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Hive – A Petabyte Scale Data Warehouse Using Hadoop

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Facebook Data Infrastructure

ICDE 2010

Agenda

- Motivation for Hive
- Usage in Facebook
- Hive Details
  - System Architecture
  - Data Model
  - Query Language
- Hive Optimizations
  - Group By and Join Optimizations
- Extensibility Features
- Future Work

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Motivation for Hive

Why Another Data Warehousing System?

Data, data and more data

200GB per day in March 2008

15+TB(compressed) raw data per day today

Existing solutions

- Not available
- Not scalable
- Expensive
- Proprietary

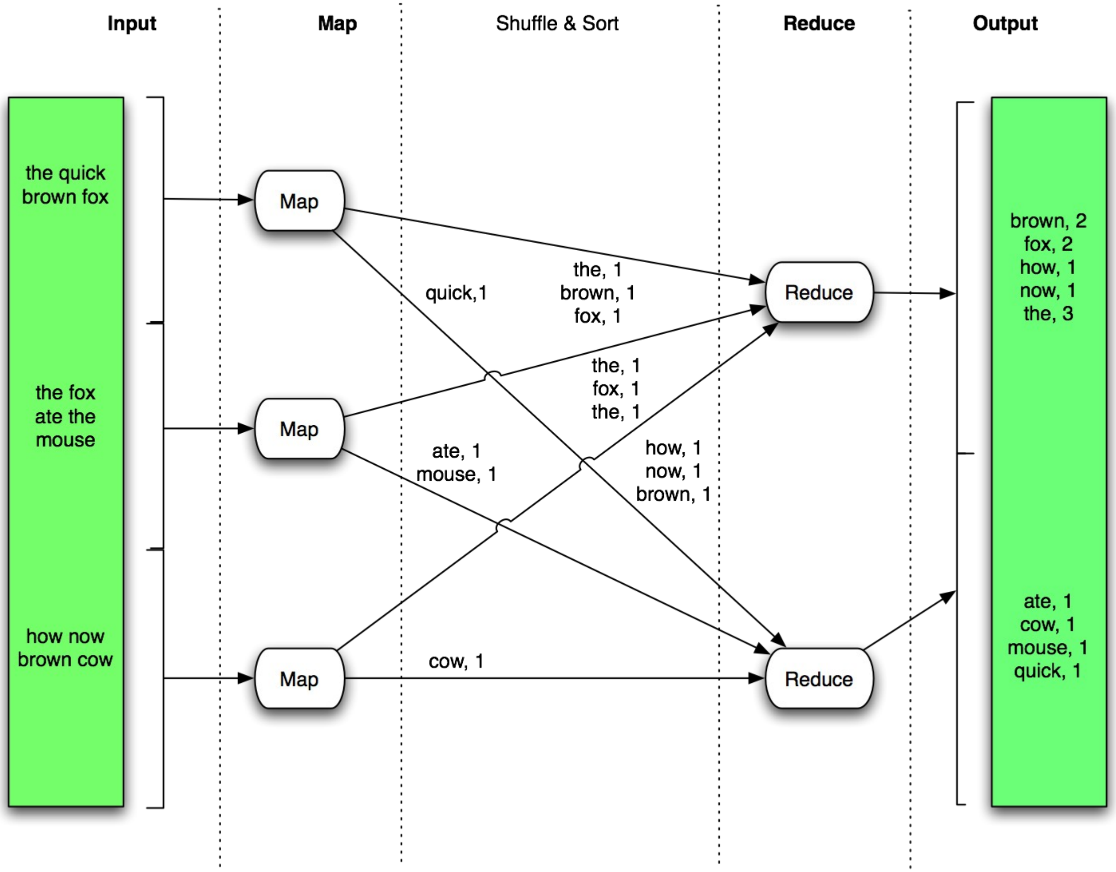
Lets try Hadoop…

- Pros
  - Superior in availability/scalability/manageability

- Cons: Programmability and Metadata
  - Efficiency not that great, but throw more hardware
  - Map-reduce hard to program (users know sql/bash/python)
  - No schema

- Solution: HIVE

Word Count using Map Reduce



What is HIVE?

