TiDB Analyze

A Deep Dive

Based on TiDB v8.1.0

RUSTIN LIU

Press Space to Start

Rustin Liu

PingCAP Optimizer Team Member.

Cargo/Crates.io/Rustup Maintainer.

Tokio Console Maintainer.

 hi-rustin

 hi-rustin.rs

Agenda

Analyze Overview

Data Structure Overview

Data Flow Overview

Data Structure & Data Flow (TiKV Perspective)

Data Structure & Data Flow (TiDB Perspective)

Q&A

Analyze Overview

Analyze Statement

```
-- Analyze Tables
ANALYZE TABLE t1, t2;

-- Analyze Partitions
ANALYZE TABLE t PARTITION p1, p2;

-- Analyze Columns
ANALYZE TABLE t COLUMNS c1, c2;

-- Analyze Indexes
ANALYZE TABLE t INDEX idx1, idx2;

-- Analyze Partitions' Columns
ANALYZE TABLE t PARTITION p1 COLUMNS c1, c2;

-- Analyze Partitions' Indexes
ANALYZE TABLE t PARTITION p1 INDEX idx1, idx2;

-- Analyze Predicate Columns
ANALYZE TABLE t PREDICATE COLUMNS;

-- Analyze With Only 20 Top N
ANALYZE TABLE t COLUMNS c1, c2 WITH 20 TOPN;
```

Data Structure Overview

Data Structure Overview

A simple example.

Create table

```
use test;
create table t (a int);
```

Insert 2000 rows

```
import { Client } from "https://deno.land/x/mysql/mod.ts";

const client = await new Client().connect({...});

for (let i = 0; i < 2000; i++) {
  await client.execute(`INSERT INTO t (a) VALUES (?)`, [i]);
  if (i % 2 === 0) {
    await client.execute(`INSERT INTO t (a) VALUES (?)`, [i]);
  }
}

await client.close();
```

Data Structure Overview

Column Selectivity

```
explain select * from t where a = 100;
```

id	estRows	task	access object	operator info
TableReader_7	2.00	root		data:Selection_6
└──Selection_6	2.00	cop[tikv]		eq(test.t.a, 100)
└──TableFullScan_5	3000.00	cop[tikv]	table:t	keep order:false

```
func equalRowCountOnColumn(encodedVal []byte...) {
  rowcount, ok := c.TopN.QueryTopN(sctx, encodedVal)
  if ok {
    return float64(rowcount), nil
  }
}
```

Data Structure Overview

Column Selectivity

TopN

```
select * from mysql.stats_top_n order by value limit 5;
```

table_id	is_index	hist_id	value	count
106	0	1	0x038000000000000000	2
106	0	1	0x038000800000000002	2
106	0	1	0x038000800000000004	2
106	0	1	0x038000800000000006	2
106	0	1	0x038000800000000008	2

Data Structure Overview

Column Selectivity

```
explain select * from t where a = 1999;
```

id	estRows	task	access object	operator info
TableReader_7	1.00	root		data:Selection_6
└──Selection_6	1.00	cop[tikv]		eq(test.t.a, 1999)
└──TableFullScan_5	3000.00	cop[tikv]	table:t	keep order:false

```
func equalRowCountOnColumn(encodedVal []byte...) {
  histCnt, matched := c.Histogram.EqualRowCount(sctx, val, true)
  if matched {
    return histCnt, nil
  }
}
```

Data Structure Overview

Column Selectivity

```
select hist_id, bucket_id, count, repeats,
       CAST(lower_bound AS SIGNED) AS lower_bound,
       CAST(upper_bound AS SIGNED) AS upper_bound,
       ndv
from mysql.stats_buckets order by lower_bound desc limit 5;
```

hist_id	bucket_id	count	repeats	lower_bound	upper_bound	ndv
1	229	1	1	1999	1999	0
1	228	9	2	1993	1998	0
1	227	9	2	1987	1992	0
1	226	9	2	1981	1986	0
1	225	9	2	1975	1980	0

