Hortonworks Premier Inside-out Apache Druid

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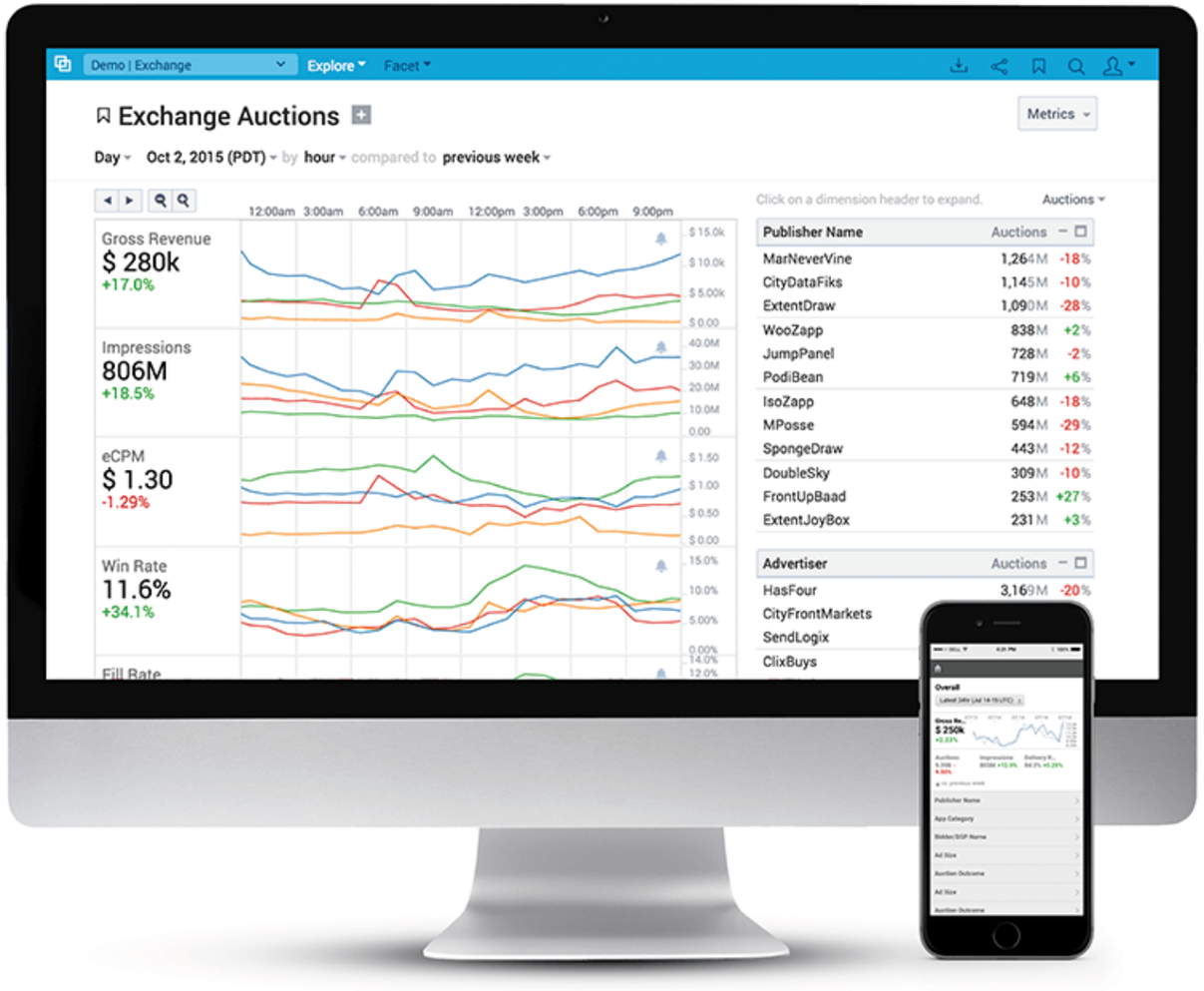
History

- Development started at Metamarkets in 2011
- Initial use case
  - power ad-tech analytics product
- Open sourced in late 2012
  - GPL licensed initially
  - Switched to Apache V2 in early 2015
- 150+ committers today




METAMARKETS
YAHOO!
PayPal
ebay
Alibaba Group
SK telecom
Time Warner Cable
CISCO
NETFLIX
LDmobile
ARCHIVE-IT
WIKIMEDIA FOUNDATION
CONDÉ NAST
ONE APM
hulu
{LIFE}BUZZ
redborder
YOUKU 优酷
Easemob IM&Service Cloud
SKYPORT SYSTEMS
gumgum
airbnb
criteo
DS DripStat
Streamlyzer
JOLATA
Making the network for you
ViralGains
DiDi
More than a journey
ITALIAONLINE
N3TWORK
YeahMobi
vigiglobe
triplelift
Optimizely
AppsFlyer
liquid
videoamp
PubNative
monetate

Why use Druid?

- Sub-second OLAP Queries
- Real-time Streaming Ingestion
- Multi-tenant with support for 1000+ users
- Cost Effective
- Highly Available
- Scalable

How’s Druid used in prod today?

Ad-hoc analytics.
High concurrency user-facing real-time slice-and-dice.
Real-time loads of 10s of billions of events per day.

Powers infrastructure anomaly detection dashboards.
Ingest rates > 2TB per hour.

Exploratory analytics on clickstream sessions.

Real-time user behavior analytics.

Druid is design for Time-Series use cases

- Time series data workload != normal database workload
  - Queries always contain date columns as group by keys
  - Queries Filters by time
  - Queries touch few columns (< 10)
  - Queries have very selective Filters (< thousands of rows out of billions)

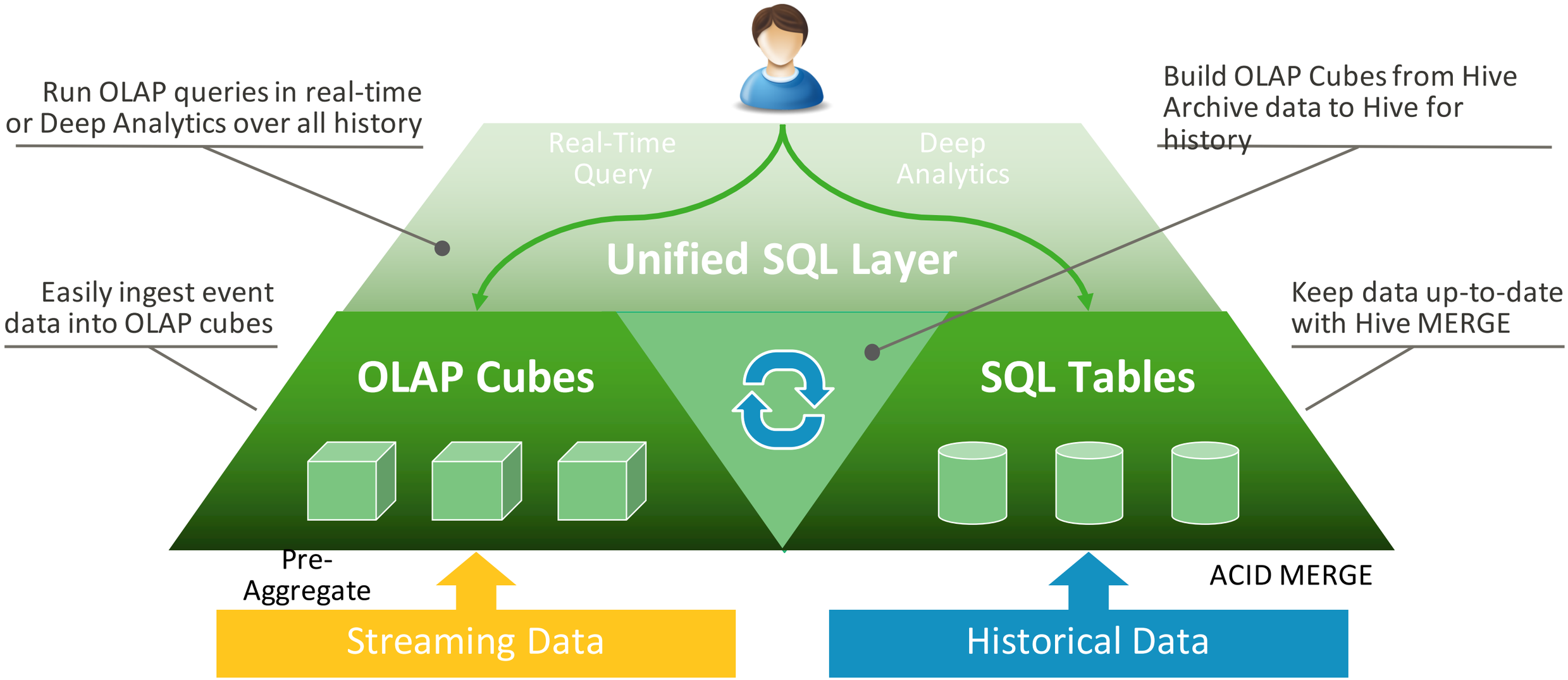
```
SELECT `user`, sum(`c_added`) AS s, EXTRACT(year FROM `__time`)
FROM druid_table
WHERE EXTRACT(year FROM `__time`)
  BETWEEN 2010 AND 2011
GROUP BY `user`, EXTRACT(year FROM `__time`)
ORDER BY s DESC
LIMIT 10;
```

Where do time series data coming from?

- Mostly an insert/append workload, very few updates
  - Event stream data
  - Application/server logs
  - Sensor logs
- Schema less
  - New event types
  - New server/application/OS type or upgrade
  - New sensors

Druid @ HDP

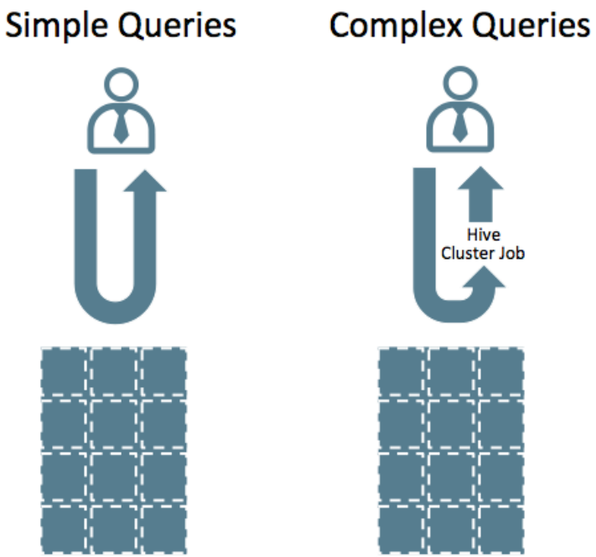
Hive + Druid = Insight When You Need It



Why Use Druid From Hortonworks?

