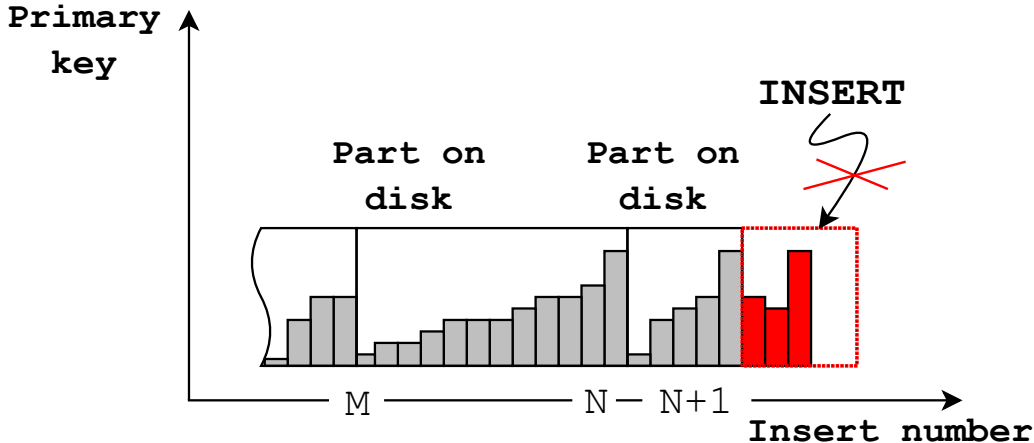

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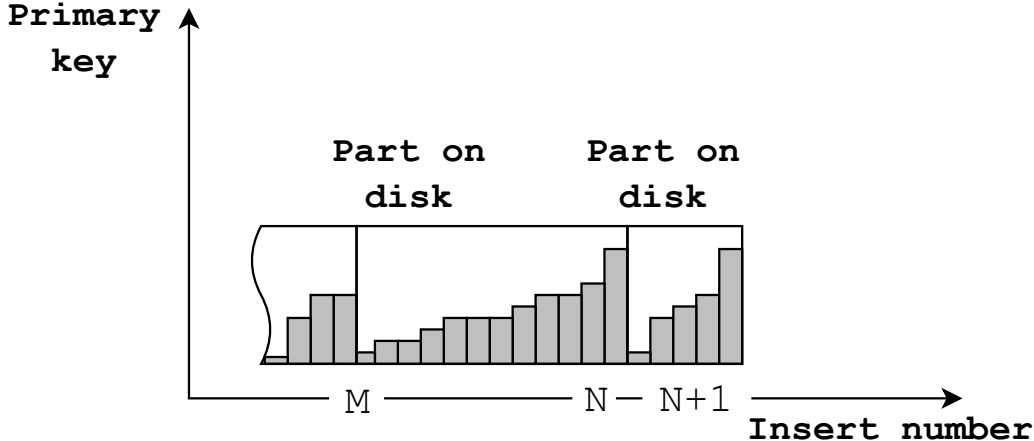

Read

Parts: Data

```
$ ls /var/lib/clickhouse/data/default/mt/201810_1_4_1
GoalNum.bin GoalNum.mrk BannerID.bin ...
primary.idx checksums.txt count.txt columns.txt
partition.dat minmax_EventDate.idx
```

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Contents:

- `primary.idx` – primary key on disk

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- `primary.idx` – primary key on disk
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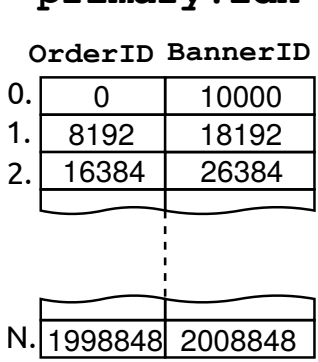
- `partition.dat` – partition id
- `...` – a lot of other useful files

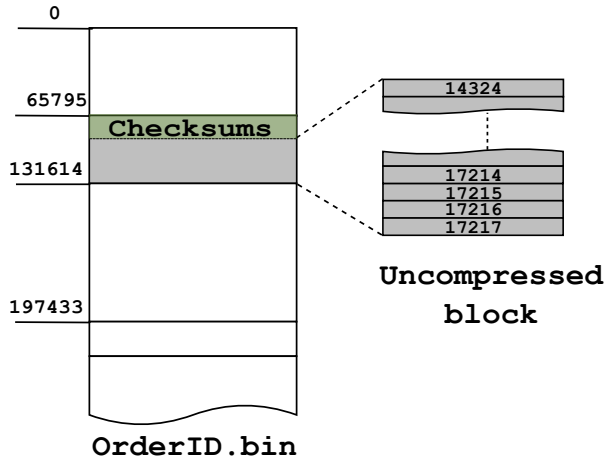
Index

- Row-oriented
- Sparse (each 8192 row)
- Stored in memory
- Uncompressed



Columns

- Each column in separate file
- Compressed by blocks
- Checksums for each block



How to Use Index?

Problem:

- Index is sparse and contain rows
- Columns contain compressed blocks

How to match index with columns?