- A system for managing and querying structured data built on top of Hadoop
  - Map-Reduce for execution
  - HDFS for storage
  - Metadata on hdfs files

- Key Building Principles:
  - SQL is a familiar language
  - Extensibility – Types, Functions, Formats, Scripts
  - Performance

Hive: Simplifying Hadoop – New Technology Familiar Interfaces

```
hive> select key, count(1) from kv1 where key > 100
   group by key;
```

vs.

```
$ cat > /tmp/reducer.sh
uniq -c | awk '{print $2"\t"$1}`
$ cat > /tmp/map.sh
awk -F '\001' '{if($1 > 100) print $1}`
$ bin/hadoop jar contrib/hadoop-0.19.2-dev-streaming.jar
   -input /user/hive/warehouse/kv1 -mapper map.sh -file
   /tmp/reducer.sh -file /tmp/map.sh -reducer reducer.sh
   -output /tmp/largekey -numReduceTasks 1
$ bin/hadoop dfs -cat /tmp/largekey/part*
```

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Usage in Facebook

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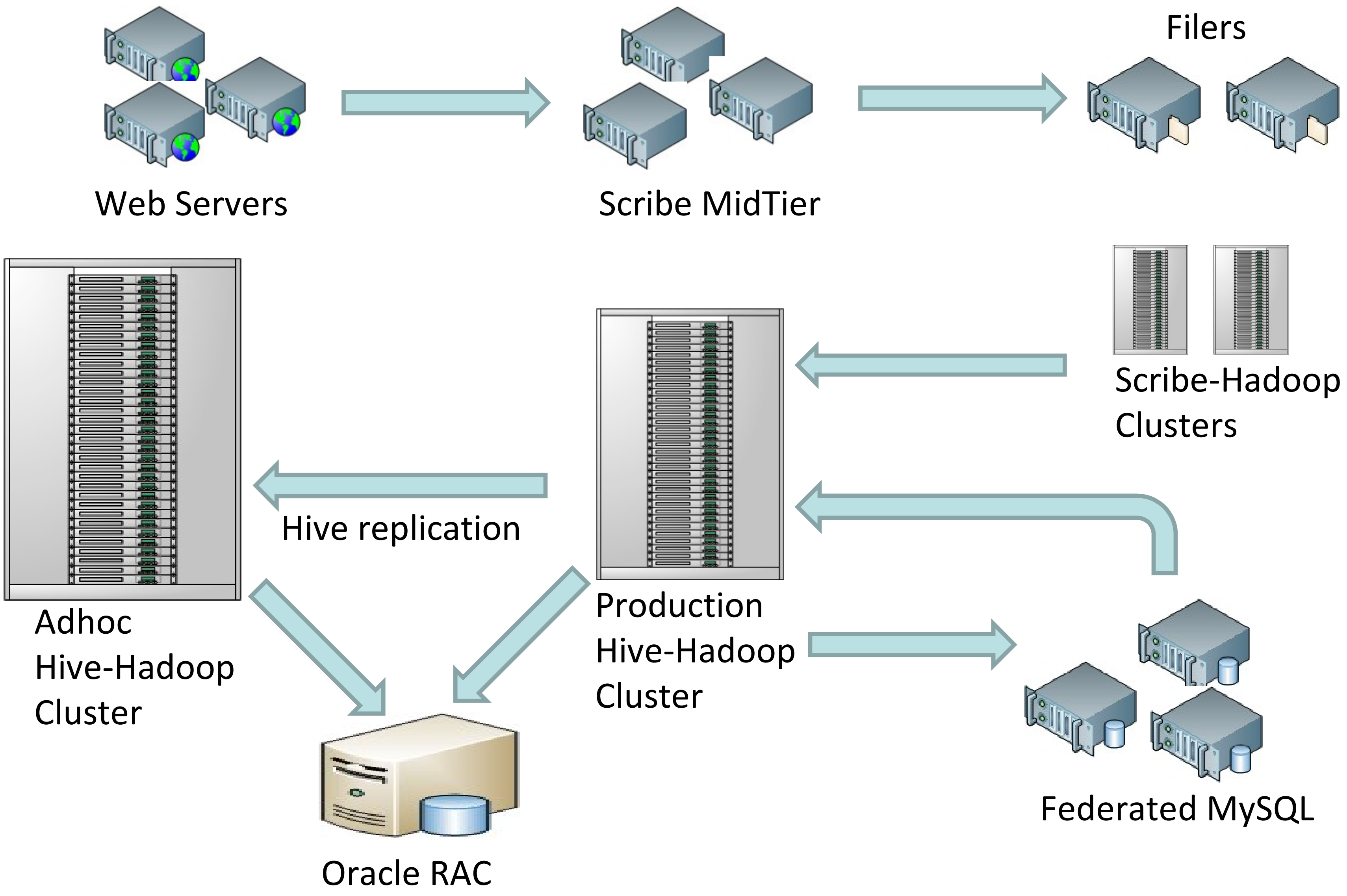
Data Flow Architecture at Facebook



Warehousing at Facebook

- Instrumentation
- Automatic ETL
  - Realtime (work in progress)
- Metadata Discovery (CoHive)
- Query (HIVE)
- Workflow specification and execution (Chronos)
- Reporting tools
- Monitoring and alerting

Hadoop & Hive Cluster @ Facebook

- **Production Cluster**
  - 300 nodes/2400 cores
  - 3PB of raw storage
- **Adhoc Cluster**
  - 1200 nodes/9600 cores
  - 12PB of raw storage
- **Node (DataNode + TaskTracker) configuration**
  - 2CPU, 4 core per cpu
  - 12 x 1TB disk (900GB usable per disk)

