TPC-DS and Apache Beam - the time has come!

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beam

⚠️WARNING #1

This is a **Work In Progress (WIP)** presentation

Lots of early progress but also still lots of things to be done

Motivation: Beam Overhead Performance FUD or Reality?

User Reports of Performance Issues

Beam / BEAM-9440

Performance Issues with Beam Runners compared with Native Systems

Edit | Comment | Assign | More | Start Progress | Resolve issue | Need more information

Details

Type:	Bug	Status:	OPEN
Priority:	P3	Resolution:	Unresolved
Affects Version/s:	None	Fix Version/s:	None
Component/s:	runner-apex, runner-flink, runner-spark		
Labels:	None		

Description

While doing a performance evaluation of Apache Beam with Spark Runner - I found that even for a simple word count problem on a text file – Beam with Spark runner was slower by a factor of 5 times as compared to Spark for a dataset as small as 14 GB.

Our employer (product team comments)

"Previewing the result of pipelines takes too much time (~30s for tiny data)"
Anonymous Software Engineer #1

"Running jobs takes too long"
Anonymous QA Engineer #1

Quantitative Impact Evaluation of an Abstraction Layer for Data Stream Processing Systems

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Abstract—**With the demand to process ever-growing data volumes, a variety of new data stream processing frameworks have been developed. Moving an implementation from one such system to another, e.g., for performance reasons, requires adapting existing applications to new interfaces. Apache Beam addresses these high substitution costs by providing an abstraction layer that enables executing programs on any of the supported streaming frameworks. In this paper, we present a novel benchmark architecture for comparing the performance impact of using Apache Beam on three streaming frameworks: Apache Spark Streaming, Apache Flink, and Apache Apex. We find significant performance penalties when using Apache Beam for application development in the surveyed systems. Overall, usage of Apache Beam for the examined streaming applications caused a high variance of query execution times with a slowdown of up to a factor of 58 compared to queries developed without the abstraction layer. All developed benchmark artifacts are publicly**

Apache Beam [2], which provides a unified programming model for describing both batch and streaming data-parallel processing pipelines. Pipelines are described using a single Software Development Kit (SDK) and can then be executed by a variety of different frameworks, without developers needing detailed knowledge of the employed implementations. Thus, execution frameworks can be exchanged without the need to adapt code. As an additional benefit, Apache Beam enables to benchmark multiple systems with a single implementation. Conceptually, this idea can be compared to object-relational mapping (ORM), where data stored in database tables is encapsulated in objects. Data can be queried and manipulated just by using these objects instead of writing SQL [3].

A question concerning abstraction layers is if their usage has

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Guenter Hesse*, Christoph M

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encapsulated in objects. Data can be queried and manipulated just by using these objects instead of writing SQL [3].

A question concerning abstraction layers is if their usage has

* This is worse case but paper highlights an average 3-7X overhead

The eternal question:

What is the overhead of Beam?

Let’s run a benchmark to find out…

“If you can’t measure it, you can’t improve it.”

⚠️WARNING #2

Performance results can be HEAVILY biased

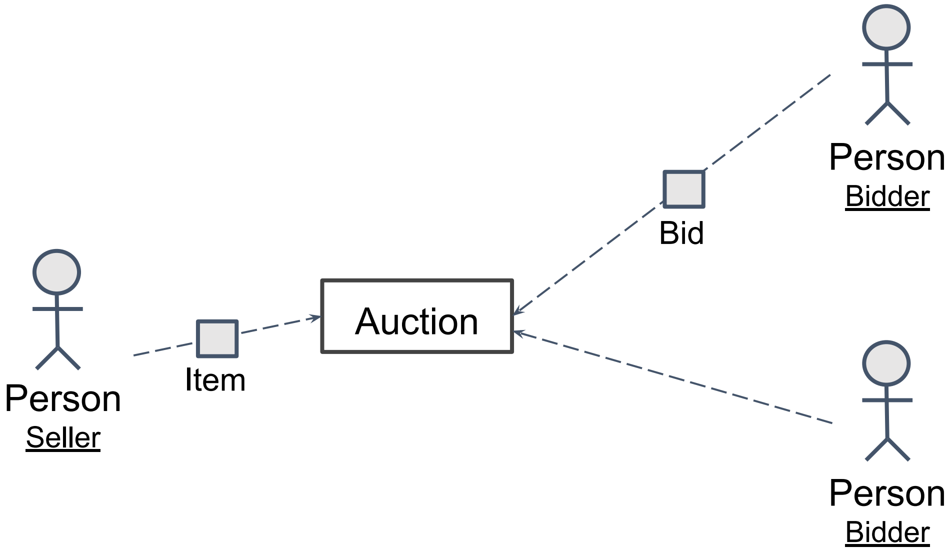
Benchmarketing. Convenient narrative (my project as the winner)
Results not reproducible or worse backed by any data

Is Raw Performance the only thing that matters?

- Correctness
- Reliability
- Price

Nexmark (current Beam benchmark)

Benchmark for queries over data streams
Online Auction System



Example:
Query 4: What is the average selling price for each auction category?

Nexmark

8 (+5) benchmark queries of a continuous processing system

- Continuous queries a good match for the Beam Model
- Run regularly on Beam and helped find MANY issues + regressions

but

- Not ran at scale (*mea culpa - Ismaël*)
- Unpublished research paper (not Industry standard)
- You cannot compare results with other systems

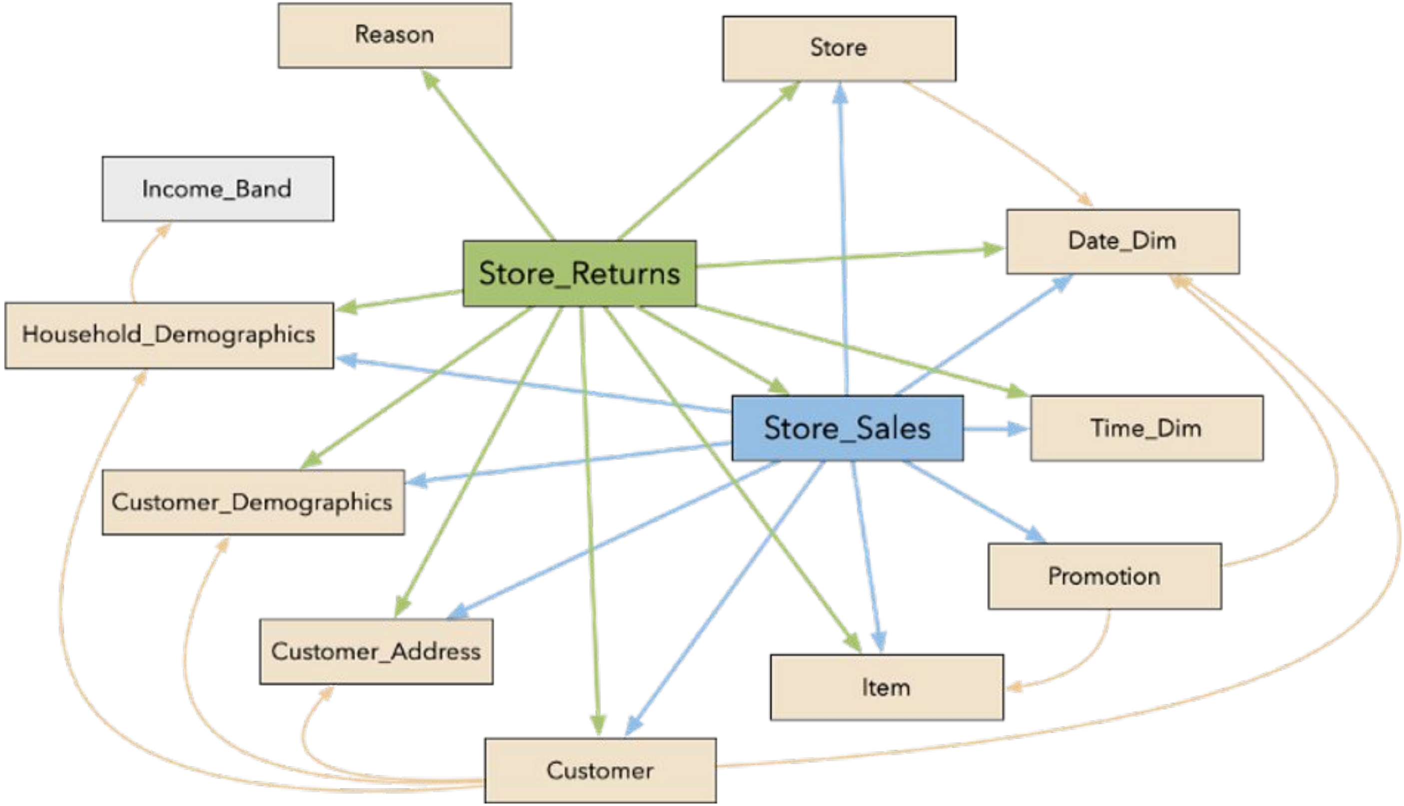
What is TPC-DS?