Solution: Marks

- Mark – offset in compressed file and uncompressed block
- Stored in `column_name.mrk` files
- One for each index row

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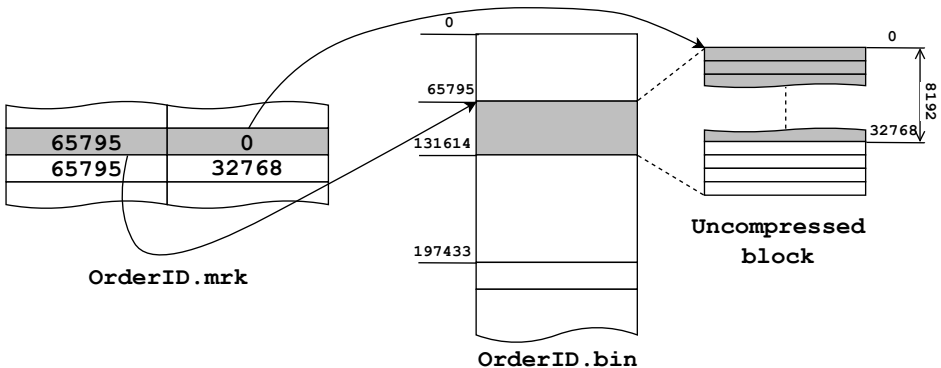


Put it all together

Algorithm:

- Determine required index rows
- Found corresponding marks
- Distribute granules (stripe of marks) among threads
- Read required granules

Properties:

- Read granules concurrently
- Threads can steal tasks

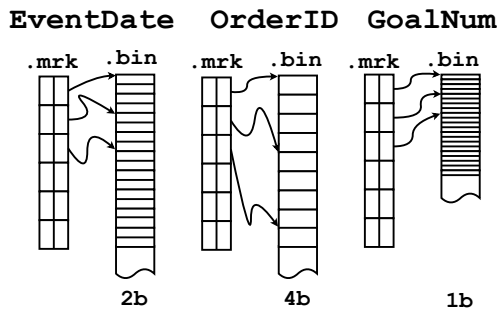
Read Data from Disk

primary.idx

OrderID	BannerID
0	10000
8192	18192
16384	26384
1998848	2008848

KeyCondition

```
SELECT any(EventDate),
max(GoalNum) FROM mt
WHERE OrderID BETWEEN
6123 AND 17345
```



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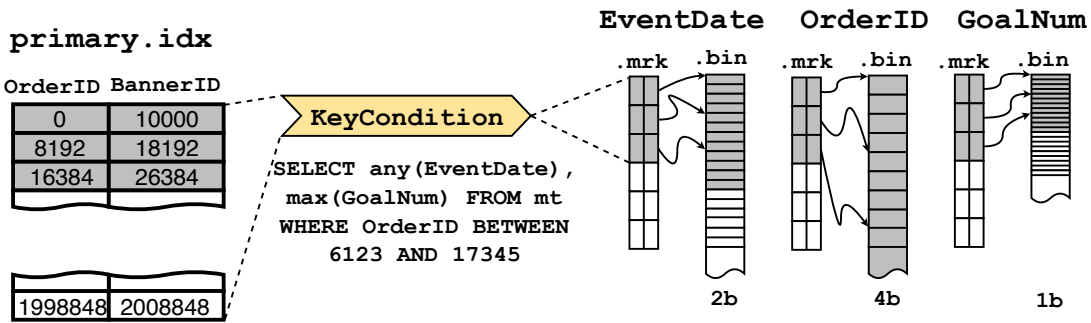

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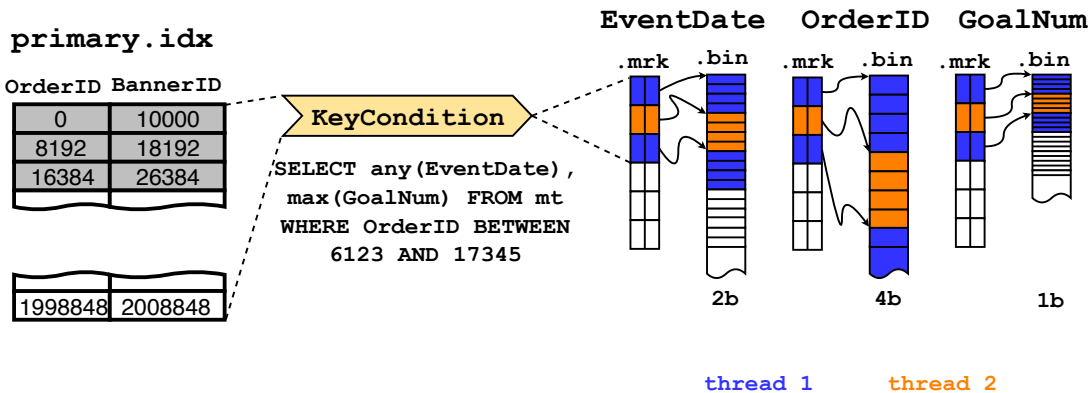

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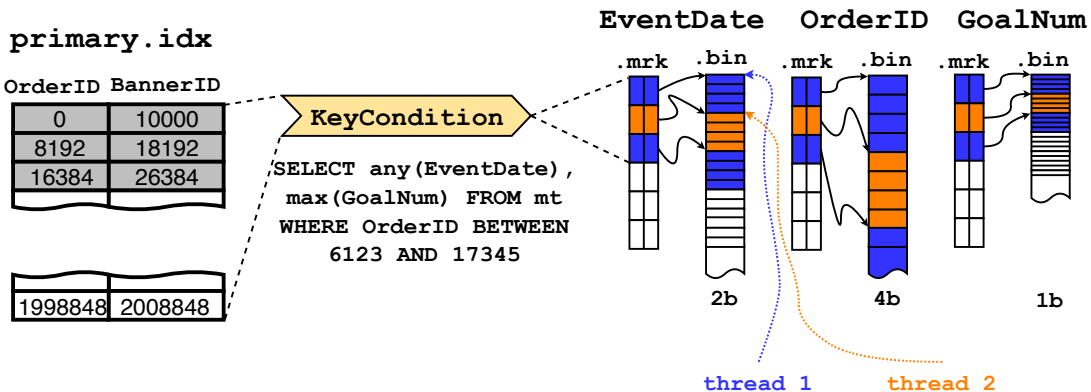

