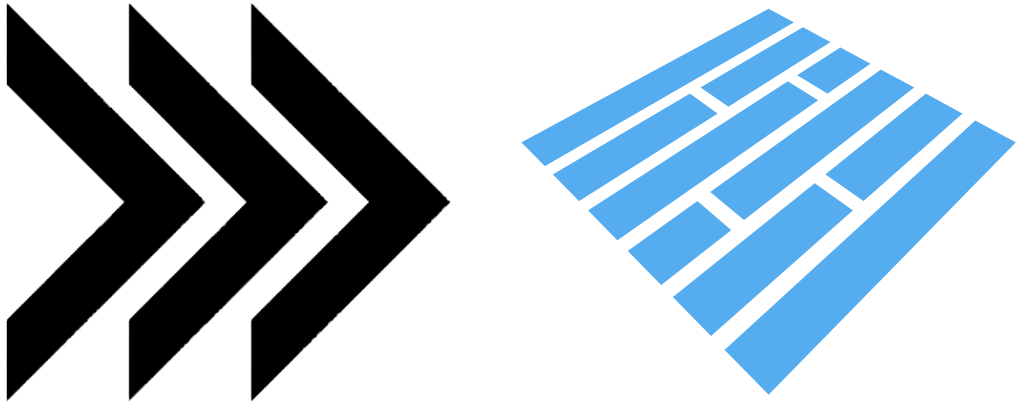

Efficient Data formats for analytics with Parquet and Arrow

Julien Le Dem
Principal Architect, Dremio
VP Apache Parquet, Apache Arrow PMC

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Julien Le Dem

@J_

- Architect at @Dremio
- Formerly Tech Lead at Twitter on Data Platforms.
- Creator of Parquet
- Apache member
- Apache PMCs: Arrow, Incubator, Pig, Parquet

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Agenda

- Benefits of Columnar formats
  - On disk (Apache Parquet)
  - In memory (Apache Arrow)
- Community Driven Standard
- Interoperability and Ecosystem

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Benefits of Columnar format

@EmrgencyKittens

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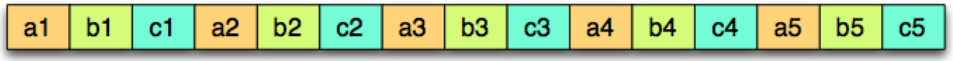
Columnar layout

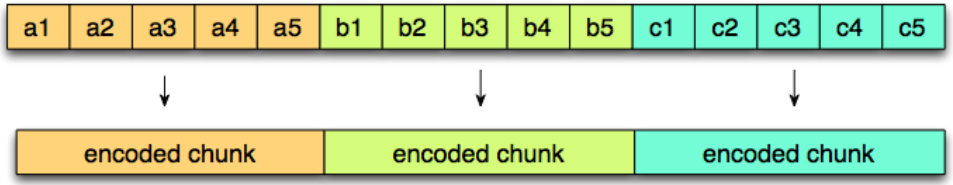
Logical table representation

a	b	c
a1	b1	c1
a2	b2	c2
a3	b3	c3
a4	b4	c4
a5	b5	c5

Row layout



Column layout



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On Disk and in Memory

- Different trade offs
  - On disk: Storage.
    - Accessed by multiple queries.
    - Priority to I/O reduction (but still needs good CPU throughput).
    - Mostly Streaming access.
  - In memory: Transient.
    - Specific to one query execution.
    - Priority to CPU throughput (but still needs good I/O).
    - Streaming and Random access.