TPC-DS Benchmark

TPC-DS is a decision support benchmark that models several generally applicable aspects of a decision support system, including queries and data maintenance.

- Industry standard benchmark (OLAP/Data Warehouse)
  - http://www.tpc.org/tpcds/
- Implemented for many analytical processing systems
  - RDBMS, Apache Spark, Apache Flink, etc
- Wide range of different queries (SQL)
- Existing tools to generate input data of different sizes

TPC-DS Tables



TPC-DS Input Data

Data source:

- Input files are generated with CLI tool (CSV)
- The tool constraints the minimum amount of data to be generated to 1GB.
- TPC-DS *dsdgen* tool for text (CSV) generation.

Generated datasets:

- Total sizes: 1GB / 10GB / 100GB / 1000GB

TPC-DS Queries

- **99 distinct** *SQL-99* queries (including OLAP extensions)
- Each query answers a **business question**, which illustrates the business context in which the query could be used
- All queries are "*templated*" with random **input parameters**.
- Used to **compare SQL implementation** of completeness and performance

TPC-DS via Beam SQL

TPC-DS extension in Beam

- **Goals**:
  - Compare the performance of Beam SQL for different runners and their different versions
  - Run Beam SQL on different environments
  - Detect missing Beam SQL features / incompatibilities
  - Find Performance issues in Beam

TPC-DS extension in Beam

- Initially contributed by *Yuwei Fu* as a part of GSoC 2020 project [BEAM-9891]
  - Supported only Dataflow runner
  - Text files (CSV) as an input source
  - 3 (of 99) queries passing

- Later adjusted
  - + support of Spark Runner
  - + support of Parquet input (on the way). Why? Let's talk a bit later....
  - + 25 (of 103) queries passing

TPC-DS extension in Beam

- 103 SQL queries (99 + 4) to run
  - 25 passed
  - 78 failed
- The most common issues:
  - *“java.lang.UnsupportedOperationException: Non equi-join is not supported”*
  - *“java.lang.UnsupportedOperationException: CROSS JOIN, JOIN ON FALSE is not supported!”*
  - *“java.lang.UnsupportedOperationException: ORDER BY without a LIMIT is not supported!”*
  - *org.apache.calcite.plan.RelOptPlanner$CannotPlanException: There are not enough rules to produce a node with desired properties: convention=BEAM_LOGICAL. All the inputs have relevant nodes, however the cost is still infinite.”*

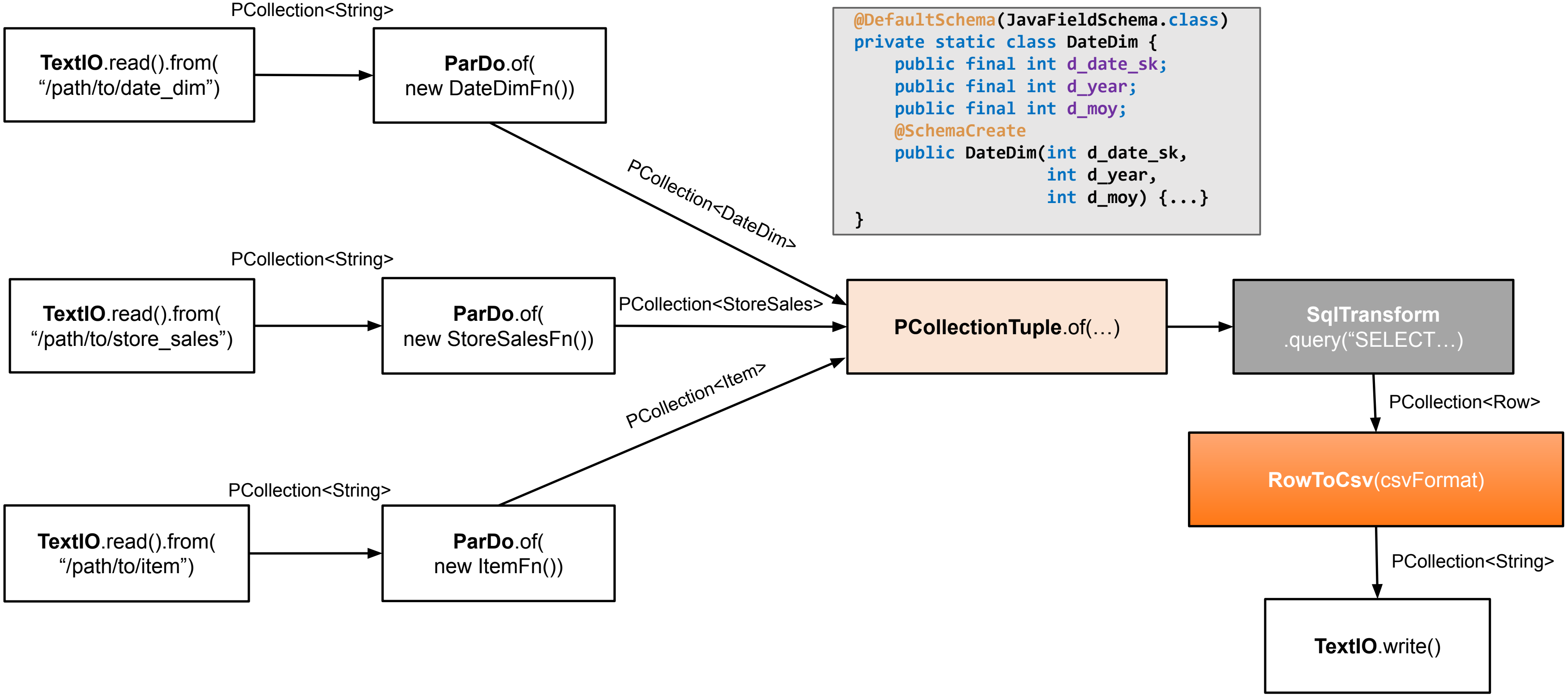
Different implementations of TPC-DS queries in Beam

TPC-DS Query 3

Query3 is a good example that contains all main data processing primitives (filtering, aggregation, sorting, selecting, etc) and implemented in different ways as Beam and Spark pipelines.

```
   SELECT dt.d_year, item.i_brand_id brand_id, item.i_brand  brand,
          SUM(ss_ext_sales_price) sum_agg
     FROM date_dim dt, store_sales, item
    WHERE dt.d_date_sk = store_sales.ss_sold_date_sk
      AND store_sales.ss_item_sk = item.i_item_sk
      AND item.i_manufact_id = 128
      AND dt.d_moy=11
 GROUP BY dt.d_year, item.i_brand, item.i_brand_id
 ORDER BY dt.d_year, sum_agg desc, brand_id
    LIMIT 100
```

TPC-DS Query 3, Beam SQL, CSV



Is CSV the best format to benchmark?

