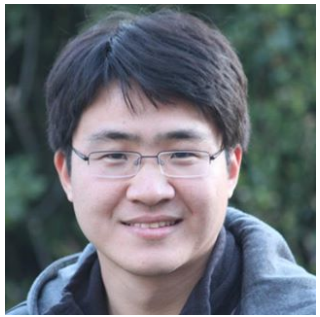
Search at Uber over Apache Lucene

Sia (Egyptian God of Perception)
or
Search In Action

Yupeng Fu, Uber

About Me

Uber



- Yupeng Fu
- Search Platform (Sia)
- Real-time Data Platform
- yupeng9@github
- Apache Pinot Committer/PMC
- Alluxio PMC

Vision

A scalable, high-performance platform supporting flexible ranking for Uber's search and discovery needs

Agenda

- Search Use Cases
- Architecture
  - Component Overview
  - Indexing
  - Serving
- Feature Highlights

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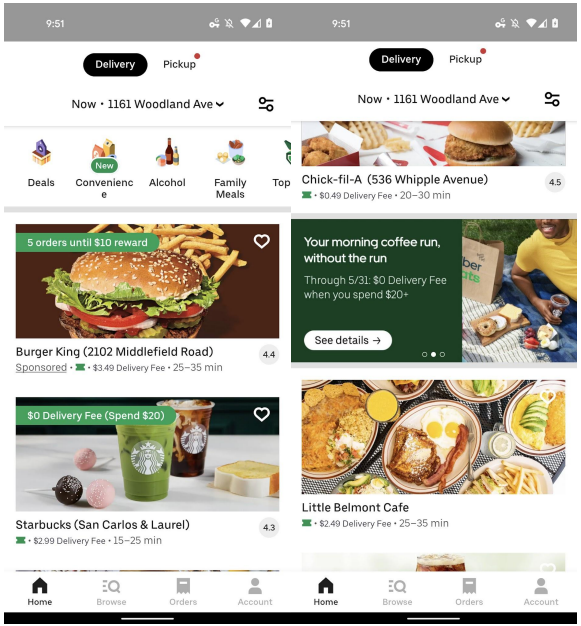
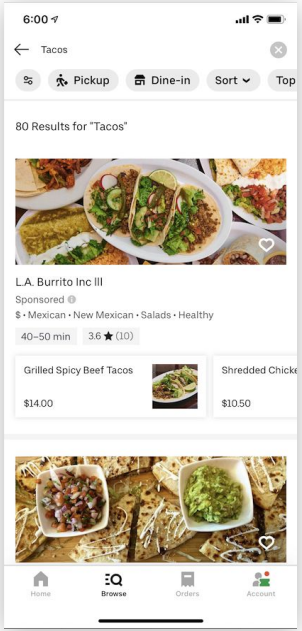
Eats

Feed and Search are two main entries for consumers to discover Eats inventories including restaurants, dishes, grocery stores, etc

Feed



Search



Eats Feed: The Choice Problem

There are 1M+ restaurants on Eats. The average Eater has 1000- restaurants/dishes to choose from when they open the app / website.

Variable intent
They don't necessarily know what they want

Complex decision making
Selection (cuisines, restaurants, dishes), price, speed, reliability, dietary restrictions, party size and preferences.

Discovery is about **helping Eaters decide what they want to eat or buy.**

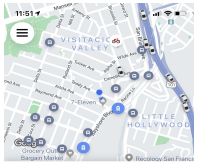
4th Street Pizza
$$ · Category · Category
20–30 Min | 4.8 ★ (108) | $2.50 Fee

Amy's Ice Cream
$$ · Category · Category
20–30 Min | 4.8 ★ (108) | $2.50 Fee

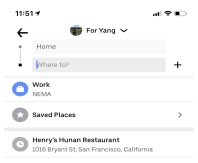
Estrella Taqueria
$$ · Category · Category
20–30 Min | 4.8 ★ (108) | $2.50 Fee

Just Mac
$$ · Category · Category
20–30 Min | 4.8 ★ (108) | $2.50 Fee

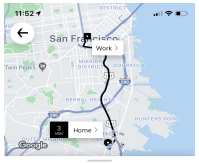
Pindrop: Build a **magical** pickup/dropoff experience for everyone



Home Screen

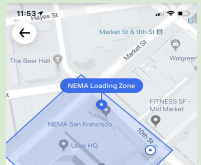


Location Editor

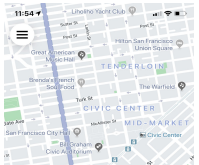


Product Selection

Pickup Setting

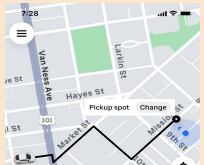


Pickup Refinement



Dispatching

Rendezvous



En Route

Request/Check out Flow

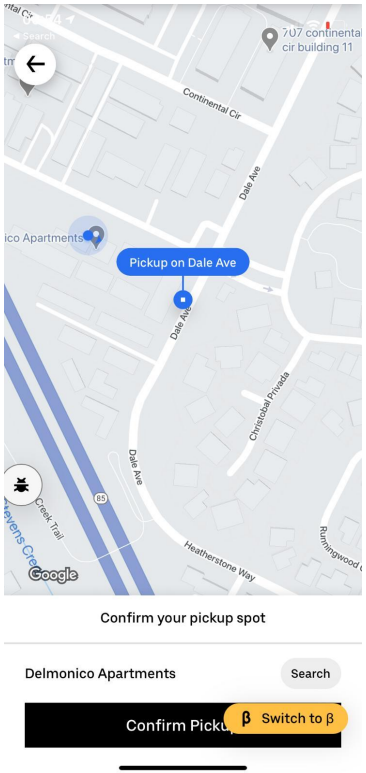
Enroute flow

How do we determine the pickup location?

Two Steps:

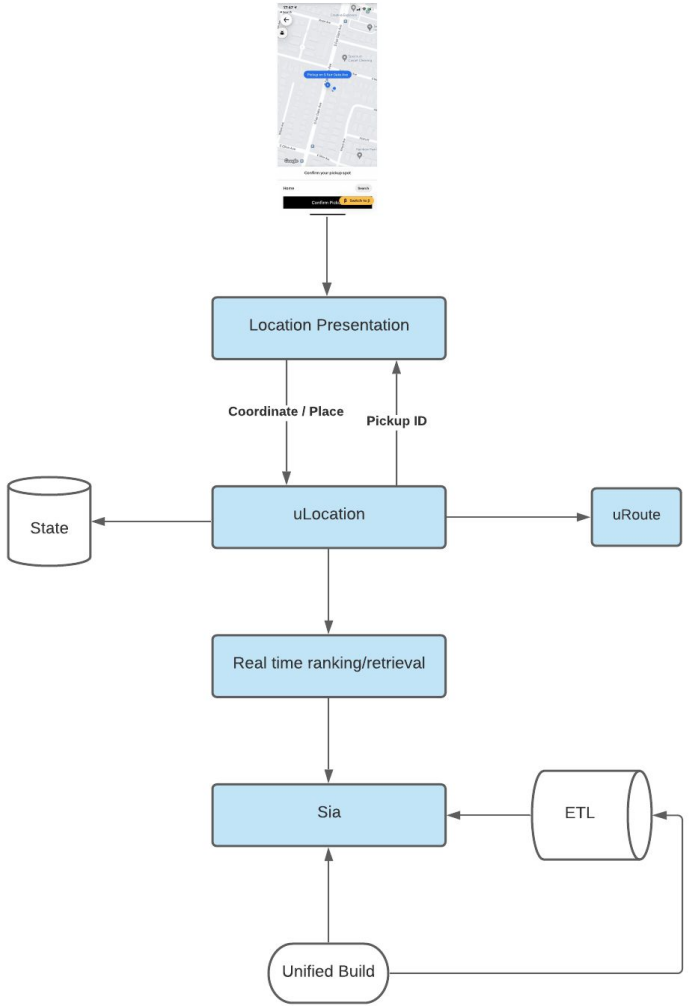
1. Where is the Rider? (Request Location)
2. Where should the rider get picked up? (Rendezvous Location)