Hive & Hadoop Usage @ Facebook

- **Statistics per day:**
  - 10TB of compressed new data added per day
  - 135TB of compressed data scanned per day
  - 7500+ Hive jobs per day
  - 80K compute hours per day

- **Hive simplifies Hadoop:**
  - New engineers go though a Hive training session
  - ~200 people/month run jobs on Hadoop/Hive
  - Analysts (non-engineers) use Hadoop through Hive
  - 95% of hadoop jobs are Hive Jobs

Hive & Hadoop Usage @ Facebook

- Types of Applications:
  - Reporting
    - Eg: Daily/Weekly aggregations of impression/click counts
    - Measures of user engagement
    - Microstrategy dashboards
  - Ad hoc Analysis
    - Eg: how many group admins broken down by state/country
  - Machine Learning (Assembling training data)
    - Ad Optimization
    - Eg: User Engagement as a function of user attributes
  - Many others

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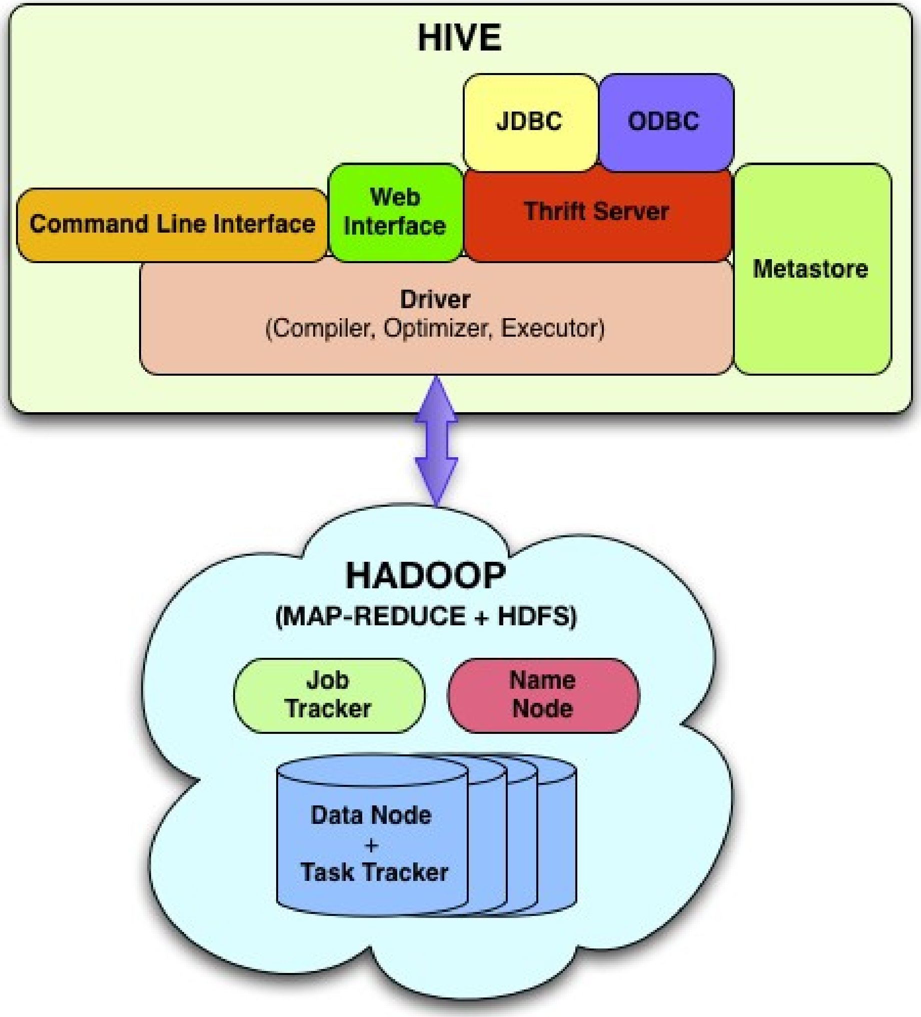
HIVE DETAILS

System Architecture



Data Model

Hive Entity	Sample Metastore Entity	Sample HDFS Location
Table	T	/wh/T
Partition	date=d1	/wh/T/date=d1
Bucketing column	userid	/wh/T/date=d1/part-0000 … /wh/T/date=d1/part-1000 (hashed on userid)
External Table	extT	/wh2/existing/dir (arbitrary location)

Column Data Types

- Primitive Types
    - integer types, float, string, date, boolean
- Nest-able Collections
    - array<any-type>
    - map<primitive-type, any-type>
- User-defined types
    - structures with attributes which can be of any-type