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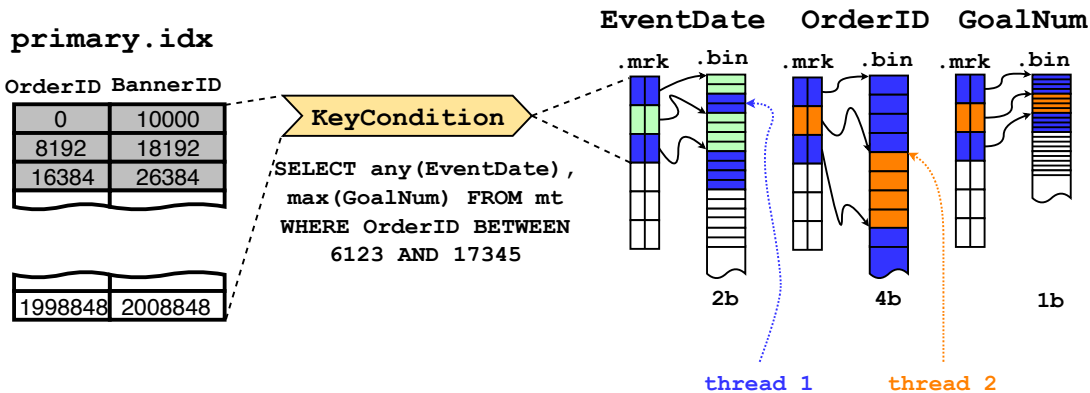

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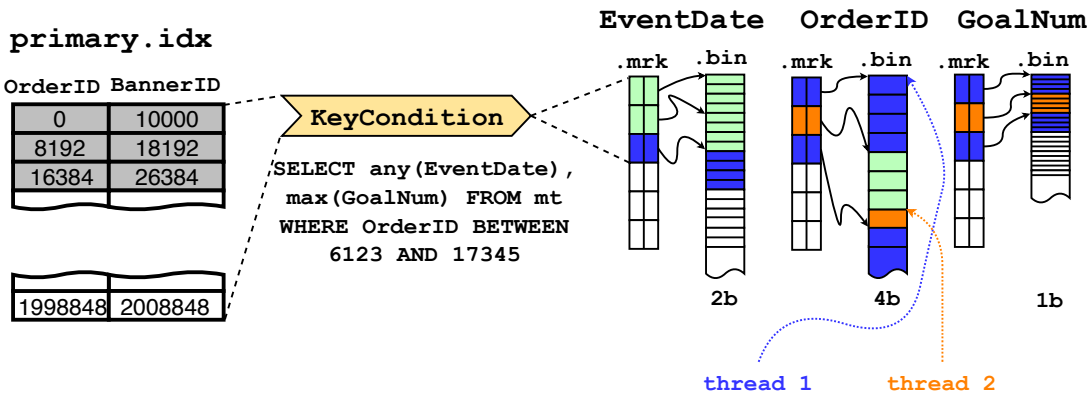

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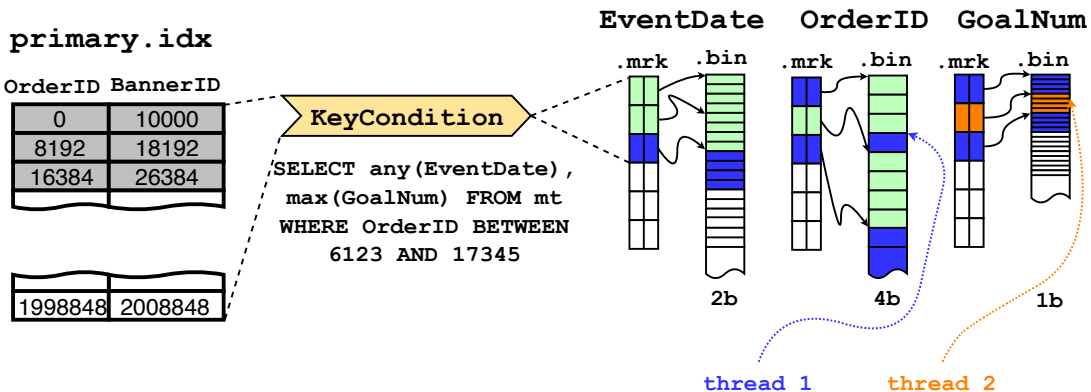

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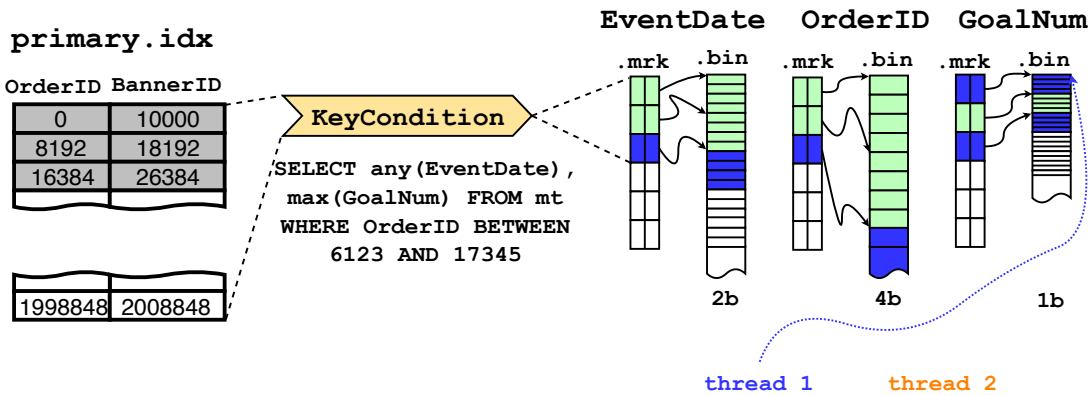

