Parquet performance tuning: The missing guide

Ryan Blue
Strata + Hadoop World NY 2016

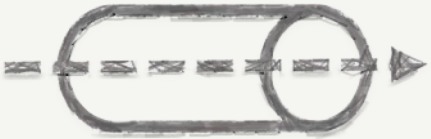
NETFLIX

Contents.

- Big data at Netflix
- Parquet format background
- Optimization basics
- Stats and dictionary filtering
- Format 2 and compression
- Future work

Big data at Netflix.

Big data at Netflix.



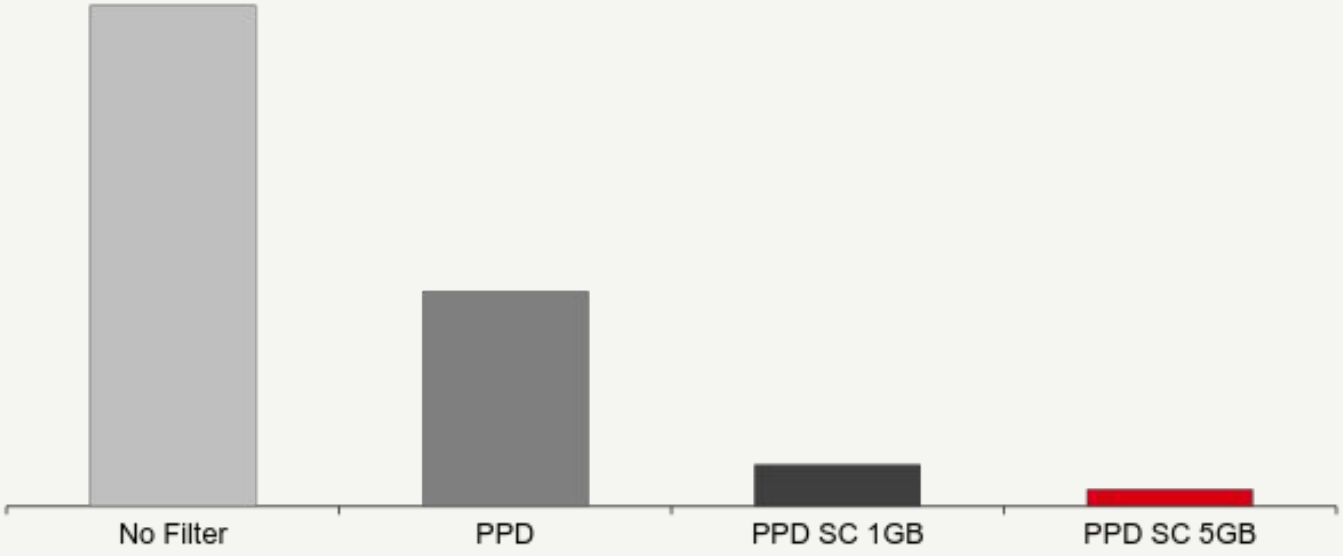
600B Events

40+ PB DW

Read 3PB

Write 300TB

Strata San Jose results.



Metrics dataset.

Based on Atlas, Netflix's telemetry platform.

- Performance monitoring backend and UI
- http://techblog.netflix.com/2014/12/introducing-atlas-netflixs-primary.html

Example metrics data.

- Partitioned by **day**, and **cluster**
- Columns include metric **time**, **name**, **value**, and **host**
- Measurements for each minute are stored in a Parquet table

Parquet format background.

Parquet data layout.

ROW GROUPS.

- Data needed for a group of rows to be reassembled
- Smallest task or input split size
- Made of **COLUMN CHUNKS**

COLUMN CHUNKS.