- Works with the TPC-DS generated data via *dsdgen*
- Nice to compare with other benchmarks running on raw TPC-DS
- CSV-like format is not good enough for SQL data optimizations
  - column projection, filter predicates, etc
- More realistic Big Data use case (Datalake)

Parquet to the rescue!
Databricks TPC-DS Kit to generate Parquet files (re-uses *dsdgen*)

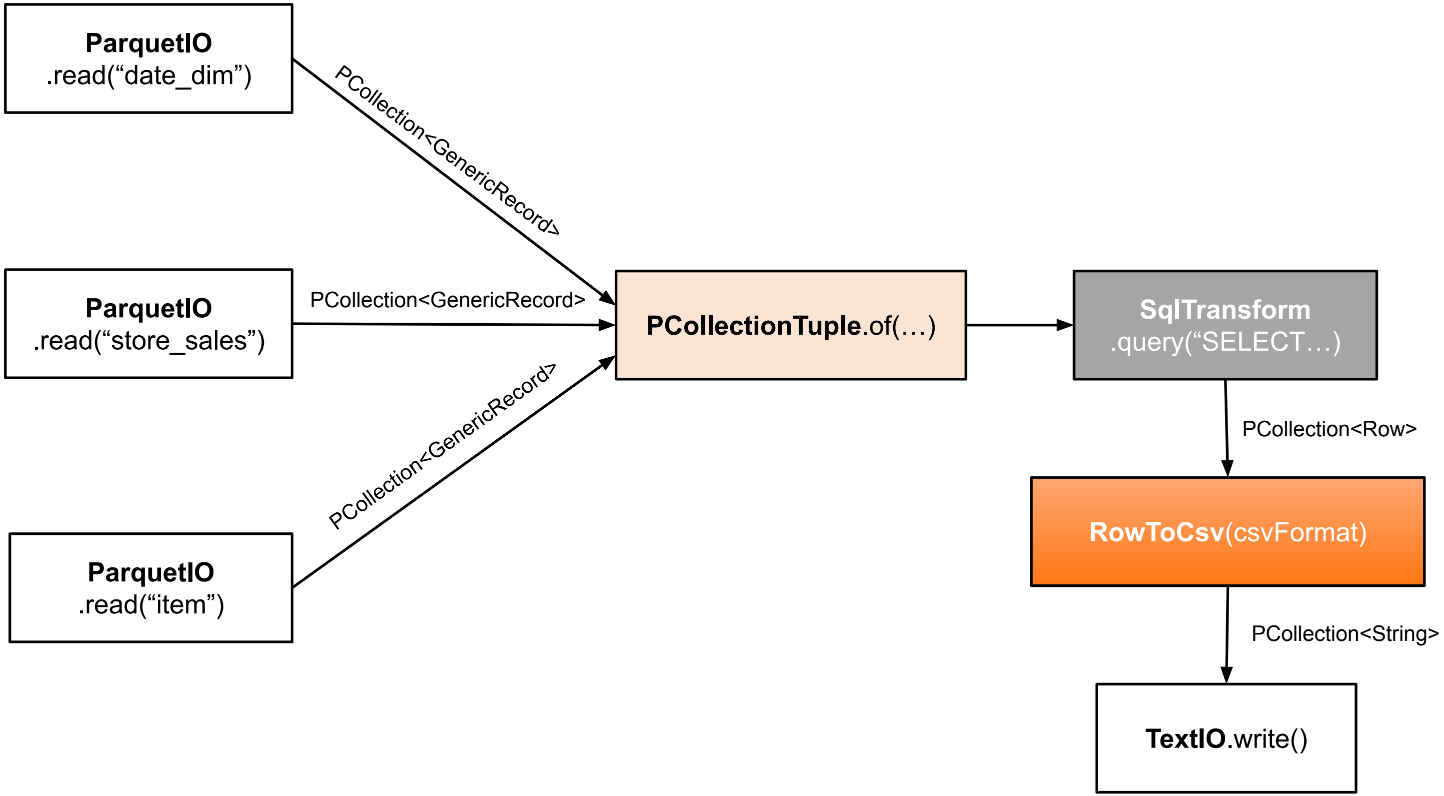
TPC-DS Query 3, Beam SQL, Parquet

```
Schema schemaDateDim = Utils.getAvroSchema("date_dim");
Schema schemaDateDimProjected =
        getProjectedSchema(new String[] {"d_date_sk", "d_year", "d_moy"}, schemaDateDim);

PCollection<GenericRecord> recordsDateDim = pipeline.apply(
            ParquetIO.read(schemaDateDim)
                . . .
                .withProjection(schemaDateDimProjected);
...
PCollection<GenericRecord> recordsStoreSales = ...;
PCollection<GenericRecord> recordsItem = ...;

PCollectionTuple tuple = PCollectionTuple.of(new TupleTag<>("date_dim"), recordsDateDim)
        .and(new TupleTag<>("store_sales"), recordsStoreSales)
        .and(new TupleTag<>("item"), recordsItem);
```

TPC-DS Query 3, Beam SQL, Parquet



Other missing SQL features

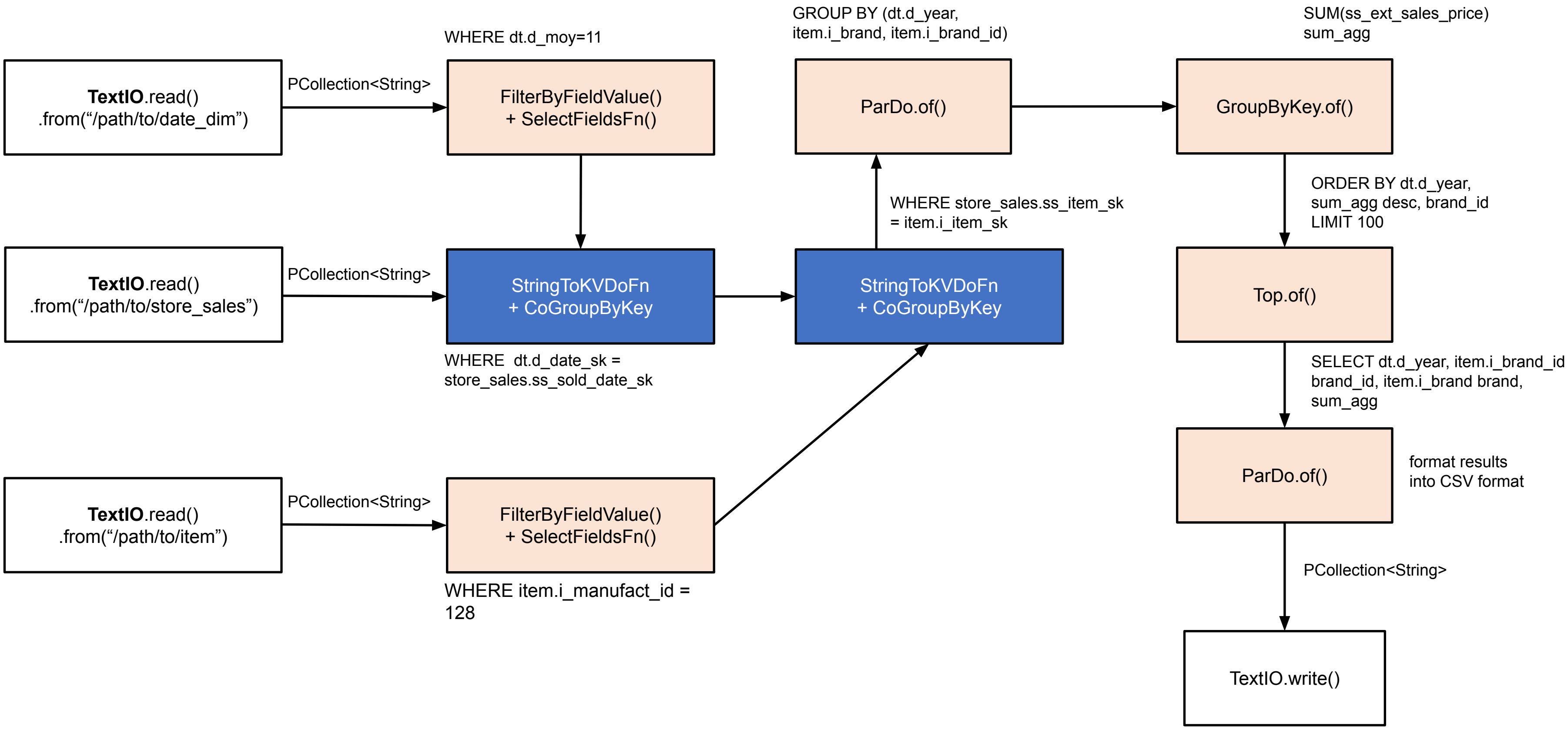
BEAM-12315 Support PARTITIONED BY on Beam's SQL DDL
Databricks TPC-DS Parquet generation tool partitions date columns as paths