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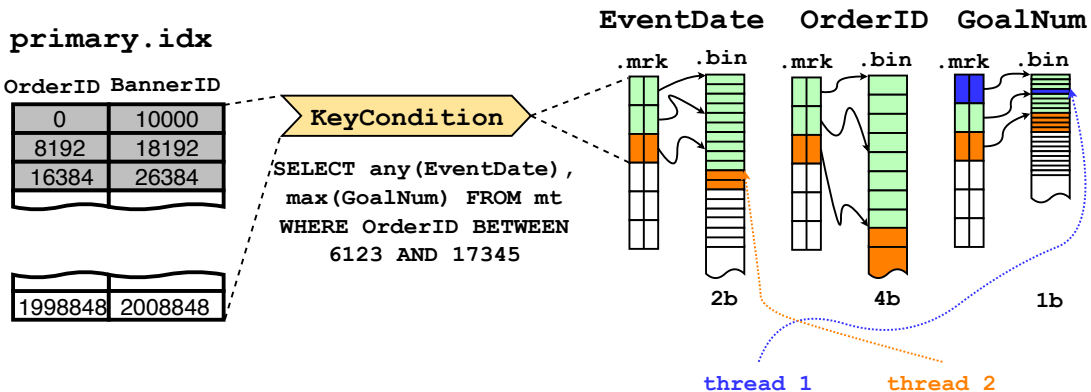

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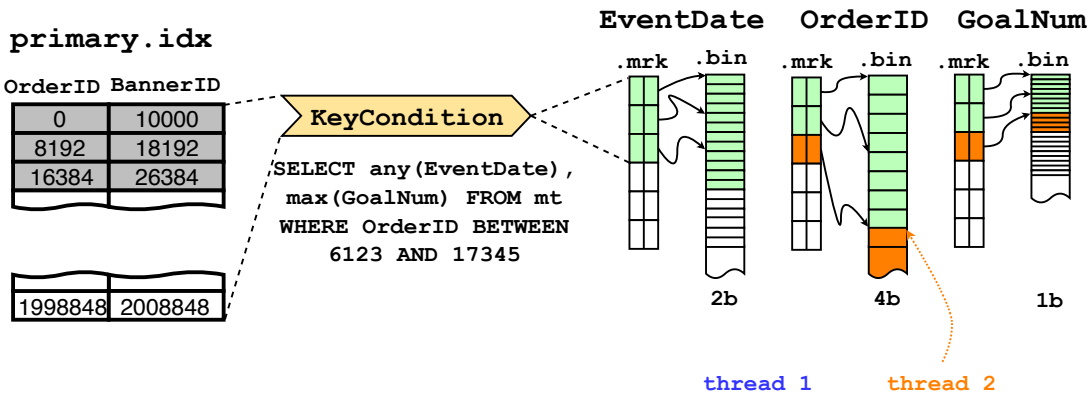

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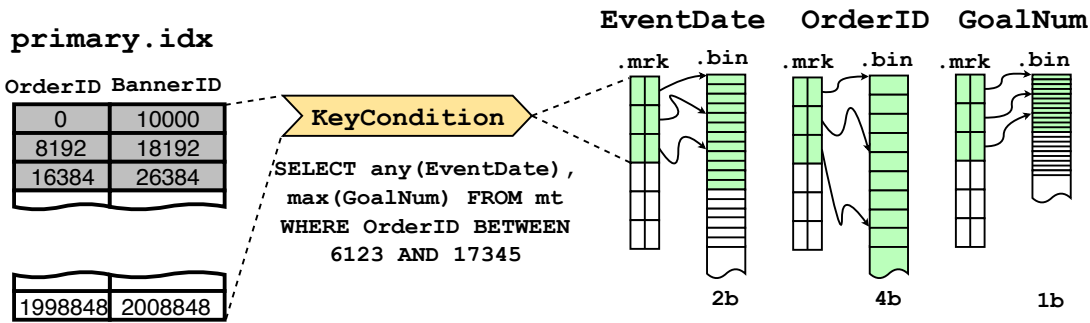

Compaction

Problem: Amount Files in Parts

Test example: Almost OK

```
$ ls /var/lib/clickhouse/data/default/mt/201810_1_4_1 | wc -l
14
```

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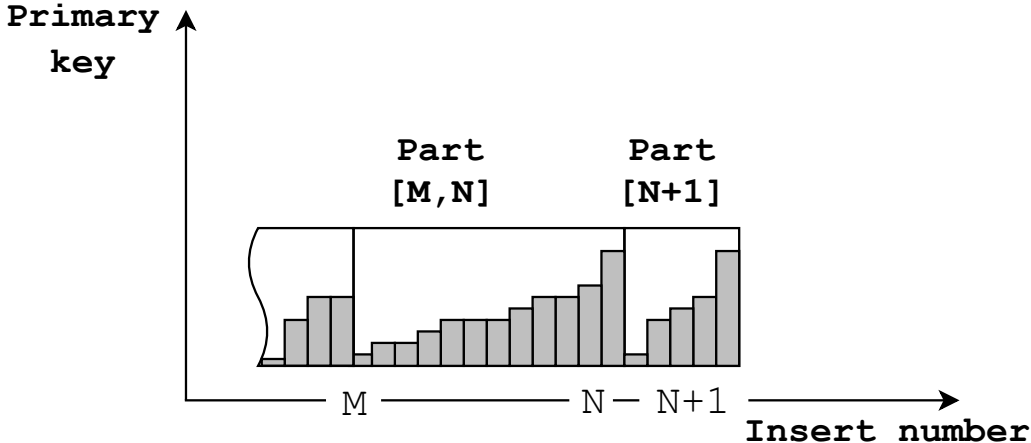
```
$ ls /var/lib/clickhouse/data/default/mt/201810_1_4_1 | wc -l
14
```

