Hortonworks

ORC Files

Owen O'Malley
owen@hortonworks.com
@owen_omalley

June 2013

Who Am I?

- First committer added to Hadoop in 2006
- First VP of Hadoop at Apache
- Was architect of MapReduce
- Was architect of Security
- Broke terasort, minute, and petasort record
- Working on Hive for last 1.5 years
  - Working on Hive code
  - Deep engagement with a large Hive user

History

- Originally Hive used MapReduce's FileFormats
  - Text
  - SequenceFile
- RCFile was developed to improve matters
  - Only read required columns (projection)
  - Each column is stored separately
  - Compresses columns separately
  - Avoid deserializing extra columns
  - select * from people where age > 99
  - Lazy deserialization

Remaining Challenges

- Stores columns as type-free binary blobs
  - Can’t optimize representation by type
  - Can’t keep meaningful indexes
  - Complex types were not decomposed
- Seeking into file requires byte by byte search
  - Need to find the sync marker
- Compression done using stream-based codecs
  - Decompress column from start of group
- Metadata is added at beginning of file
- Lazy deserialization is very slow

Requirements

- Two Primary Goals
  - Improve query speed
  - Improve storage efficiency
- Support for the Hive type model
  - Complex types (struct, list, map, union)
  - New types (datetime, decimal)
- A single file as output of each task.
  - Dramatically simplifies integration with Hive
  - Lowers pressure on the NameNode
- Bound the amount of memory required