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Parquet on disk columnar format

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Parquet on disk columnar format

- Nested data structures
- Compact format:
  - type aware encodings
  - better compression
- Optimized I/O:
  - Projection push down (column pruning)
  - Predicate push down (filters based on stats)

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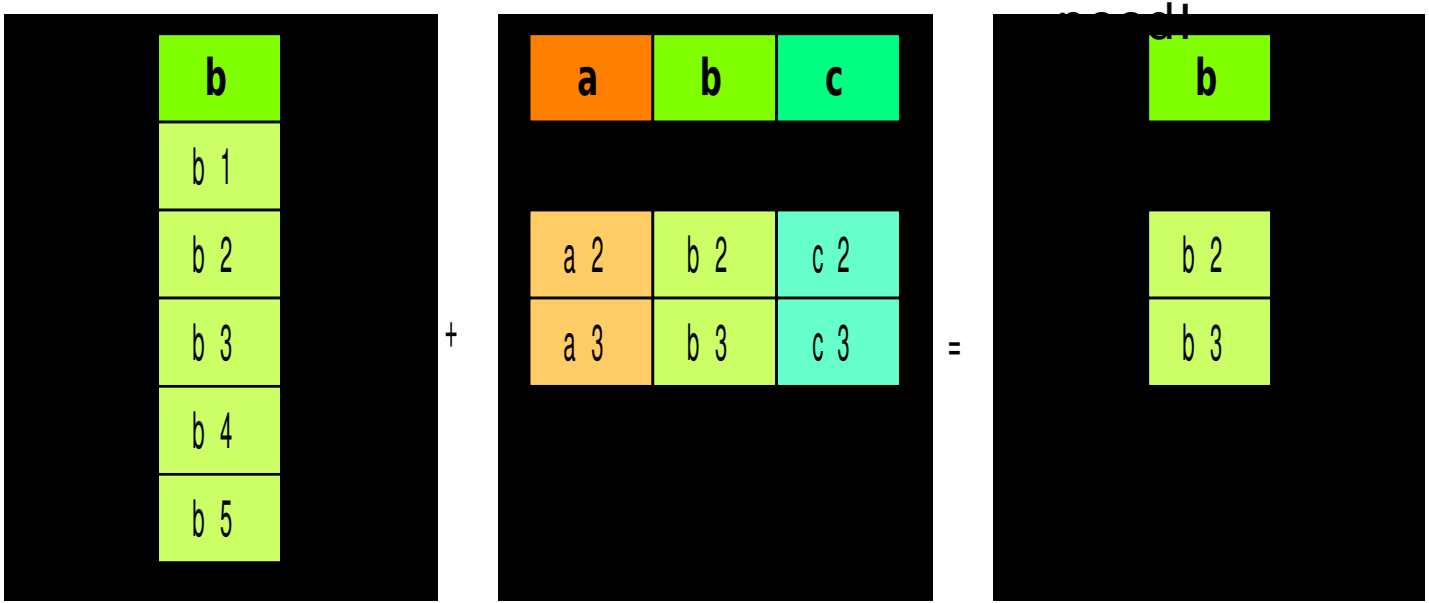
Access only the data you need

Columnar

Statistics

Read only the data you need!



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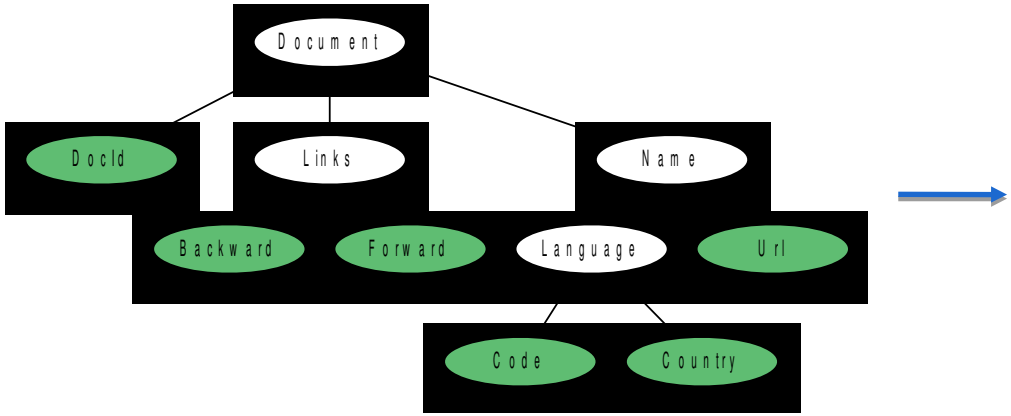
Parquet nested representation