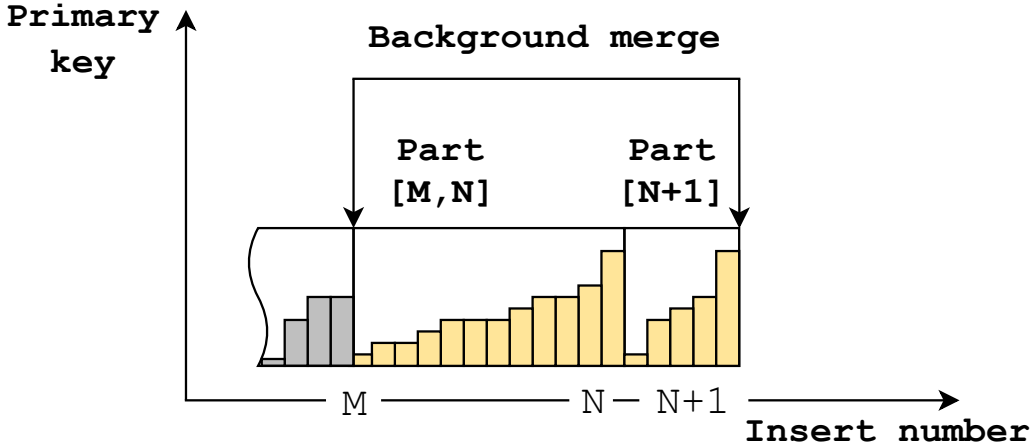
Production: Too much

```
$ ssh -A root@mtgiga075-2.metrika.yandex.net
# ls /var/lib/clickhouse/data/merge/visits_v2/202002_4462_4462_0 | wc -l
1556
```

Solution: Merges



Solution: Merges



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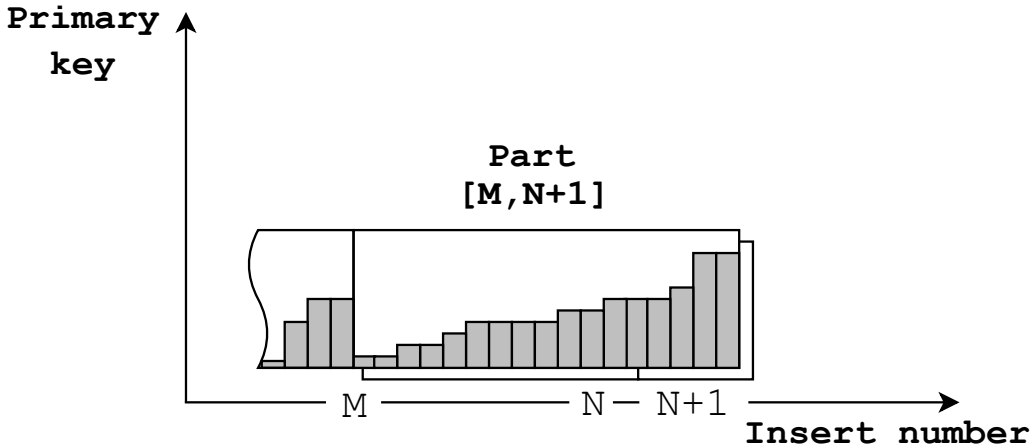

Properties of Merge

- Each part participate in a single successful merge
- Source parts became **inactive**
- Addional logic during merge

Things to do while merging

Replace/update records

- `ReplacingMergeTree` – replace
- `SummingMergeTree` – sum
- `CollapsingMergeTree` – fold
- `VersionedCollapsingMergeTree` – fold rows + versioning

Pre-aggregate data

- `AggregatingMergeTree` – merge aggregate function states

Metrics rollup

- `GraphiteMergeTree` – rollup in graphite fashion

Modify

Partitioning

```
ENGINE = MergeTree() PARTITION BY toYYYYMM(EventDate) ORDER BY ...
```

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- Logical entities (doesn't stored on disk)
- Table can be partitioned by any expression (default: by month)
- Parts from different partitions never merged
- `MinMax` index by partition columns
- Easy manipulation of partitions:

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- `MinMax` index by partition columns
- Easy manipulation of partitions:

```
ALTER TABLE mt DROP PARTITION 201810
ALTER TABLE mt DETACH/ATTACH PARTITION 201809
```

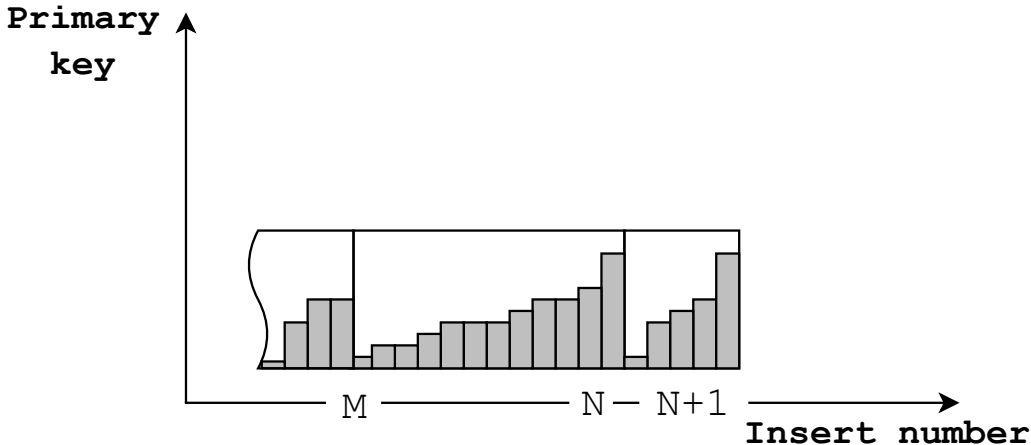
Mutations

```
ALTER TABLE mt DELETE WHERE OrderID < 1205
ALTER TABLE mt UPDATE GoalNum = 3 WHERE BannerID = 235433;
```

Features

- NOT designed for regular usage
- Overwrite all touched parts on disk
- Work in background
- Original parts became **inactive**