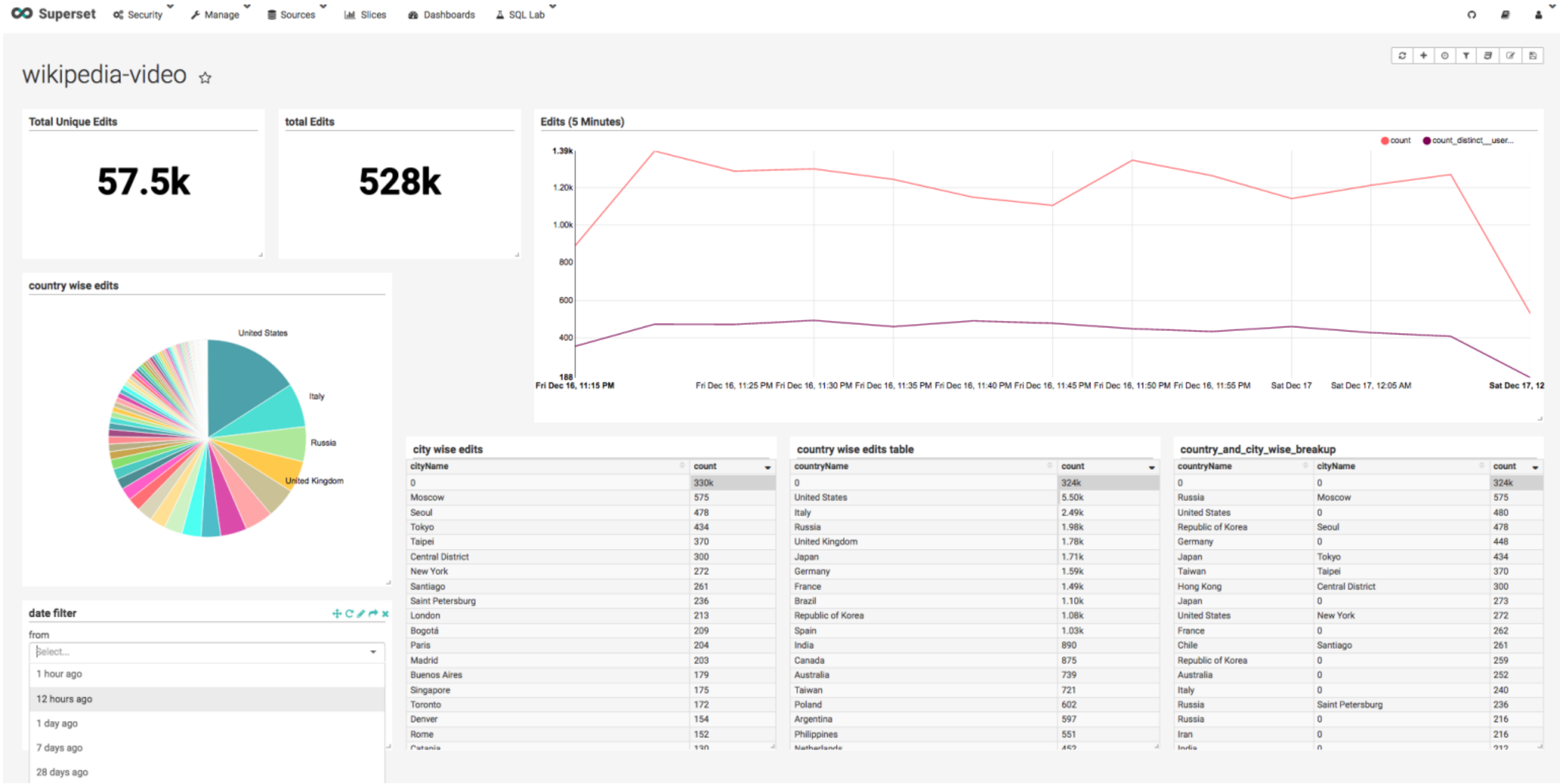
	With HDP	Druid Alone
Interactive Analytics	✓	✓
Analyze Data Streams	✓	✓
Spatial Analytics	✓	✓
Horizontally Scalable	✓	✓
SQL:2011 Interface	✓	✗
Join Historical and Real-time Data	✓	✗
Management and Monitoring with Ambari	✓	✗
Managed Rolling Upgrades	✓	✗
Visualization with Superset	✓	✗
Easy App Development with Hortonworks SAM	✓	✗

Druid-Hive integration makes things easy



Layer	Strongest Access Pattern	Features
Hive Layer	Large scale brute-force analytics	Joins Subqueries Windowing Functions Transformations Complex Aggregations Advanced Sorting UDFs
Druid Layer	Needles-in-a-haystack queries with large numbers of dimensions	Dimensional Aggregates Top N Queries Min / Max Values Timeseries Queries

Superset UI for Fast, Interactive Dashboards and Exploration



Agenda

- Druid overview
- Time series data
- Druid architecture
- Demo
- Questions

Druid Internals: Segments (indexes)

Druid is design for Time-Series use cases

- Time series data workload != normal database workload
- Queries always contain date columns as group by keys.
- Queries Filters by time
- Queries touch few columns (< 10)
- Queries have very selective Filters (< thousands of rows out of billions)

```
SELECT `user`, sum(`c_added`) AS s, EXTRACT(year FROM `__time`)
FROM druid_table
WHERE EXTRACT(year FROM `__time`)
  BETWEEN 2010 AND 2011
GROUP BY `user`, EXTRACT(year FROM `__time`)
ORDER BY s DESC
LIMIT 10;
```

Druid: Segment Data Structures

- Within a Segment:
  - Timestamp Column Group.
  - Dimensions Column Group.
  - Metrics Column Group.
  - Indexes that facilitate fast lookup and aggregation.

Timestamp | Dimensions | Metrics

Timestamp	Page	Username	Gender	City	Characters Added	Characters Removed
2011-01-01T01:00:00Z	Justin Bieber	Boxer	Male	San Francisco	1800	25
2011-01-01T01:00:00Z	Justin Bieber	Reach	Male	Waterloo	2912	42
2011-01-01T02:00:00Z	Ke$ha	Helz	Male	Calgary	1953	17
2011-01-01T02:00:00Z	Ke$ha	Xeno	Male	Taiyuan	3194	170

Data is partitioned by time !

timestamp	publisher	advertiser	gender	country	...	click	price
2011-01-01T00:01:35Z	bieberfever.com	google.com	Male	USA		0	0.65
2011-01-01T00:03:63Z	bieberfever.com	google.com	Male	USA		0	0.62
2011-01-01T00:04:51Z	bieberfever.com	google.com	Male	USA		1	0.45
2011-01-01T01:00:00Z	ultratrimfast.com	google.com	Female	UK		0	0.87
2011-01-01T02:00:00Z	ultratrimfast.com	google.com	Female	UK		0	0.99
2011-01-01T02:00:00Z	ultratrimfast.com	google.com	Female	UK		1	1.53
...							

- Time partitioned immutable partitions.
- Typically 5 Million row per segment.
- Druid segments are stored in a column orientation (only what is needed is actually loaded and scanned).

COLUMN COMPRESSION - DICTIONARIES

timestamp	publisher	advertiser	gender	country	...	click	price
2011-01-01T00:01:35Z	bieberfever.com	google.com	Male	USA		0	0.65
2011-01-01T00:03:63Z	bieberfever.com	google.com	Male	USA		0	0.62
2011-01-01T00:04:51Z	bieberfever.com	google.com	Male	USA		1	0.45
2011-01-01T01:00:00Z	ultratrimfast.com	google.com	Female	UK		0	0.87
2011-01-01T02:00:00Z	ultratrimfast.com	google.com	Female	UK		0	0.99
2011-01-01T02:00:00Z	ultratrimfast.com	google.com	Female	UK		1	1.53
...							

- Create ids
  - bieberfever.com -> 0, ultratrimfast.com -> 1
- Store
  - publisher -> [0, 0, 0, 1, 1, 1]
  - advertiser -> [0, 0, 0, 0, 0, 0]

BITMAP INDEXES

timestamp	publisher	advertiser	gender	country	...	click	price
2011-01-01T00:01:35Z	bieberfever.com	google.com	Male	USA		0	0.65
2011-01-01T00:03:63Z	bieberfever.com	google.com	Male	USA		0	0.62
2011-01-01T00:04:51Z	bieberfever.com	google.com	Male	USA		1	0.45
2011-01-01T01:00:00Z	ultratrimfast.com	google.com	Female	UK		0	0.87
2011-01-01T02:00:00Z	ultratrimfast.com	google.com	Female	UK		0	0.99
2011-01-01T02:00:00Z	ultratrimfast.com	google.com	Female	UK		1	1.53
...							

- bieberfever.com -> [0, 1, 2] -> [111000]
- ultratrimfast.com -> [3, 4, 5] -> [000111]
- Compress using Concice or Roaring (take advantage of dimension sparsity)

FAST AND FLEXIBLE QUERIES

Rows	POETS
0	JUSTIN BIEBER
1	JUSTIN BIEBER
2	KE$HA
3	KE$HA

JUSTIN BIEBER
[1, 1, 0, 0]

KE$HA
[0, 0, 1, 1]

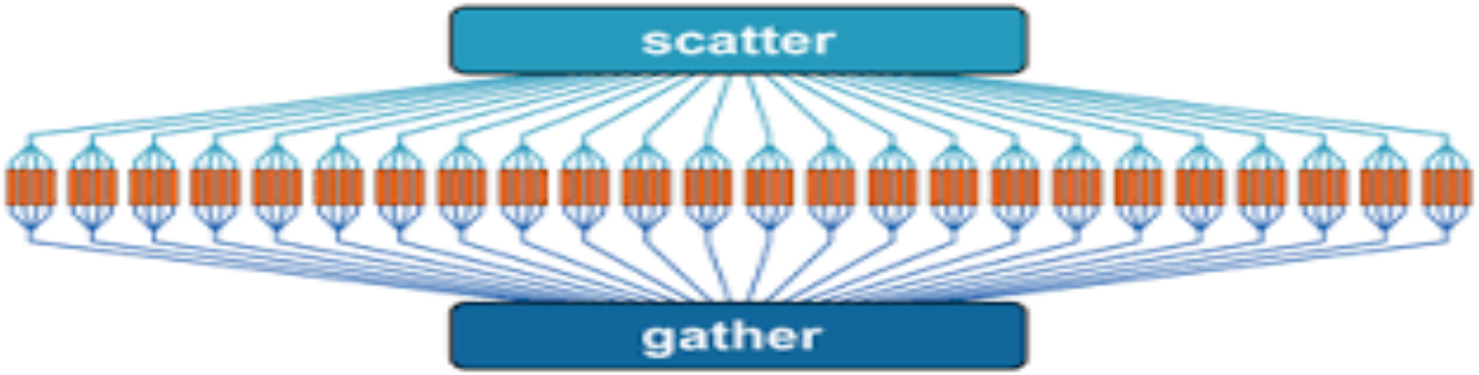
JUSTIN BIEBER
OR
KE$HA
[1, 1, 1, 1]

Queries that solely aggregate metrics based on filters do not need to touch the list of dimension values !

