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Ask Bigger Questions

Introduction to Apache Hive and Cloudera Impala

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About Me

- Contributor to Apache Hive, Impala packaging
- Section Author of O'Reilly's Programming Hive book
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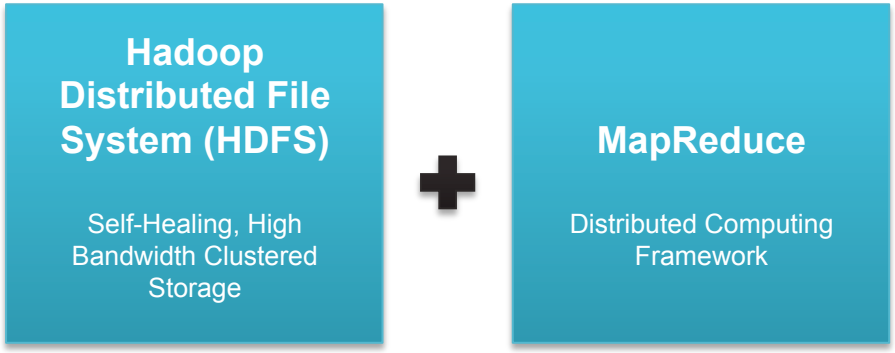
What is Apache Hadoop?

Apache Hadoop is an open source platform for data storage and processing that is…

- ✓ Scalable
- ✓ Fault tolerant
- ✓ Distributed

CORE HADOOP SYSTEM COMPONENTS



Has the Flexibility to Store and Mine Any Type of Data

- Ask questions across structured and unstructured data that were previously impossible to ask or solve
- Not bound by a single schema

Excels at Processing Complex Data

- Scale-out architecture divides workloads across multiple nodes
- Flexible file system eliminates ETL bottlenecks

Scales Economically

- Can be deployed on commodity hardware
- Open source platform guards against vendor lock

So why not just MapReduce?

- Catered to developers
- Lot of boilerplate to do simple aggregations
- Tons of analysts out there who understand SQL

Hive

- Data warehouse system for Hadoop
- Enables Extract/Transform/Load (ETL)
- Associate structure with a variety of data formats
  - Logical Table -> Physical Location
  - Logical Table -> Physical Data Format Handler (SerDe)
- Integrates with HDFS, HBase, MongoDB, etc.
- Query execution in MapReduce

Why use Hive?

- MapReduce is catered towards developers
- Run SQL-like queries that get compiled and run as MapReduce jobs
- Data in Hadoop even though generally unstructured has some vague structure associated with it
- Benefits of MapReduce + HDFS (Hadoop)
  - Fault tolerant
  - Robust
  - Scalable

Hive features

- Create table, create view, create index - DDL
- Select, where clause, group by, order by, joins
- Pluggable User Defined Functions - UDFs (e.g from_unixtime)
- Pluggable User Defined Aggregate Functions - UDAFs (e.g. count, avg)
- Pluggable User Defined Table Generating Functions - UDTFs (e.g. explode)

Hive features

- Pluggable custom Input/Output format
- Pluggable Serialization Deserialization libraries (SerDes)
- Pluggable custom map and reduce scripts

What Hive does NOT support

- OLTP workloads - low latency
- Correlated subqueries
- Not super performant with small amounts of data
  - How much data do you need to call it “Big Data”?

Other Hive features

- Partitioning
- Sampling
- Bucketing
- Various join optimizations
- Integration with HBase and other storage handlers
- Views – Unmaterialized
- Complex data types – arrays, structs, maps