Hive Query Language

- DDL
  - {create/alter/drop} {table/view/partition}
  - create table as select
- DML
  - Insert overwrite
- QL
  - Sub-queries in from clause
  - Equi-joins (including Outer joins)
  - Multi-table Insert
  - Sampling
  - Lateral Views
- Interfaces
  - JDBC/ODBC/Thrift

Example Application

- Status updates table:

  -
    ```
    status_updates(userid int, status string, ds
    string)
    ```
- Load the data from log files:

  -
    ```
    LOAD DATA LOCAL INPATH ‘/logs/status_updates’ INTO
    TABLE status_updates PARTITION (ds=’2009-03-20’)
    ```
- User profile table

  -
    ```
    profiles(userid int, school string, gender int)
    ```

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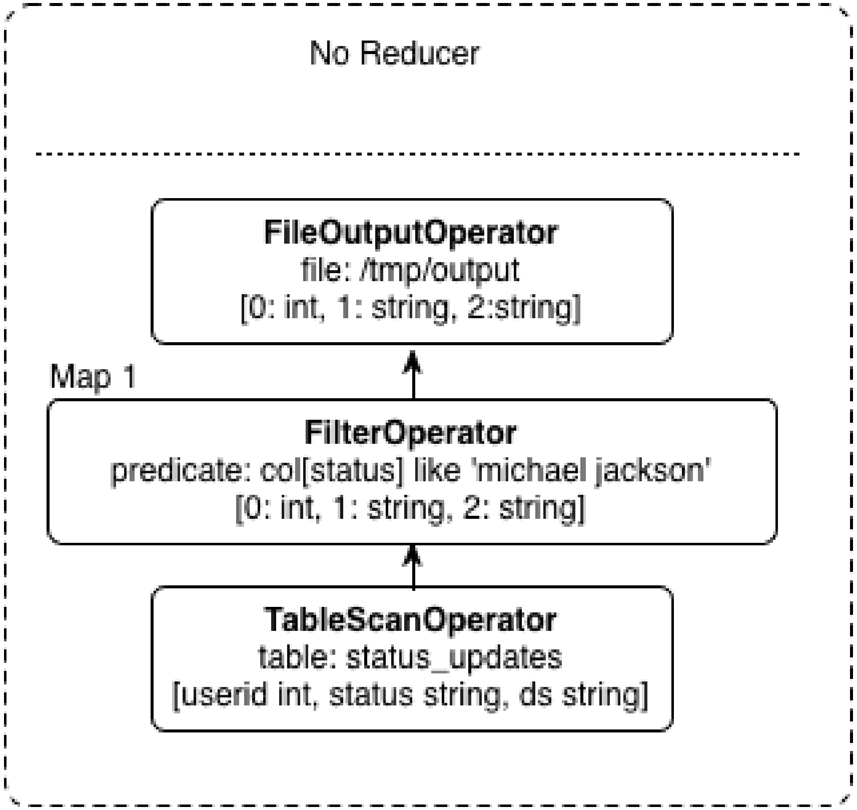
Example Query (Filter)

- Filter status updates containing ‘michael jackson’
  - SELECT * FROM status_updates WHERE status LIKE ‘michael jackson’



No Reducer

Map 1

FileOutputOperator
file: /tmp/output
[0: int, 1: string, 2:string]

FilterOperator
predicate: col[status] like 'michael jackson'
[0: int, 1: string, 2: string]

TableScanOperator
table: status_updates
[userid int, status string, ds string]

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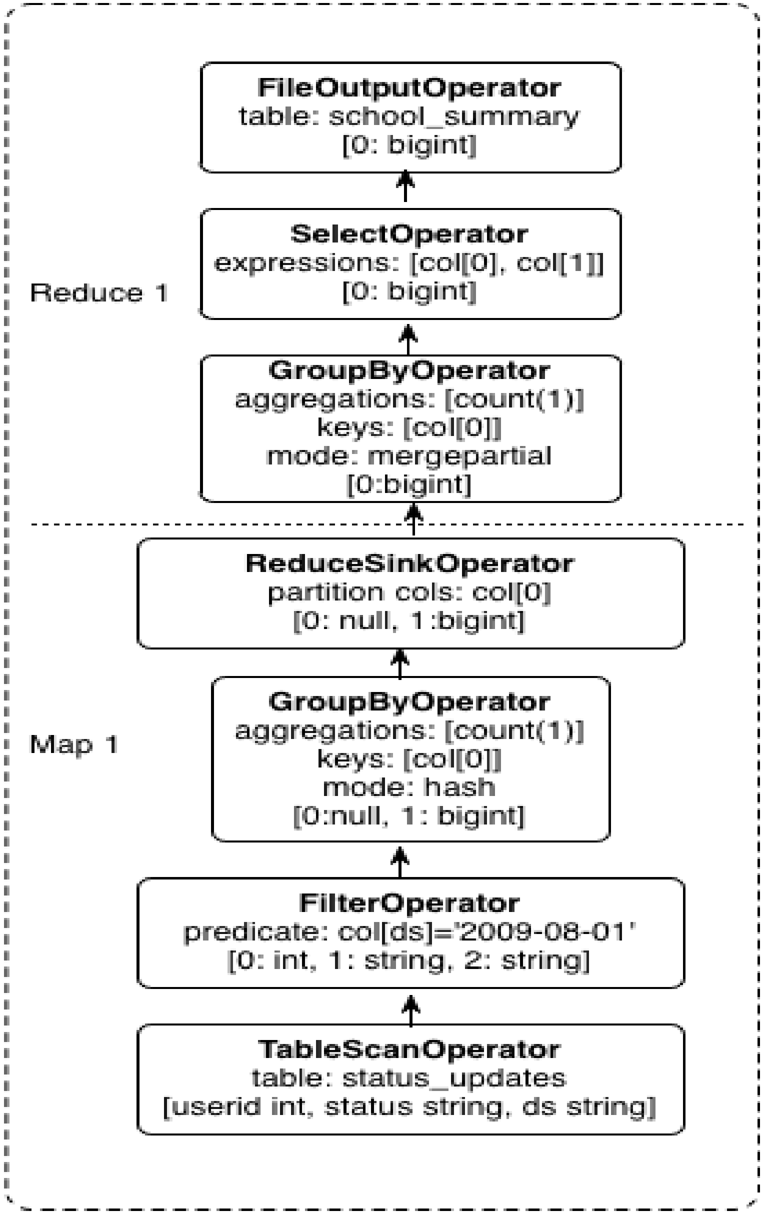
Example Query (Aggregation)

- Figure out total number of status_updates in a given day
  - SELECT COUNT(1) FROM status_updates WHERE ds = ’2009-08-01’



Example Query (multi-group-by)