Druid Architecture

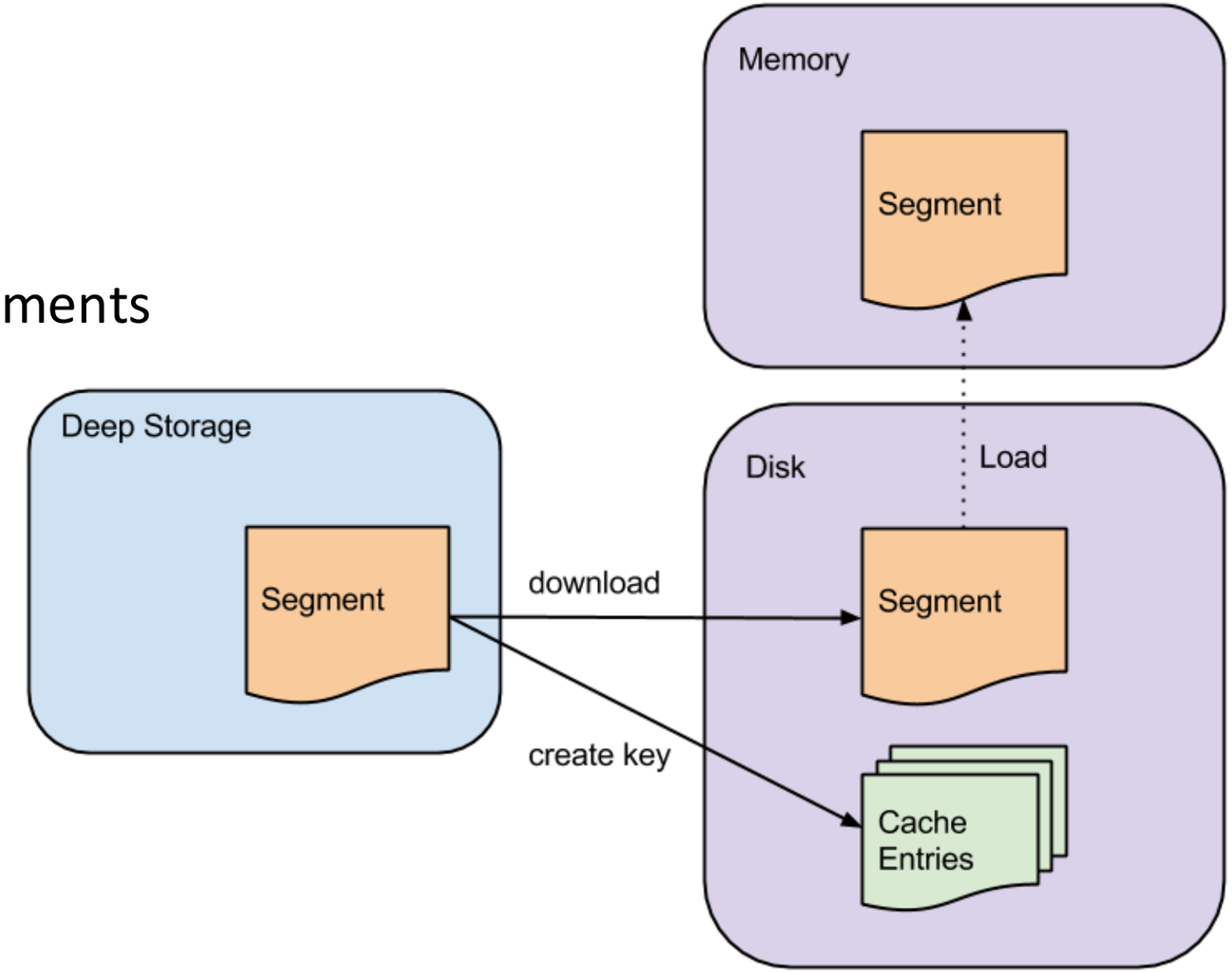
Broker Nodes

- Keeps track of segment announcements in cluster
  - (This information is kept in **Zookeeper**, much like Storm or HBase do.)
- Scatters query across historical and realtime nodes
  - (Clients issue queries to this node, but queries are processed elsewhere.)
- Merge results from different query nodes
- (Distributed) caching layer

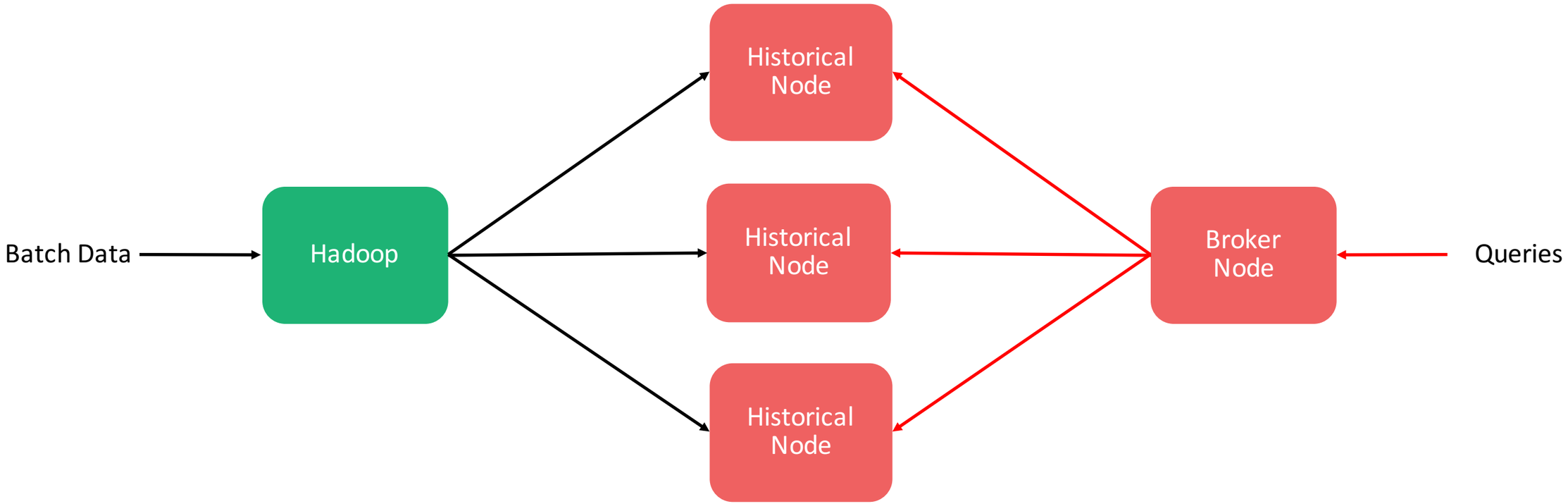


Historical Nodes

- Shared nothing architecture
- Main workhorses of druid cluster
- Load immutable read optimized segments
- Respond to queries
- Use memory mapped files to load segments