BEAM-7929 ParquetTable support for column projection and filter predicate
We completed Column Projection, Filter Predicate (pending PR)

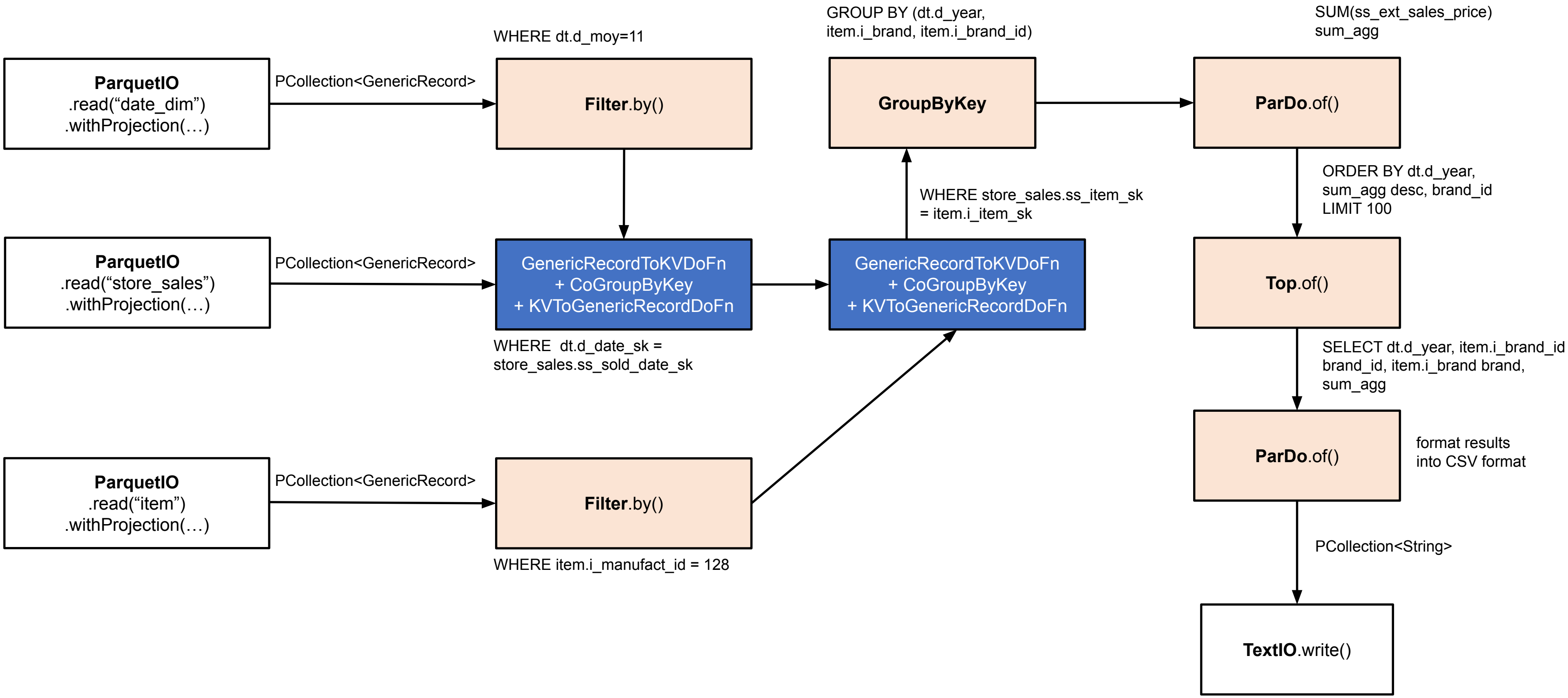
BEAM-12134 Add Table statistics / Row estimation for ParquetTable
(Cost-Based Optimization)

- E.g. Query3 joins 2 small tables with a big one (star-like) so it could benefit of a Map-Side based Join strategy

TPC-DS Query 3, Beam SDK, CSV



TPC-DS Query 3, Beam SDK, Parquet



Local benchmark runs

Configuration:

Dependencies:

- Beam 2.28.0
- Spark 2.4.7

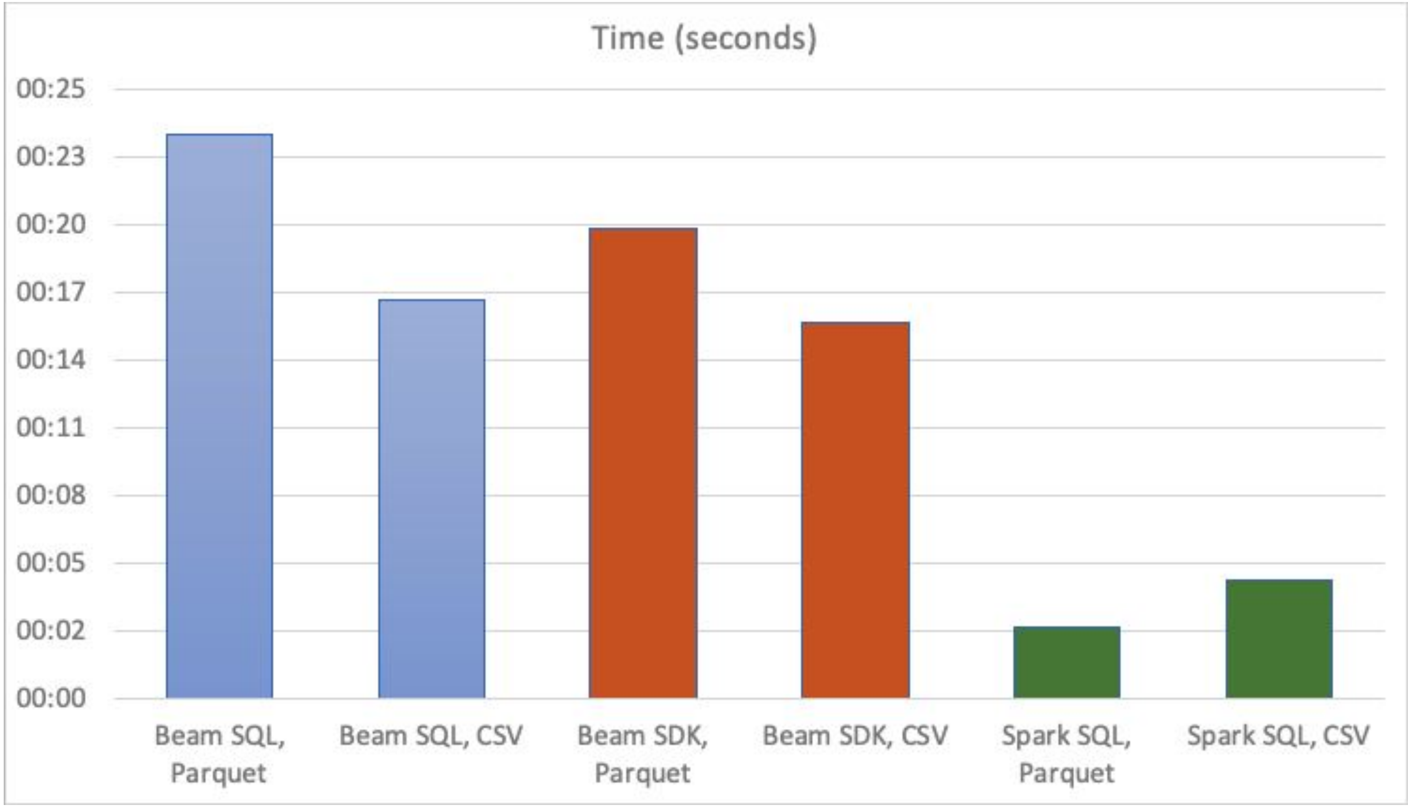
4 workers

- local[4] or parallelism=4

1Gb input data set

- Parquet / CSV, local files
- Macbook Pro 2017, 2,9 GHz Intel Core i7, RAM 16 GB

TPC-DS Query 3, 1Gb dataset, Spark




Distributed Execution Time!