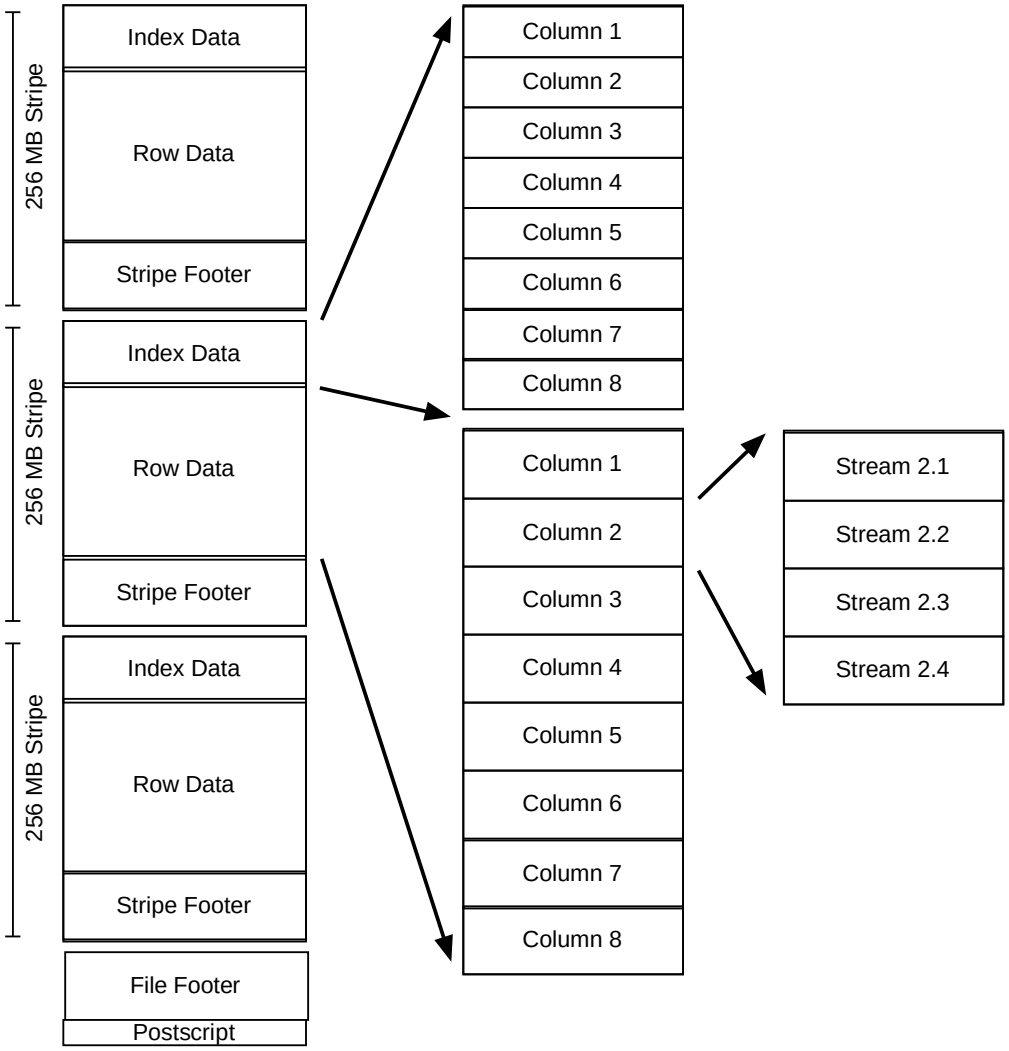
File Structure

- Break file into sets of rows called a stripe.
  - Default stripe size is 256 MB
  - Large size enables efficient read of columns
- Footer
  - Contains list of stripe locations
  - Self-describing types
  - Count, min, max, and sum for each column
- Postscript
  - Contains compression parameters
  - Size of compressed footer

Stripe Structure

- Data
  - Composed of multiple streams per column
- Index
  - Required for skipping rows
  - Defaults to every 10,000 rows
  - Position in each stream
  - Min and max for each column
- Footer
  - Directory of stream locations
  - Encoding of each column

File Layout



Compression

- Light-Weight Compression
  - Type specific (int, string, timestamp, etc.)
  - Always enabled
  - Focus on being very inexpensive
- Generic Compression
  - Support for none, Snappy, LZO, and Zlib
  - Entire file uses the same compression
  - Applied to each stream and footer
  - Applied after light-weight compression

Integer Column Serialization

- Protobuf style variable length integers
  - Small integers have small representations
- Run Length Encoding
  - Uses byte for run length
  - Runs can include very small fixed delta
  - Non-runs use only 1 extra byte / 128 values
- Integer columns have two streams:
  - Present bit stream – is the value non-null?
  - Data stream – stream of integers

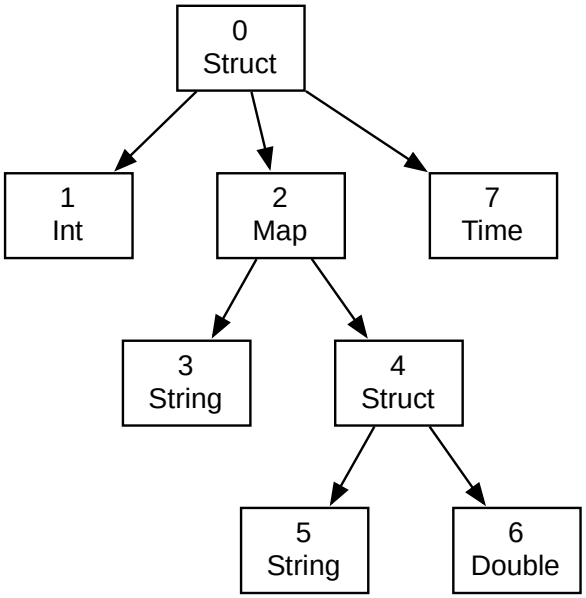
String Column Serialization

- Use a dictionary to uniquify column values
  - Speeds up predicate filtering
  - Improves compression
  - Uses the same run length encoding
- String columns have four streams:
  - Present bit stream – is the value non-null?
  - Dictionary data – the bytes for the strings
  - Dictionary length – the length of each entry
  - Row data – the row values

Hive Compound Types

- Create a tree of readers/writers
- A different class of reader or writer for each type
- Compound types use children for their values

```
create table Tbl (
  col1 int,
  col2 map<string,
                struct<col5:string,
                       col6:double>>,
  col7 timestamp)
```



Compound Type Serialization

- Lists
  - Encode the number of items in each value
  - Uses the same run length encoding
  - Uses child writer for value
- Maps
  - Encode the number of items in each value
  - Uses the same run length encoding
  - Uses the key and value child writers

Generic Compression

- Codecs are used to compress blocks of bytes
  - Each compression block is prefixed by a 3 byte header
  - Was the codec used or not?
  - What is the compressed length?
- To record a position in a compressed stream:
  - Offset of the start of compression header
  - Number of uncompressed bytes in block
  - Also the count from run length encoding