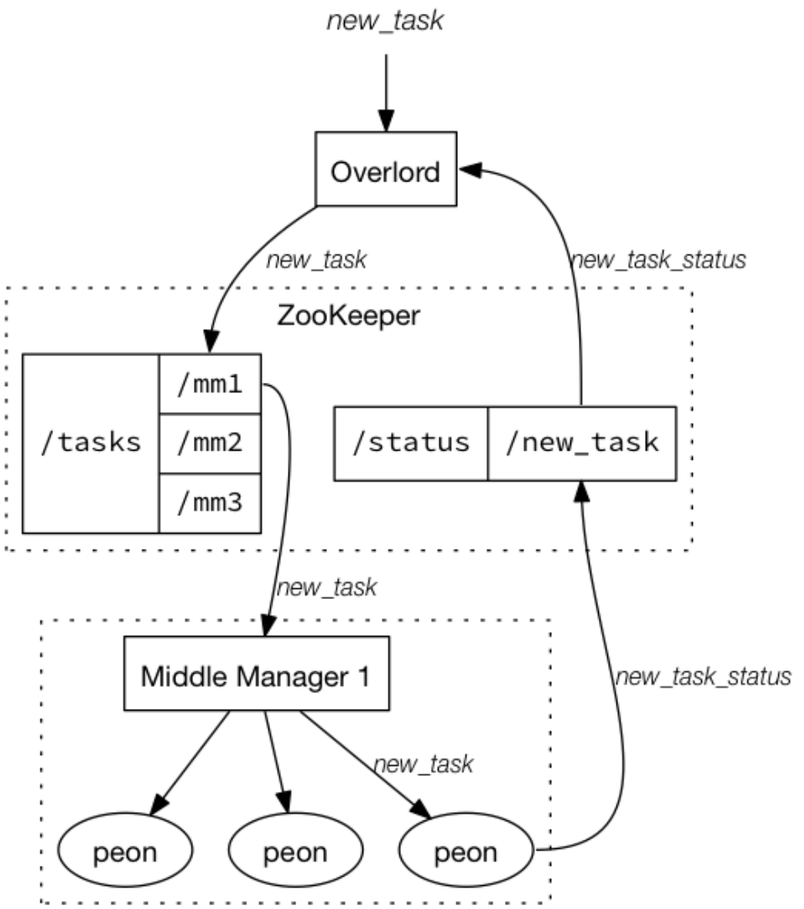


Early Druid Architecture

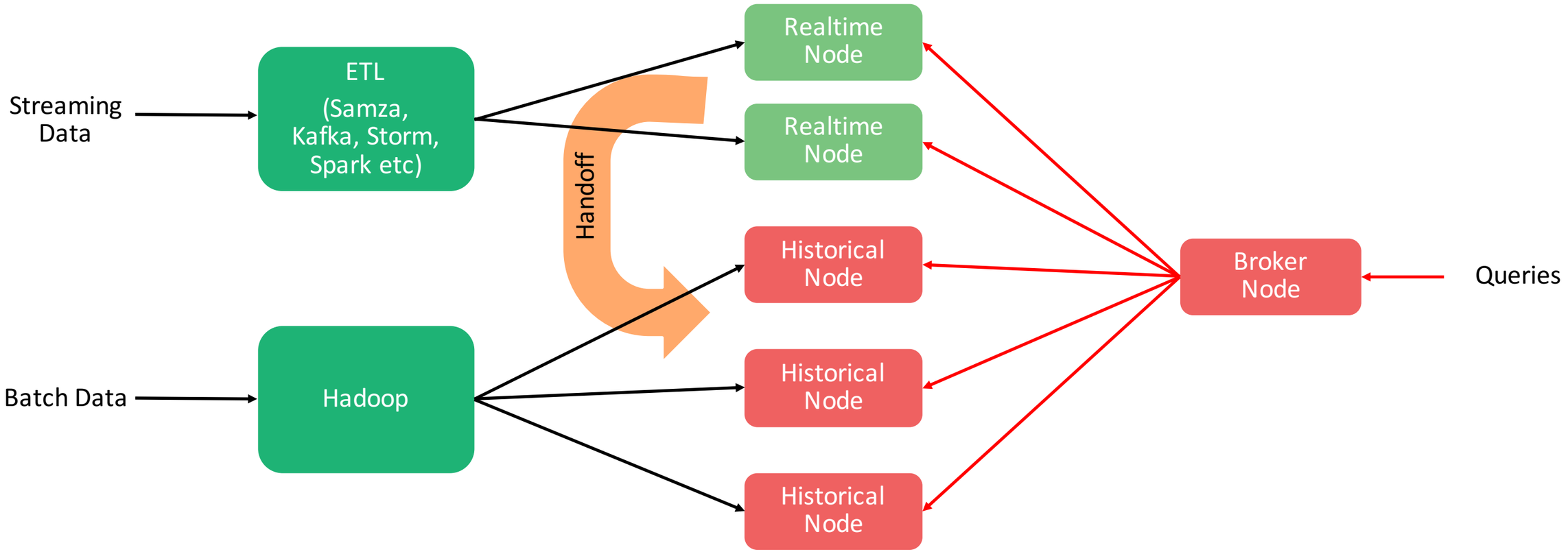


Druid: Batch Indexing

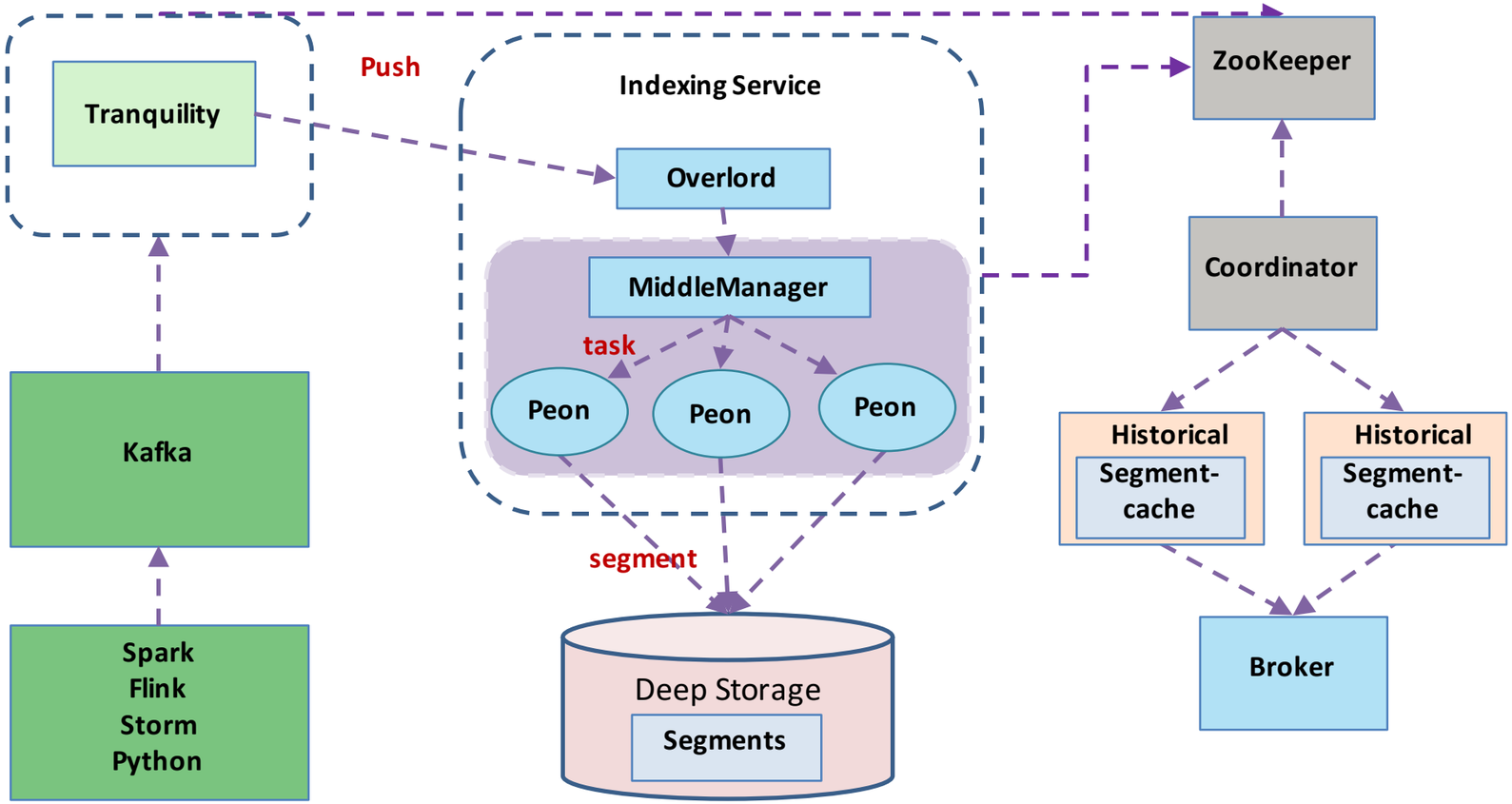
- Indexing is performed by related components:
  - Overlord (N = 1)
  - Middle Managers (N >= 1)
- Indexing is done via MapReduce jobs that build Segment files.
- Batch indexing is done on data that already exists in Deep Storage (e.g. HDFS).
- Index definition is specified via a JSON file and submitted to the Overlord.