⚠️WARNING #3

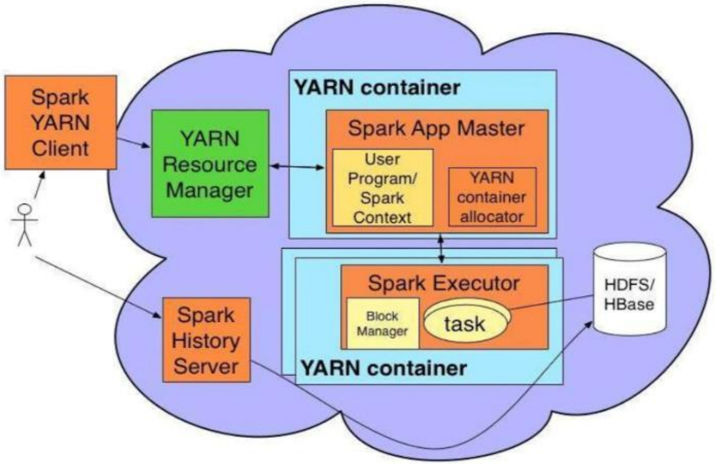
Fair Benchmarking is HARD

- Instance Variability (CPU/RAM speed)
- Cloud Networking Performance Variability
- Bad Default Configurations
- Other silly configuration issues


The Curious Case of the Broken Benchmark: Revisiting Apache Flink® vs. Databricks Runtime

December 15, 2017 | by Aljoscha Krettek

Cluster Setup – Amazon EMR



yarn-cluster

m4.xlarge (4 CPUS / 16GB RAM)

- 1 YARN master
- 5 YARN workers (1 master + 4 workers)

AWS EMR 5.32.0 (us-east-1)

- Hadoop 2.10.1
- Spark 2.4.7
- Flink 1.11.2

Input dataset and results in **AWS S3**

Goal: Test default configurations. Only change for similarity between systems purposes for example same parallelism.

Cluster runs – Amazon EMR

Implementations (5)	Datasets (4)	Runs (3)
Beam SDK Parquet	1GB	
Beam SQL Parquet	10GB	
Beam SQL CSV	100GB	
Spark SQL Parquet	1000GB*	
Spark SQL CSV		

* Beam SQL CSV version not working on this size on Spark Runner (yet)

1GB	10GB	100GB	1000GB

1GB	10GB	100GB	1000GB
❌			

Runtime System Issues

- BEAM-11958 Jackson MethodNotFoundException on EMR ✔️
  - AWS SDK for Java available by default in the EMR classpath and it uses a Jackson dependency older than Beam's.

- BEAM-10430 Jackson JaxbAnnotationModule breaks Flink Runner on EMR 🚧

1GB	10GB	100GB	1000GB
✅	❌		

IO and File System surprises

BEAM-12070 Make ParquetIO splittable by default ✔️
ParquetIO Read default implementation was NOT Splittable so it OOM-ed on workers

```
ParquetIO
    .read(schema)
    .from(path)
    .withSplit()
```

1GB	10GB	100GB	1000GB
✅	✅	✅	❌

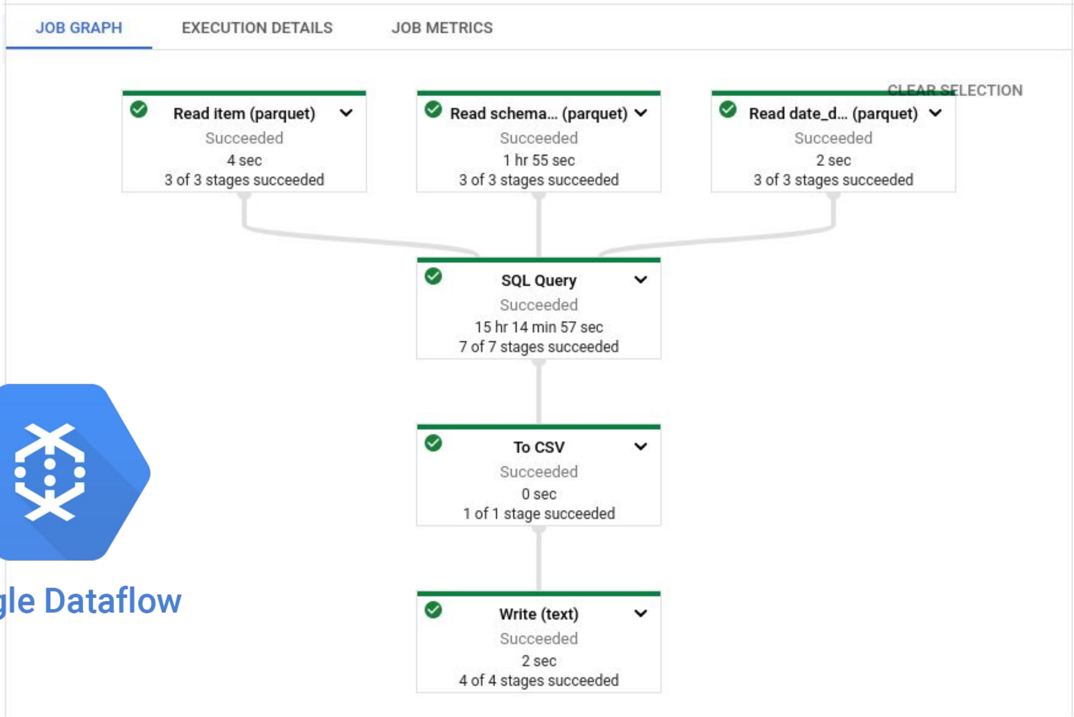
IO and File System surprises

BEAM-11972 ParquetIO should close all opened channels/readers ✔️
AWS S3 cancels reads when connections are kept open.

BEAM-12329 S3 logs warnings about non-drained InputStreams ✔️

1GB	10GB	100GB	1000GB
✅	✅	✅	✅

Cluster runs - Google Dataflow



Google Dataflow

Constrained cluster 4 x e2-standard-4 workers + Data stored on Google Cloud Storage (GCS)

Cluster runs – Google Dataflow

Implementations (3)	Datasets (4)	Runs (3x2)
Beam SDK Parquet	1GB	4 workers
Beam SQL Parquet	10GB	Unlimited workers
Beam SQL CSV	100GB	
	1000GB	

Google Dataflow

1GB	10GB	100GB	1000GB
✅	✅	✅	✅

Credit where credit is due: Everything ran smoothly on Dataflow

Runner Translation Issues

Reports of read performance regressions on the Mailing List (ML)

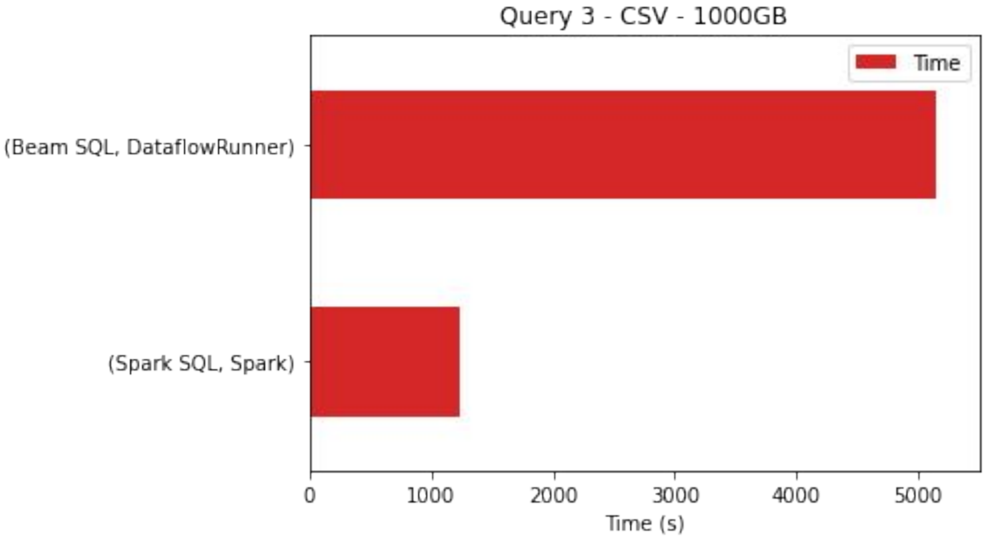
25-30% Read performance degradation on Spark Runner when using the SplittableDoFn based Read translation