```
FROM (SELECT a.status, b.school, b.gender
      FROM status_updates a JOIN profiles b
           ON (a.userid = b.userid and
               a.ds='2009-03-20' )
      ) subq1
INSERT OVERWRITE TABLE gender_summary
                       PARTITION(ds='2009-03-20')
SELECT subq1.gender, COUNT(1)
GROUP BY subq1.gender
INSERT OVERWRITE TABLE school_summary
                            PARTITION(ds='2009-03-20')
SELECT subq1.school, COUNT(1)
GROUP BY subq1.school
```

Hive Optimizations

Optimizations

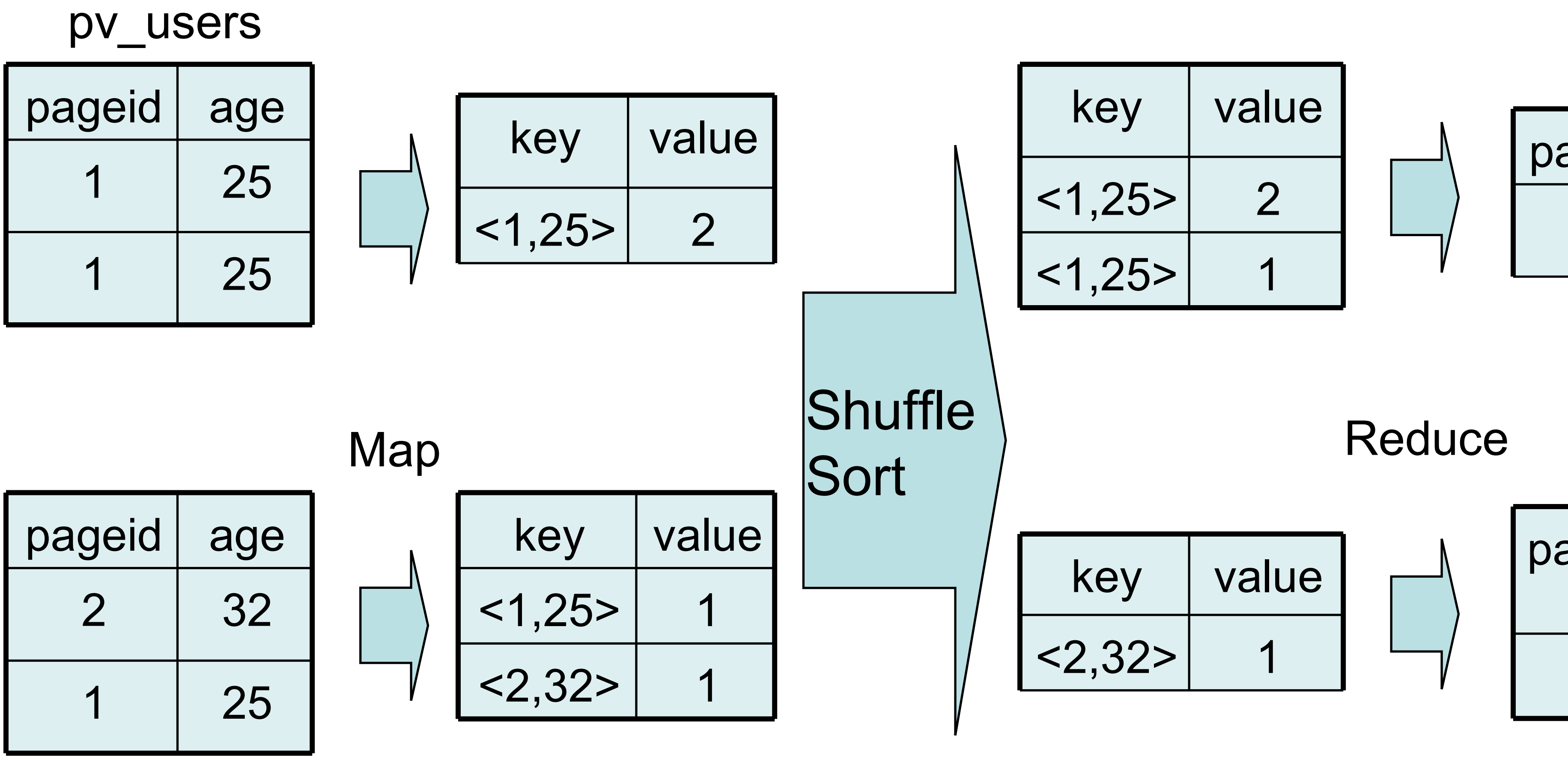
- Column Pruning
  - Also pushed down to scan in columnar storage (RCFILE)
- Predicate Pushdown
  - Not pushed below Non-deterministic functions (eg. rand())
- Partition Pruning
- Sample Pruning
- Handle small files
  - Merge while writing
  - CombinedHiveInputFormat while reading
- Small Jobs
  - SELECT * with partition predicates in the client
- Restartability (Work In Progress)

Group By Optimizations

Group By Implementation