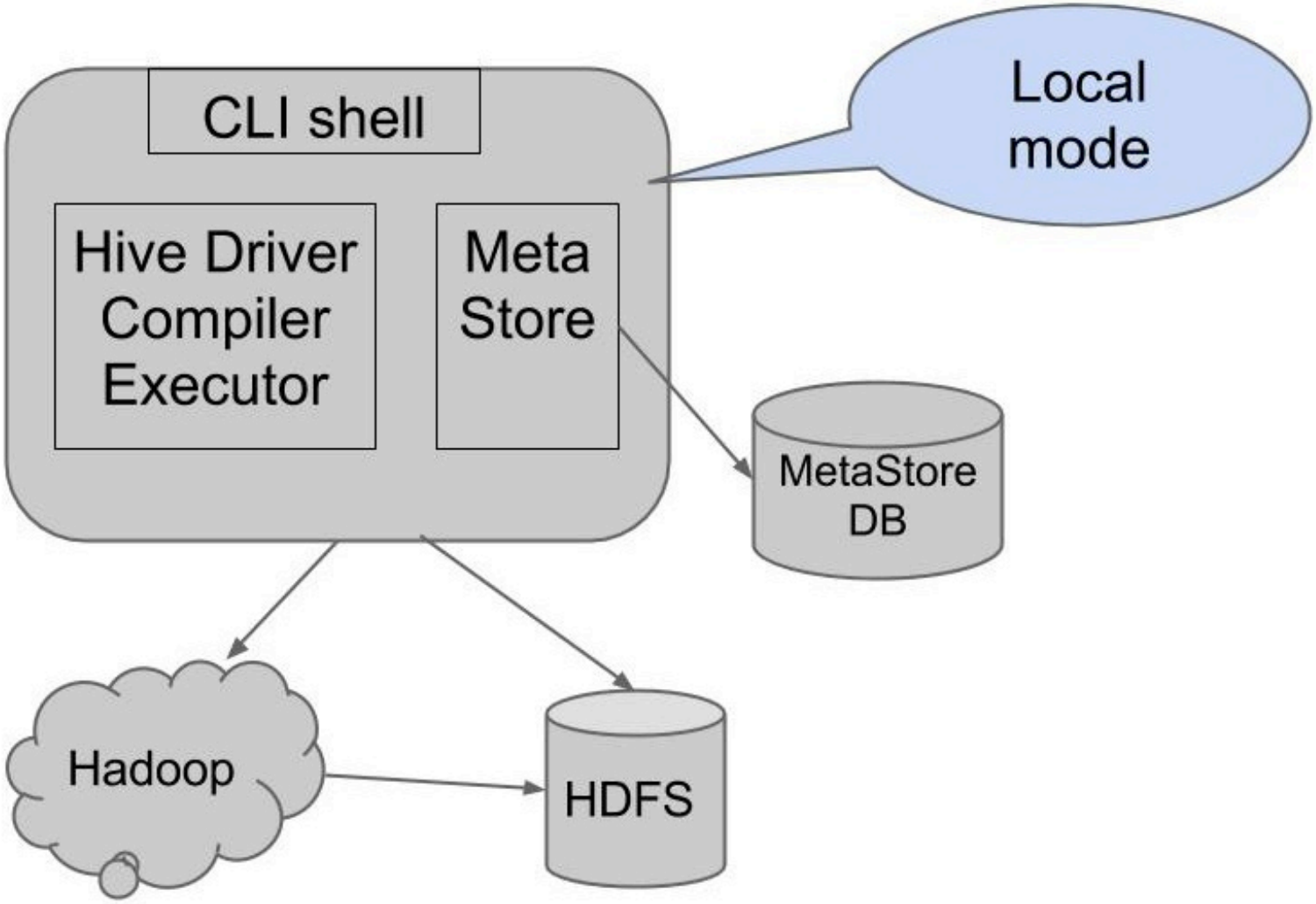
Connecting to Hive

- Hive Shell
- JDBC driver
- ODBC driver
- Thrift client

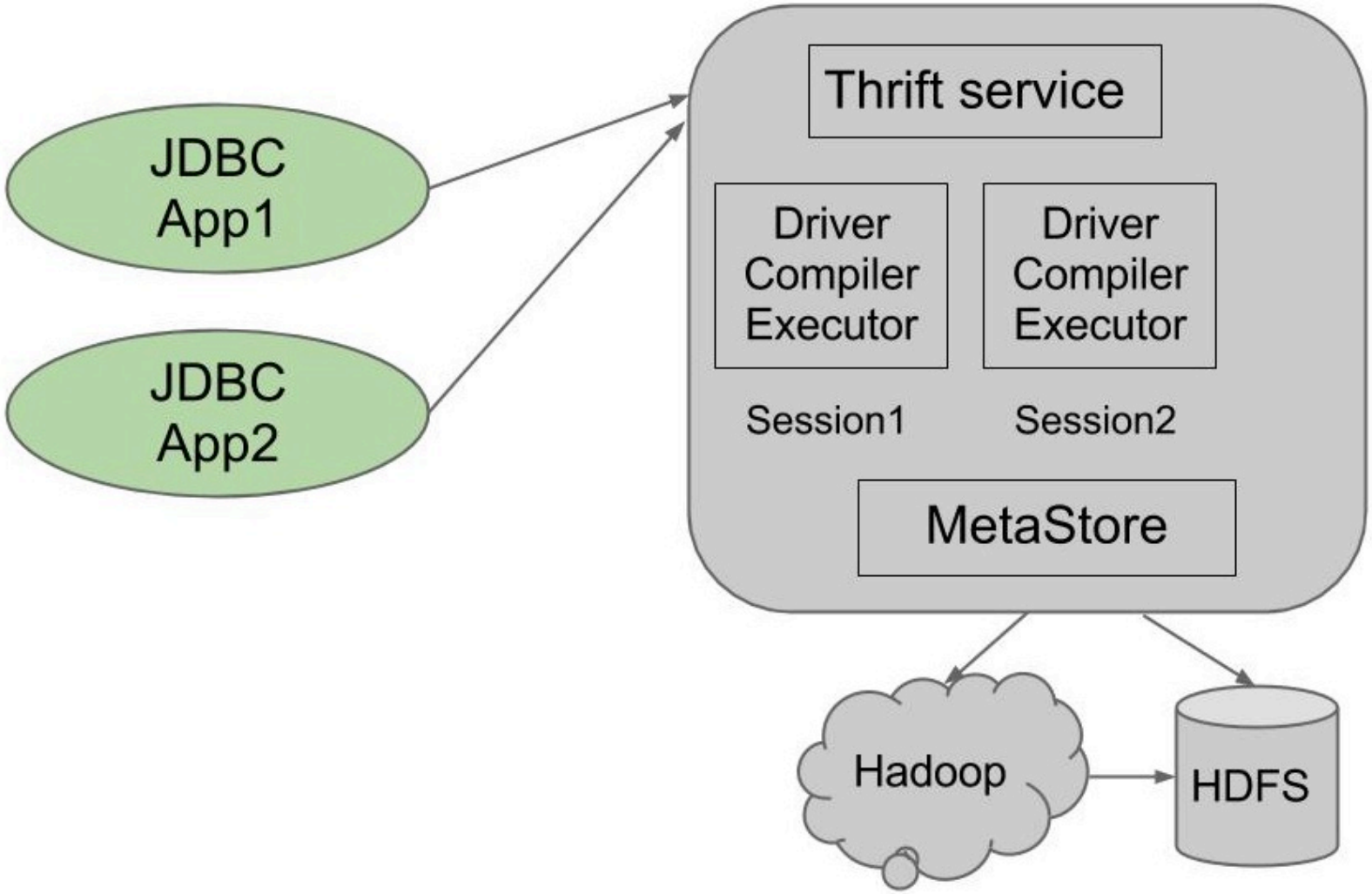
Hive metastore

- Backed by RDBMS
  - Derby, MySQL, PostgreSQL, etc. supported
- Default Embedded Derby
  - Not recommend for anything but a quick Proof of Concept
- 3 different modes of operation:
  - Embedded Derby (default)
  - Local
  - Remote