BEAM-10670 Use non-SDF translation for Read by default on Spark Runner ✔️

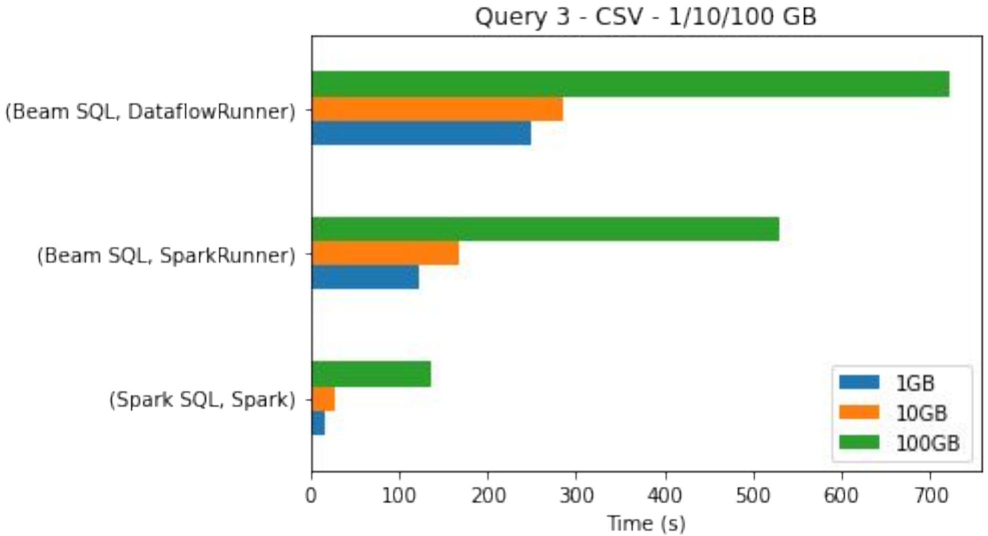
No performance difference on Dataflow 🤔

And finally the benchmark results...

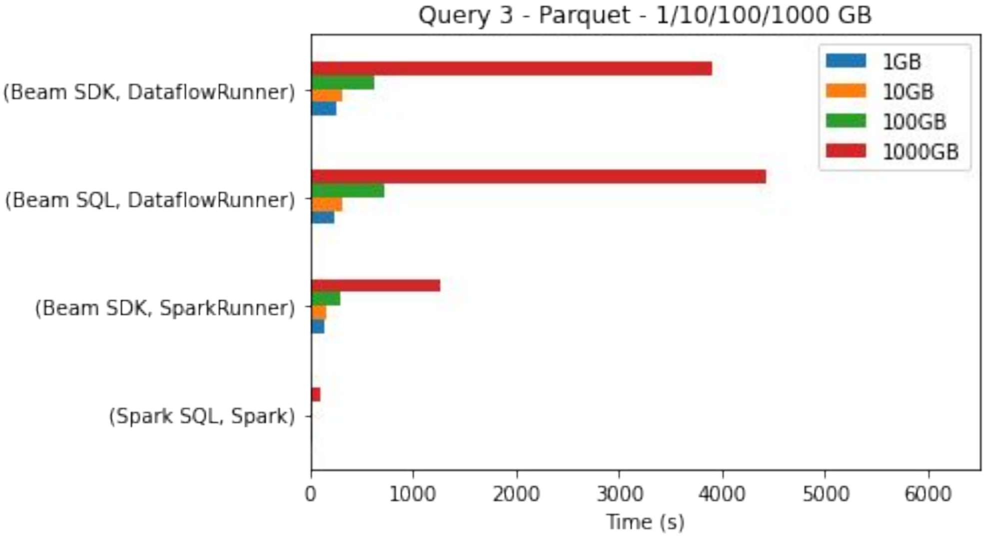
Cluster runs – EMR – Query 3 – CSV - 1TB



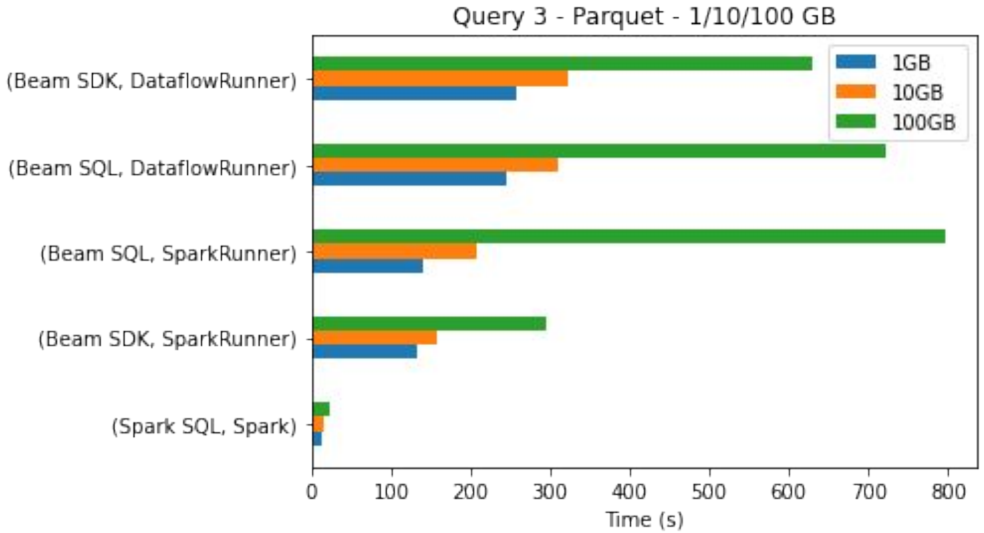
Cluster runs – EMR – Query 3 – CSV – 1-100 GB



Cluster runs – EMR – Query 3 - Parquet - 1TB

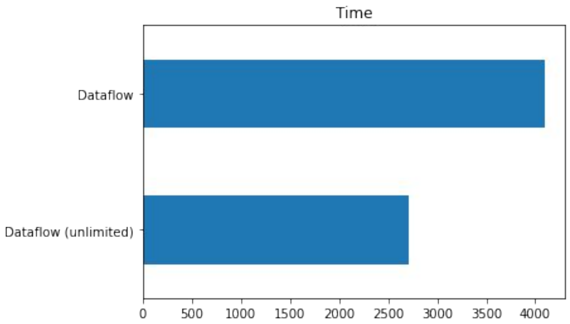


Cluster runs – EMR – Query 3 – Parquet – 1-100GB

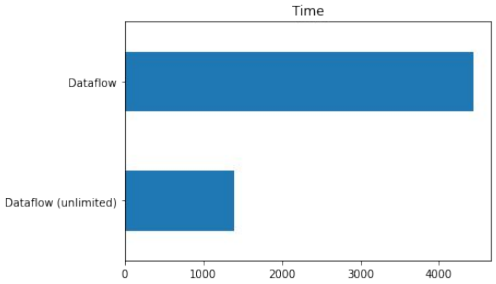


Cluster runs – Google Dataflow – Unlimited Workers

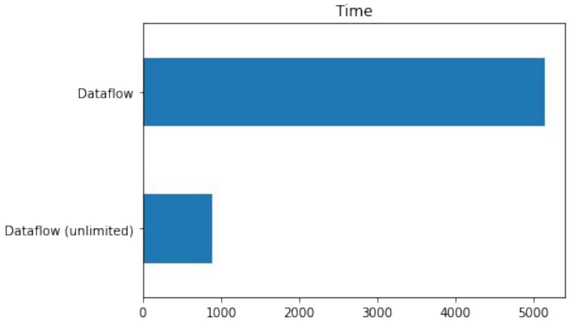
Parquet - Beam SDK



Parquet - Beam SQL



CSV - Beam SQL



* Unlimited workers give us results closer to raw Spark

Now the question became:

Where is the overhead of Beam?