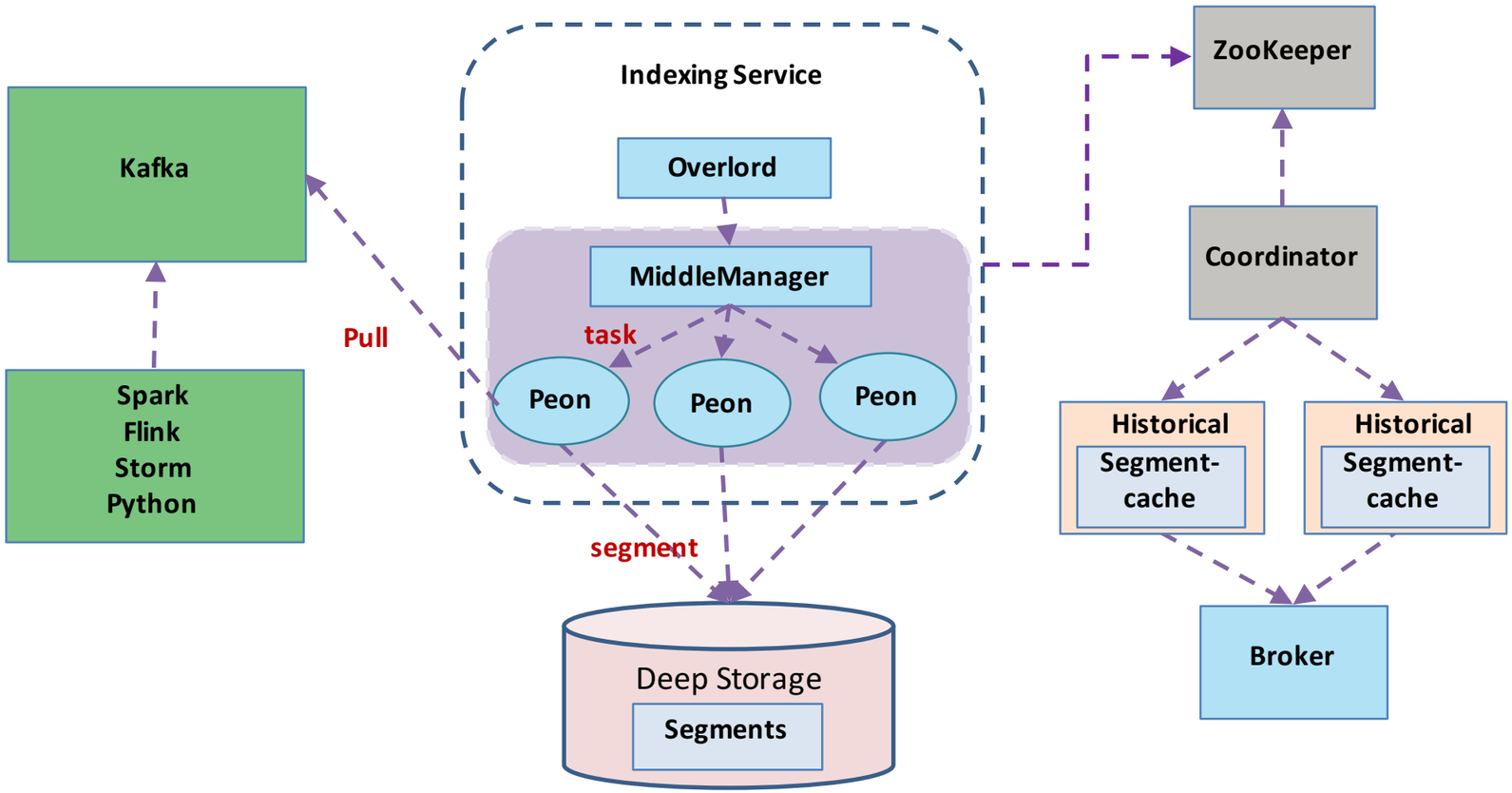
Current Druid Architecture



Druid: Realtime Indexing Push Mode

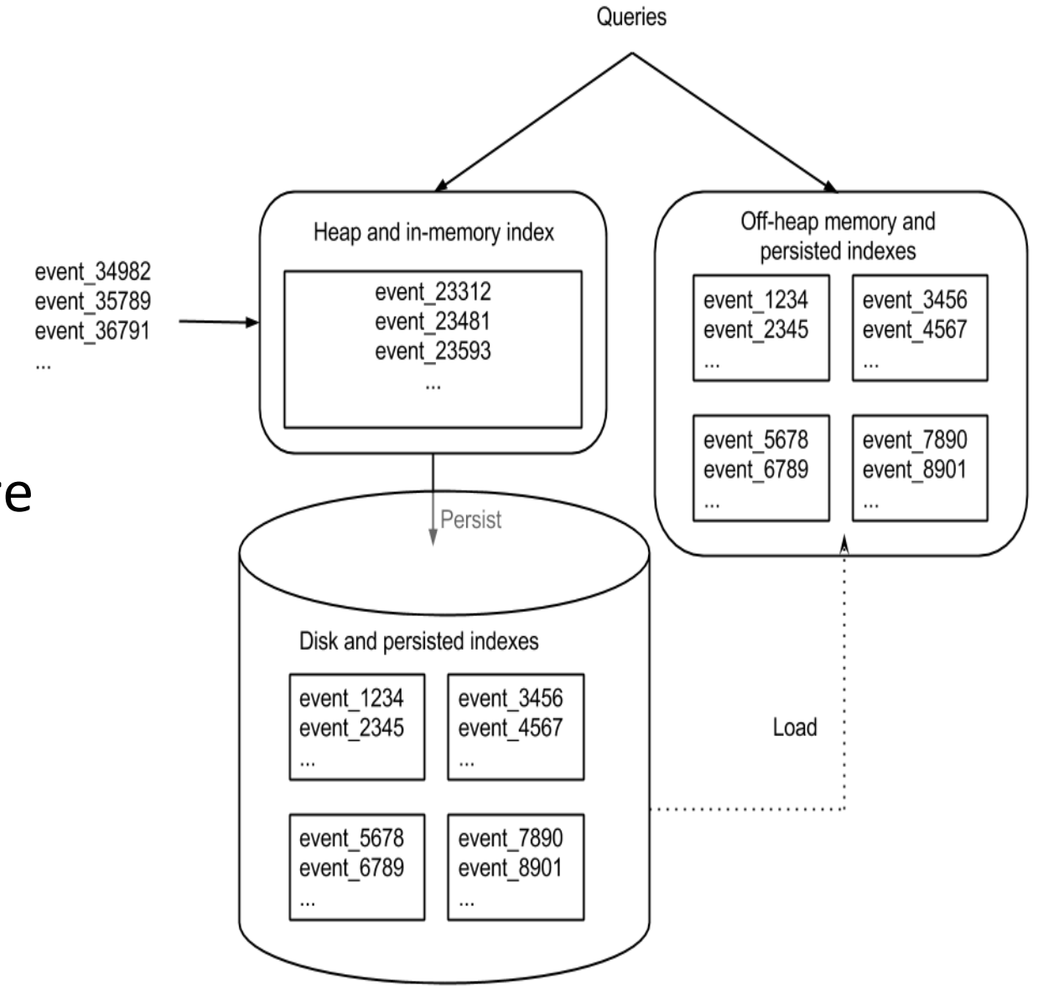


Druid: Realtime Indexing Pull Mode



Realtime Nodes

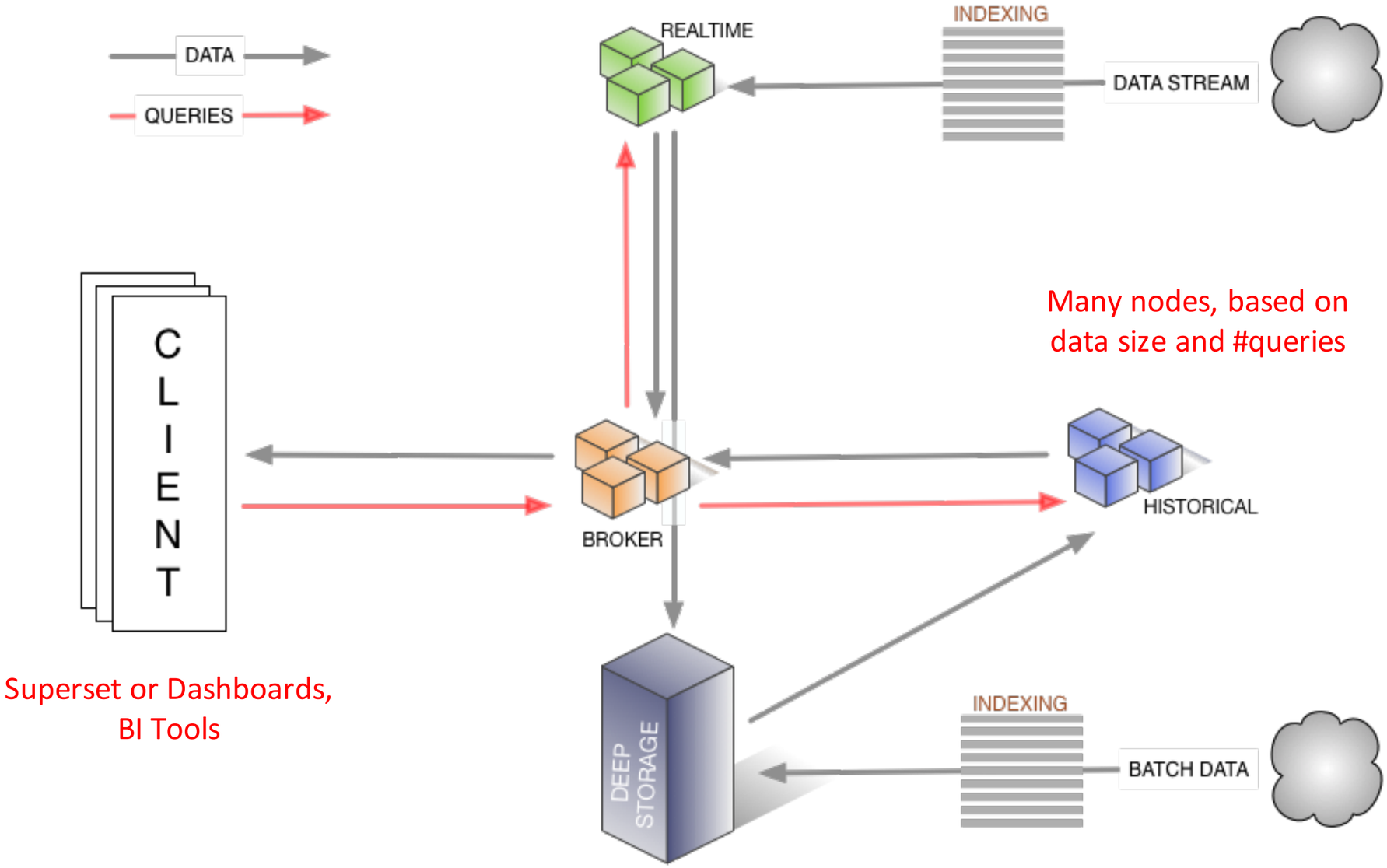
- Ability to ingest streams of data
- Both push and pull based ingestion
- Stores data in write-optimized structure
- Periodically converts write-optimized structure to read-optimized segments
- Event query-able as soon as it is ingested



Coordinator Nodes

- Assigns segments to historical nodes
- Interval based cost function to distribute segments
- Makes sure query load is uniform across historical nodes
- Handles replication of data
- Configurable rules to load/drop data

A Typical Druid Deployment



Registering and creating Druid data sources

Druid data sources in Hive

- User needs to provide Druid data sources information to Hive
- Two different options depending on requirements
  - Register Druid data sources in Hive
    - Data is already stored in Druid
  - Create Druid data sources from Hive
    - Data is stored in Hive
    - User may want to pre-process the data before storing it in Druid

Druid data sources in Hive

Registering Druid data sources

- Simple *CREATE EXTERNAL TABLE* statement

```
CREATE EXTERNAL TABLE druid_table_1
STORED BY 'org.apache.hadoop.hive.druid.DruidStorageHandler'
TBLPROPERTIES ("druid.datasource" = "wikiticker");
```

Hive table name
Hive storage handler classname
Druid data source name

  - Broker node endpoint specified as a Hive configuration parameter
  - Automatic Druid data schema discovery: *segment metadata* query

Druid data sources in Hive

Creating Druid data sources

- Use *Create Table As Select (CTAS)* statement

```
CREATE TABLE druid_table_1
STORED BY 'org.apache.hadoop.hive.druid.DruidStorageHandler'
TBLPROPERTIES ("druid.datasource" = "wikiticker", "druid.segment.granularity" = "DAY")
AS
SELECT __time, page, user, c_added, c_removed
FROM src;
```

Hive table name
Hive storage handler classname
Druid data source name
Druid segment granularity

Querying Druid data sources

Querying Druid data sources

- Automatic rewriting when query is expressed over Druid table
  - Powered by **Apache Calcite**
  - Main challenge: identify patterns in logical plan corresponding to different kinds of Druid queries (*Timeseries*, *TopN*, *GroupBy*, *Select*)
- Translate (sub)plan of operators into valid Druid JSON query
  - Druid query is encapsulated within Hive TableScan operator
- Hive TableScan uses **Druid input format**
  - Submits query to Druid and generates records out of the query results
- It might not be possible to push *all* computation to Druid
  - Our contract is that the query should always be executed

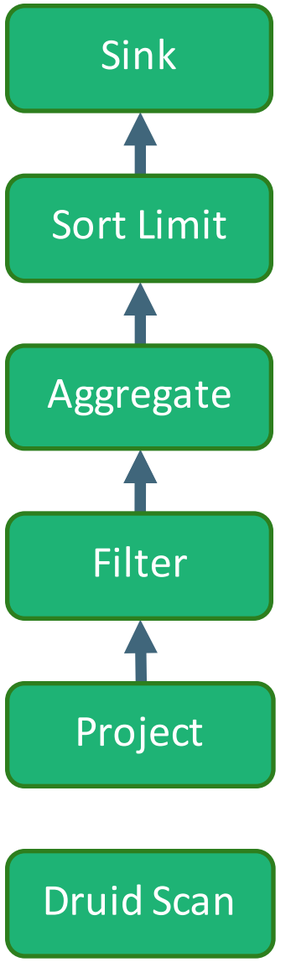
Druid query recognition (powered by Apache Calcite)

Apache Hive - SQL query

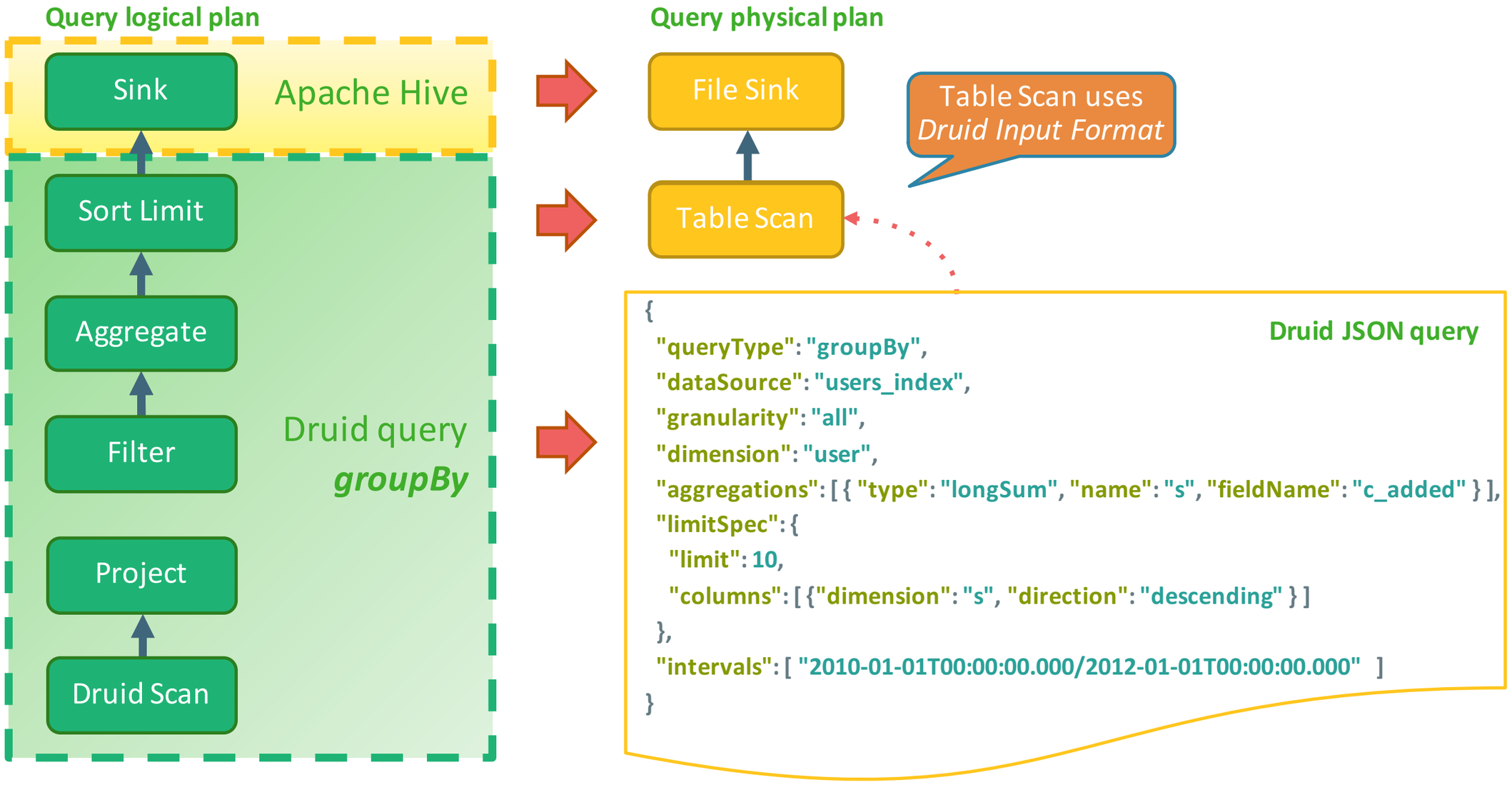
```
SELECT `user`, sum(`c_added`) AS s
FROM druid_table_1
WHERE EXTRACT(year FROM `__time`)
  BETWEEN 2010 AND 2011
GROUP BY `user`
ORDER BY s DESC
LIMIT 10;
```

- *Top 10 users that have added more characters from beginning of 2010 until the end of 2011*

Query logical plan



Physical plan transformation



Road ahead

- Tighten integration between **Druid** and **Apache Hive**/**Apache Calcite**
  - Recognize more functions → Push more computation to Druid
  - Support complex column types
  - Close the gap between semantics of different systems
    - Time zone handling, *null* values