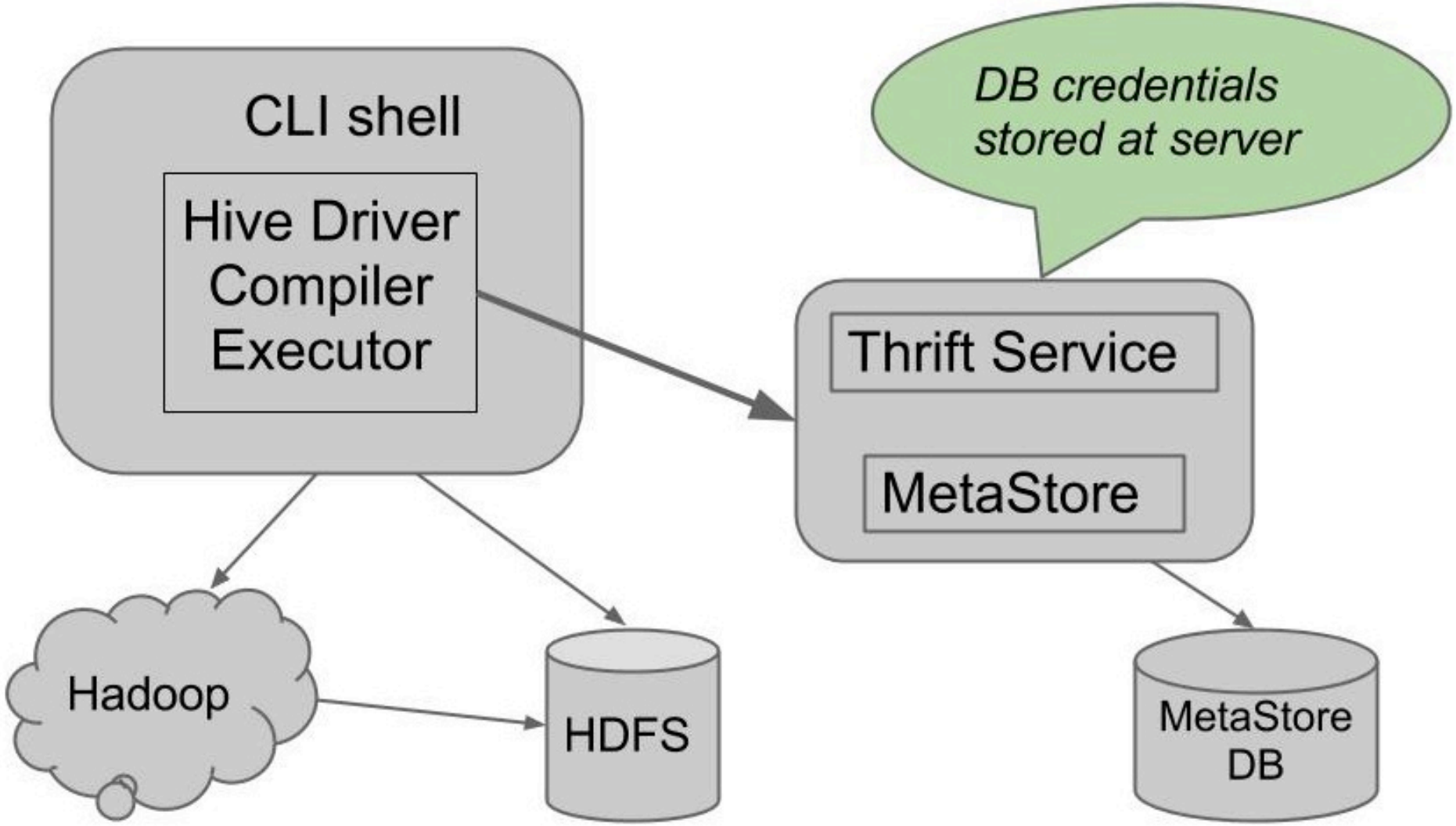
Hive architecture



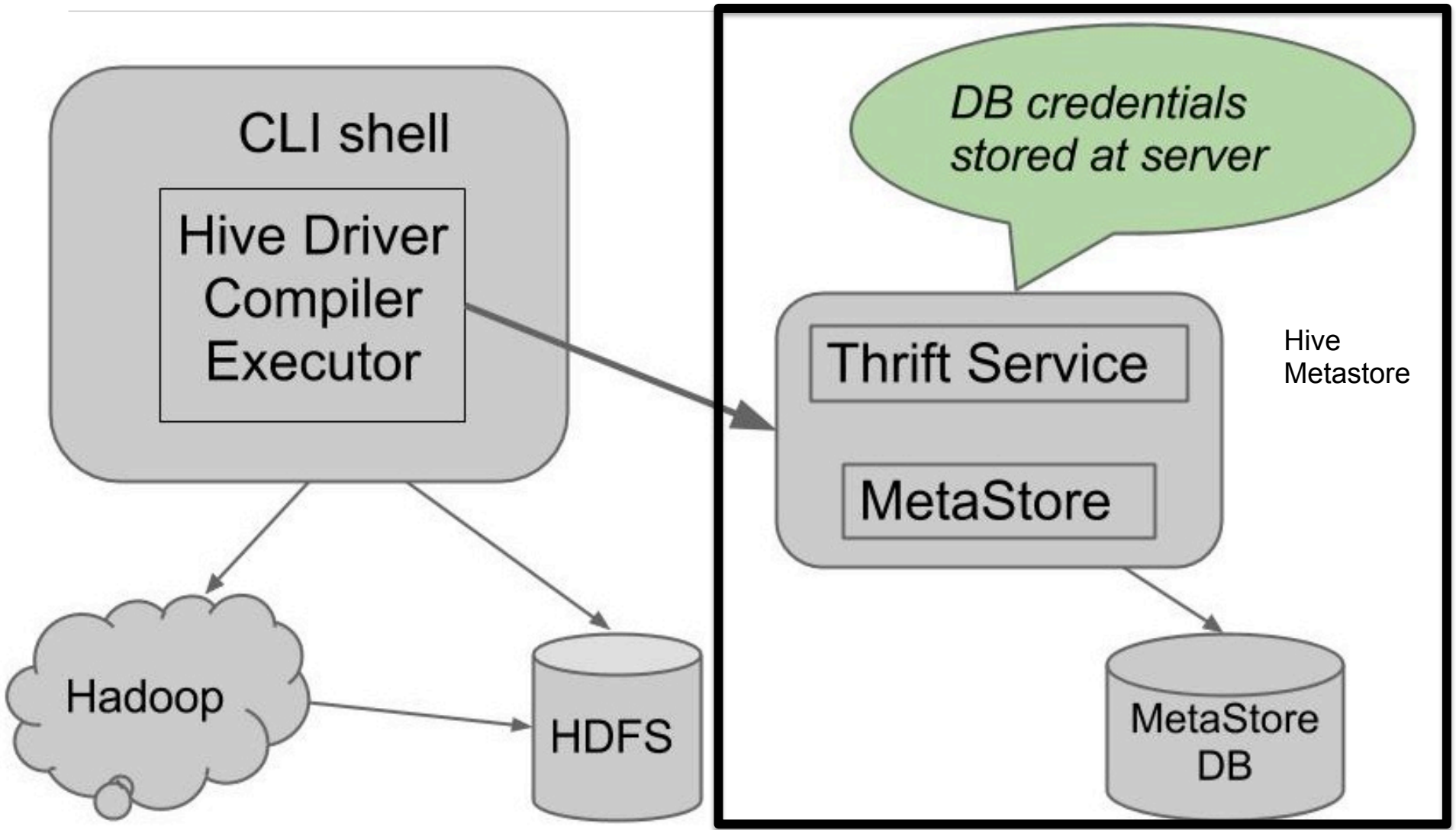
Hive server 2



Hive Remote Mode



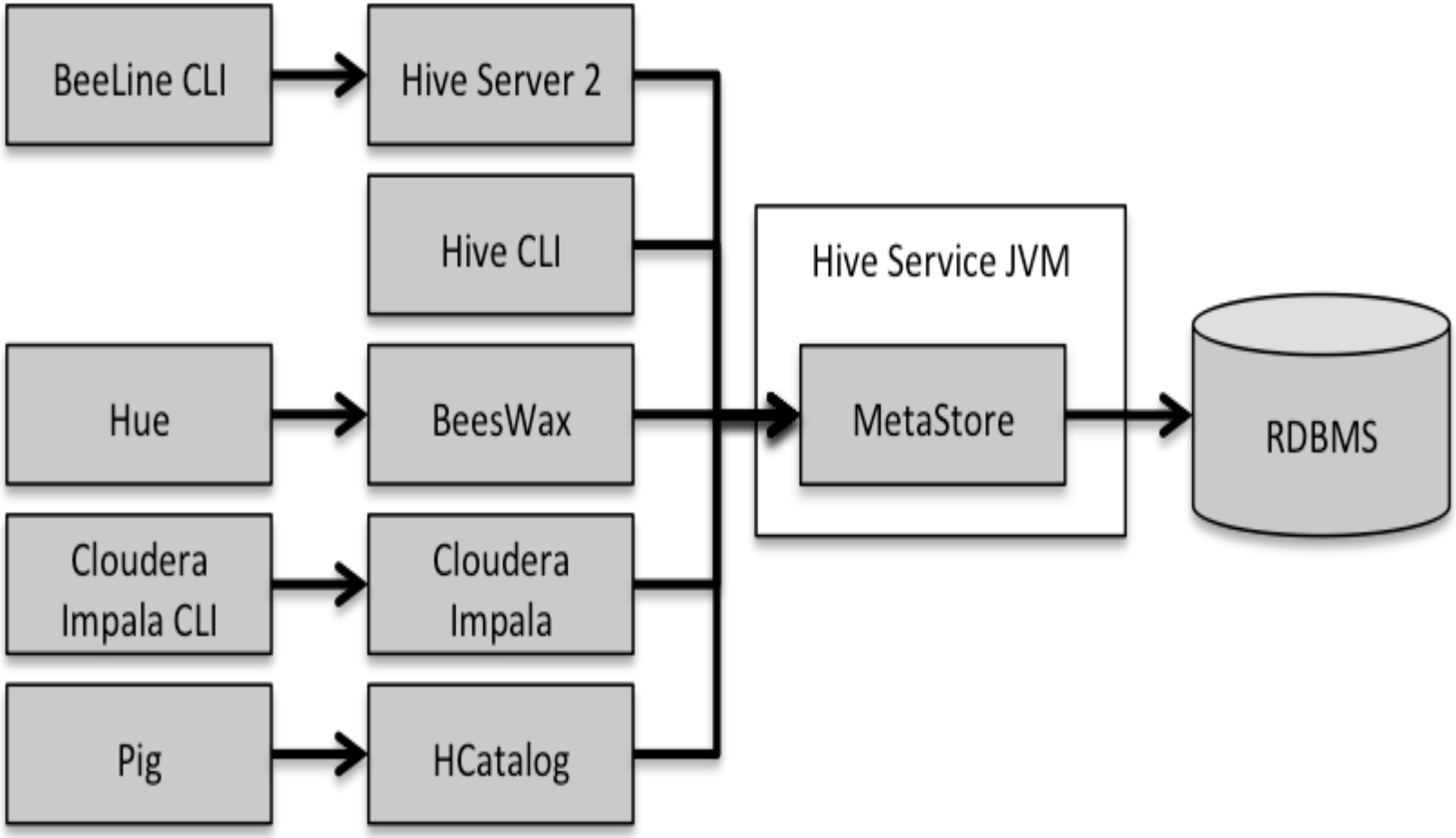
Metadata in Hive



Metadata

- Hive metastore has become the de-facto metadata repository
- HCatalog makes Hive metastore accessible to other applications (Pig, MapReduce, custom apps, etc.)

Hive + HCatalog



Demo!

Why is Hive not enough?

- Batch-oriented
- Need something for interactive querying

Batch vs real-time

- ETL processing
  - Extract-Transform-Load
  - Historically done by ETL tools
  - Batch but has tight SLAs
- Interactive BI
  - By BI applications or analysts
  - Require interactive response times
  - Real-time

Impala Overview: Goals

- General-purpose SQL query engine:
  - Works for both for analytical and transactional/single-row workloads
  - Supports queries that take from milliseconds to hours
- Runs directly within Hadoop:
  - reads widely used Hadoop file formats
  - talks to widely used Hadoop storage managers
  - runs on same nodes that run Hadoop processes
- High performance:
  - C++ instead of Java
  - runtime code generation
  - completely new execution engine – No MapReduce

User View of Impala: Overview

- Runs as a distributed service in cluster: one Impala daemon on each node with data
- Highly available: no single point of failure
- User submits query via ODBC/JDBC, Impala CLI or Hue to any of the daemons
- Query is distributed to all nodes with relevant data
- Impala uses Hive's metadata interface, connects to Hive metastore

User View of Impala: Overview

- There is no 'Impala format'!
- Supported file formats:
  - uncompressed/lzo-compressed text files
  - sequence files and RCFile with snappy/gzip compression
  - Avro data files
  - Parquet columnar format

User View of Impala: SQL support