Issues affecting TPC-DS on Beam performance

- SQL features and optimizations
- IO Connector
- Runtime
- Runner translation
- Implementation issues
- Beam Model overhead

Finding implementation issues - Profiling Beam

Method Name – Allocation Call Tree	Live Bytes [%]	Live Bytes
char[]		1,703,... (100
java.util.Arrays.**copyOf** (char[], int)		954,17... (56
java.lang.AbstractStringBuilder.**ensureCapacityInternal** (int)		953,54... (56
java.lang.AbstractStringBuilder.**append** (String)		952,20...(55.9
java.lang.StringBuilder.**append** (String)		952,20...(55.9
org.apache.beam.sdk.schemas.utils.AvroUtils.**checkTypeName** (org.apache.beam.sdk.schemas.Schema.TypeName, org.apache.beam.sdk.schemas.Schema.Type		945,46...(55.5
sun.net.www.protocol.jar.Handler.**parseURL** (java.net.URL, String, int, int)		1,664 B (0.1
java.net.URLStreamHandler.**parseURL** (java.net.URL, String, int, int)		1,504 B (0.1
java.io.UnixFileSystem.**resolve** (String, String)		1,216 B (0.1
com.sun.jmx.remote.internal.ServerCommunicatorAdmin.**logtime** (String, long)		968 B (0.1
java.lang.management.ThreadInfo.**initialize** (Thread, int, Object, Thread, long, long, long, long, StackTraceElement[], java.lang.management.MonitorInfo[], java.la		760 B (0
sun.net.www.protocol.jar.Handler.**parseContextSpec** (java.net.URL, String)		416 B (0
org.slf4j.impl.SimpleLogger.**log** (int, String, Throwable)		216 B (0
java.lang.AbstractStringBuilder.**append** (char[], int, int)		680 B (0
java.lang.AbstractStringBuilder.**append** (char)		656 B (0
java.lang.String.**concat** (String)		584 B (0
java.lang.String.**<init>** (char[])		48 B (0
java.util.Arrays.**copyOfRange** (char[], int, int)		438,94...(25.8
java.lang.String.**<init>** (char[], int, int)		438,94...(25.8
java.lang.StringBuilder.**toString** ()		435,20...(25.5
org.apache.beam.sdk.schemas.utils.AvroUtils.**checkTypeName** (org.apache.beam.sdk.schemas.Schema.TypeName, org.apache.beam.sdk.schemas.Schema.TypeNa		415,96...(24.4

BEAM-12210 Performance issue in AvroUtils.checkTypeName ✔
BEAM-12247 Reduce memory allocations in InMemoryTimerInternals ✔
BEAM-12248 Reduce ArrayList allocation in Row/RowUtils ✔

* Thanks Dan Kulp for the profiling analysis/fixes

Beam Model Overhead

"Every element on Beam has an associated event timestamp"

`WindowedValue` is the internal representation of a value (~13 bytes overhead)

```
{value, timestamp, [windows], paneInfo}
```

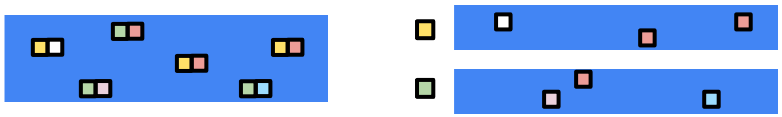
- More memory required per-element + extra GC
- Bigger shuffle size

Shuffle overhead can be improved by smarter encoding

Beam Model Overhead

GroupByKey in Beam also groups by Window, and...

- Merge windows if possible
- Adjust timestamps if multiple inputs
- Drop data from expired windows
- Emit results based on triggers



Extra CPU use and more GC
And there is also the Timers/State overhead

BEAM-12135 Batch optimized translation for Spark Runner

Row conversion and Coder improvements (2-3%)

BEAM-12135 Use ParamWindowedValueCoder for Bounded PCollections 🚧

BEAM-11571 Avoid conversion if input and output types are equal on Convert transform ✔️

BEAM-12328 Conversion from Avro GenericRecords to Beam Rows takes too much time 🚧

Conclusions

Contributions

8 Issues required to run TPC-DS found (8 fixed)
10 Nice to have issues reported (5 fixed)
11 Performance Improvement Issues found (3 fixed / 3 pending)

Lessons Learned

- Defaults matter (A LOT!)
- You need real life scale runs to find real life issues
- Execution in different platforms/clouds matters for a project like Beam
- Measuring Big Data pipelines performance in the cloud is hard
- It is hard to compare specific execution systems:
  - Spark has been optimized for the batch data-lake use case for at least 6 years
- Price of abstractions

Future work

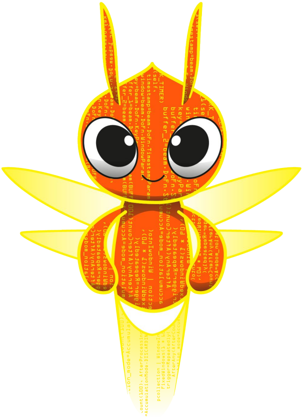
Still LOTS of things to do (wanna join?)

- Make more queries pass and other SQL improvements
- Automate daily runs on big size datasets
- Benchmark open source runners on Google Dataproc / Kubernetes
- Continue performance improvements runners translation
- Run also via Portability: Python / Go queries

Open Questions

- Are native system optimizations blocked by model translation?
- Can we have a schema-based translation of Beam pipelines?

Questions ?



Extra Slides

TPC-DS Query 29

```
SELECT
    i_item_id,
    i_item_desc,
    s_store_id,
    s_store_name,
    sum(ss_quantity) AS store_sales_quantity,
    sum(sr_return_quantity) AS store_returns_quantity,
    sum(cs_quantity) AS catalog_sales_quantity,
FROM
    store_sales,
    store_returns,
    catalog_sales,
    date_dim d1,
    date_dim d2,
    date_dim d3,
    store,
    item
WHERE
    d1.d_moy            = 9 AND
    d1.d_year           = 1999 AND
    d1.d_date_sk        = ss_sold_date_sk AND
    i_item_sk           = ss_item_sk AND
    s_store_sk          = ss_store_sk AND
    ss_customer_sk      = sr_customer_sk AND
    ss_item_sk          = sr_item_sk AND
    ss_ticket_number    = sr_ticket_number AND
    sr_returned_date_sk = d2.d_date_sk AND
    d2.d_moy BETWEEN 9 AND  9 + 3 AND
    d2.d_year           = 1999 AND
    sr_customer_sk      = cs_bill_customer_sk AND
    sr_item_sk          = cs_item_sk AND
    cs_sold_date_sk     = d3.d_date_sk AND
    d3.d_year IN (1999,1999+1,1999+2)
GROUP BY
    i_item_id,
    i_item_desc,
    s_store_id,
    s_store_name
ODRDER BY
    i_item_id,
    i_item_desc,
    s_store_id,
    s_store_name
LIMIT 100
```