Borrowed from the Google Dremel paper



Columns:
docid
links.backward
links.forward
name.language.code
name.language.coun
try
name.url

https://blog.twitter.com/2013/dremel-made-simple-with-parquet

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Arrow in memory columnar format

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Arrow in memory columnar format

- Nested Data Structures
- Maximize CPU throughput
  - Pipelining
  - SIMD
  - cache locality
- Scatter/gather I/O

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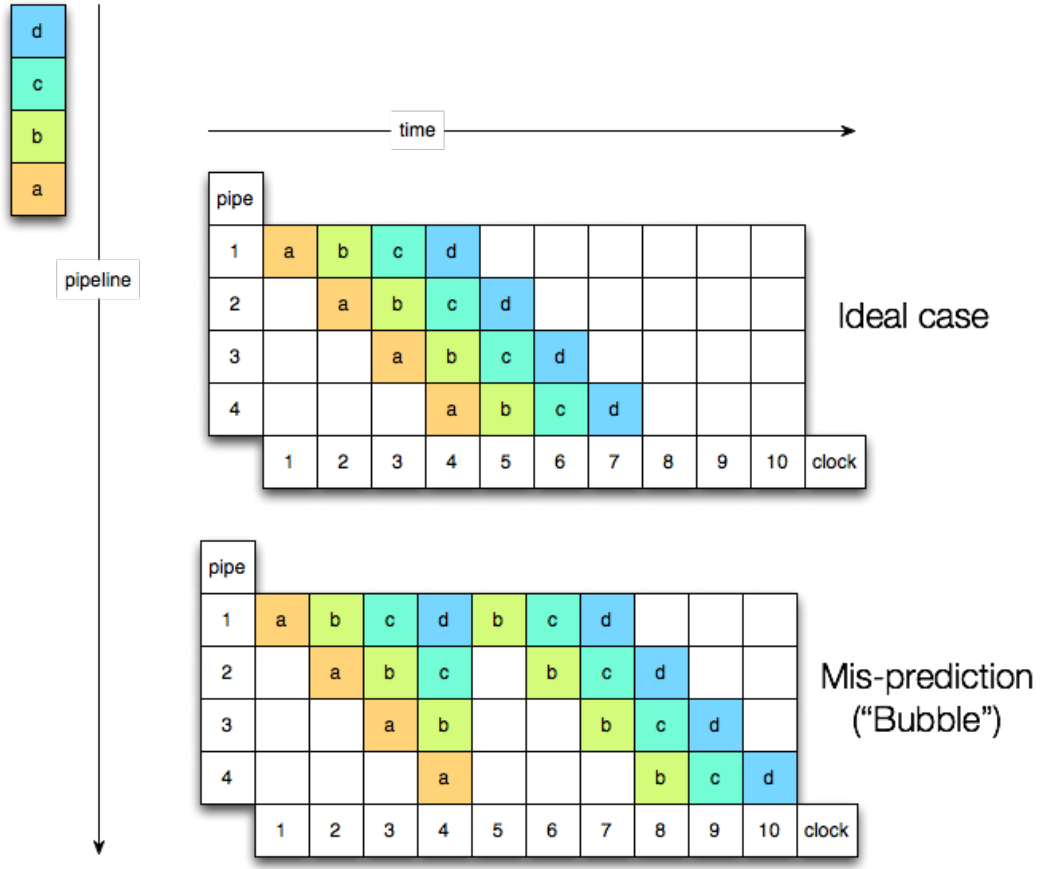
CPU pipeline



