Fast, Scalable and Reliable Logging at Uber with Clickhouse

February 11, 2020

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Agenda

- Mission and Goals of Logging
- Background and Challenges
- ClickHouse Evaluation
- ClickHouse Based Logging Architecture
- Questions

Mission and Goals of Logging

Vision of Reliability Platform

Uber engineers have the platforms, tools, and support to rapidly develop and confidently operate their services reliably at scale

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Logging Mission

- *Make it work*: Maximize the speed at which engineers can act upon operational data
- *Make it scale*: Scale to meet today's needs and tomorrow's growth
- *Make it cheap*: Ensure a consistent and sustainable cost model

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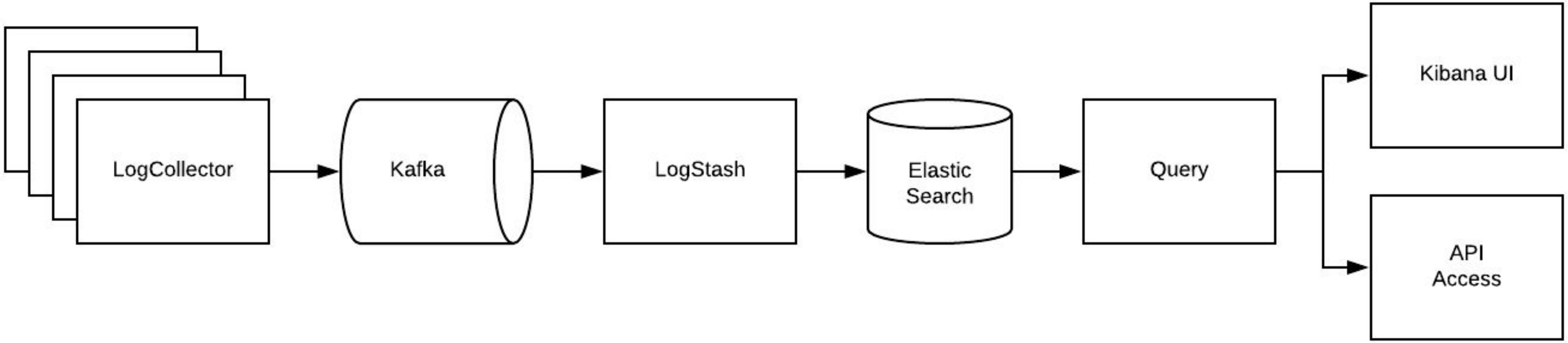
Background and Challenges

High-Level Architecture



Current Scale of Logging

- We collect a lot of things
  - **Thousands of** Services emitting **hundreds TB** logs per day
- We store a lot of things
  - **Low Petabytes** of logs stored
- We query them for real-time debugging, offline troubleshooting, analytics, etc.
  - **hundreds queries / s** from dashboards and API queries

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Challenge: Developer Productivity

- Logging users want schema-free logging
  - Services can write logs with very different structures
  - Log schema evolves over time (new fields, changing field types, etc.)
- ElasticSearch requires a consistent schema per index
- Type conflicts: log field type inconsistency => ElasticSearch exceptions
  - Disable field, drop logs
  - Can significantly degrade ES performance and affect co-tenants in cluster
  - Requires back-and-forth between logging team and service owner to fix

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Challenge: Performance

- Performance challenges
    - End-to-end ingestion latency
        - >2 minute latency for large indices
        - ES indexes data in batches, reducing batch time can result in significant performance degradation due to higher indexing overhead
    - Query latency
        - Poor resource isolation, expensive queries can significantly degrade cluster performance, and sometimes render cluster unresponsive even after query stops.