We serve 500+ locations per second across rides and eats

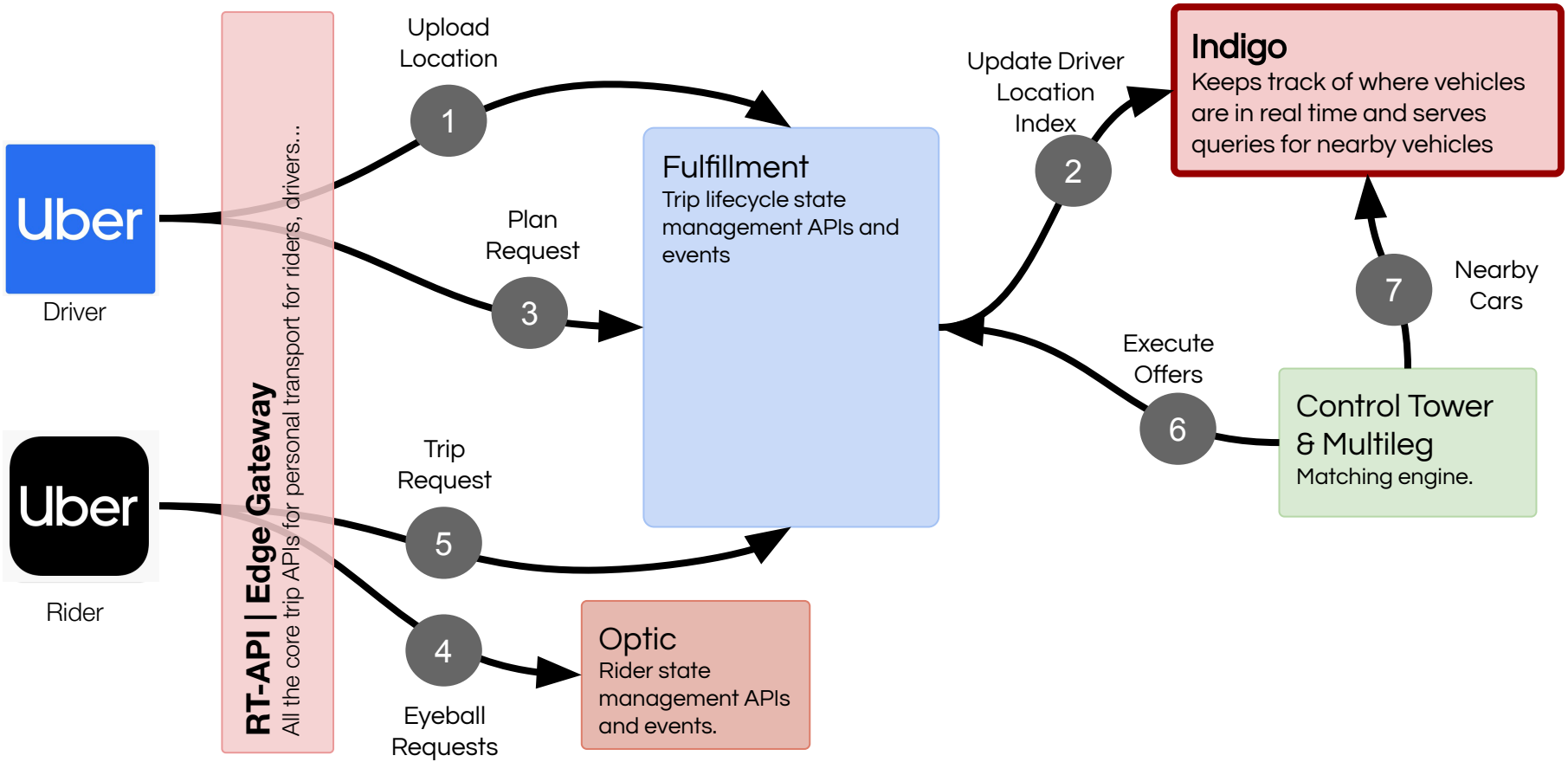


Search powered pickups

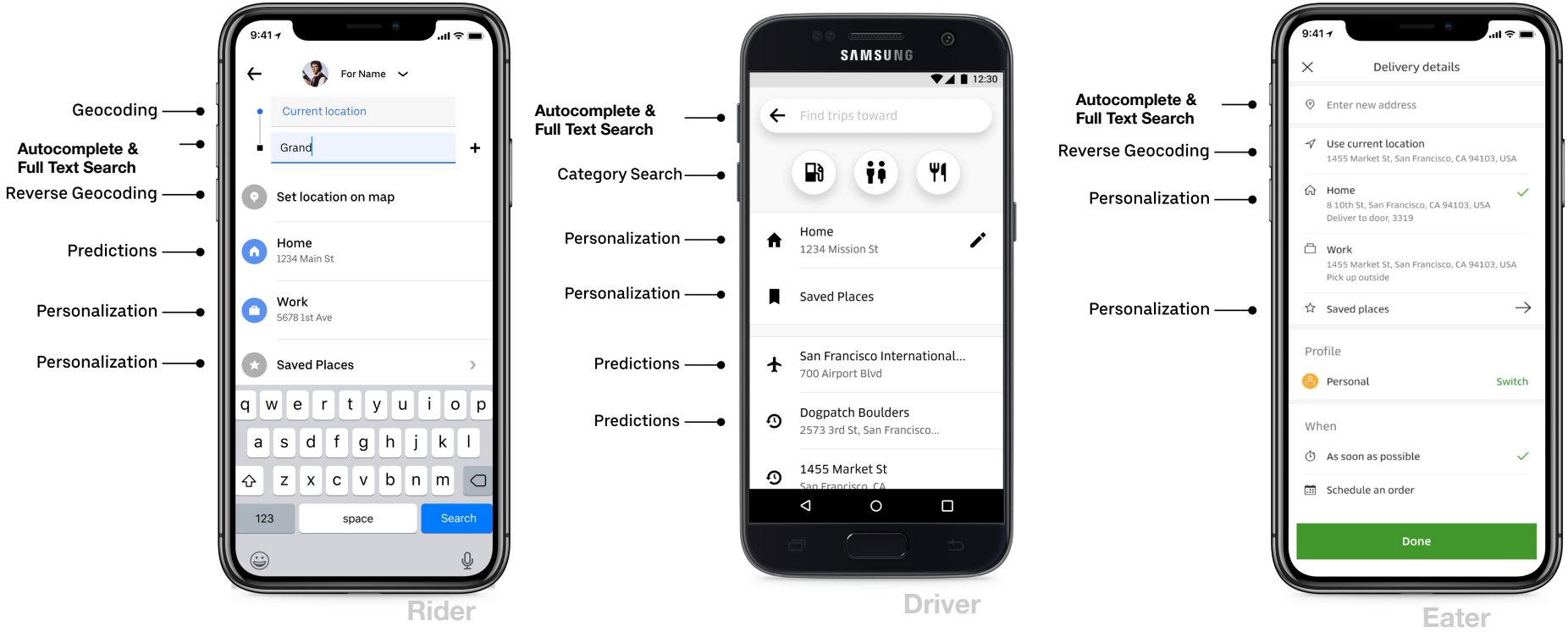
- Deterministic & limited set of locations
- Features be computed offline globally
- Sia supports ID based lookups
- Search for pre-generated Pickup Locations
- Rank based on request parameters and user preferences