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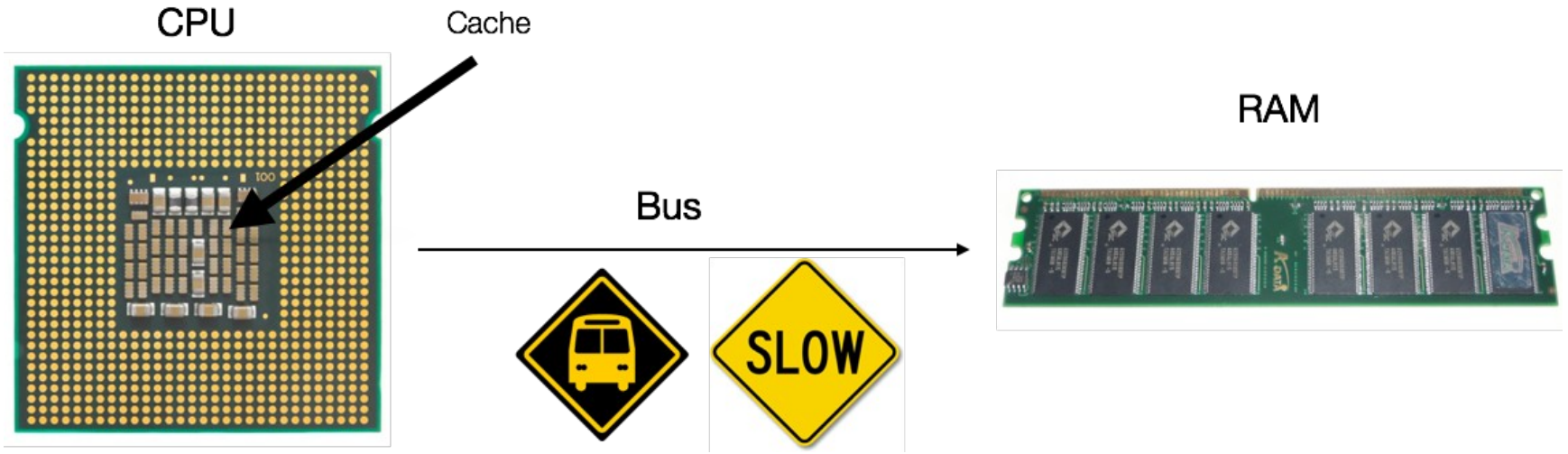
Minimize CPU cache misses



a cache miss costs 10 to 100s cycles depending on the level

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Focus on CPU Efficiency

- Cache Locality
- Super-scalar & vectorized operation
- Minimal Structure Overhead
- Constant value access
  - With minimal structure overhead
- Operate directly on columnar compressed data

	session_id	timestamp	source_ip
Row 1	1331246660	3/8/2012 2:44PM	99.155.155.225
Row 2	1331246351	3/8/2012 2:38PM	65.87.165.114
Row 3	1331244570	3/8/2012 2:09PM	71.10.106.181
Row 4	1331261196	3/8/2012 6:46PM	76.102.156.138

Traditional Memory Buffer

Row 1	1331246660
	3/8/2012 2:44PM
	99.155.155.225
Row 2	1331246351
	3/8/2012 2:38PM
	65.87.165.114
Row 3	1331244570
	3/8/2012 2:09PM
	71.10.106.181
Row 4	1331261196
	3/8/2012 6:46PM
	76.102.156.138

Arrow Memory Buffer

session_id	1331246660
	1331246351
	1331244570
	1331261196
timestamp	3/8/2012 2:44PM
	3/8/2012 2:38PM
	3/8/2012 2:09PM
	3/8/2012 6:46PM
source_ip	99.155.155.225
	65.87.165.114
	71.10.106.181
	76.102.156.138