- essentially SQL-92, minus correlated subqueries
- INSERT INTO … SELECT …
- only equi-joins; no non-equi joins, no cross products
- Order By requires Limit
- (Limited) DDL support
- SQL-style authorization via Apache Sentry (incubating)
- UDFs and UDAFs are supported

User View of Impala: SQL

- Functional limitations:
  - No file formats, SerDes
  - no beyond SQL (buckets, samples, transforms, arrays, structs, maps, xpath, json)
  - Broadcast joins and partitioned hash joins supported
  - Smaller table has to fit in aggregate memory of all executing nodes

User View of Impala: HBase

- Functionality highlights:
  - Support for SELECT, INSERT INTO … SELECT …, and INSERT INTO … VALUES(…)
  - Predicates on rowkey columns are mapped into start/stop rows
  - Predicates on other columns are mapped into SingleColumnValueFilters
- But: mapping of HBase tables metastore table patterned after Hive
  - All data stored as scalars and in ascii
  - The rowkey needs to be mapped into a single string column

User View of Impala: HBase

- Roadmap
  - Full support for UPDATE and DELETE
  - Storage of structured data to minimize storage and access overhead
  - Composite row key encoding, mapped into an arbitrary number of table columns

Impala Architecture

- Three binaries: impalad, statestored, catalogd
- Impala daemon (impalad) – N instances
  - handles client requests and all internal requests related to query execution
- State store daemon (statestored) – 1 instance
  - Provides name service and metadata distribution
- Catalog daemon (catalogd) – 1 instance
  - Relays metadata changes to all impalad's

Impala Architecture

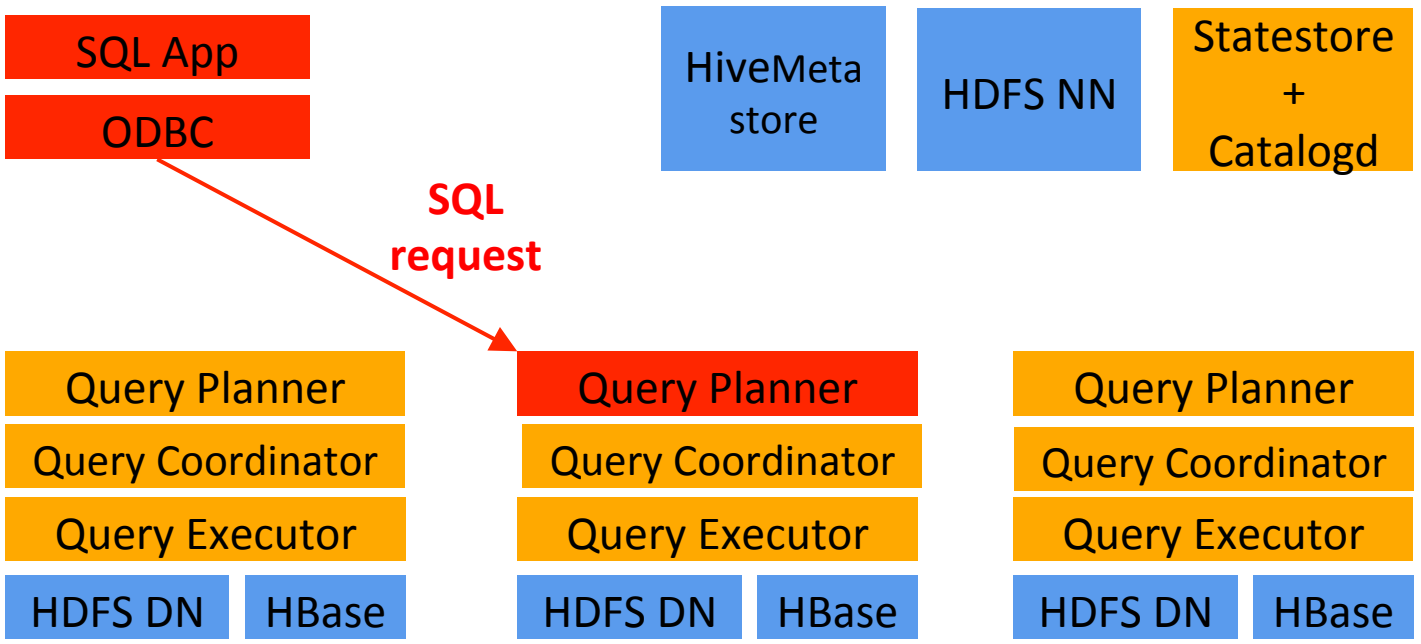
- Query execution phases
  - request arrives via odbc/jdbc
  - planner turns request into collections of plan fragments
  - coordinator initiates execution on remote impalad's