Column Projection

- Hive puts the list of required column numbers for the current query in the configuration.
  - Only has ability to request top-level columns
  - Can’t request the empty list of columns
- ORC uses the stripe footer to find the requested columns’ data streams
  - Reads of adjacent streams are merged
  - Large stripe size means the HDFS reads are reasonable size

How Do You Use ORC

- Added as a storage choice
  - create table Tbl (col int) stored as orc;
- **Do NOT change the Serde!**
  - ORC in/output formats require OrcSerde
- Control table properties
  - orc.compress default ZLIB
  - orc.compress.size default 256K
  - orc.stripe.size default 256MB
  - orc.row.index.stride default 10K

Managing Memory

- The entire stripe needs to be buffered
- ORC uses a memory manager
  - Scales down buffer sizes as number of writers increase
  - Configured using hive.exec.orc.memory.pool
  - Defaults to 50% of JVM heap size
- It may improve performance to provide more memory to insert queries.
  - Scaling down stripe size cuts disk IO size
  - Use MapReduce's High RAM jobs

Pavan's Trick

- During data ingest, you often need to write to many dynamic partitions.
  - Pavan was writing to thousands of partitions
  - Even RCFile's small 4MB buffers were OOM
- Re-wrote query as:

  from staging
    - insert into partition(part) where key is between x1 and x2
    - insert into partition(part) where key is between x2 and x3
- Reads input once, but splits writing tasks so that each writes to fewer partitions

Looking at ORC File Structures

- A useful tool is orc file dump
- Invoked as “hive –service orcfiledump file.orc”
- Shows file information, statistics, and stripe info

Rows: 21000 **Compression:** ZLIB **Compression size:** 10000
Type: struct<i:int,l:bigint,s:string>
Statistics:
Column 0: count: 21000
Column 1: count: 21000 **min:** -214 **max:** 214 **sum:** 193017
Column 2: count: 21000 **min:** -922 **max:** 922 **sum:** 45060
Column 3: count: 21000 **min:** Darkness, **max:** worst

Looking at ORC File Structures

Stripes:

Stripe: offset: 3 data: 69638 rows: 5000 tail: 85 index: 126

column 0 section ROW_INDEX start: 3 length 10

column 1 section ROW_INDEX start: 13 length 38

column 2 section ROW_INDEX start: 51 length 42

column 3 section ROW_INDEX start: 93 length 36

column 1 section PRESENT start: 129 length 11

column 1 section DATA start: 140 length 22605

column 2 section PRESENT start: 22745 length 11

column 2 section DATA start: 22756 length 43426

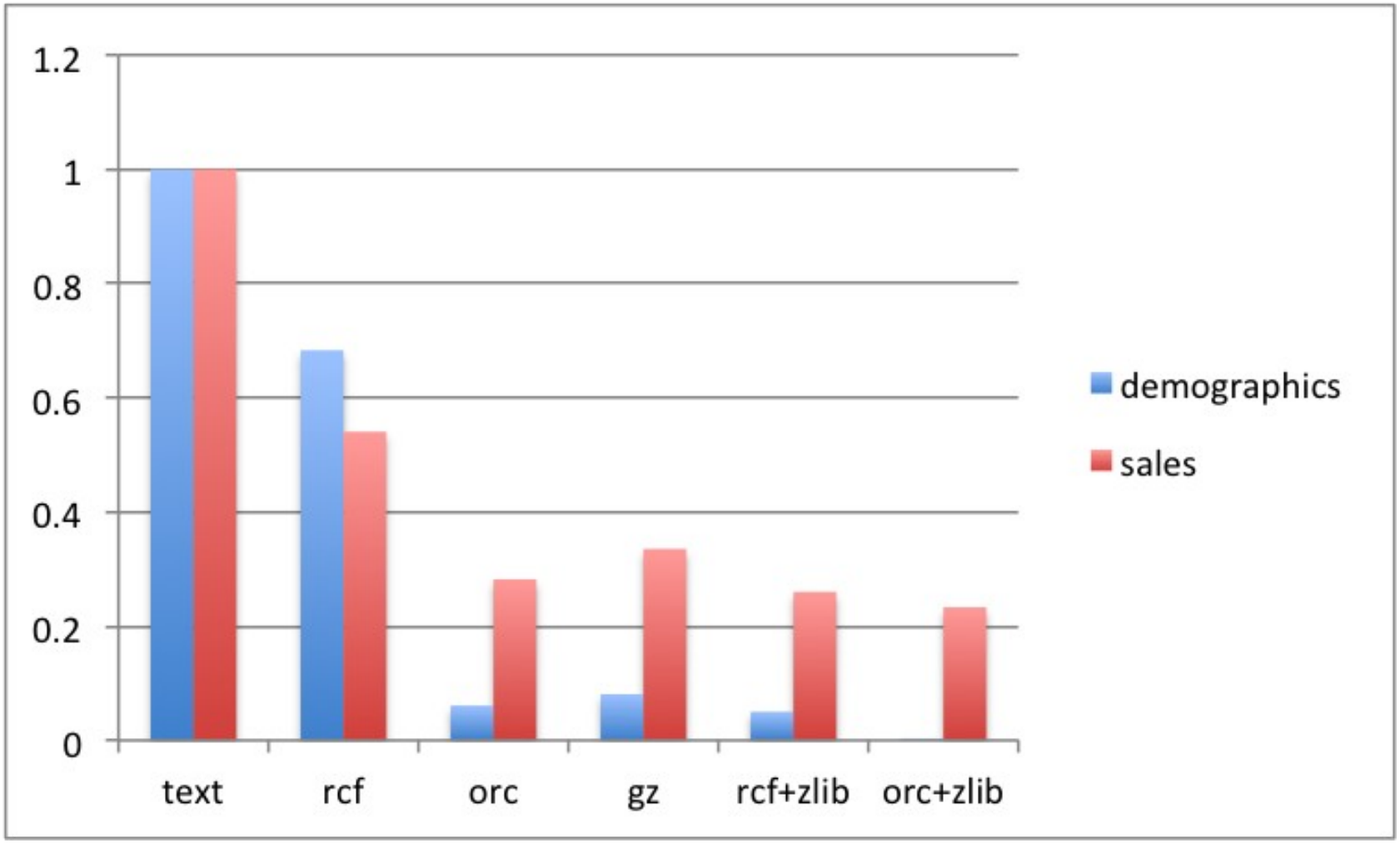
column 3 section PRESENT start: 66182 length 11

column 3 section DATA start: 66193 length 3403

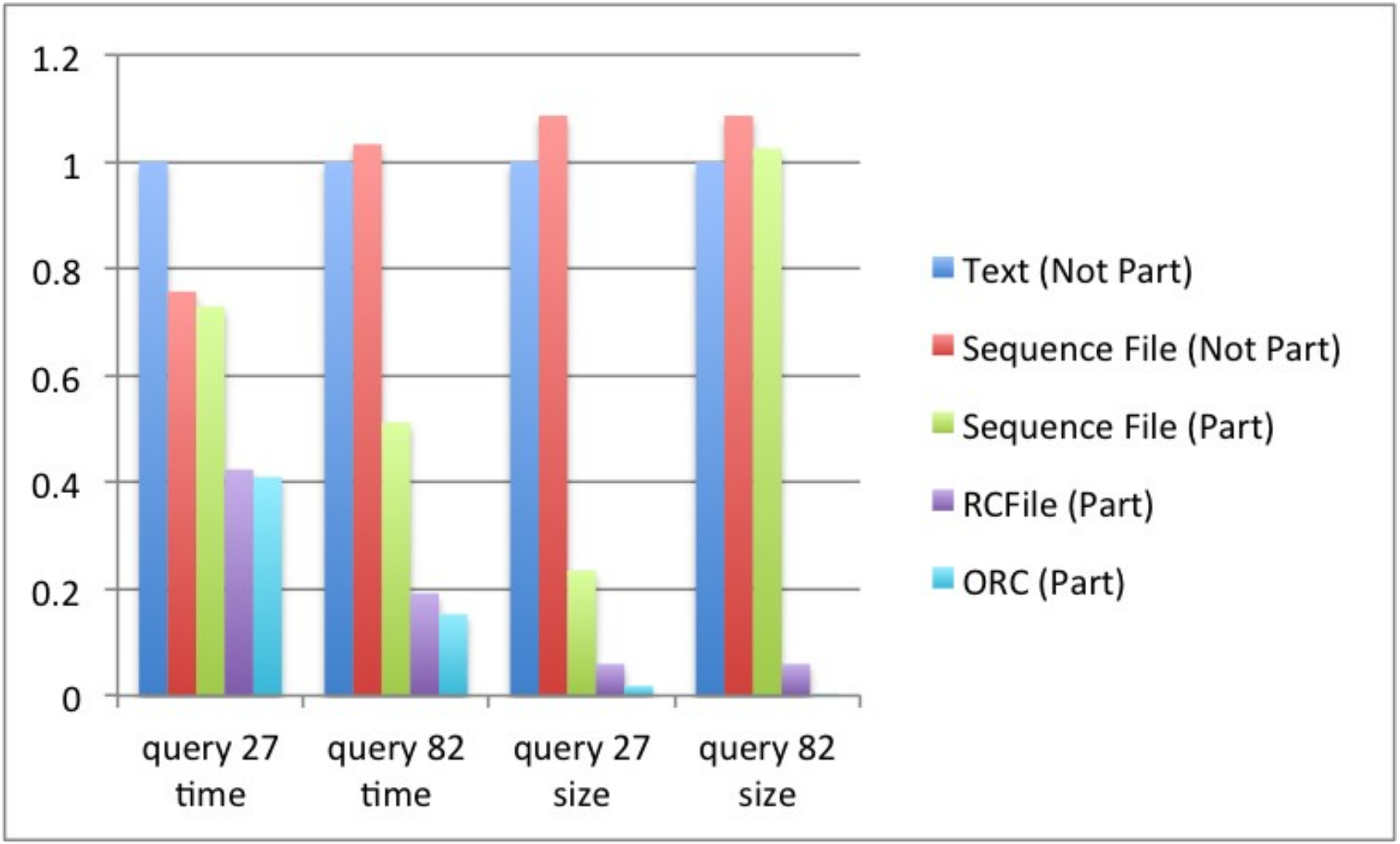
column 3 section LENGTH start: 69596 length 38