Indigo: Real-time geospatial search for Ride's match



Geosearch: Uber's in-house location search engine



- Multi-billions queries globally per month

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- **Architecture**
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Challenges

- Large volume of serving traffic: tens of thousands QPS
- Geospatial data heavy
  - Discoverability
  - Deliverability
- Frequent updates
  - Driver/Rider location
  - Store open/close
  - Availability of dishes/items
- Complex ranking methods
  - Fulfillment match
  - Semantic search
- Integrate with Uber infra components

Evolution from ElasticSearch® over Lucene®

- Updates to index are costly:
  - Pushed at document granularity
  - Includes database like consistency guarantees, replication logs
  - Search nodes have to double as indexing nodes
- Very hard to rebuild index
- Schema changes difficult
- Obsolete data in index difficult to delete
- Document order in index cannot be specified
- Query and ranking functionality not tuned for Uber’s needs
- Difficult to integrate with Uber components

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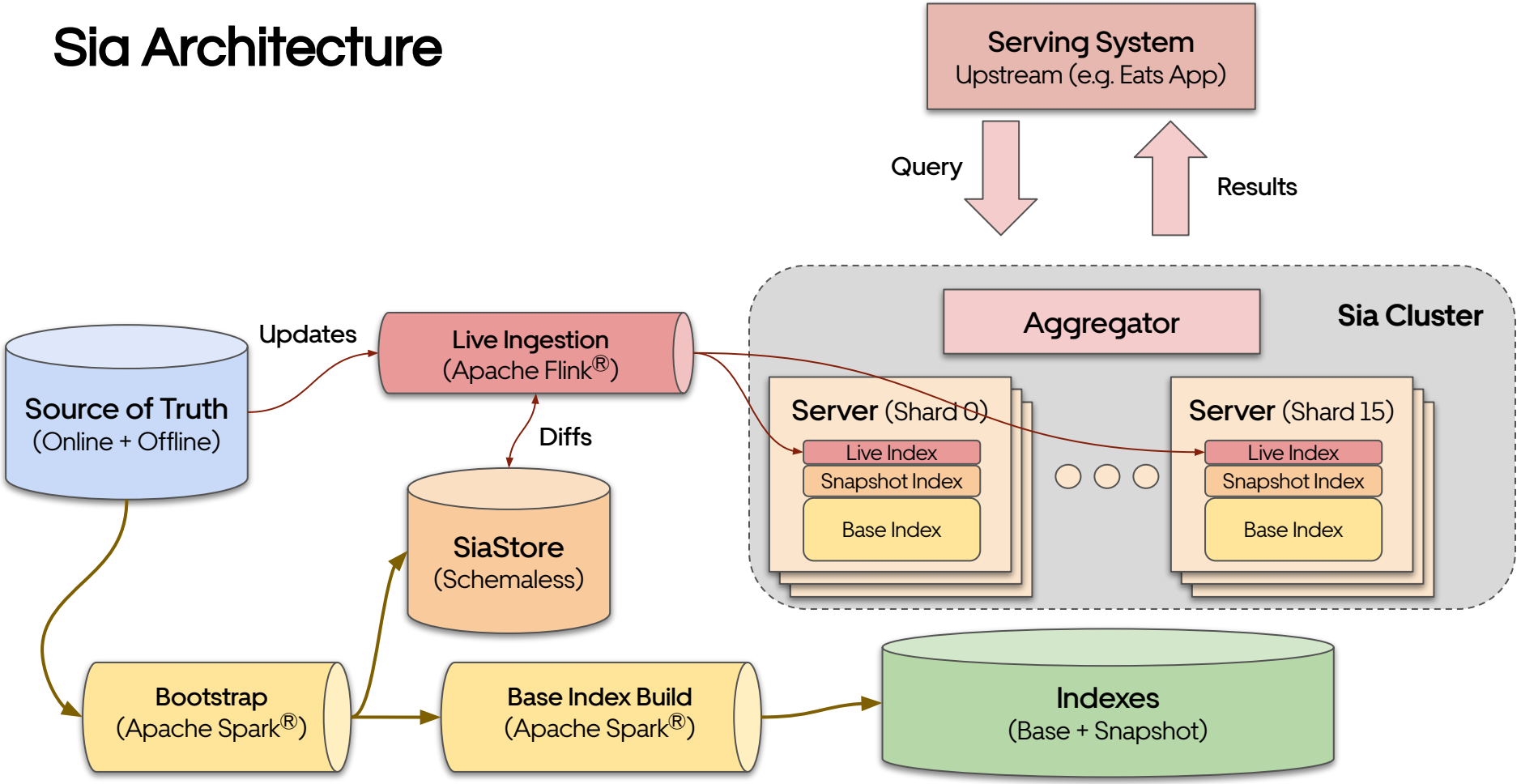
Sia Architecture



Sia Overview

- **Powered by Lucene**
- **Inspired by Linkedin's Galene**
- **Ingestion**
  - Offline index building
  - Streaming index updates
- **Serving**
  - Search nodes
  - Aggregator
- **Geo-sharding**
  - Latitude-based
  - Hexagon-based
- **Static ranking and early termination**
- **Integrates with Uber components**
  - gRPC, Muttley
  - Rate limiting, circuit breaker
  - Apache Kafka®, ELK®, M3
  - Terrablob(ObjectStore), Hadoop
  - Schemaless, DocStore
  - Security/Compliance