Impala Architecture

- During execution
  - intermediate results are streamed between executors
  - query results are streamed back to client
  - subject to limitations imposed to blocking operators (top-n, aggregation)

Impala Architecture: Query Execution

- Request arrives via odbc/jdbc



Impala Architecture: Query Execution

- Planner turns request into collections of plan fragments
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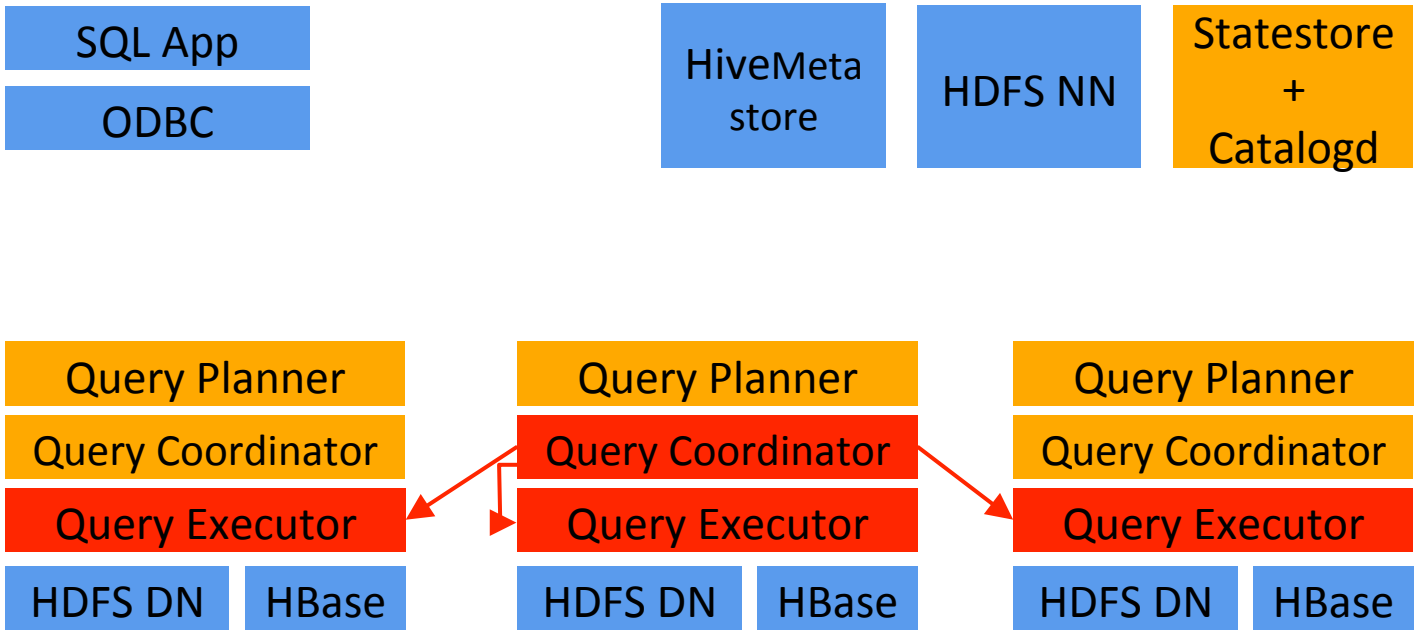
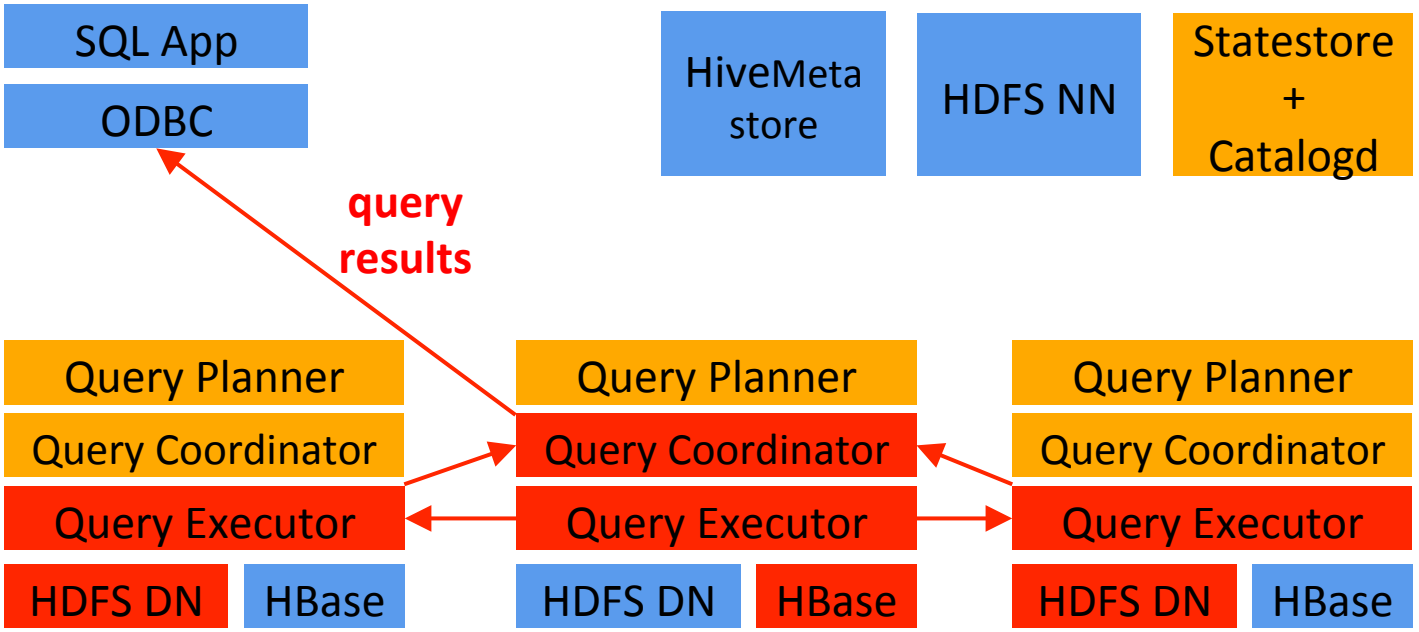