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Challenge: Scalability and Operability

- High cost makes it expensive to scale
- Operational challenges at scale
  - Running multiple ES clusters
    - Having too many nodes in one cluster puts strain on the master node
  - General reliability issues
    - JVM heap lockup after a single expensive query requires bouncing the entire cluster

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ClickHouse Evaluation

Evaluation Setup

- Ingested production logs from Kafka into candidate storage cluster under evaluation
- Continuously evaluating common types of production queries against candidate storage cluster:
  - Group by query: "For time range X and services Y, give me the top 5 most frequently accessed endpoints matching filter Z"
  - Histogram query: "For time range X and services Y, give me the number of log events per minute matching filter Z"
  - Raw query: "For time range X and services Y, give me the most recent 500 logs matching filter Z ordered by time"

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Key Observations about Logging Use Cases

- Observations:
  - Schema-free logging is highly desirable
  - Number of logs queried << number of logs ingested
  - Number of log fields accessed << number of log fields stored
  - Indexing on all fields incurs significant performance overhead
- A columnar storage that
  - Provides mechanisms to support schema-free logging for developer productivity
  - Indexes on only the necessary fields but no more
    - Performance for querying indexed fields
    - Efficiency for not indexing all fields

What's ClickHouse?

- An open-source, distributed, high performance columnar DBMS
- High throughput ingestion with asynchronous segment merging, requires no locks during concurrent writes
- High performance parallelized query execution
- Supports a query language covering majority of SQL capabilities (GROUP BY, ORDER BY, JOIN, etc.)
- Built-in clustering mechanism supports configurable sharding, multi-master shard-level writing and replication, and distributed query processing

"Why Clickhouse: Ingestion"

- Writes 3x - 4x throughput compared to ES
- Ingest performance scales close to linearly to cluster size
    - Writes evenly distributed across the cluster results in even load distribution
    - Independent shard design maximizes single-node performance as cluster size increases
    - Multi-master replication ensures no SPOF in design

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"Why Clickhouse: Query"

- Data scanning speed during query processing
  - ~5x query speed of ES
  - Vectorized execution and parallelized processing across cores achieves high scanning speed
- Expected to support high hundreds in QPS
- Better control on resource allocation
- Increases in query concurrency beyond max levels does not cause cluster instability
  - OTOH, ES may experience cluster-wide lockup due to high query load even after query is cancelled / timeout

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"Why Clickhouse: Storage"

- Configurable column-level compression algorithm
  - LZ4, ZSTD, …
  - Allows more efficient storage, faster disk I/O, and bigger raw dataset to fit in filesystem cache
- Compression ratios
  - LZ4: 3x for logs with complex schema, 20x for small, structured logs
  - ZSTD: 2x - 3x better compression ratio than LZ4 at 15% higher CPU cost
- Data are partitioned by configurable partition keys allowing pruning large amount of data partitions during query execution.
- Supports dynamically building and asynchronously backfilling materialized columns and data skipping indices, further speeding up log field queries

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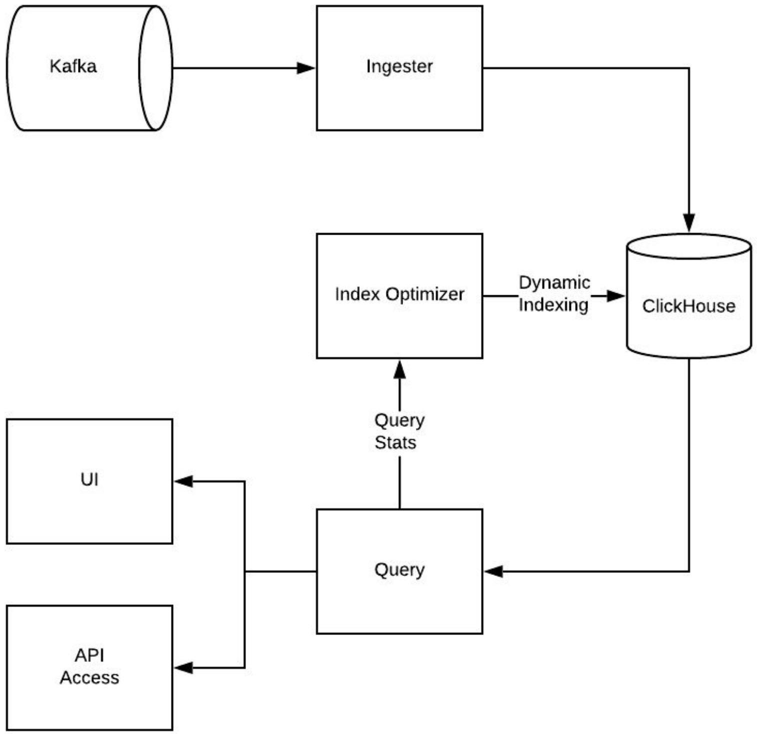
ClickHouse Based Logging Architecture