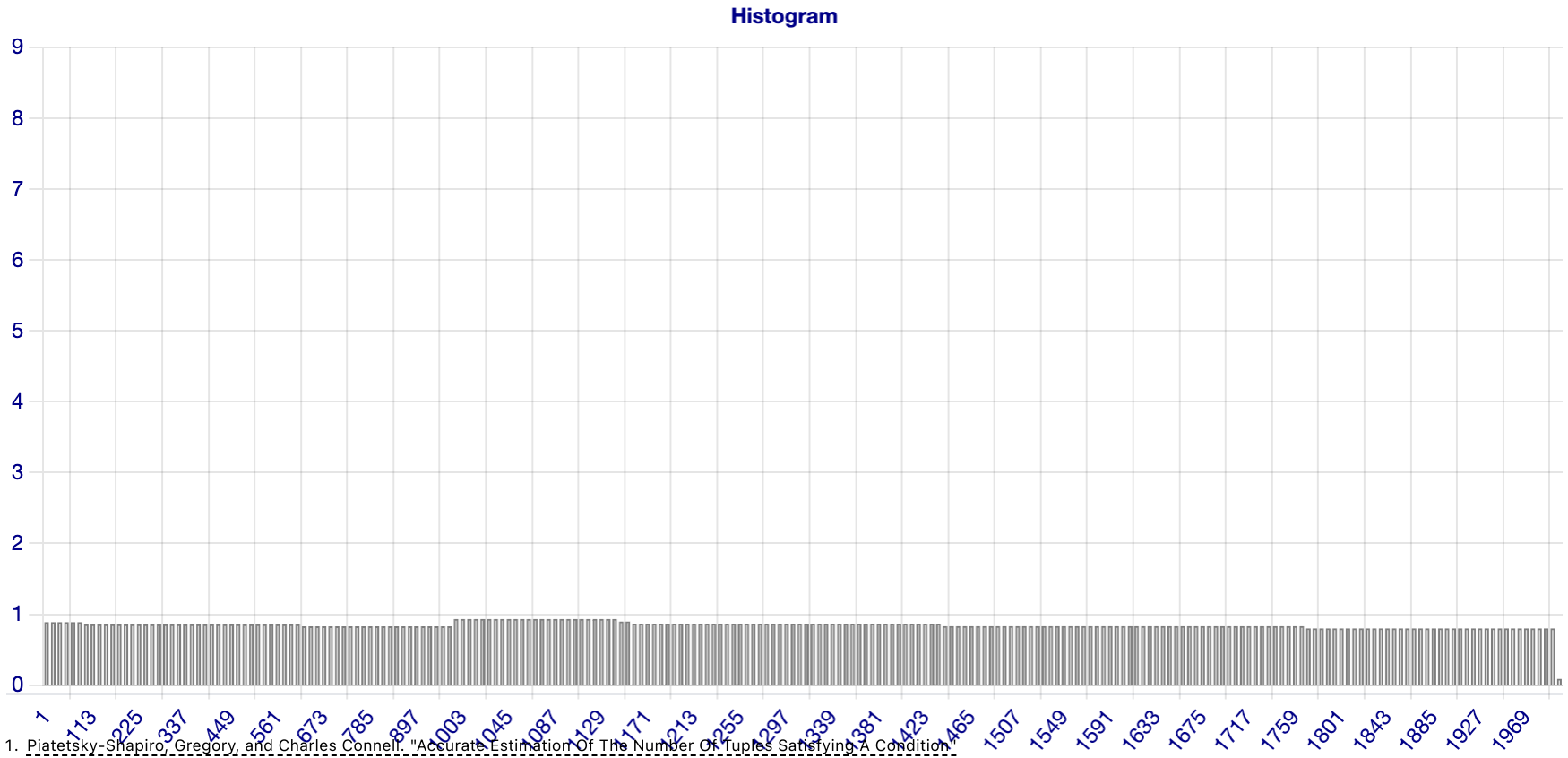
Data Structure Overview

Histogram Bucket

- Bucket ID: The bucket ID of the histogram.
- Count: The number of values till the bucket.(**cumulative**)
- Repeats: The number of repeated values at the upper bound.
- Lower Bound: The lower bound of the bucket.
- Upper Bound: The upper bound of the bucket.
- NDV: The number of distinct values in the bucket.(**Deprecated, always 0**)


```
{
    "bucket_id": 228,
    "count": 9,
    "repeats": 2,
    "lower_bound": 1993,
    "upper_bound": 1998,
    "ndv": 0
}
```

Data Structure [1]



1. Piatetsky-Shapiro, Gregory, and Charles Connell. "Accurate Estimation Of The Number Of Tuples Satisfying A Condition."

Data Structure Overview

Column Selectivity

```
explain select * from t where a = 9999;
```

id	estRows	task	access object	operator info
TableReader_7	1.33	root		data:Selection_6
└──Selection_6	1.33	cop[tikv]		eq(test.t.a, 2000)
└──TableFullScan_5	3000.00	cop[tikv]	table:t	keep order:false

```
func equalRowCountOnColumn(encodedVal []byte...) {
  histNDV := float64(c.Histogram.NDV - int64(c.TopN.Num()))
  if histNDV <= 0 {
    return 0, nil
  }
  return c.Histogram.NotNullCount() / histNDV, nil
}
```

Data Structure Overview

Column Selectivity

- Not Null Count: The number of not null values in the column.
- NDV: The number of distinct values in the column.