```
SELECT pageid, age, count(1)
FROM pv_users
GROUP BY pageid, age;
```

Group By in Map Reduce



pv_users

pageid	age
1	25
1	25

key	value
<1,25>	2

pageid	age
2	32
1	25

Map

key	value
<1,25>	1
<2,32>	1

Shuffle
Sort

key	value
<1,25>	2
<1,25>	1

key	value
<2,32>	1

Reduce

Group By Optimizations

- Map side partial aggregations
  - Hash-based aggregates
  - Sort-based aggregates
- Load balancing for data skew
  - Using multiple map-reduce jobs

Multi Group By

- Same distinct key across n group-by queries

```
FROM pv_users
  INSERT OVERWRITE TABLE pv_gender_sum
          SELECT gender, count(DISTINCT userid), count(1)
     GROUP BY gender
   INSERT OVERWRITE TABLE pv_age_sum
          SELECT age, count(DISTINCT userid), count(1)
     GROUP BY age
```

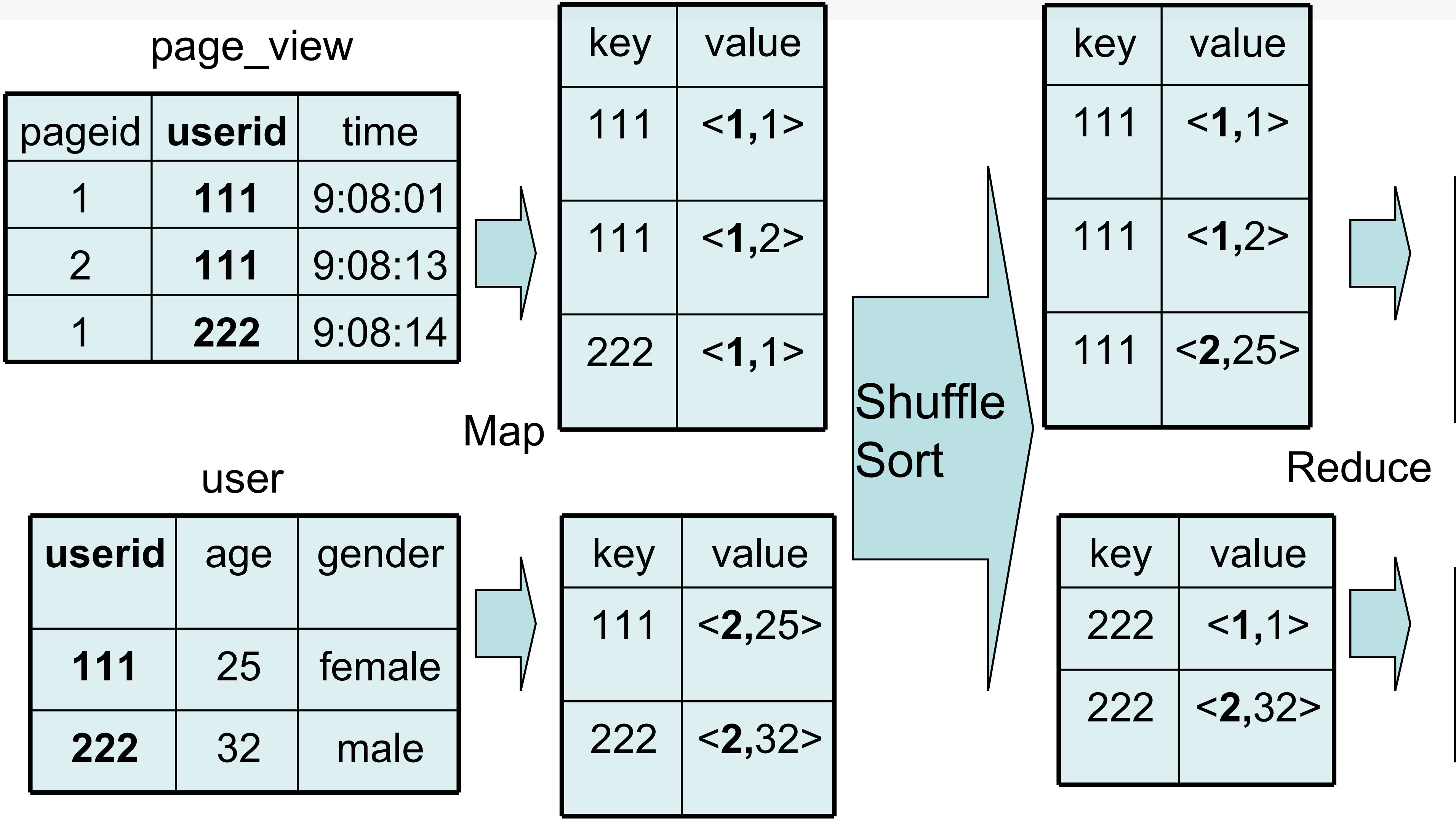
- Single scan of input table, n+1 map-reduce jobs
  - Spray/sort by userid
  - Compute partial aggregates on common reducer
  - Spray by gender and age separately

Join Optimizations

Join Implementation

```
INSERT OVERWRITE TABLE pv_users
SELECT pv.pageid, u.age
FROM page_view pv
  JOIN user u
  ON (pv.userid = u.userid);
```

Join in Map Reduce



page_view

pageid	**userid**	time
1	**111**	9:08:01
2	**111**	9:08:13
1	**222**	9:08:14

user

userid	age	gender
111	25	female
222	32	male

Map

key	value
111	<**1**,1>
111	<**1**,2>
222	<**1**,1>

key	value
111	<**2**,25>
222	<**2**,32>

Shuffle Sort

key	value
111	<**1**,1>
111	<**1**,2>
111	<**2**,25>

key	value
222	<**1**,1>
222	<**2**,32>

Reduce

Multi-way Join Optimization