Impala Architecture: Query Execution

- Intermediate results are streamed between impalad's
  Query results are streamed back to client



Query Planning: Overview

- 2-phase planning process:
  - single-node plan: left-deep tree of plan operators
  - plan partitioning: partition single-node plan to maximize scan locality, minimize data movement
- Parallelization of operators:
  - All query operators are fully distributed

Query Planning: Single-Node Plan

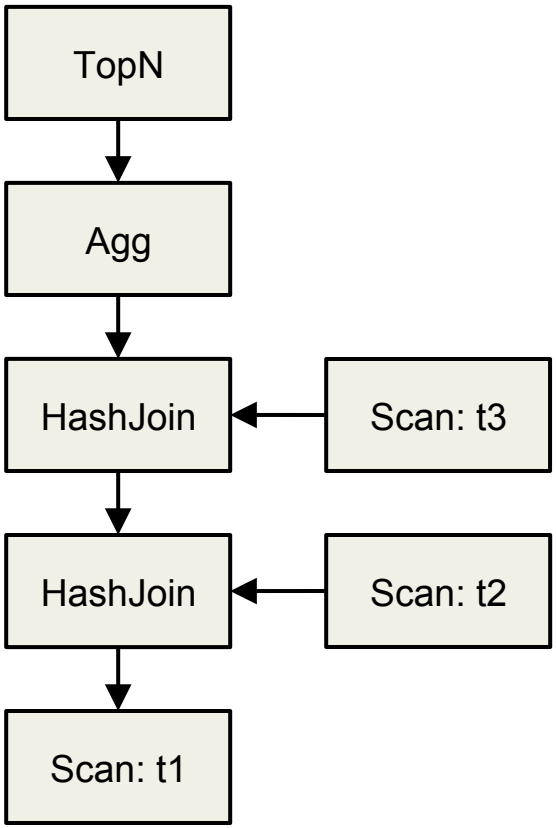
- Plan operators: Scan, HashJoin, HashAggregation, Union, TopN, Exchange

Single-Node Plan: Example Query

```
SELECT t1.custid,
    SUM(t2.revenue) AS revenue
FROM LargeHdfsTable t1
JOIN LargeHdfsTable t2 ON (t1.id1 = t2.id)
JOIN SmallHbaseTable t3 ON (t1.id2 = t3.id)
WHERE t3.category = 'Online'
GROUP BY t1.custid
ORDER BY revenue DESC LIMIT 10;
```

Query Planning: Single-Node Plan

- Single-node plan for example:



Query Planning: Distributed Plans

- Goals:
  - maximize scan locality, minimize data movement
  - full distribution of all query operators (where semantically correct)
- Parallel joins:
  - broadcast join: join is collocated with left input; right-hand side table is broadcast to each node executing join
    -> preferred for small right-hand side input
  - partitioned join: both tables are hash-partitioned on join columns
    -> preferred for large joins
  - cost-based decision based on column stats/estimated cost of data transfers

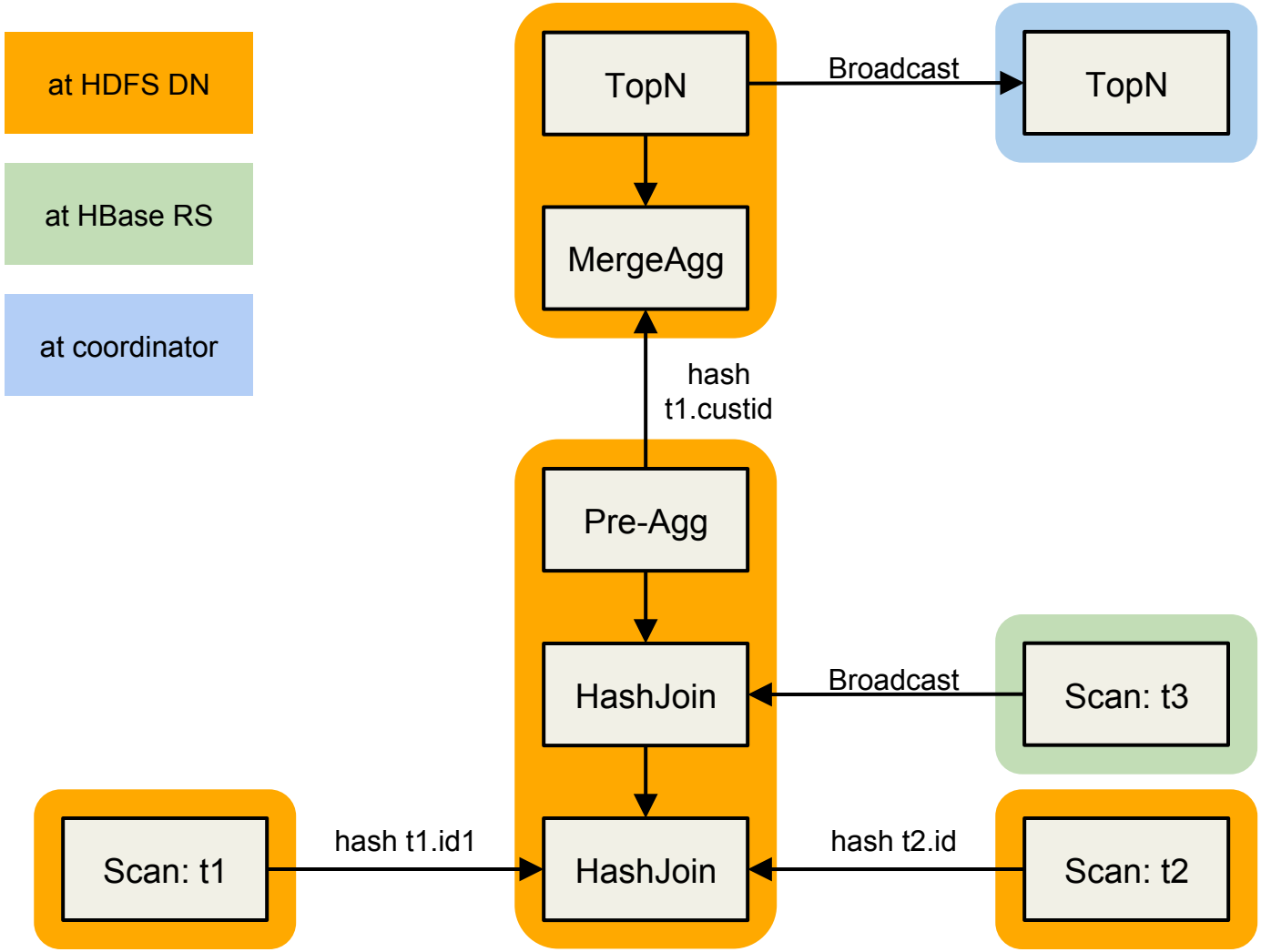
Query Planning: Distributed Plans

- Parallel aggregation:
  - pre-aggregation where data is first materialized
  - merge aggregation partitioned by grouping columns
- Parallel top-N:
  - initial top-N operation where data is first materialized
  - final top-N in single-node plan fragment

Query Planning: Distributed Plans

- In the example:
  - scans are local: each scan receives its own fragment
  - 1st join: large x large -> partitioned join
  - 2nd scan: large x small -> broadcast join
  - pre-aggregation in fragment that materializes join result
  - merge aggregation after repartitioning on grouping column
  - initial top-N in fragment that does merge aggregation
  - final top-N in coordinator fragment

Query Planning: Distributed Plans



Metadata Handling

- Impala metadata:
  - Hive's metastore: logical metadata (table definitions, columns, CREATE TABLE parameters)
  - HDFS NameNode: directory contents and block replica locations
  - HDFS DataNode: block replicas' volume ids

Metadata Handling

- Caches metadata: no synchronous metastore API calls during query execution
- impalad instances read metadata from metastore at startup
- Catalog Service relays metadata when you run DDL or update metadata on one of Impalad's
- REFRESH [<tbl>]: reloads metadata on all impalad's (if you added new files via Hive)
- INVALIDATE METADATA: reloads metadata for all tables
- Roadmap: HCatalog

What makes Impala fast?