How to calculate the NDV(Non-Distinct Value)?

We use FMSketch(Flajolet-Martin Sketch) to calculate the NDV.

Data Flow Overview

Data Flow Overview

Data Structure & Data Flow

TiKV Perspective

In TiKV, we only do two things:

1. Calculate the FMSketch.
2. Sample the data.

Data Structure - FMSketch

TiKV Perspective

Mathematical Assumptions [1]

1. **Independence of Hash Functions**:
   - Assume a good hash function **h(x)** that uniformly distributes input elements over a large range of integers.
2. **Expectation of Trailing Zeros in Hash Values**:
   - For uniformly distributed hash values, the number of trailing zeros in their binary representation follows a geometric distribution.

---

1. Flajolet, Philippe; Martin, G. Nigel (1985). "Probabilistic counting algorithms for data base applications"

Data Structure - FMSketch

TiKV Perspective

Algorithm Principles

1. **Hash Mapping**:
   - Map each element of the set to an integer using the hash function h(x).
2. **Trailing Zeros Counting**:
   - For each hash value, count the number of trailing zeros in its binary representation. Record the maximum count **R**.
3. **Cardinality Estimation**:
   - Use the maximum trailing zero count **R** to estimate the cardinality of the set with the formula 2^R.

Flajolet-Martin Sketch

a b c d e f g h i j k l m n o p

Generate Hash Values

Flajolet-Martin Sketch - A Bad Case

a b c d e f g h i j k l m n o jj

Generate Hash Values

Data Structure - Distinct Sampling

TiKV Perspective

Core Principles [1]

1. **Hash Function:**
   - Use a hash function that maps each distinct value to a random `die-level`.
2. **Sample Maintenance:**
   - Maintain a sample S of distinct values and a current level `l`.
3. **Sampling Criterion:**
   - Keep values in S only if their `die-level ≥ l`.
4. **Cardinality Estimation:**
   - Estimate distinct items as $|S| * 2^l$

---

1. Phillip B. Gibbons. "Distinct Sampling for Highly-Accurate Answers to Distinct Values Queries and Event Reports"

Data Structure - Distinct Sampling

TiKV Perspective

Algorithm Steps

1. **Initialization:**
   - Start with l = 0 and an empty sample S.
2. **Processing Each Row:**
   - For each row r with target attribute value v:
     - Compute die-level = $h(v)$
     - If die-level ≥ l:
       - Add r to S
3. **Sample Size Control:**
   - If $|S| > k$, increment l and remove items with die-level < l.

Distinct Sampling

Sample Size: 8

a b c d e f g h i j k l m n o jj

Process Next

Die Level: 0

Current Sample Size: 0

Estimated NDV: 0

Data Structure - Distinct Sampling

TiKV Perspective

Estimation and Analysis

1. **Accuracy:**
   - Provides estimates within 0%-10% relative error
   - Much more accurate than previous sampling methods
2. **Efficiency:**
   - Single pass over the data.
   - Only one hash function required.

Data Structure - Bernoulli Sampling

General Perspective

Mathematical Assumptions

1. **Independence of Sample Selection**:
   - Each sample in the data set is selected independently from other samples.
2. **Uniform Sampling Probability**:
   - Each sample is selected with a fixed probability $p(0 \leq p \leq 1)$, uniformly across the entire data set.
3. **Bernoulli Distribution**:
   - Each sample selection follows a Bernoulli distribution with parameter p.

Data Structure - Bernoulli Sampling

General Perspective

Algorithm Principles

1. **Probability Definition**:
   - Define a sampling probability p for selecting each sample.
2. **Independent Sampling**:
   - For each sample in the data set, generate a random number and compare it to p. If the random number is less than p, include the sample in the resulting subset.