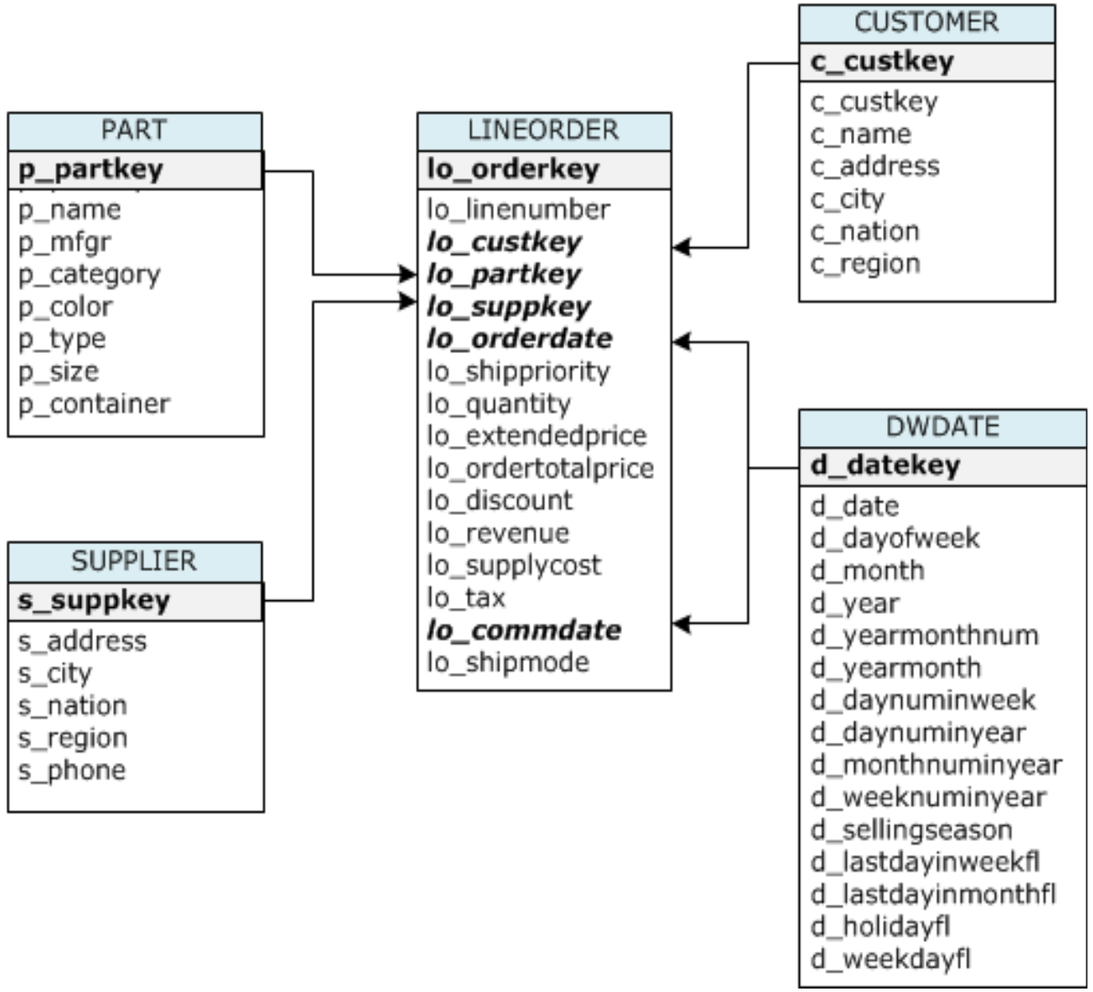
- Broader perspective
  - **Materialized views** support in Apache Hive
    - Data stored in Apache Hive
    - Create materialized view in Druid
      - Denormalized star schema for a certain time period
    - Automatic input query rewriting over the materialized view (Apache Calcite)

SSB Benchmarks

Schema and Data Model: Base Tables

Star schema benchmark

- Line order 6 billion rows
- Customer 30,000,000 rows
- Supplier 2,000,000
- Parts 1,400,000



Picture Credit

http://docs.aws.amazon.com/redshift/latest/dg/tutorial-tuning-tables-create-test-data.html

Benchmark Setup

Platform

- 11 Nodes 2x Intel(R) Xeon(R) CPU E5-2640 v2 @ 2.00GHz with 16 CPU threads each
- 256G of Ram per node
- 6x WDC WD4000FYYZ-0 1K02 4TB SCSI disks per node
- Not 100% dedicated (part of Yarn managed cluster)

Druid

- 10 / 5 /3 Historical nodes (Workhorse)
  - -Xmx12g -Xms12g -XX:NewSize=6g -XX:MaxNewSize=6g -XX:MaxDirectMemorySize=128g
- 1 node Broker
  - -Xmx25g -Xms25g -XX:NewSize=6g -XX:MaxNewSize=6g -XX:MaxDirectMemorySize=64g
- No segments replication
  - Query to server mapping is one to one
- No caching
- No Tuning out of the box configuration

Schema and Data Model: Denormalized Table in Druid

- 6 Billion rows (no Rollups)
- 174 GB over 7 years
- Segmented by month
  - One partition is worth 1/9 month of data
  - 10 Million rows per partition
  - Segment size ~ 262 MB
  - 9 Million rows per partition
  - 707 partitions in total

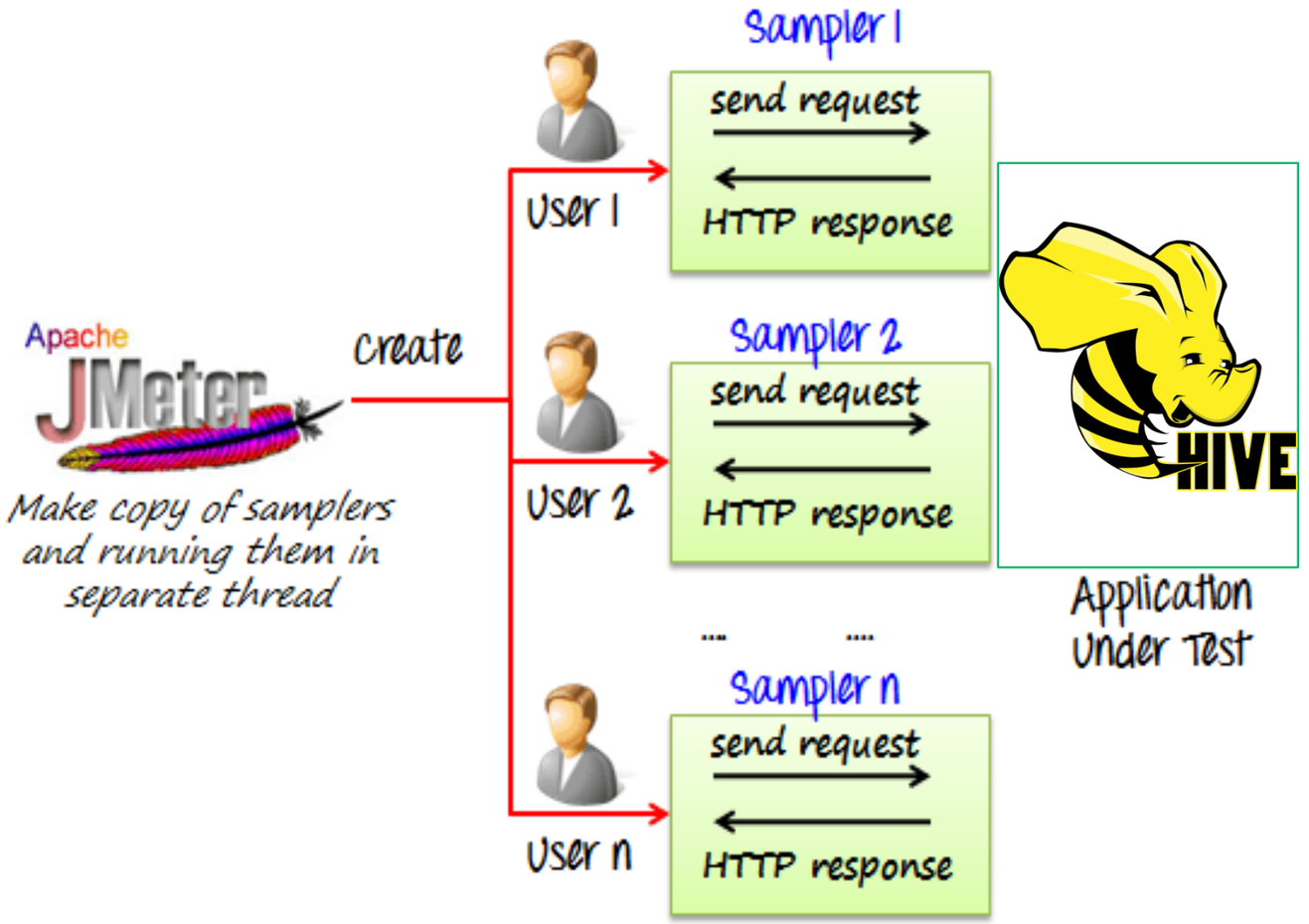
```
CREATE TABLE ssb_druid_month
STORED BY 'org.apache.hadoop.hive.druid.DruidStorageHandl
TBLPROPERTIES (
  "druid.datasource" = "ssb_druid",
  "druid.segment.granularity" = "MONTH",
  "druid.query.granularity" = "DAY")
AS
SELECT
  cast(d_year || '-' ||
       d_monthnuminyear || '-' ||
       d_daynuminmonth as timestamp) as '__time',
  cast(c_city as string) c_city,
  cast(c_nation as string) c_nation,
  cast(c_region as string) c_region,
  cast(d_weeknuminyear as string) d_weeknuminyear,
  cast(d_year as string) d_year,
  cast(d_yearmonth as string) d_yearmonth,
  cast(d_yearmonthnum as string) d_yearmonthnum,
  cast(lo_discount as string) lo_discount,
  cast(lo_quantity as string) lo_quantity,
  cast(p_brand1 as string) p_brand1,
  cast(p_category as string) p_category,
  cast(p_mfgr as string) p_mfgr,
  cast(s_city as string) s_city,
  cast(s_nation as string) s_nation,
  cast(s_region as string) s_region,
  lo_revenue,
  lo_extendedprice * lo_discount discounted_price,
  lo_revenue - lo_supplycost net_revenue
FROM
  ssb_1000_flat_orc.customer, ssb_1000_flat_orc.dates,
  ssb_1000_flat_orc.lineorder,
  ssb_1000_flat_orc.part, ssb_1000_flat_orc.supplier
where
  lo_orderdate = d_datekey and lo_partkey = p_partkey
and lo_suppkey = s_suppkey and lo_custkey = c_custkey;
```


SSB Queries

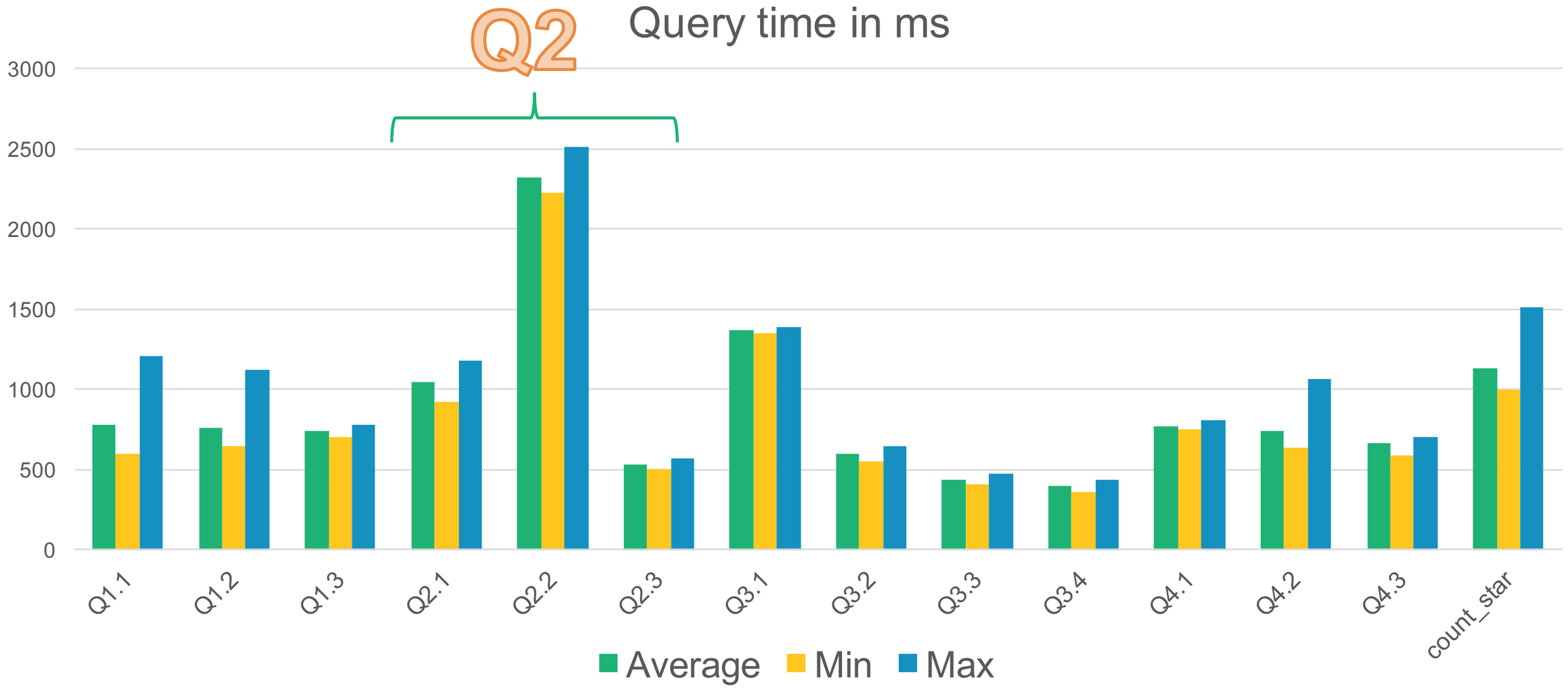
- Q1 (Quick metrics) the amount of revenue increase that would have resulted from eliminating certain company
  - No Group by
  - Years to weeks of data
- Q2 (Product sales insights) compares revenue for some product classes, for suppliers in a certain region, grouped by more restrictive product classes and all years of orders.
  - Couple of Group by keys
  - All data to one month
  - Less selective to very selective filter
- Q3 (Customer insights) revenue volume by customer nation and supplier nation and year within a given region, in a certain time period
  - Greater than 3 Group by keys
  - Years of data
- Q4 "What-If" sequence, of the OLAP type
  - Same as Q3