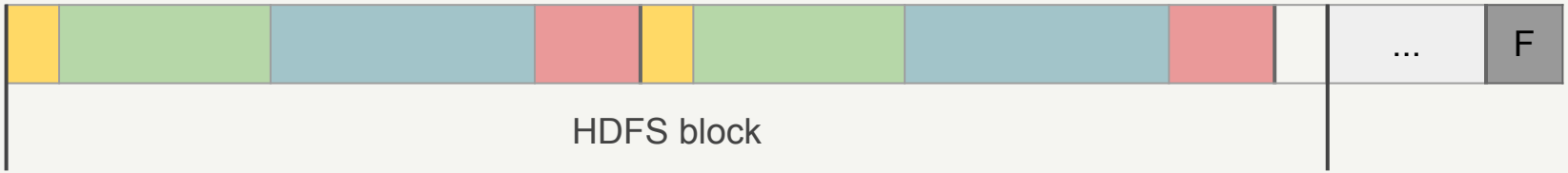
- Contiguous data for a single column
- Made of **DATA PAGES** and an optional **DICTIONARY PAGE**

DATA PAGES.

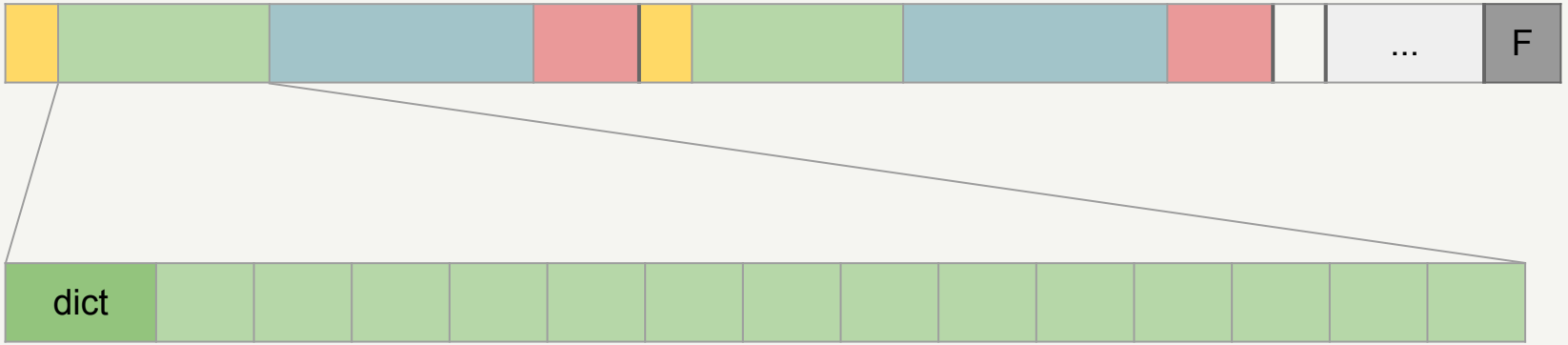
- Encoded and compressed runs of values

Row groups.

A	B	C	D
a1	b1	c1	d1
...	...	...	...
aN	bN	cN	dN
...	...	...	...



Column chunks and pages.



Read less data.

Columnar organization.

- Encoding: make the data smaller
- Column projection: read only the columns you need

Row group filtering.

- Use **footer stats** to eliminate row groups
- Use **dictionary pages** to eliminate row groups

Page filtering.

- Use **page stats** to eliminate pages

Basics.

Setup.

Parquet writes:

- Version 1.8.1 or later – includes fix for incorrect statistics, PARQUET-251
- 1.9.0 due in October

Reads:

- Presto: Used 0.139
- Spark: Used version 1.6.1 reading from Hive
- Pig: Used parquet-pig 1.9.0 for predicate push-down

Pig configuration.

```
-- enable pushdown/filtering
set parquet.pig.predicate.pushdown.enable true;

--  enables stats and dictionary filtering
set parquet.filter.statistics.enabled true;
set parquet.filter.dictionary.enabled true;
```

Spark configuration.

```
// turn on Parquet push-down, stats filtering, and dictionary filtering
sqlContext.setConf("parquet.filter.statistics.enabled", "true")
sqlContext.setConf("parquet.filter.dictionary.enabled", "true")
sqlContext.setConf("spark.sql.parquet.filterPushdown", "true")

// use the non-Hive read path
sqlContext.setConf("spark.sql.hive.convertMetastoreParquet", "true")

// turn off schema merging, which turns off push-down
sqlContext.setConf("spark.sql.parquet.mergeSchema", "false")
sqlContext.setConf("spark.sql.hive.convertMetastoreParquet.mergeSchema",
                   "false")
```

Writing the data.