-way join with same join key across all joins

```
INSERT OVERWRITE TABLE pv_users
SELECT pv.pageid, u.age
FROM page_view p JOIN user u
  ON (pv.userid = u.userid)
  JOIN newuser x on (u.userid = x.userid);
```

erge into 1 map-reduce job (OUTER joins also)

- Use n tags

map-reduce job instead of n map-reduce jobs

Bag-Join Optimizations

- By default, stream rightmost table
  - Allow hint to specify largest table (which will get streamed)
- Slight skews handled by spilling to local disk on reducer
- Large skews handled by
  - Spilling to hdfs
  - follow-up map-reduce job where skewed table is streamed

Map-Side Join Optimizations

- No reducer needed
- User specified small tables stored in hash tables (backed by local disk) on the mapper
- Bucketized join
  - If two tables are bucketized similarly on join key
- Sort-Merge join (work in progress)

Hive Extensibility Features

Hive is an open system

- Different on-disk data formats
  - Text File, Sequence File, RCFile
- Different in-memory data formats
  - Java Integer/String, Hadoop IntWritable/Text …
- User-provided map/reduce scripts
  - In any language, use stdin/stdout to transfer data …
  - Configurable serialization formats to transfer data
- User-defined Functions
  - Substr, Trim, From_unixtime …
- User-defined Aggregation Functions
  - Sum, Average …
- User-define Table Functions
  - Explode …

File Format Example

-
  ```
  CREATE TABLE mylog (
     user_id BIGINT,
     page_url STRING,
     unix_time INT)
  STORED AS TEXTFILE;
  ```