High-Level System Architecture



Ingestion

- Consumes log events from Kafka, and flatten JSON logs into structured fields.
  - Honor field types: foo.String vs foo.Number
- Buffers log events into big batches, and routes them to the proper ClickHouse tables.
- No need to sanitize logs to prevent type conflicts

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Dynamic Indexing

- By default, ingest everything, index nothing.
  - Basic query performance with base table schema with native ClickHouse functions
  - < 5% of log fields are ever accessed, don't pay the price for indexing the other 95%
  - No blind indexing == High ingestion throughput
- Indexing is still important and necessary for the 5% to ensure low query latency.
  - Much less data scanned at query time
  - Taking full advantage of columnar storage and vectorized processing.
- Dynamic indexing
  - Adaptive to query patterns: Index log fields that are frequently queried.

Materialized Columns

- Materialized columns derive their values from base columns
- Can be created or dropped at runtime
    - `ALTER TABLE <table_name> ADD COLUMN "endpoint.String" ...`
- When a materialized column is created
    - Automatically populated for new incoming rows
    - Asynchronously backfill from historical values during data merging
    - Querying such column will automatically "do the right thing"
- Scanning speed for materialized columns
    - >10x faster than scanning base schema

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Data Skipping Indices

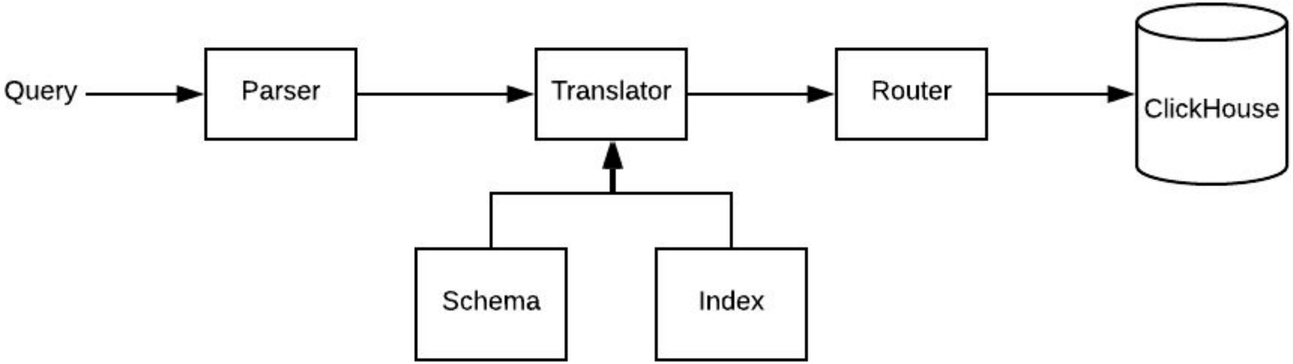
- Types of data skipping indices
  - Token-based and n-gram based bloom filter indices: `equals`, `in`, ...
  - MinMax indices
  - Set-based indices
- Using the right indices can significantly speed up queries
  - Token-based bloom filter index for UUID matches
  - 15x query latency reduction compared to when no index is used

On-Demand Indexing

- Adaptive to query pattern and user input on the fly
  - Feedback loop in minutes
  - New incoming data are immediately indexed
  - Asynchronously backfilling indices for historical data during segment merging, can be accelerated if needed

Query

- Parses incoming query and translates it into a SQL expression understood by ClickHouse
  - Uses schema to determine available fields and their types
    - Conflict resolution when a field has multiple types
  - Favors materialized columns, fall back to base schema scans if unavailable
  - ClickHouse makes use of data skipping indices transparently if available



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Query (Cont'd)