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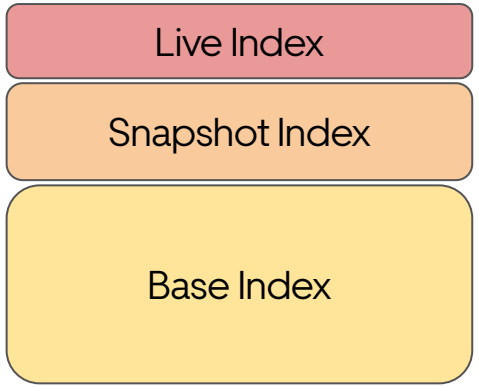
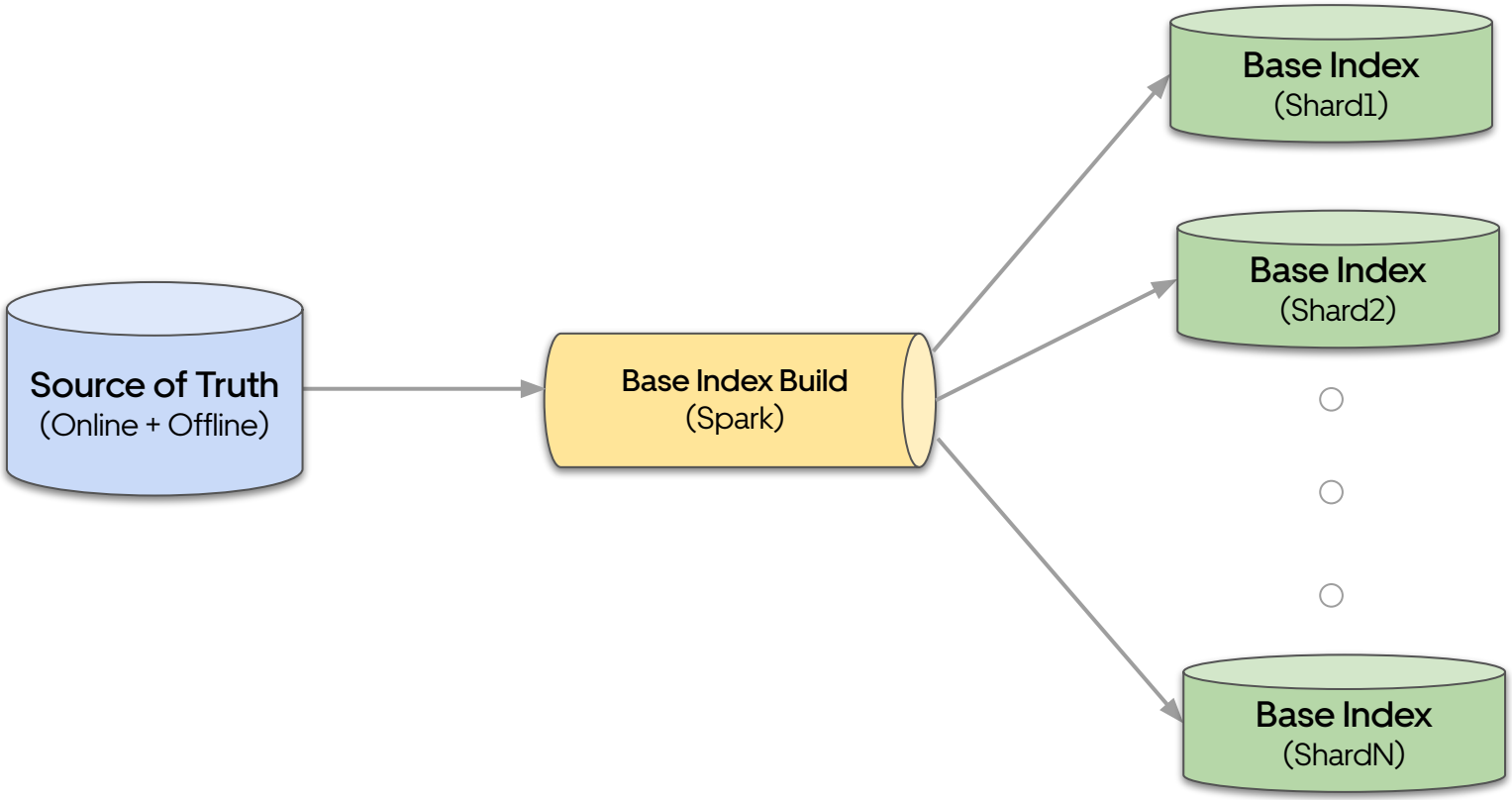
Sia Overview - Indexing

- **Lambda Architecture** for indexing
- **Three layer Index**
  - **Base Index**: Immutable index of **Lucene** segments built periodically
  - **Snapshot Index**: Continuous snapshots of **Lucene** segments for node recovery, before getting merged into base eventually
  - **Live Index**
    - Support field level updates
    - In-memory implementation of lucene datastures with lock-free updates
    - Updates are immediately available for querying (vs waiting for “commit” on ES)



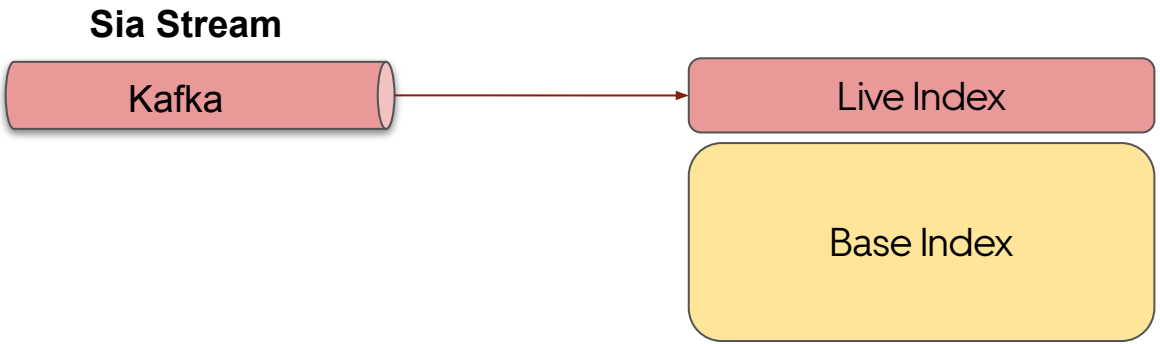
The Base Index



The Base Index

- Normal Lucene index
- Mapped to memory for serving
- Offline index builds - no impact on search performance
- Clean reset
- Schema changes, versioning become easy
- Index building can be parallelized via mini shards
- Index merge from mini shards
- Can control order of documents in index

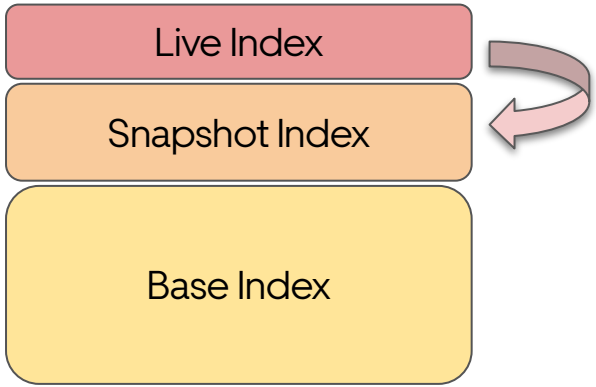
The Live Index



The Live Index

- In-memory data structure
- Ingestion from Kafka
- Lock-free updates
- Updates at finest level of granularity
- Updates have almost no impact on query latencies
- Layered on top of Base Index (overrides Base Index)
- Tombstoning to support deletes
- Preserves document ordering in Base Index
- Supports addition of new documents
- Off-heap SkipList for better memory management and quick access

The Snapshot Index



The Snapshot Index

- Normal Lucene index
- Periodically persisted from Live Index
- More compacted form by merging live index
- Layered on top of Base Index (overrides Base Index)
- Layered below Live Index (overridden by Live Index)
- New documents carried over from Live Index
- Tombstones carried over from Live Index
- Preserves document ordering in Base Index