Spark:

```
sqlContext
  .table("raw_metrics")
  .write.insertInto("metrics")
```

Pig:

```
metricsData = LOAD 'raw_metrics'
  USING SomeLoader;
STORE metricsData INTO 'metrics'
  USING ParquetStorer;
```

Writing the data.

Spark:

```
sqlContext
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Pig:

```
metricsData = LOAD 'raw_metrics'
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```

OutOfMemoryError

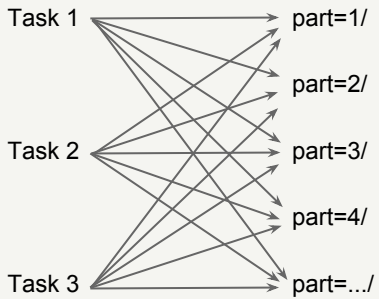
or

ParquetRuntimeException

Writing too many files.

Data doesn't match partitioning.

- Tasks write a file per partition



Symptoms:

- OutOfMemoryError
- ParquetRuntimeException: New Memory allocation 1047284 bytes is smaller than the minimum allocation size of 1048576 bytes.
- Successfully write lots of small files, slow split planning

Account for partitioning.

Spark.

```
sqlContext
  .table("raw_metrics")
  .sort("day", "cluster")
  .write.insertInto("metrics")
```

Pig.

```
metrics = LOAD 'raw_metrics'
  USING SomeLoader;
metricsSorted = ORDER metrics
  BY day, cluster;
STORE metricsSorted INTO 'metrics'
  USING ParquetStorer;
```

Filter to select partitions.

Spark.

```
val partition = sqlContext
  .table("metrics")
  .filter("day = 20160929")
  .filter("cluster = 'emr_adhoc'")
```

Pig.

```
metricsData = LOAD 'metrics'
  USING ParquetLoader;
partition = FILTER metricsData BY
  date == 20160929 AND
  cluster == 'emr_adhoc'
```

Stats filters.

Sample query.

Spark.

```
val low_cpu_count = partition
  .filter("name =
      'system.cpu.utilization'")
  .filter("value < 0.8")
  .count()
```

Pig.

```
low_cpu = FILTER partition BY
  name == 'system.cpu.utilization' AND
  value < 0.8;
low_cpu_count = FOREACH
  (GROUP low_cpu ALL) GENERATE
  COUNT(name);
```

My job was 5 minutes faster!

Did it work?

- Success metrics: S3 bytes read, CPU time spent

```
S3N: Number of bytes read: 1,366,228,942,336
CPU time spent (ms): 280,218,780
```

- **Filter didn’t work.** Bytes read shows the entire partition was read.

- What happened?

Inspect the file.

- Stats show what happened:

```
Row group 0:  count: 84756  845.42 B records
         type      encodings count     avg size   nulls   min / max
name     BINARY    G   _     84756     61.52 B    0       "A..." / "z..."
...
Row group 1:  count: 84756  845.42 B records
         type      encodings count     avg size   nulls   min / max
name     BINARY    G   _     85579     61.52 B    0       "A..." / "z..."
```

- **Every row group matched the query**

Add query columns to the sort.

Spark.

```
sqlContext
  .table("raw_metrics")
  .sort("day", "cluster", "name")
  .write.insertInto("metrics")
```

Pig.

```
metrics = LOAD 'raw_metrics'
  USING SomeLoader;
metricsSorted = ORDER metrics
  BY day, cluster, name;
STORE metricsSorted INTO 'metrics'
  USING ParquetStorer;
```

Inspect the file, again.