Mutations



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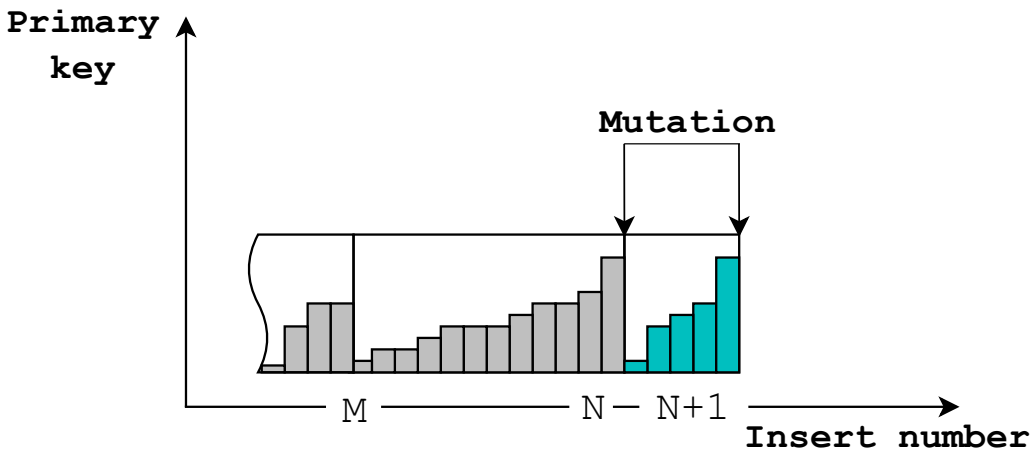

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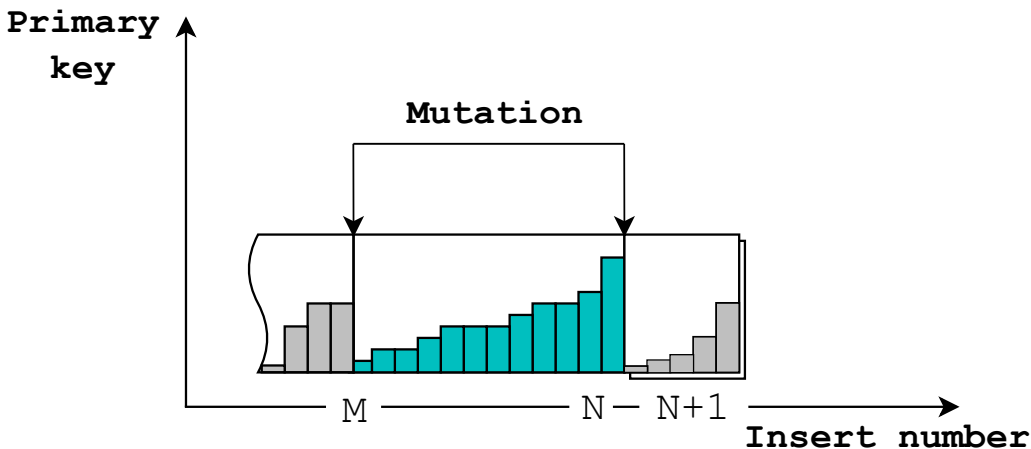

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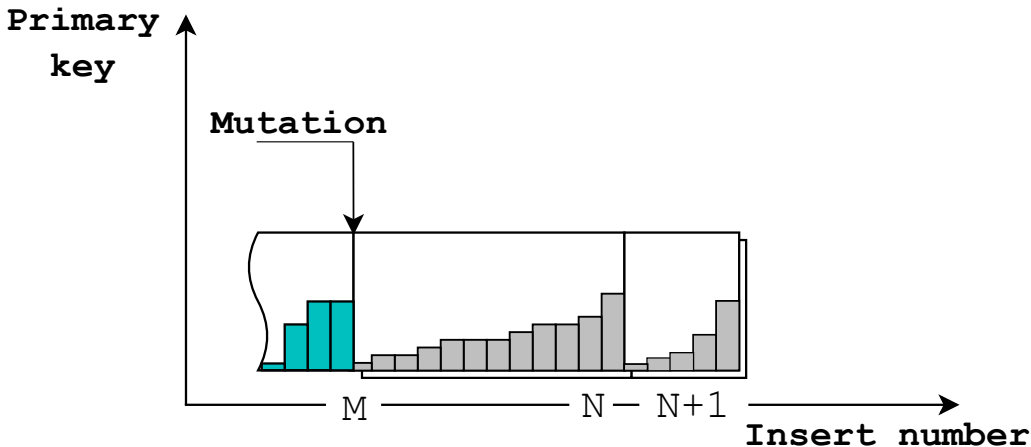
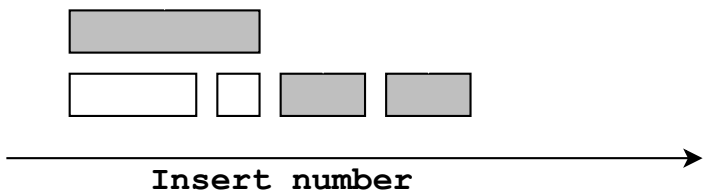


All together

Parts Lifetime



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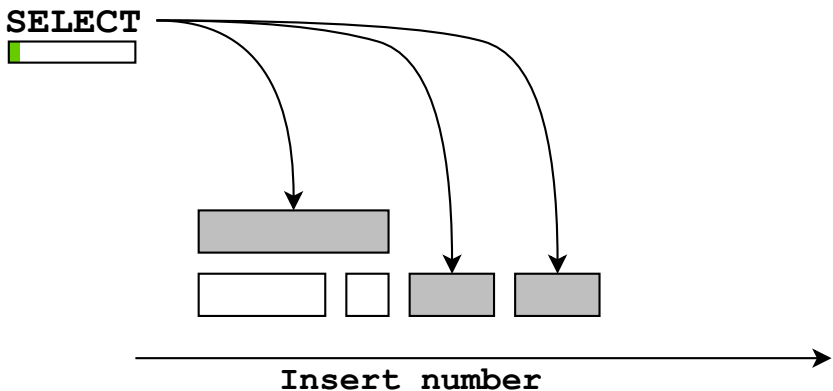