Benchmark execution setup

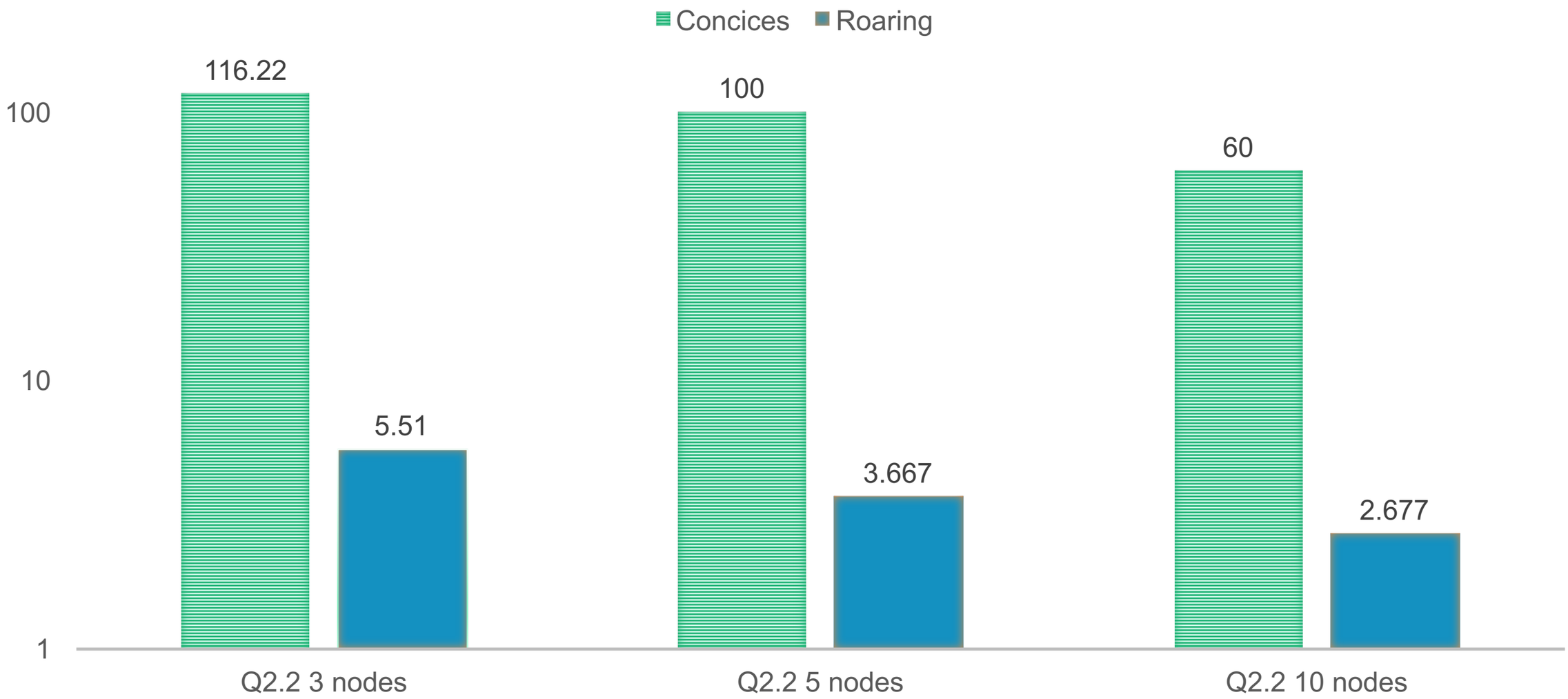
- Run using Apache Jmeter
- Every Query run 15 times capture Min/Max/AVG/STD
- Query time includes JDBC overhead
- Launch a warmup query first to initialize the metadata
- Concurrency mode Launches multiple threads via different JDBC connections
- Druid 0.9.2 (HDP 2.6)
- Hive 2.1 (HDP 2.6)



Q1.1 ({*}, {yearLevel = 1993, 1 < discountLevel < 3, quantityLevel < 25}, {sum_revenue})
Q1.2 ({*}, {yearmonthnumLevel = 199401, 4 < discountLevel < 6, 26 < quantityLevel < 35}, {sum_revenue})
Q1.3 ({weeknuminyearYearLevel}, {5 < discountLevel < 7, 26 < quantityLevel < 35}, {sum_revenue})

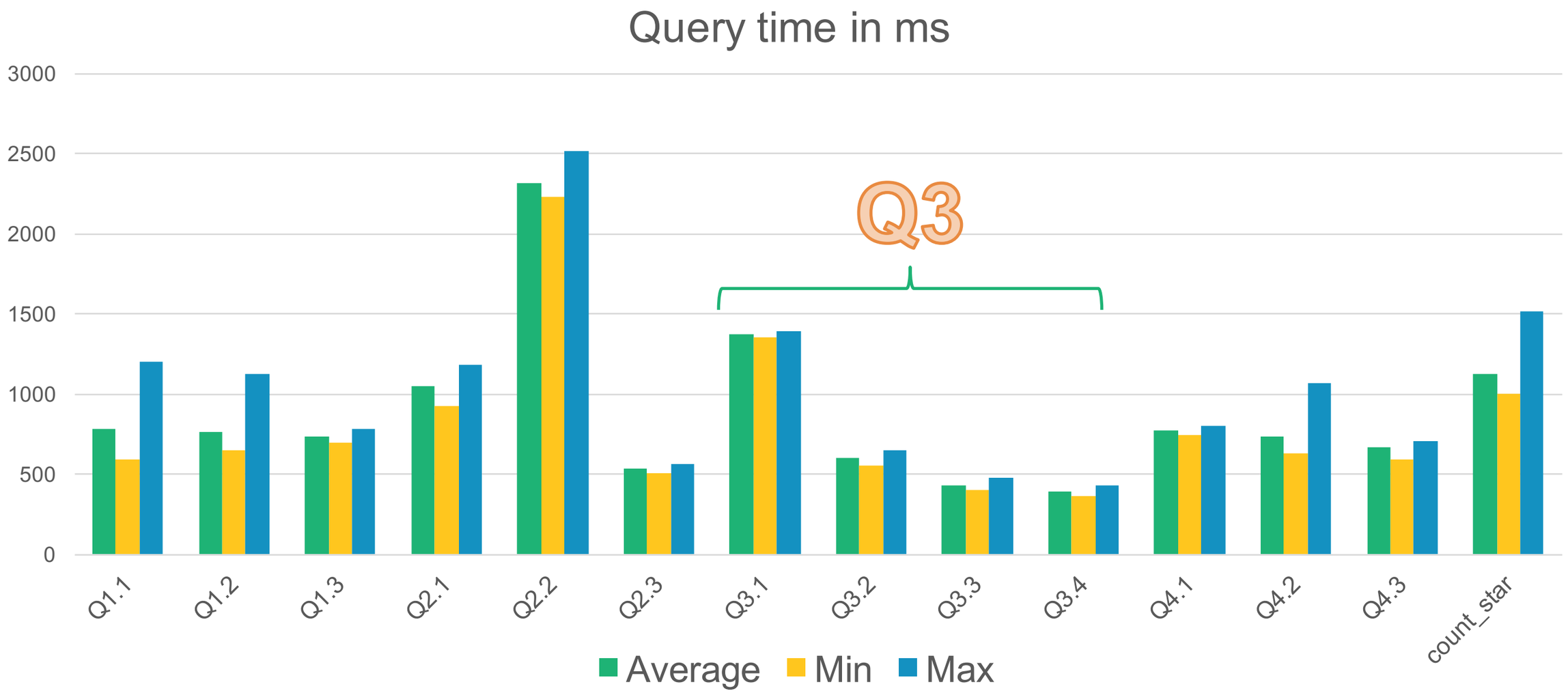


(4) ({yearLevel, brand1Level}, {categoryLevel = MFGR#12, s_regionLevel = AMERICA}, {lo_revenue})
(5)({yearLevel, brand1Level, s_regionLevel}, {brand1Level = MFGR#2221 OR ... OR brand1level = MFGR#2228,
gionLevel = ASIA}, {lo_revenue})
(6)({yearLevel, brand1Level, s_regionLevel}, {brand1Level = MFGR#2239, s_regionLevel = EUROPE}, {lo_revenue})