- Stats are fixed:

```
Row group 0:  count: 84756  845.42 B records
         type      encodings count     avg size   nulls   min / max
name     BINARY    G   _     84756     61.52 B    0       "A..." / "F..."
...
Row group 1:  count: 85579  845.42 B records
         type      encodings count     avg size   nulls   min / max
name     BINARY    G   _     85579     61.52 B    0       "F..." / "N..."
...
Row group 2:  count: 86712  845.42 B records
         type      encodings count     avg size   nulls   min / max
name     BINARY    G   _     86712     61.52 B    0       "N..." / "b..."
```

Dictionary filters.

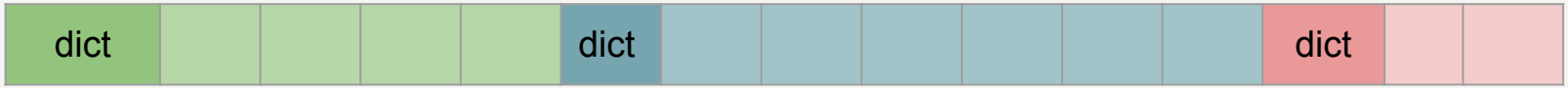
Dictionary filtering.

Dictionary is a compact list of all the values.

- Search term missing? Skip the row group
- Like a bloom filter without false positives

When dictionary filtering helps:

- When a column is sorted in each file, not globally sorted – one row group matches
- When filtering an unsorted column



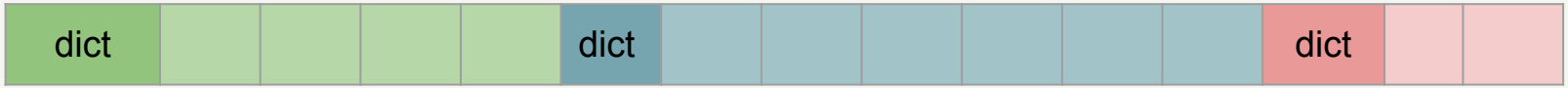
Dictionary filtering overhead.

Read overhead.

- Extra seeks
- Extra page reads

Not a problem in practice.

- Reading both dictionary and row group resulted in < 1% penalty
- Stats filtering prevents unnecessary dictionary reads



Works out of the box, right?

Nope.

- Only works when columns are completely dictionary-encoded
- Plain-encoded pages can contain any value, dictionary is no help
- All pages in a chunk must use the dictionary

Dictionary fallback rules:

- If dictionary + references > plain encoding, fall back
- If dictionary size is too large, fall back (default threshold: 1 MB)

Fallback to plain encoding.

```
parquet-tools dump -d
    utc_timestamp_ms TV=142990 RL=0 DL=1 DS:     833491 DE:PLAIN_DICTIONARY
----------------------------------------------------------------------------
    page 0:          DLE:RLE RLE:BIT_PACKED V:RLE   SZ:72912
    page 1:          DLE:RLE RLE:BIT_PACKED V:RLE   SZ:135022
    page 2:          DLE:RLE RLE:BIT_PACKED V:PLAIN SZ:1048607
    page 3:          DLE:RLE RLE:BIT_PACKED V:PLAIN SZ:1048607
    page 4:          DLE:RLE RLE:BIT_PACKED V:PLAIN SZ:714941
```

What's happening:

- Values repeat, but change over time
- Dictionary gets too large, falls back to plain encoding
- Dictionary encoding is a size win!

Avoid encoding fallback.

Increase max dictionary size.

- 2-3 MB usually worked
- `parquet.dictionary.page.size`

Decrease row group size.

- 24, 32, or 64 MB
- `parquet.block.size`
- New dictionary for each row group
- Also lowers memory consumption!

Run several tests to find the right configuration (per table).

Row group size.

Other reasons to decrease row group size:

- Reduce memory consumption – but **not** to avoid write-side OOM
- Increase number of tasks / parallelism

Results!

Results (from Pig).

CPU and wall time dropped.

- Initial: CPU Time: 280,218,780 ms Wall Time: 15m 27s
- Filtered: CPU Time: 120,275,590 ms Wall Time: 9m 51s
- Final: CPU Time: 9,593,700 ms Wall Time: 6m 47s

Bytes read is much better.