- Written in C++ for minimal execution overhead
- Internal in-memory tuple format puts fixed-width data at fixed offsets
- Uses intrinsics/special cpu instructions for text parsing, crc32 computation, etc.
- Runtime code generation for “big loops”

Impala Execution Engine

- More on runtime code generation
  - example of "big loop": insert batch of rows into hash table
  - known at query compile time: # of tuples in a batch, tuple layout, column types, etc.
  - generate at compile time: unrolled loop that inlines all function calls, contains no dead code, minimizes branches
  - code generated using llvm

Impala's Statestore

- Central system state repository
  - name service (membership)
  - Metadata
  - Roadmap: other scheduling-relevant or diagnostic state
- Soft-state
  - all data can be reconstructed from the rest of the system
  - cluster continues to function when statestore fails, but per-node state becomes increasingly stale
- Sends periodic heartbeats
  - pushes new data
  - checks for liveness

Statestore: Why not ZooKeeper?

- ZK is not a good pub-sub system
  - Watch API is awkward and requires a lot of client logic
  - multiple round-trips required to get data for changes to node's children
  - push model is more natural for our use case
- Don't need all the guarantees ZK provides:
  - serializability
  - persistence
  - prefer to avoid complexity where possible
- ZK is bad at the things we care about and good at the things we don't

Comparing Impala to Dremel

- What is Dremel?
  - columnar storage for data with nested structures
  - distributed scalable aggregation on top of that
- Columnar storage in Hadoop: Parquet
  - stores data in appropriate native/binary types
  - can also store nested structures similar to Dremel's ColumnIO
- Distributed aggregation: Impala
- Impala plus Parquet: a superset of the published version of Dremel (which didn't support joins)

More about Parquet

- What is it:
  - container format for all popular serialization formats: Avro, Thrift, Protocol Buffers
  - successor to Trevni
  - jointly developed between Cloudera and Twitter
  - open source; hosted on github
- Features
  - rowgroup format: file contains multiple horiz. slices
  - supports storing each column in separate file
  - supports fully shredded nested data; repetition and definition levels similar to Dremel's ColumnIO
  - column values stored in native types (bool, int<x>, float, double, byte array)
  - support for index pages for fast lookup
  - extensible value encodings

Comparing Impala to Hive

- Hive: MapReduce as an execution engine
  - High latency, low throughput queries
  - Fault-tolerance model based on MapReduce's on-disk checkpointing; materializes all intermediate results
  - Java runtime allows for easy late-binding of functionality: file formats and UDFs.
  - Extensive layering imposes high runtime overhead
- Impala:
  - direct, process-to-process data exchange
  - no fault tolerance
  - an execution engine designed for low runtime overhead

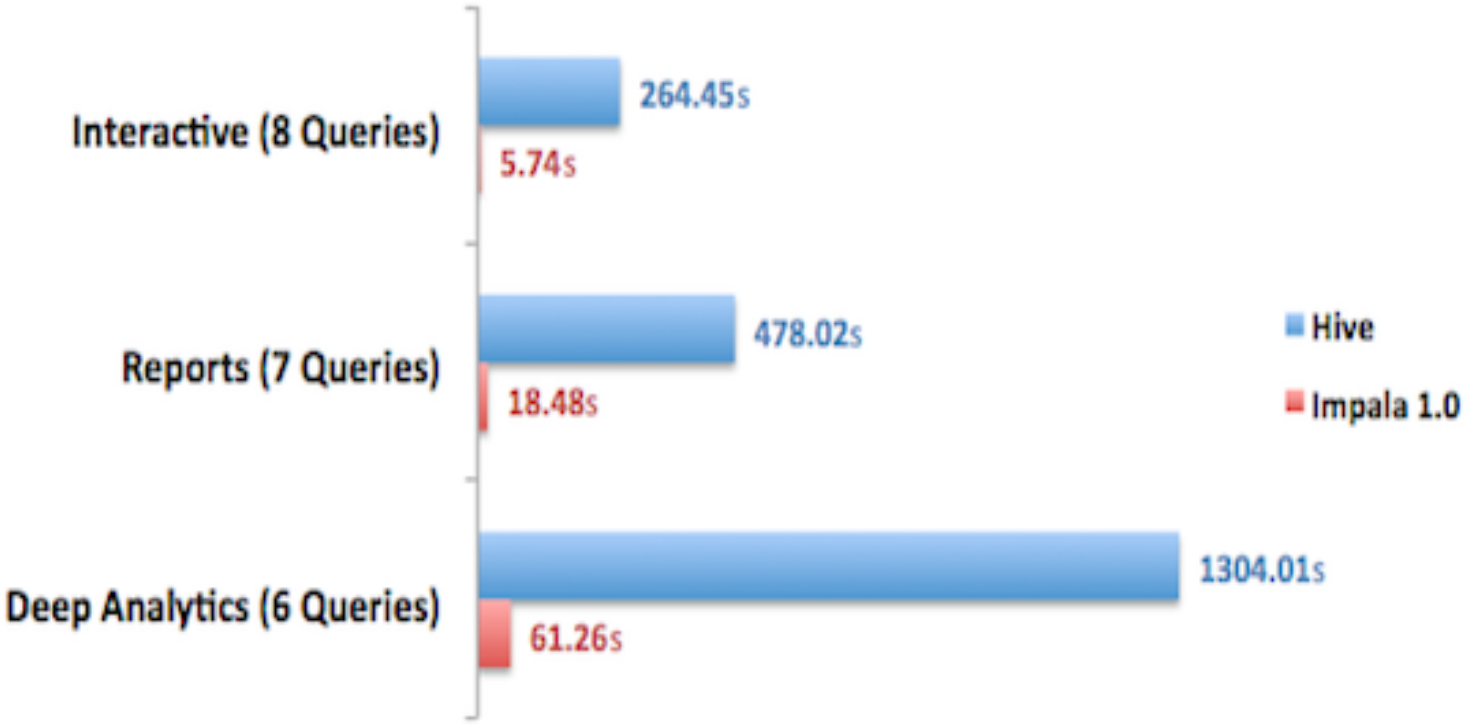
Comparing Impala to Hive

- Impala's performance advantage over Hive: no hard numbers, but
  - Impala can get full disk throughput (~100MB/sec/disk); I/O-bound workloads often faster by 3-4x
  - queries that require multiple map-reduce phases in Hive see a higher speedup
  - queries that run against in-memory data see a higher speedup (observed up to 100x)