Bernoulli Sampling

a b c d e f g h i j k l m n o p

Sample Rate: 0.3

Perform Bernoulli Sampling

Data Structure & Data Flow

TiDB Perspective

In TiDB, we do the following things:

1. Merge all FMSketches and Sample Data.
2. Build TopN and Histogram.
3. Update statistics to system tables.

Data Structure & Data Flow

Overview

🤡Nobody can really master TiDB analyze.jpg

Configuration Name	Description	Default Value	Scope	Affected Component
tidb_build_stats_concurrency	The number of concurrent workers to analyze tables or partitions	2	Global/Session	TiDB + TiKV
tidb_auto_build_stats_concurrency	The number of concurrent workers to automatically analyze tables or partitions	1	Global (only for auto analyze)	TiDB (Owner) + TiKV
tidb_analyze_distsql_scan_concurrency	The number of concurrent workers to scan regions	4	Global/Session	TiKV
tidb_sysproc_scan_concurrency	The number of concurrent workers to scan regions	1	Global (only for auto analyze)	TiKV
tidb_build_sampling_stats_concurrency	1. The number of concurrent workers to merge FMSketches and Sample Data from different regions 2. The number of concurrent workers to build TopN and Histogram	2	Global/Session	TiDB
tidb_analyze_partition_concurrency	The number of concurrent workers to save statistics to the system tables	2	Global/Session	TiDB

Data Structure & Data Flow

TiDB Perspective - Analyze tables or partitions concurrently

tidb_build_stats_concurrency

Data Structure & Data Flow

TiDB Perspective - Scan regions concurrently

tidb_analyze_distsql_scan_concurrency

Data Structure & Data Flow

TiDB Perspective - Merge FMSketches and Sample Data

tidb_build_sampling_stats_concurrency

Data Structure & Data Flow

TiDB Perspective - Build TopN and Histogram

tidb_build_sampling_stats_concurrency

Build TopN

Count: 200 **Sample Length:** 23

Samples

104	23	45	164	57	34	212	92
69	176	116	140	116	128	80	152
188	224	13	200	200	5	5	

TopN List

Current:

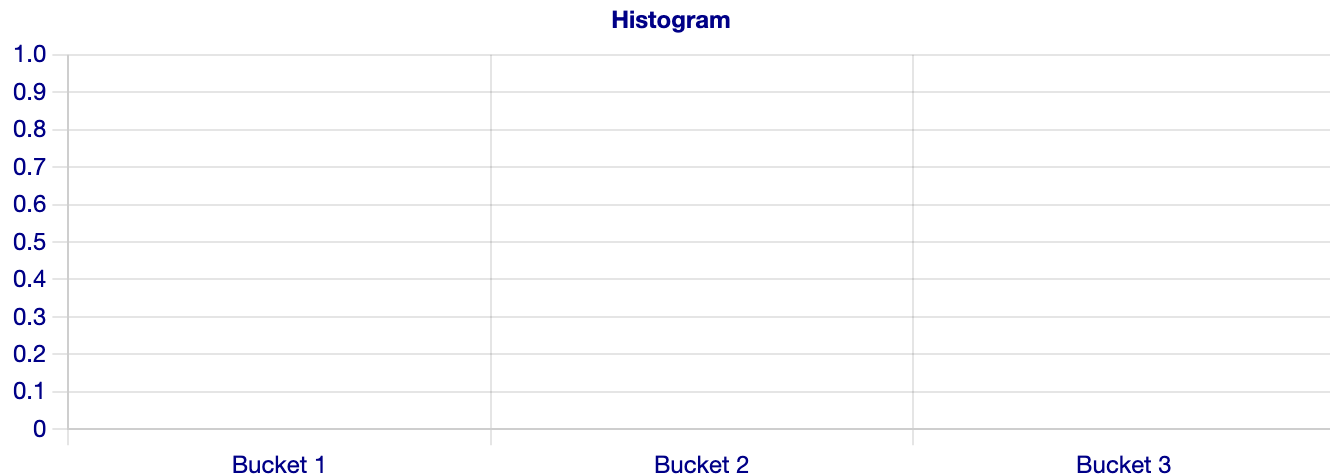
Current Count: 0

Step:

Next Step Reset

Build Histogram

Count: 200 **Sample Length:** 17



Sample Factor: 11.8 **Per Bucket:** 78.4 **Current Sample:** N/A **Current Bucket:** 1

Step: Click Next Step to start

Next Step Reset

Data Structure & Data Flow

TiDB Perspective - Save Statistics

tidb_analyze_partition_concurrency

Data Structure & Data Flow

TiDB Perspective - Merge Global Statistics

tidb_merge_partition_stats_concurrency

Improve the Analyze

What can we do?

Tracking Document

Statistics Project Planning and Implementation

Statistics Tech Debt

Blogs

I started a new series blog post to discuss the Analyze feature improvement.

NCRMTA1: Surprise analyze-partition-concurrency-quota

NCRMTA2: Accelerate Auto-Analyze of Partitioned Tables

Q&A

Do you have any questions?

Thank You!