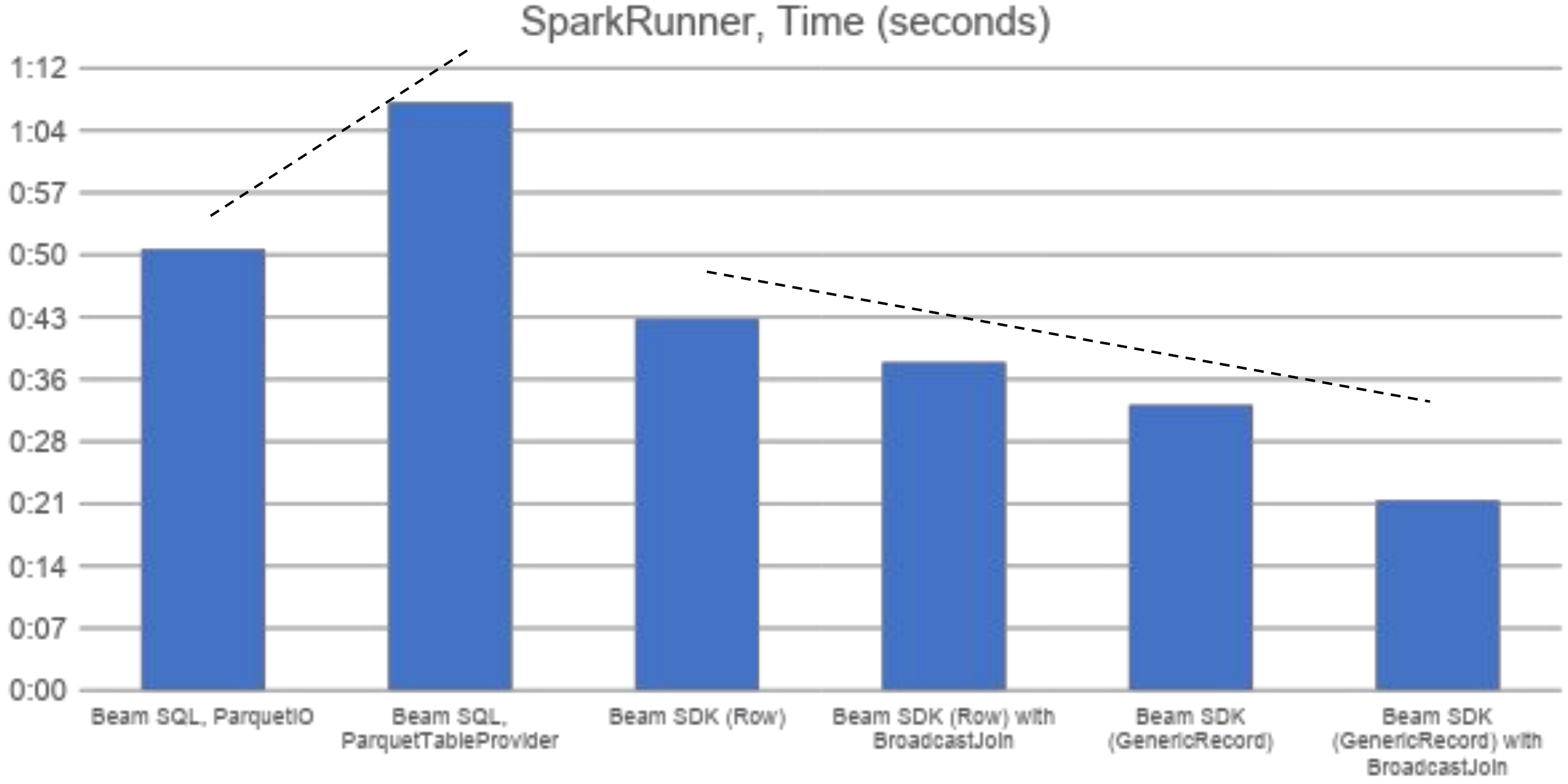
TPC-DS Query 29

Types of implementations:

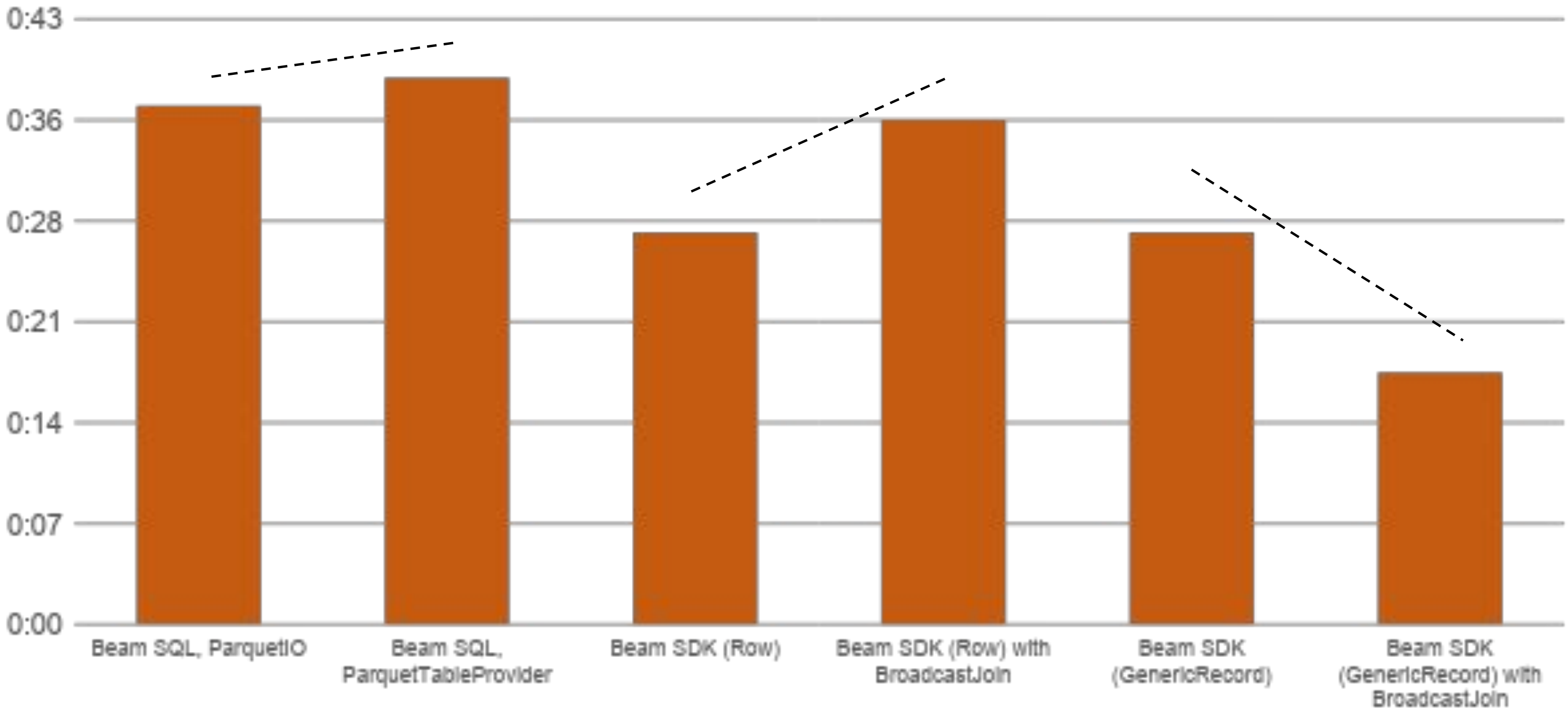
Beam SQL
- ParquetIO
- Parquet Table Provider

Beam SDK (Java)
- Avro GenericRecord
- Beam Schema & Row

TPC-DS Query 29, 1Gb dataset



TPC-DS Query 29, 1Gb dataset



User Reports of Performance Issues

Extremely Slow DirectRunner

[redacted]

to dev@beam.apache.org

May 8, 2021, 12:57 AM

Hi all,

I'm experiencing very slow performance and startup delay when testing a pipeline locally. I'm reading data from a Google PubSub subscription as the data source, and before each pipeline execution I ensure that data is present in the subscription (readable from GCP console).

I'm seeing startup delay on the order of minutes with DirectRunner (5-10 min). Is that expected? I did find a Jira ticket[1] that at first seemed related, but I think it has more to do with BQ than DirectRunner.

I've run the pipeline with a debugger connected and confirmed that it's minutes before the first DoFn in my pipeline receives any data. Is there a way I can profile the direct runner to see what it's churning on?