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Basic Query Infrastructure

- Lucene queries are implemented recursively
- Only term queries (the leaves in query expressions) operate directly on index
- So we only need to change the term query implementation

So: `st:orderable`

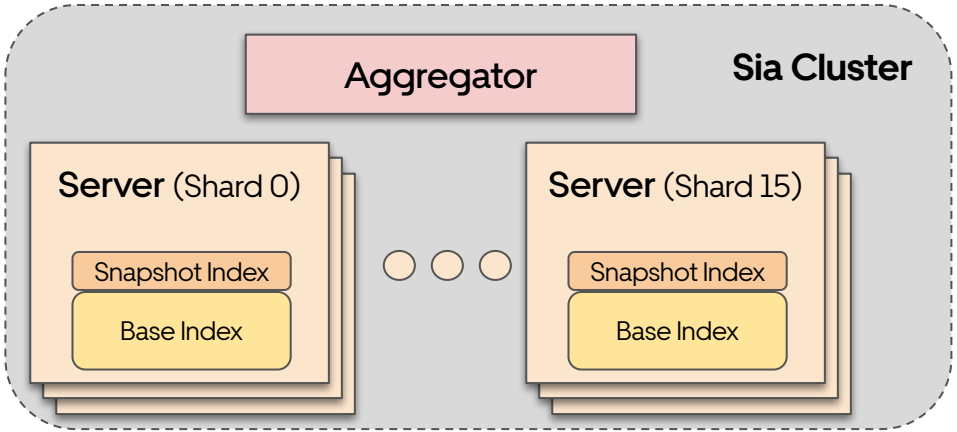
Becomes: $\texttt{st:orderable}_{base}$ `OR` $\texttt{st:orderable}_{snapshot}$ `OR` $\texttt{st:orderable}_{live}$

with consideration for tombstones and optimizations

- Therefore all Lucene and ElasticSearch queries remain supported

Serving Stack

- Aggregator + sharded search nodes
- gRPC API - same API at aggregator and search nodes
- Query understanding and query rewriting at aggregator
- Aggregator forwards rewritten query to search nodes
- Search nodes perform retrieval and at least one ranking pass
- Aggregator combines results from search nodes
- *Aggregator can be used as a library* - with in-process gRPC call (for Java only)



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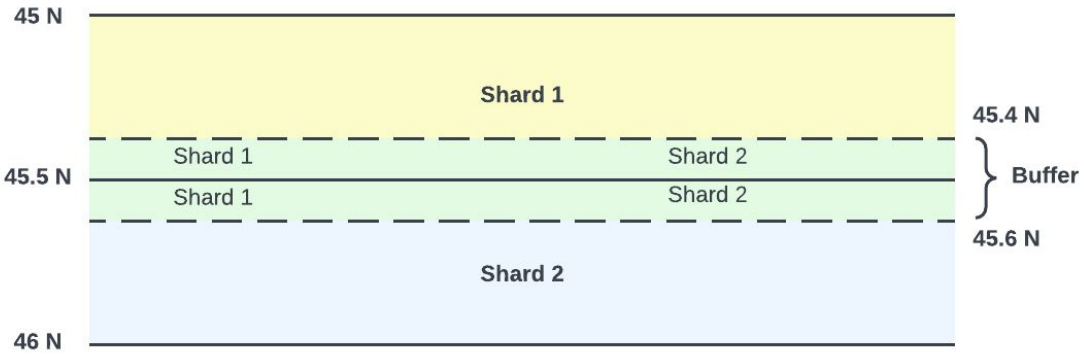
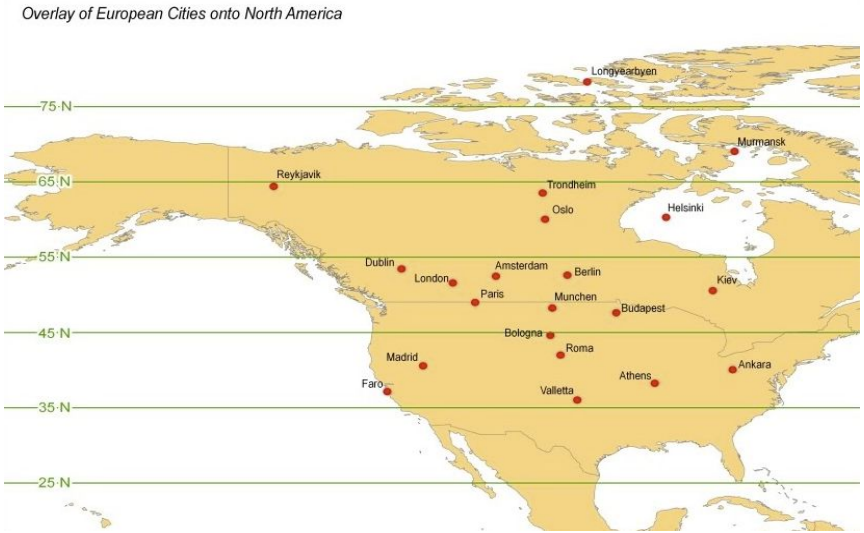
Geo-Sharding

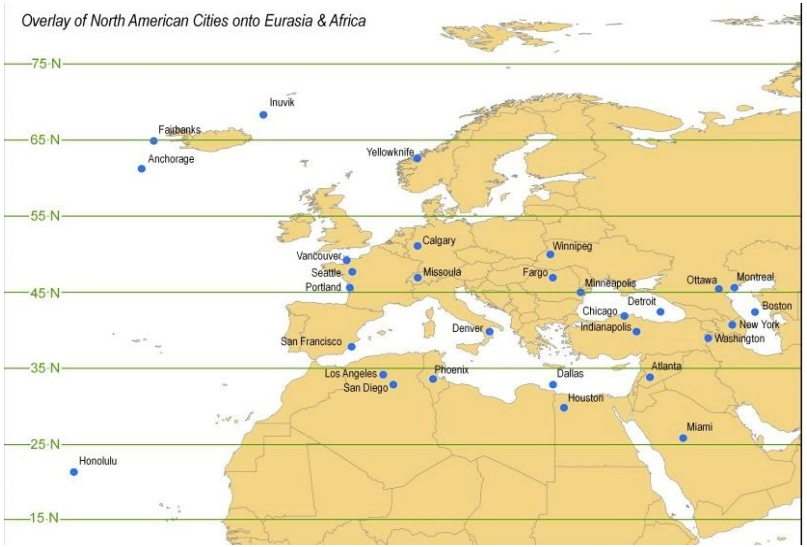
- Latitude-based sharding
- Divide the world map into narrow stripes
- Buffer degree for over indexing the docs in the search radius
- Cover all timezones for serving



Geo-Sharding

- Latitude-based sharding challenges
  - Shard size skewness
  - Unnecessary scanning in retrieval