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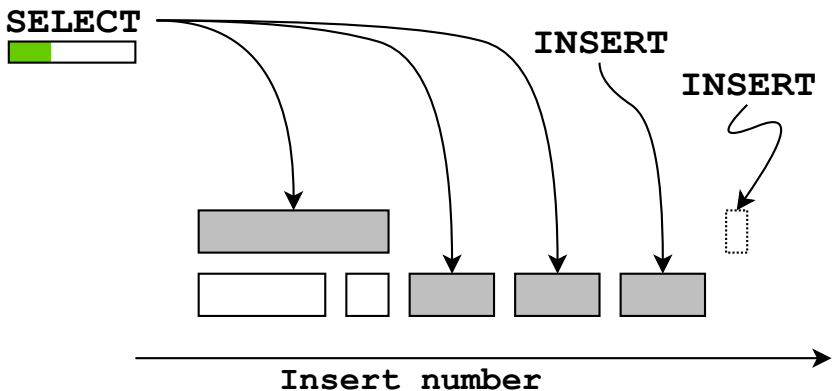

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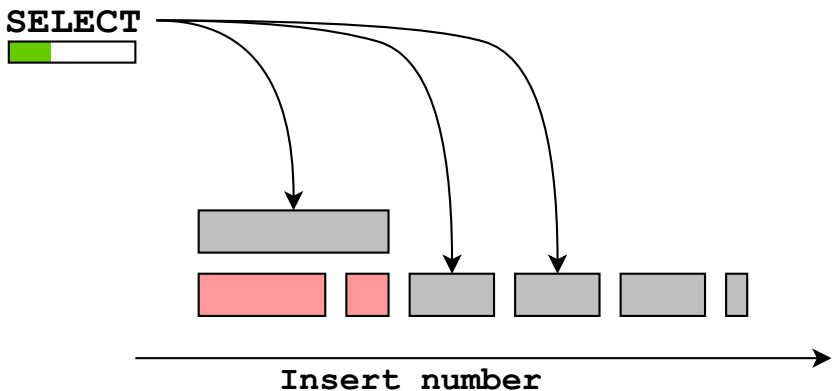

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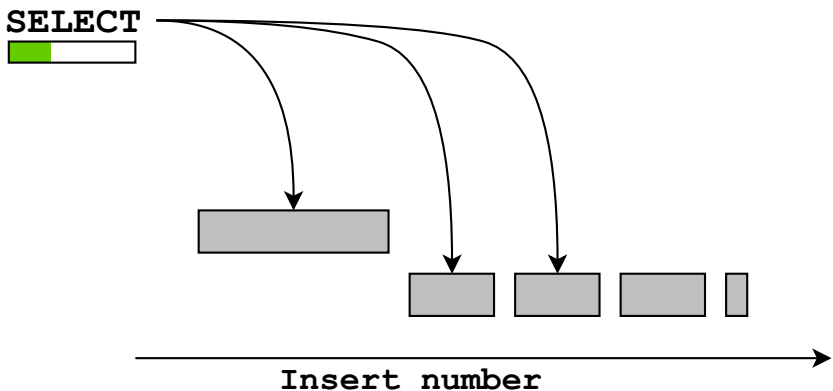

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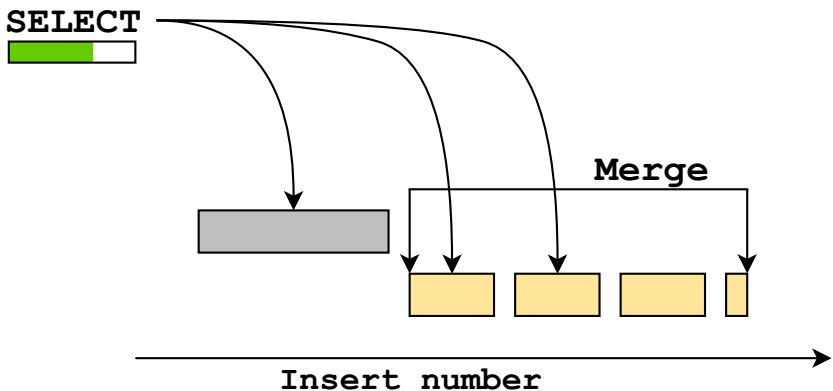

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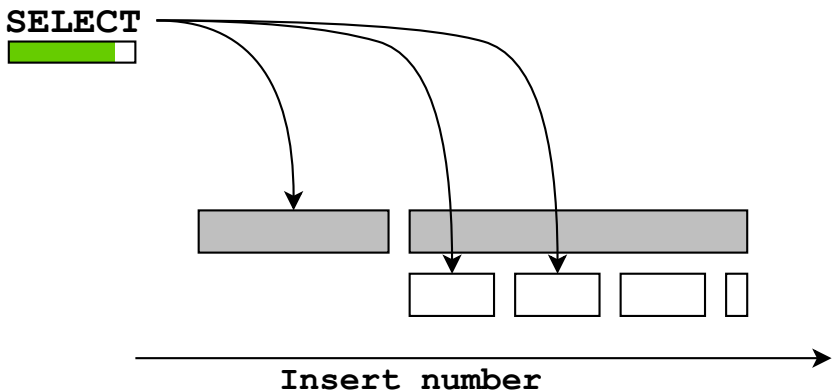