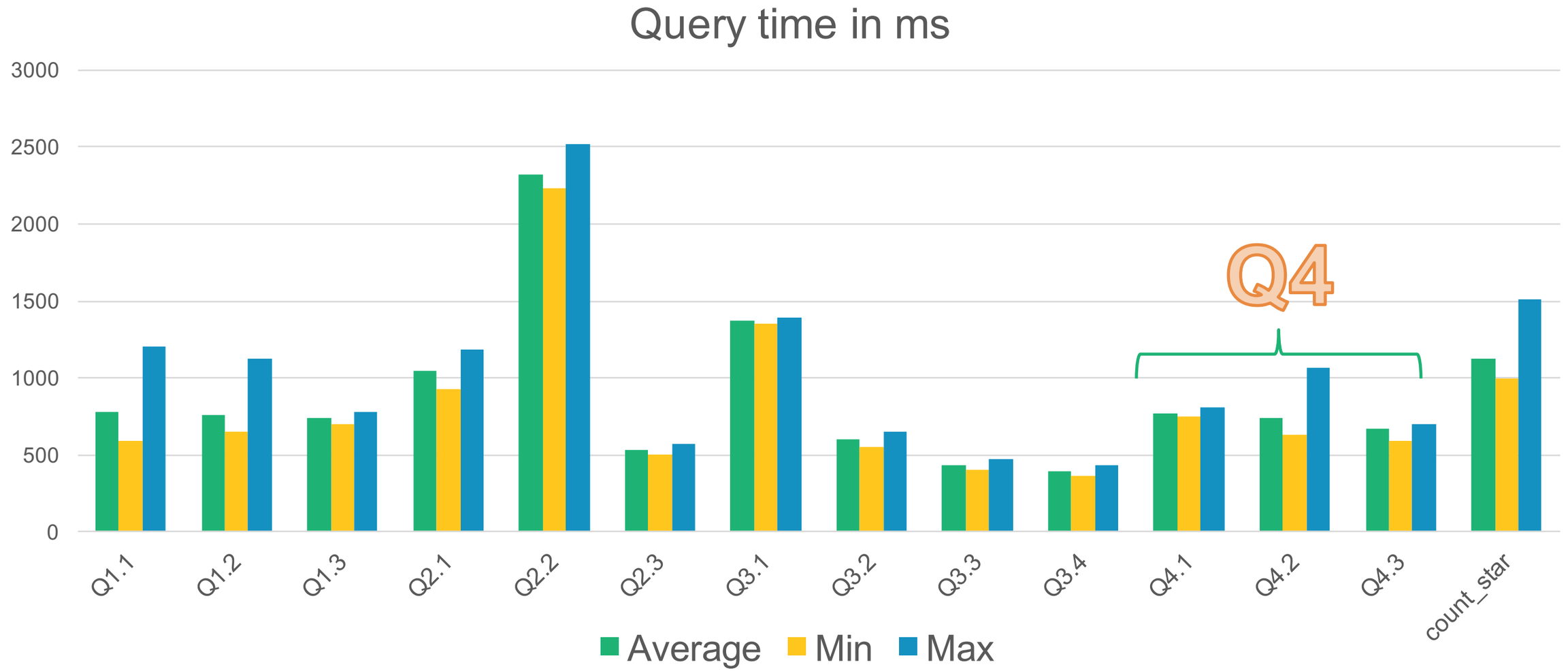


Q2.2 (5)({yearLevel, brand1Level, s_regionLevel}, {brand1Level = MFGR#2221 OR ... OR brand1level = MFGR#2228, s_regionLevel = ASIA}, {lo_revenue})

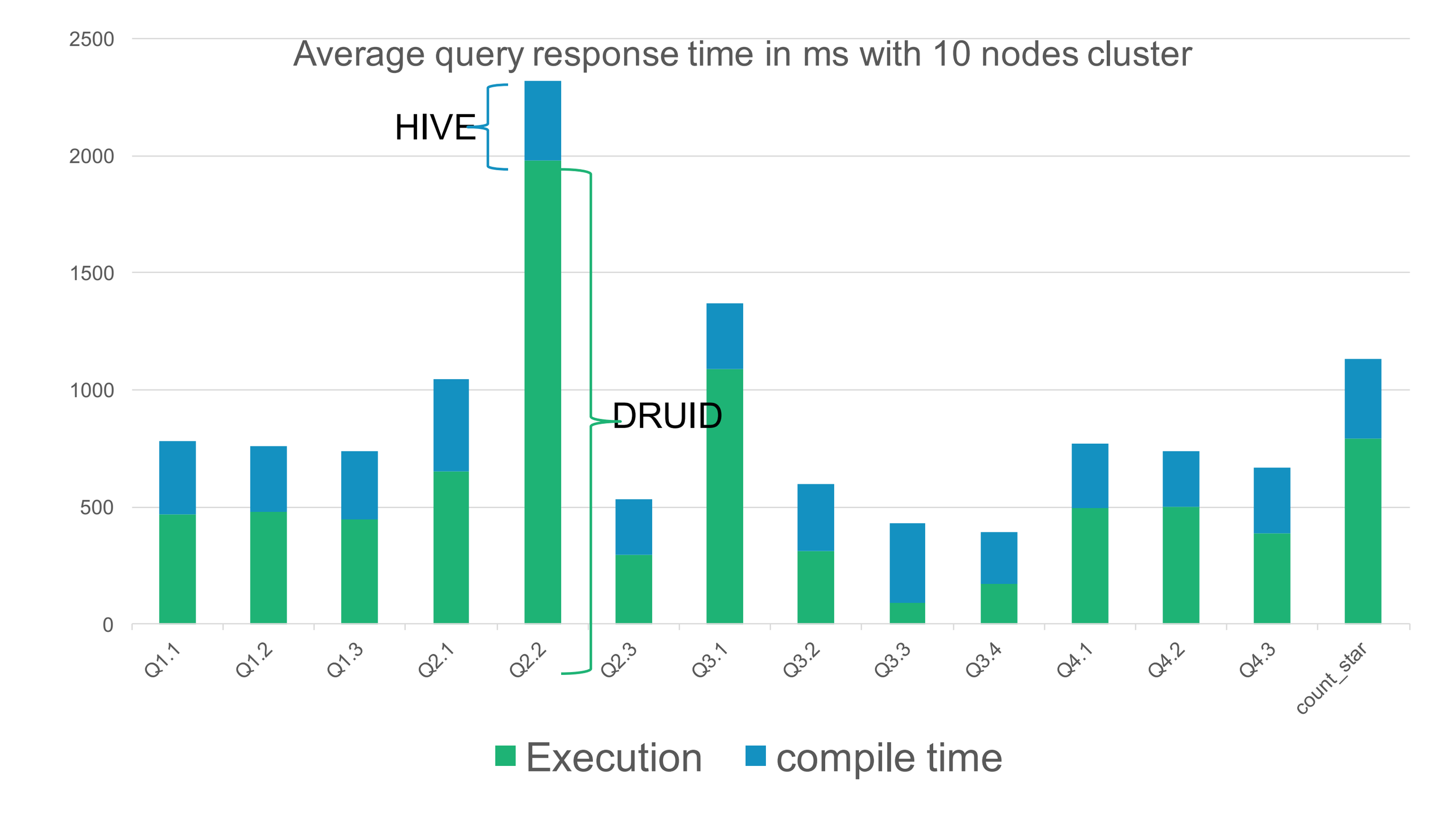
Union of bitmaps



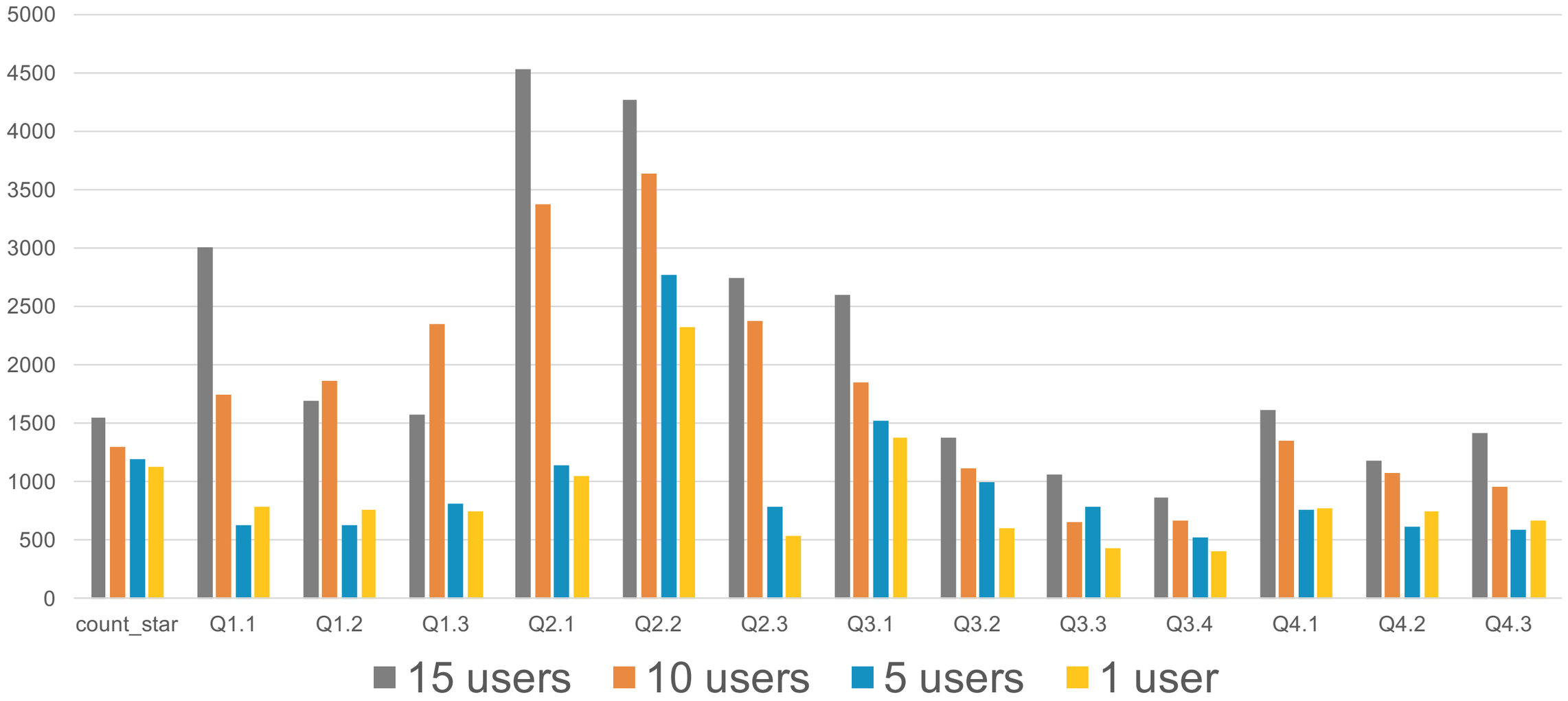
1 (7)({yearLevel, c_nationLevel,s_nationLevel}, {1992 ≤ yearLevel ≤ 1997, c_nationLevel = ASIA, s_nationLevel = ASIA}, {lo_revenue})
2 (8)(yearLevel, c_cityLevel, s_cityLevel}, {5Y, c_nationLevel = UNITED STATES, s_nationLevel = UNITED STATES}, {lo_revenue})
3 (9)(same as 3.2, {5Y, c_cityLevel = UNITED KI1 OR c_cityLevel = UNITED KI5, s_cityLevel = UNITED KI1 OR s_cityLevel = UNITED KI5}, revenue})
4 (10)({yearmonthLevel, c_cityLevel, s_cityLevel}, {yearmonthLevel = Dec1997, c_cityLevel = UNITED KI1 or c_cityLevel = UNITED KI5, tyLevel = UNITED KI1 or s_cityLevel = UNITED KI5}, {lo_revenue})



Q4.1 (11)({yearLevel, c_nationLevel, mfgrLevel, s_regionLevel}, {c_regionLevel = AMERICA, mfgrLevel = MFGR#1 OR mfgrLevel = MFGR#2, s_region = AMERICA}, {sum_profit})
Q4.2 (12)({yearLevel, c_regionLevel, categoryLevel, s_nationLevel}, {yearLevel = 1997 OR yearLevel = 1998, c_regionLevel = AMERICA, mfgrLevel = MFGR#1 OR mfgrLevel = MFGR#2 , s_regionLevel = AMERICA}, {sum_profit})
Q4.3 (13)({yearLevel, regionLevel, categoryLevel, cityLevel}, {yearLevel = 1997 OR yearLevel = 1998, c_regionLevel = AMERICA, categoryLevel = MFGR#14, s_region = UNITED STATES}, {sum_profit})


Average query response time in ms with 10 nodes cluster
HIVE
DRUID
2500
2000
1500
1000
500
0
Q1.1
Q1.2
Q1.3
Q2.1
Q2.2
Q2.3
Q3.1
Q3.2
Q3.3
Q3.4
Q4.1
Q4.2
Q4.3
count_star
Execution
compile time

Concurrency Test: Average execution time in ms
10 node cluster



- Every user is connecting via different JDBC connection.