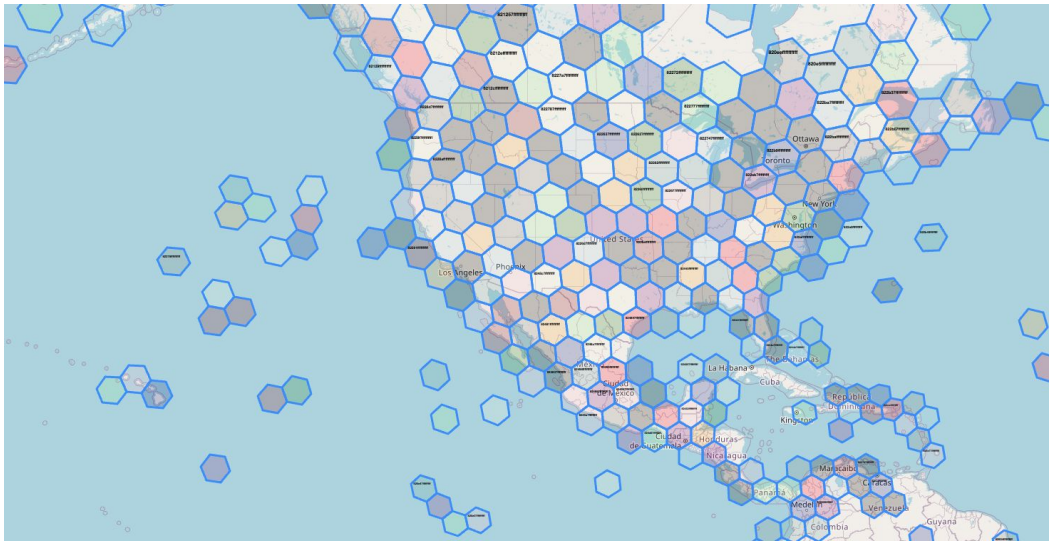


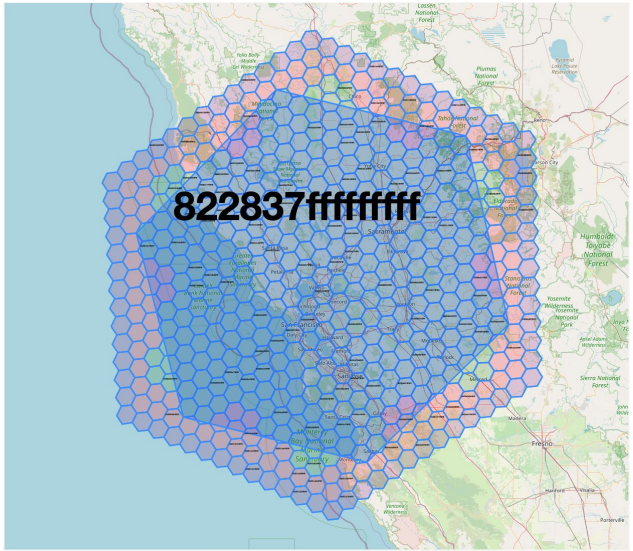


https://brilliantmaps.com/cities-transposed-latitude/

Geo-Sharding

- Hexagon-based sharding
- Tile the world map into hexagons
- Use higher-resolution hexagons for buffer
- Evenly sized shards via bin-packing solution