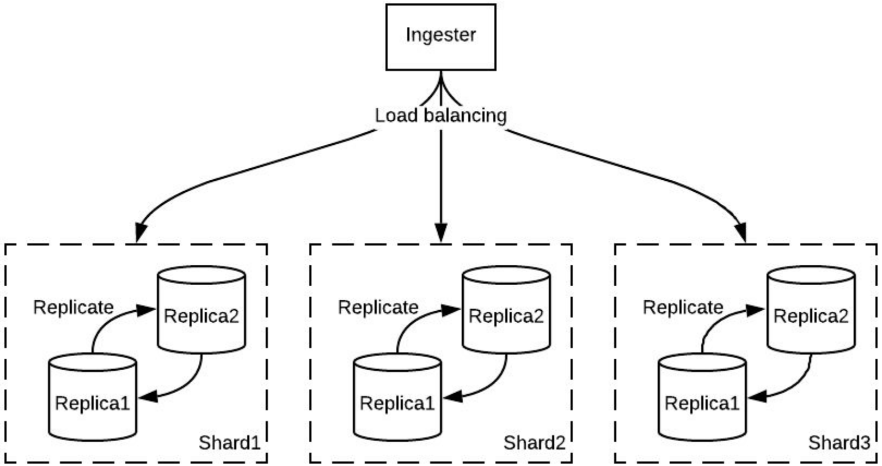
- Configurable query execution
  - Resource allocation per query
  - Workload isolation
  - Cost accounting
- Linearly scalable with more resources
  - Able to provide better performance for high priority queries by allocating more resources
- Fine-grained control for distributed query processing
  - Skip shards with errors
  - Timeout slow shards early
  - Strategy to pick from replicas in a shard

Clustering

- Fundamental clustering functions out of the box
- Uniform shard distribution, rack-aware shard topology
- Writes evenly distributed across nodes ensuring balanced ingestion load cluster wide
- "Distributed table" primitive enables distributed queries across shards and merging results happen transparently
- Efficient, multi-master replication ensuring little to no write throughput degradation with replication enabled

Clustering: Ingestion

- Writes evenly routed to any node in the cluster
- Data replicated asynchronously to the peer in the same shard



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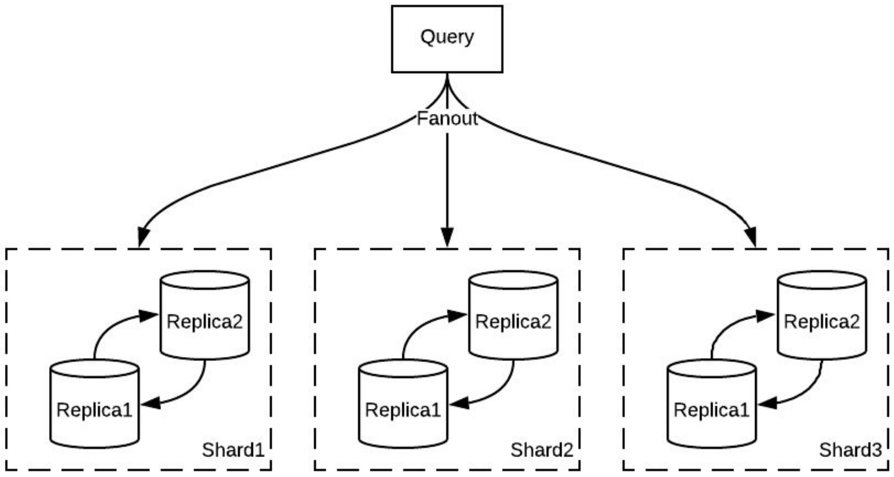
Clustering: Query

- Distributed query can be issued to query nodes
- The node fanouts sub-queries to all shards in the cluster
- The node aggregates the results from the sub-queries and return



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Unified Multi-Tenant Storage Platform

- ClickHouse natively supports zero lock contention among concurrent reads and writes
- Service placement: single-tenant vs multi-tenant
  - Isolate heavy log producers, heavy log consumers
  - Co-locate everything else
  - Limit the impact of co-location, add service in order-by
- Workload isolation
  - Configure query parallelism per query
  - Eventually limit total query resource usage per node
  - Query cost accounting, defense against expensive queries

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Q & A