- Initial: S3 bytes read: 1,366,228,942,336 (**1.24 TB**)
- Filtered: S3 bytes read: 49,195,996,736 (**45.82 GB**)

Filtered vs. final time.

Row group filtering is parallel.

- Split planning is independent of stats (or else is a bottleneck)
- Lots of very small tasks: read footer, read dictionary, stop processing

Combine splits in Pig/MR for better time.

- 1 GB splits tend to work well

Other work.

Format version 2.

What's included:

- New encodings: delta-integer, prefix-binary
- New page format to enable page-level filtering

New encodings didn't help with Netflix data.

- Delta-integer didn't help significantly, even with timestamps (high overhead?)
- Not large enough prefixes in URL and JSON data

Page filtering isn't implemented (yet).

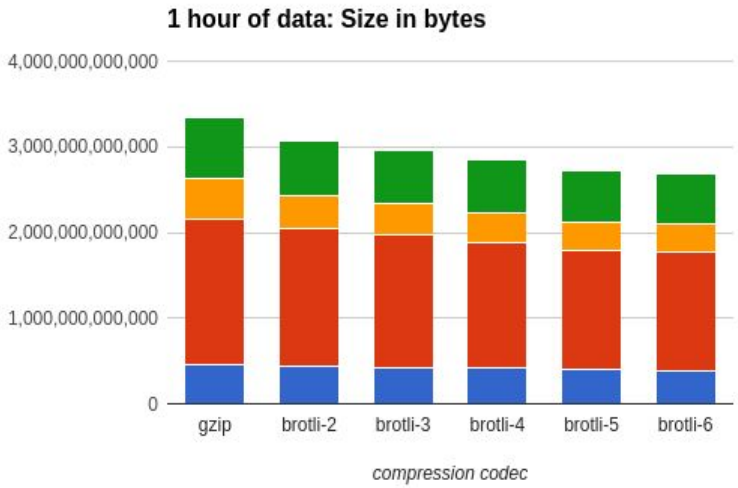
Brotli compression.

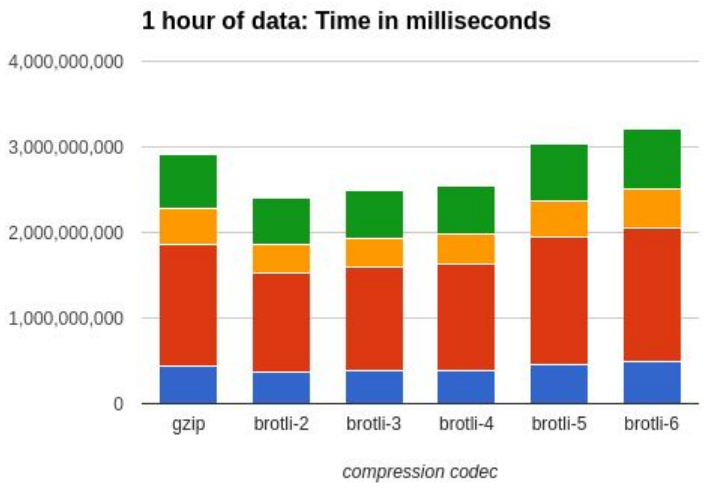
- New compression library, from Google
- Based on LZ77, with compatible license

Faster compression, smaller files, or both.

- brotli-5: **19.7% smaller**, **2.7% slower** – 1 day of data from Kafka
- brotli-4: **14.8% smaller**, **12.5% faster** – 1 hour, 4 largest Parquet tables
- brotli-1: **8.1% smaller**, **28.3% faster** – JSON-heavy dataset

Brotli compression. (continued)





Future work.

Future work.

Short term:

- Release Parquet 1.9.0
- Test Zstd compression
- Convert embedded JSON to Avro – good preliminary results

Long-term:

- New encodings: Zig-zag RLE, patching, and floating point decomposition
- Page-level filtering

Thank you!
Questions?

https://jobs.netflix.com/
rblue@netflix.com

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