-
  ```
  LOAD DATA INPATH '/user/myname/log.txt' INTO
  TABLE mylog;
  ```

Existing File Formats

	TEXTFILE	SEQUENCEFILE	RCFILE
Data type	text only	text/binary	text/binary
Internal Storage order	Row-based	Row-based	Column-based
Compression	File-based	Block-based	Block-based
Splitable*	YES	YES	YES
Splitable* after compression	NO	YES	YES

*** Splitable: Capable of splitting the file so that a single huge file can be processed by multiple mappers in parallel.**

SerDe

- SerDe is short for serialization/deserialization. It controls the format of a row.
- Serialized format:
  - Delimited format (tab, comma, ctrl-a …)
  - Thrift Protocols
- Deserialized (in-memory) format:
  - Java Integer/String/ArrayList/HashMap
  - Hadoop Writable classes
  - User-defined Java Classes (Thrift)

SerDe Examples

-
  ```
  CREATE TABLE mylog (
    user_id BIGINT,
    page_url STRING,
    unix_time INT)
  ROW FORMAT DELIMITED FIELDS TERMINATED BY '\t';
  ```

-
  ```
  CREATE table mylog_rc (
    user_id BIGINT,
    page_url STRING,
    unix_time INT)
  ROW FORMAT SERDE
    'org.apache.hadoop.hive.serde2.columnar.ColumnarSerDe'
  STORED AS RCFILE;
  ```

Existing SerDes

	LazySimpleSerDe	LazyBinarySerDe (HIVE-640)	BinarySortable SerDe
serialized format	delimited	proprietary binary	proprietary binary sortable*
deserialized format	LazyObjects*	LazyBinaryObjects*	Writable
	ThriftSerDe (HIVE-706)	**RegexSerDe**	**ColumnarSerDe**
serialized format	Depends on the Thrift Protocol	Regex formatted	proprietary column-based
deserialized format	User-defined Classes, Java Primitive Objects	ArrayList<String>	LazyObjects*

*** LazyObjects: deserialize the columns only when accessed.**

*** Binary Sortable: binary format preserving the sort order.**

Map/Reduce Scripts Examples

```
add file page_url_to_id.py;
add file my_python_session_cutter.py;
FROM
  (SELECT TRANSFORM(user_id, page_url, unix_time)
     USING 'page_url_to_id.py'
     AS (user_id, page_id, unix_time)
   FROM mylog
   DISTRIBUTE BY user_id
   SORT BY user_id, unix_time) mylog2
SELECT TRANSFORM(user_id, page_id, unix_time)
  USING 'my_python_session_cutter.py'
  AS (user_id, session_info);
```

UDF Example

- add jar build/ql/test/test-udfs.jar;
- CREATE TEMPORARY FUNCTION testlength AS 'org.apache.hadoop.hive.ql.udf.UDFTestLength';
- SELECT testlength(src.value) FROM src;
- DROP TEMPORARY FUNCTION testlength;

- UDFTestLength.java:

```
package org.apache.hadoop.hive.ql.udf;
public class UDFTestLength extends UDF {
  public Integer evaluate(String s) {
    if (s == null) {
      return null;
    }
    return s.length();
  }
}
```

UDAF Example

-
  ```
  SELECT page_url, count(1), count(DISTINCT user_id)
  FROM mylog;
  ```

-
  ```
  public class UDAFCount extends UDAF {
    public static class Evaluator implements UDAFEvaluator {
     private int mCount;
    public void init() {mcount = 0;}
    public boolean iterate(Object o) {
      if (o!=null) mCount++; return true;}
    public Integer terminatePartial() {return mCount;}
    public boolean merge(Integer o) {mCount += o; return
  true;}
    public Integer terminate() {return mCount;}
  }
  ```

Comparison of UDF/UDAF v.s. M/R scripts

	UDF/UDAF	M/R scripts
language	Java	any language
data format	in-memory objects	serialized streams
1/1 input/output	supported via UDF	supported
n/1 input/output	supported via UDAF	supported
1/n input/output	supported via UDTF	supported
Speed	Faster (in same process)	Slower (spawns new process)

Powered by Hive

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cnet

digg

Chitika
Turning page views into profits

bizo

Grooveshark

hi5

HubSpot

last.fm

Open Source Community

- Release Candidate Hive-0.5 out on 02/23/2010
- 50+ contributors and growing
- 11 committers
  - 3 external to Facebook
- Available as a sub project in Hadoop
  - http://wiki.apache.org/hadoop/Hive (wiki)
  - http://hadoop.apache.org/hive (home page)
  - http://svn.apache.org/repos/asf/hadoop/hive (SVN repo)
  - ##hive (IRC)
  - Works with hadoop-0.17, 0.18, 0.19, 0.20
- Mailing Lists:
  - hive-{user,dev,commits}@hadoop.apache.org

Future

- Dynamic Inserts into multiple partitions
- More join optimizations
- Persistent UDFs, UDAFs and UDTFs
- Benchmarks for monitoring performance
- IN, exists and correlated sub-queries
- Statistics
- Materialized Views