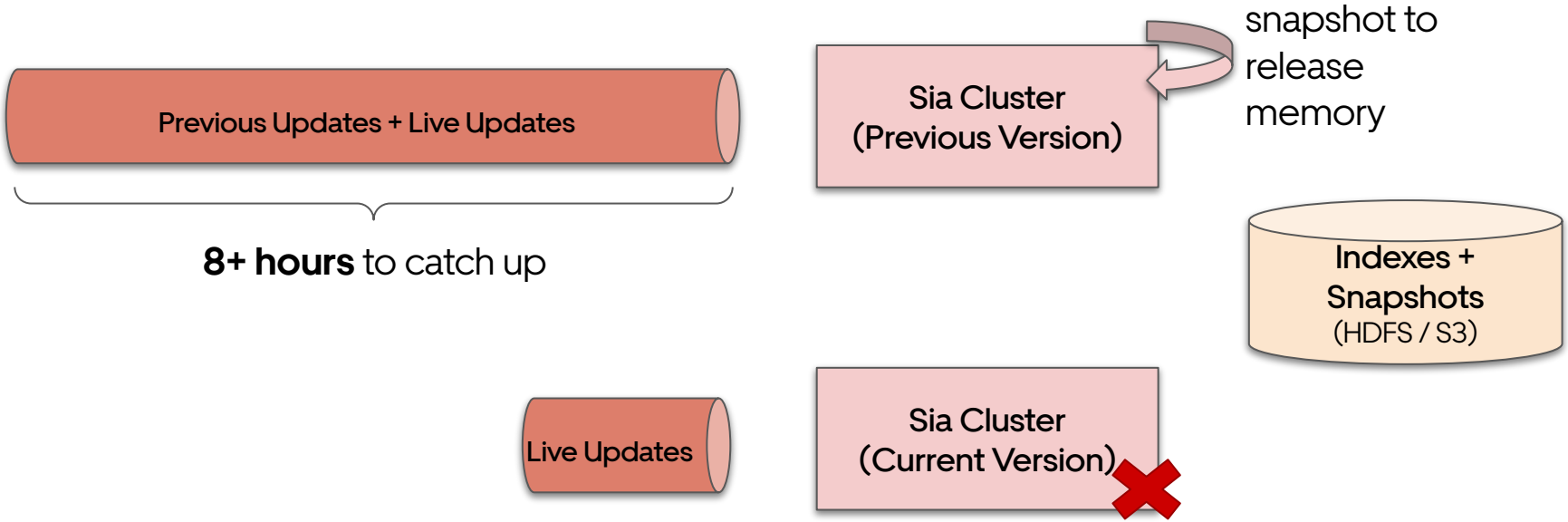




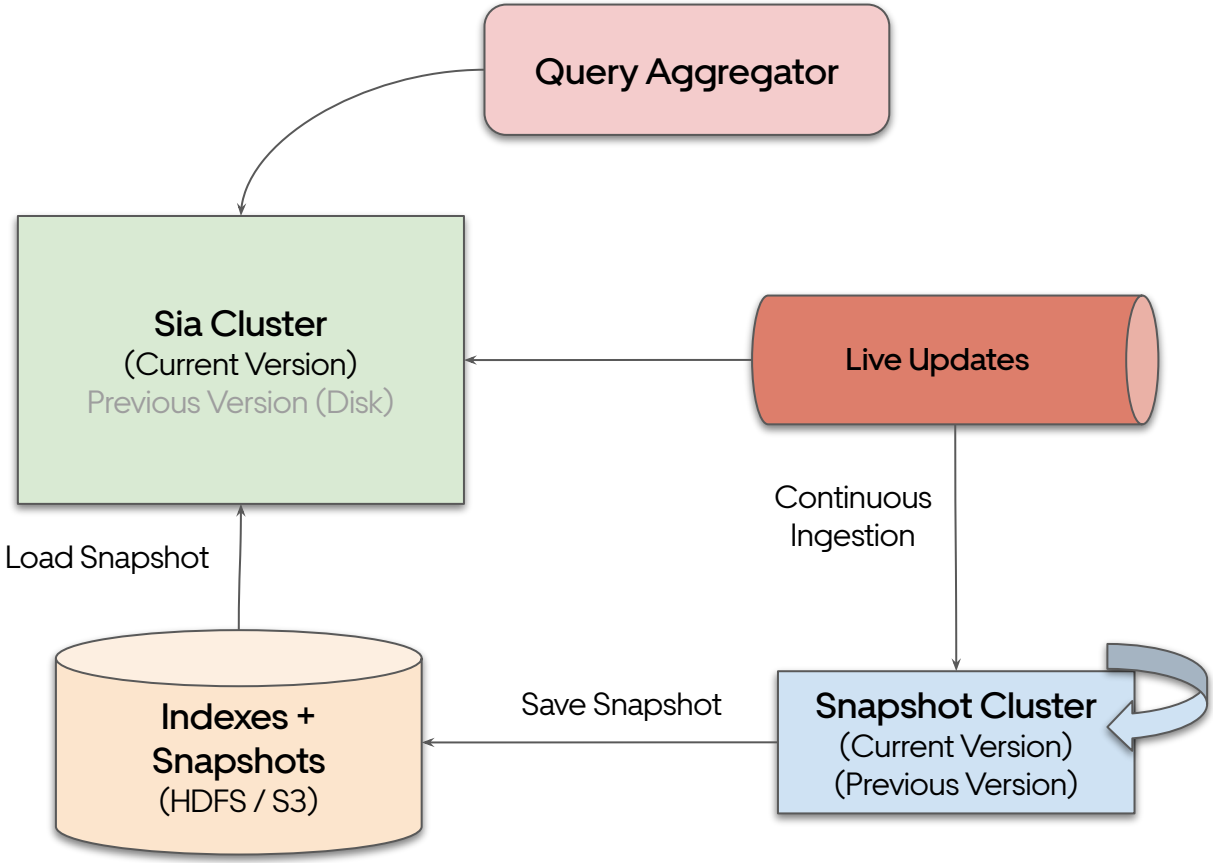
Time travel to earlier index version

Index corruption is hard to mitigate

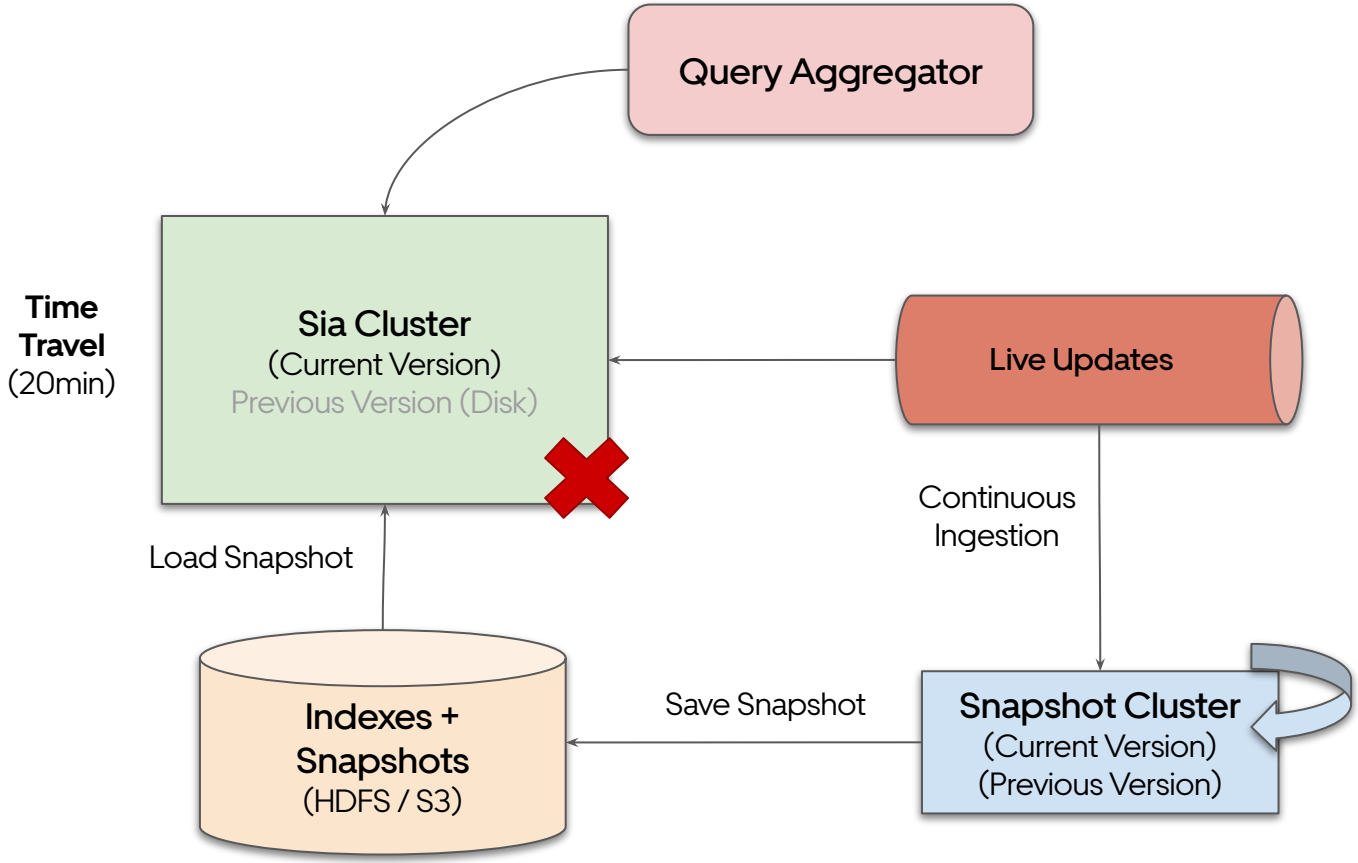
- Rolling back to previous index took hours / days
- Building a new index takes hours / days