column 3 section DICTIONARY_DATA start: 69634 length 133

TPC-DS File Sizes



TPC-DS Query Performance



Additional Details

- Metadata is stored using Protocol Buffers
  - Allows addition and removal of fields
- Reader supports seeking to a given row #
- ORC doesn’t include checksums,
  - Already done in HDFS
- User metadata can be added at any time before the ORC writer is closed.
- ORC files can be read or written from MapReduce or Pig using HCat.

Current work

- Predicate pushdown row group skipping
  - Take subset of where clause and compare to min/max values in index to skip 10k rows
- Make string columns sample the written data and pick their encoding appropriately
  - After 100k values, if dictionary has more than 80k entries use a direct encoding.
- Add optional dictionary encoding of numbers.
- Suppress present stream if no null values
- Improve run length encoding

Vectorization

- Hive uses Object Inspectors to work on a row
  - Enables level of abstraction
  - Costs major performance
  - Exacerbated by using lazy serdes.
- Inner loop has many many method calls
  - Kills performance on modern CPUs
  - Completely trashes the L1 and L2 caches
- Replace inner loop with direct data access
  - Operate on 1000 rows at once
  - Store primitives in primitive arrays

Vectorization Preliminary Results

- First rough prototype was able to run queries in memory at 100 million rows per a second.
- Tasks are getting 10 to 20 times faster
- Involves completely re-writing the engine
- Being developed in a Hive dev branch
- Will have adaptors to switch from vectorized to non-vectorized execution until all of the operators are converted.
- Thanks to Eric Hanson, Jitendra Pandey, Remus Rusanu, Sarvesh Sakalanaga, Teddy Choi, and Tony Murphy

Future Work

- Support count(*), min, max, and average from metadata
- Extend index with optional bloom filter for string columns
- Extend push down predicates with bloom filters
- Allow MapReduce InputSplits to split stripes.
- Writer may reorder rows to improve compression.
  - Must preserve requested sort order

Thanks!

- Owen O’Malley
- owen@hortonworks.com
- @owen_omalley

Comparison

	RC File	Trevni	Parquet	ORC File
Hive Type Model	N	N	N	Y
Separate complex columns	N	Y	Y	Y
Splits found quickly	N	Y	Y	Y
Default column group size	4MB	64MB*	64MB*	256MB
Files per a bucket	1	> 1	1*	1
Store min, max, sum, count	N	N	N	Y
Versioned metadata	N	Y	Y	Y
Run length data encoding	N	N	Y	Y
Store strings in dictionary	N	N	N	Y
Store row count	N	Y	N	Y
Skip compressed blocks	N	N	N	Y
Store internal indexes	N	N	N	Y