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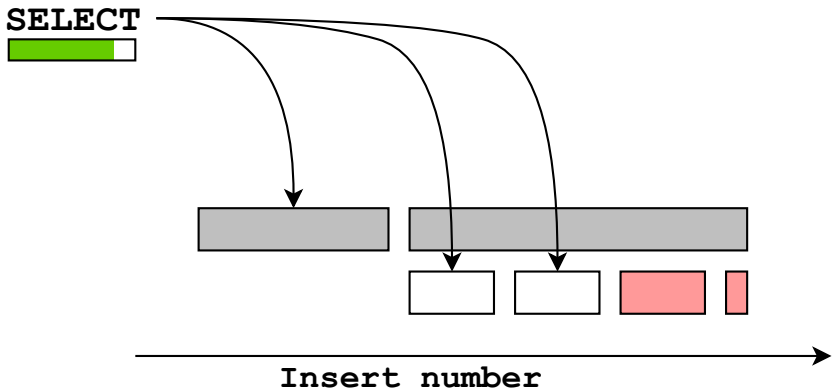

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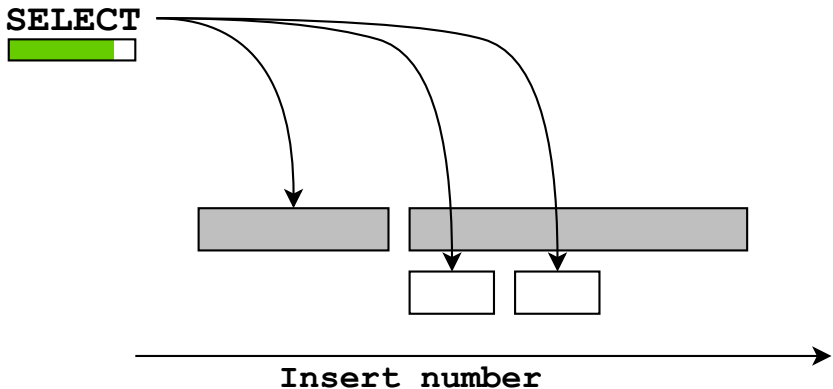
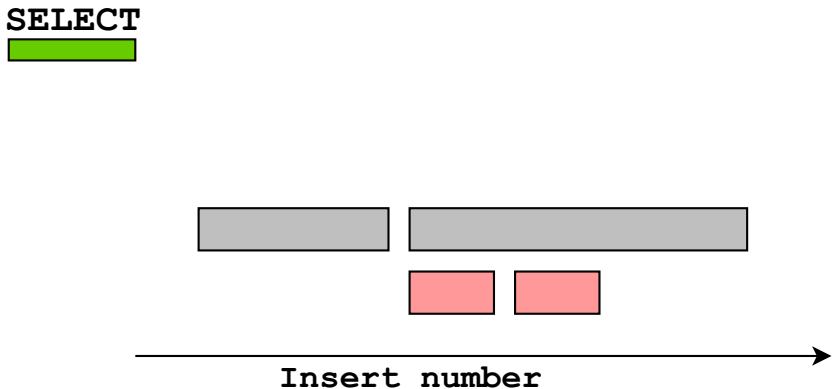


Parts Lifetime



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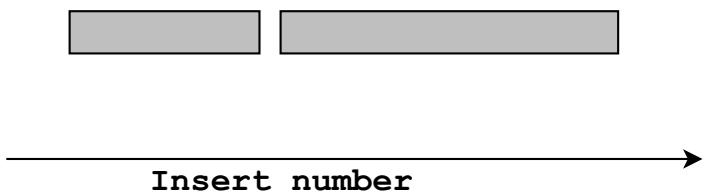

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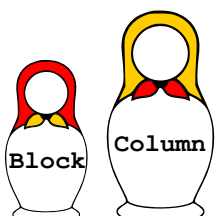

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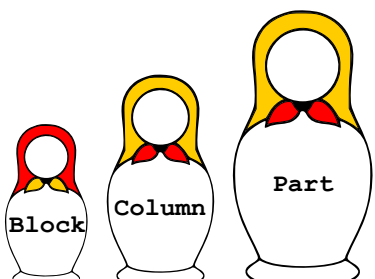

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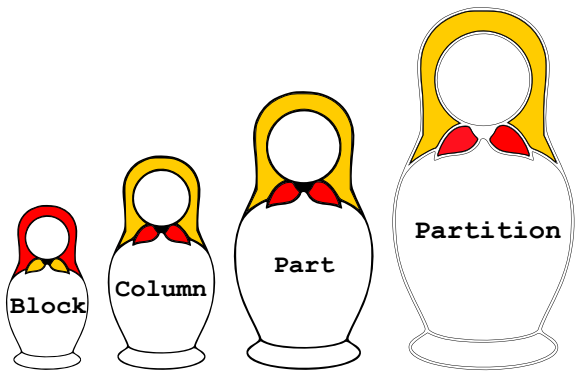

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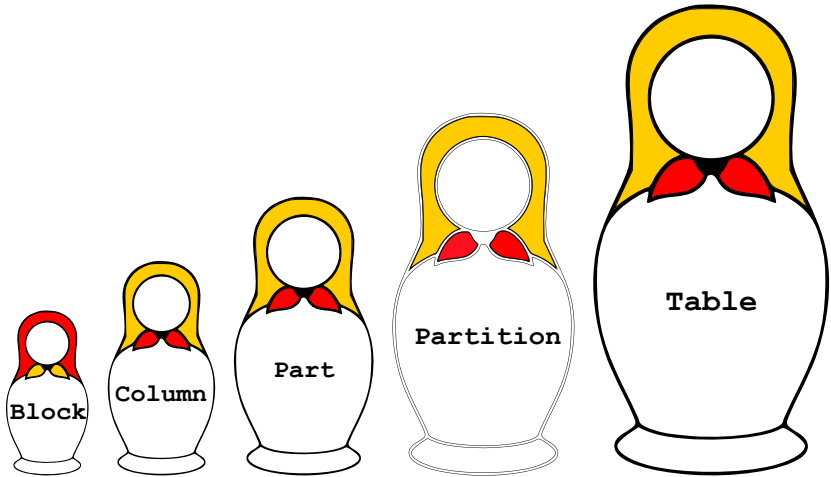

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- **Partitions** is logical entity
  - Easy manipulation with portions of data
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Thank you

QA