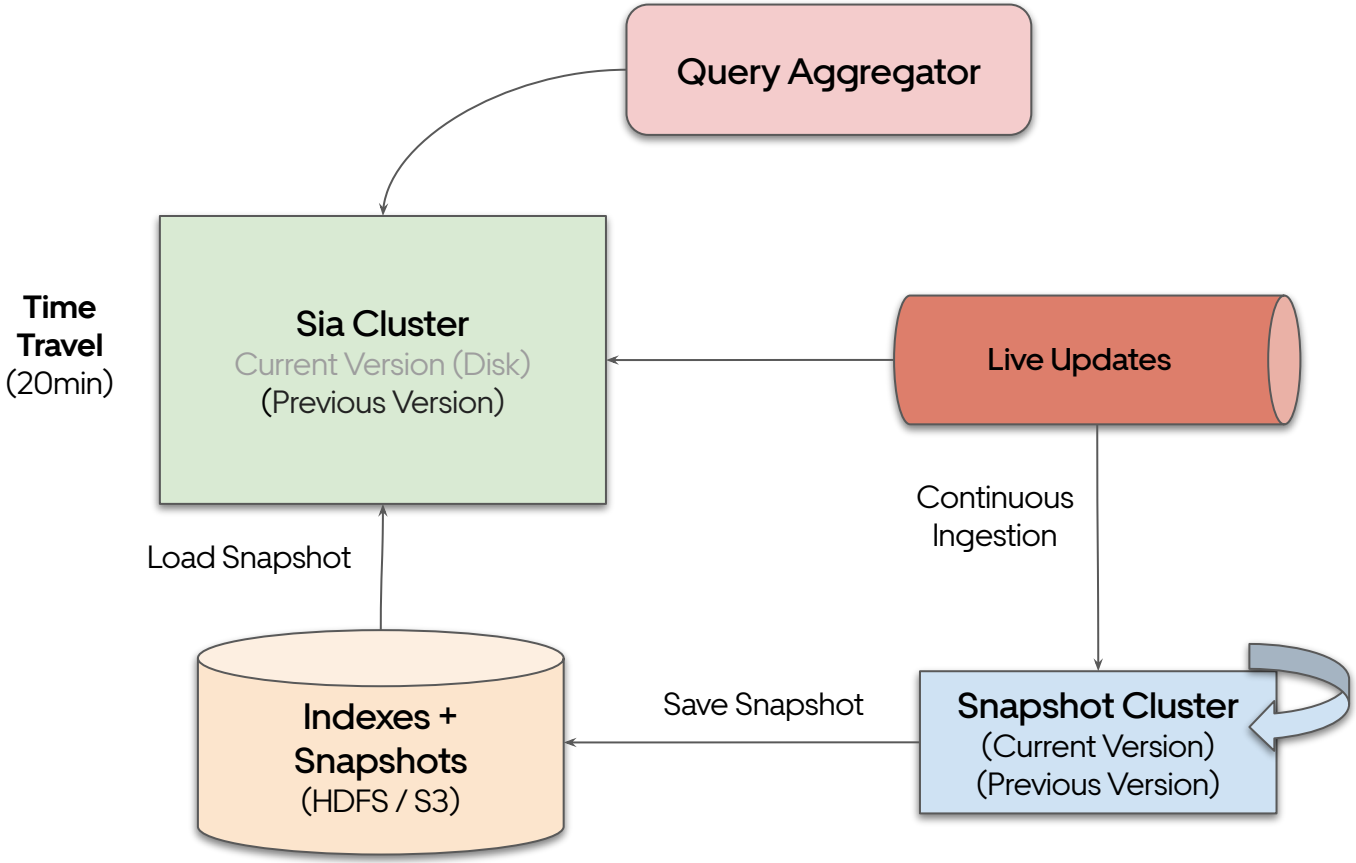
Time travel: keep all versions fresh with *snapshot cluster*



Time travel: Mitigation flow



Time travel: Mitigation flow



Semantic Search

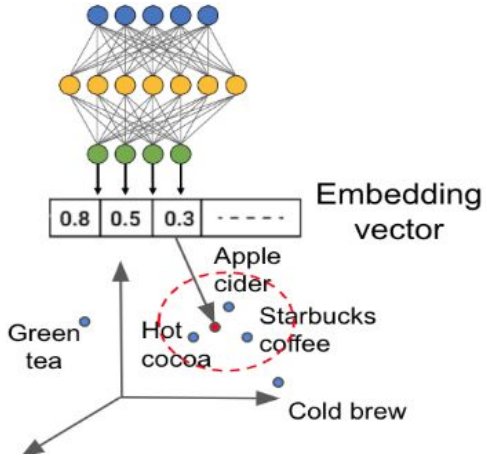
- Next-gen search architecture
- Incorporating semantic signals like context
- Deep integration with ML
- Better search quality

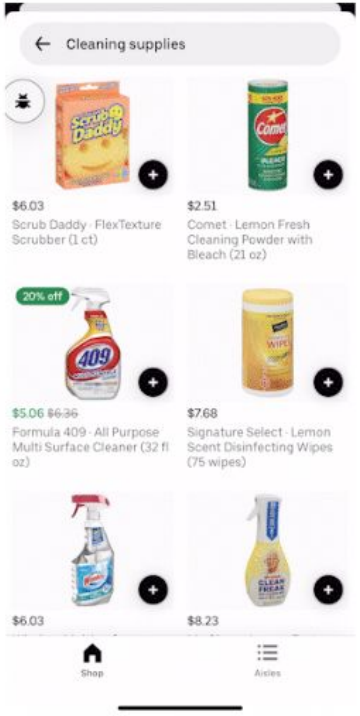
Query

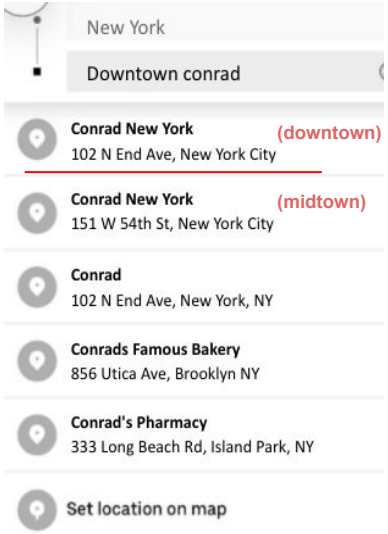
"Hot drink" +attributes

Documents

Apple cider, Hot cocoa, Starbucks coffee

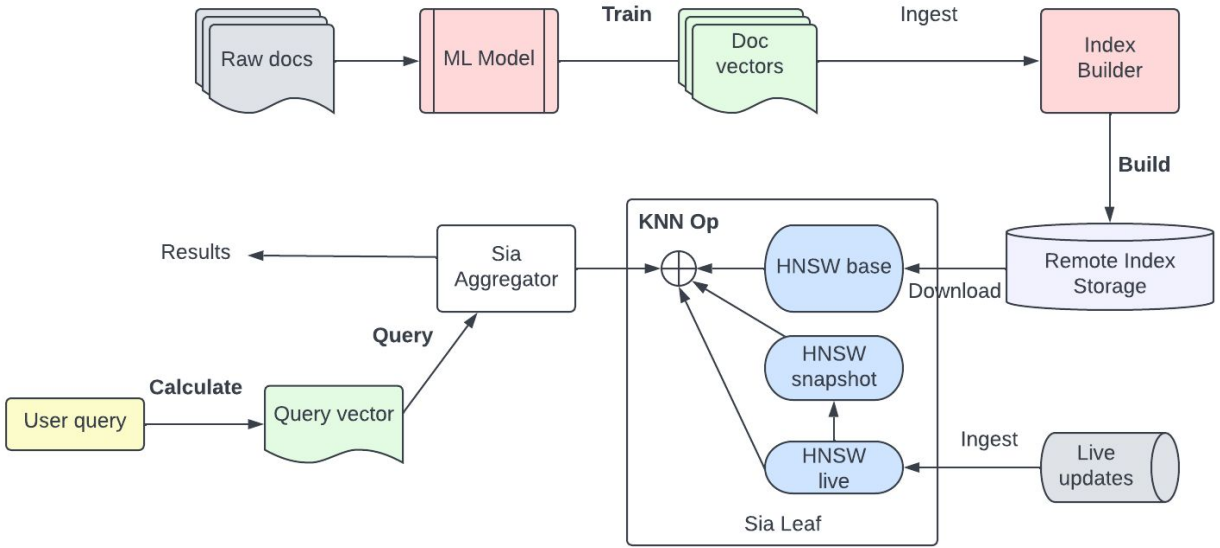






KNN in Sia

- Built on top of Lucene's KNN
- Geo-sharded HNSW graphs at Uber scale
- Pre-filter with location conditions
- Filter Cache for latency improvement



Q&A