Impala Single-User Performance

- Benchmark: 20 queries from TPC-DS, in 3 categories:
  - interactive: 1 month
  - Reports: several months
  - deep analytics: all data
- Main fact table: 5 years of data, 1TB, stored as snappy-compressed sequence files
- Cluster: 20 machines, 24 cores each

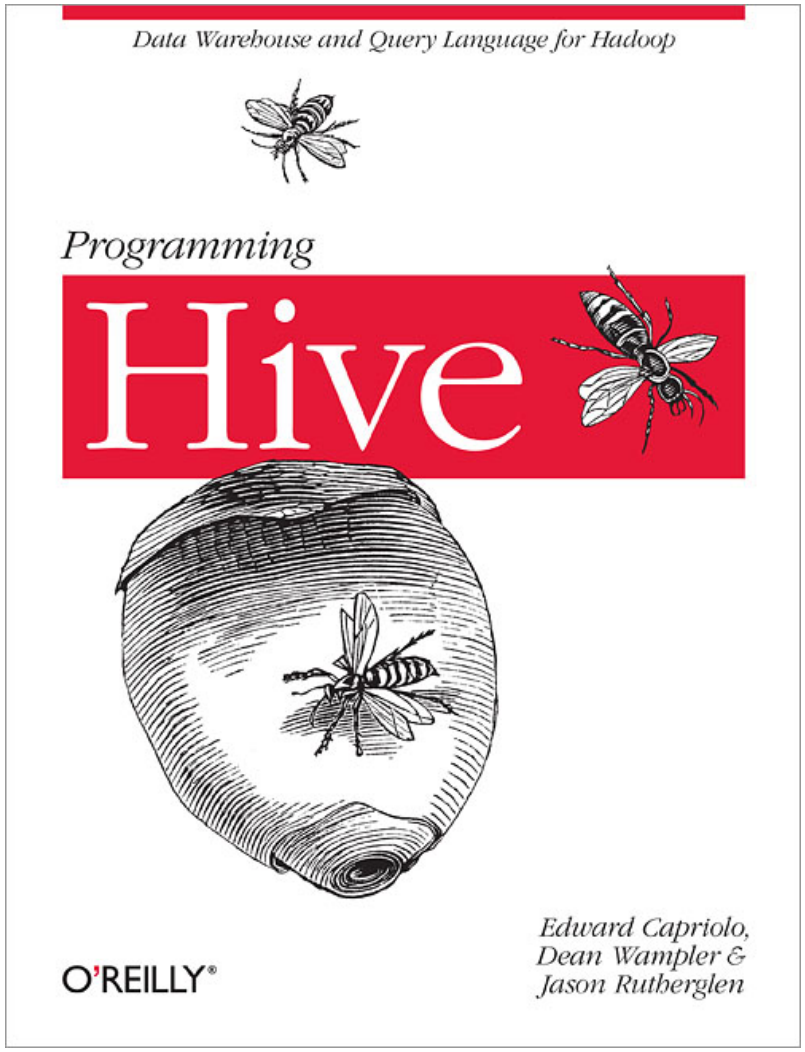
Impala Single-User Performance



Impala Single-User Performance

- Speed-up over Hive:
  - interactive: 25x - 68x
  - Reports: 6x - 56x
  - deep analytics: 6x - 55x

Want to learn more about Hive?



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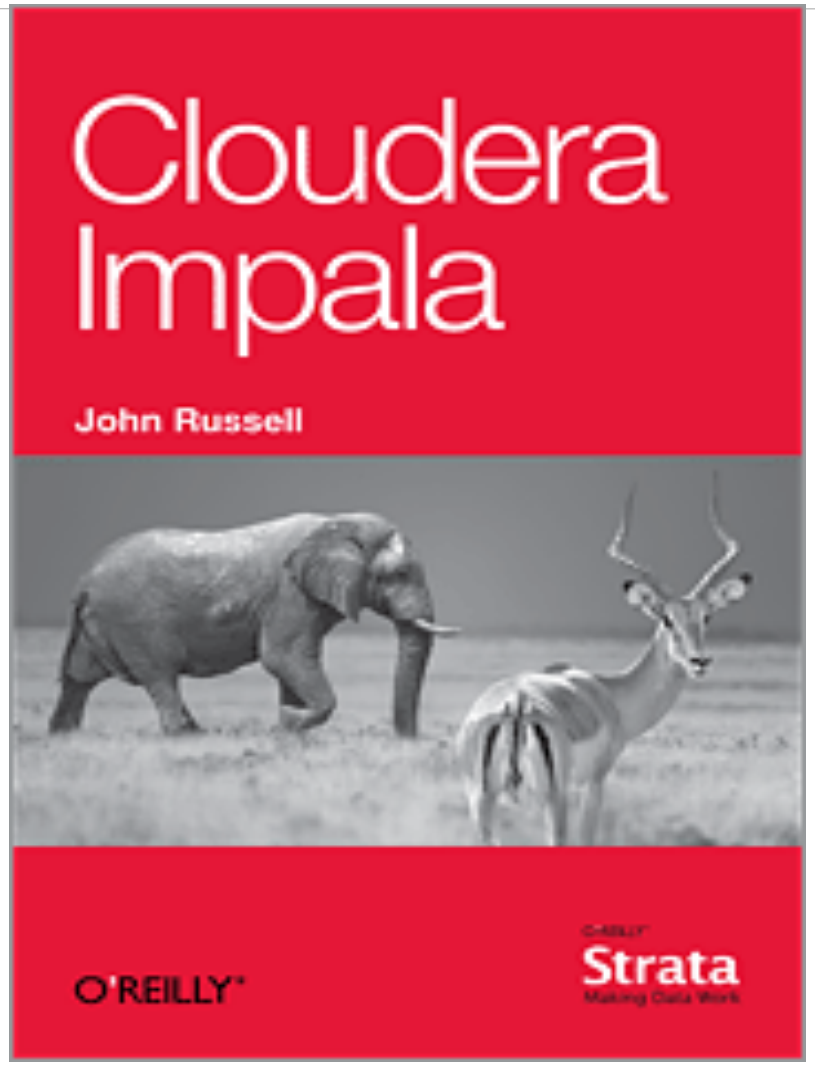

Co-authoring O'Reilly book

- Titled 'Hadoop Application Architect
- How to build end-to-end solutions u

Apache Hadoop and related tools

- Twitter: @hadooparchbook
- http://www.hadooparchitecturebook.com/

Another talk today….

- Application Architectures with Hadoop: Putting the Pieces Together Through Example
- From 3:30 – 4:45 PM today!

Demo!

Where to get Hive and Impala from?

- Open source under ASL v2
- Open source distribution: CDH
- QuickStart VM: tiny.cloudera.com/quick-start

Contact info

- Feedback: tiny.cloudera.com/mark
- @mark_grover
- github.com/markgrover
- linkedin.com/in/grovermark