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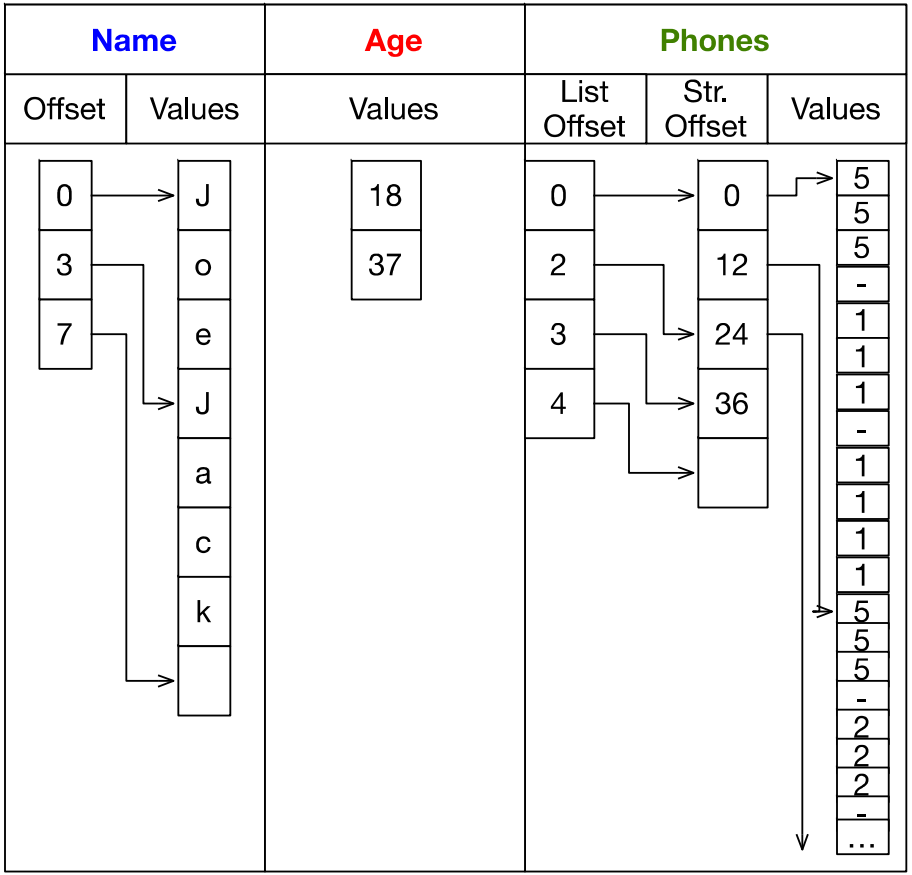
Columnar data

```
persons = [{
    name:'Joe',
    age:18,
    phones:[
        '555-111-1111',
        '555-222-2222'
    ]
},{
    name:'Jack',
    age:37,
    phones:['555-333-3333']
}]
```



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Java: Memory Management

- Chunk-based managed allocator
  - Built on top of Netty's JEMalloc implementation
- Create a tree of allocators
  - Limit and transfer semantics across allocators
  - Leak detection and location accounting
- Wrap native memory from other applications

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Community Driven Standard

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An open source standard

- Arrow: Common need for in memory columnar.
- Benefits:
  - Share the effort
  - Create an ecosystem
- Building on the success of Parquet.
- Standard from the start

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Shared Need > Open Source Opportunity

“We are also considering switching to a columnar canonical in-memory format for data that needs to be materialized during query processing, in order to take advantage of SIMD instructions” - Impala Team

“A large fraction of the CPU time is spent waiting for data to be fetched from main memory…we are designing cache-friendly algorithms and data structures so Spark applications will spend less time waiting to fetch data from memory and more time doing useful work” – Spark Team

“Drill provides a flexible hierarchical columnar data model that can represent complex, highly dynamic and evolving data models and allows efficient processing of it without need to flatten or materialize.” -Drill Team

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Arrow goals

- Well-documented and cross language compatible
- Designed to take advantage of modern CPU characteristics
- Embeddable in execution engines, storage layers, etc.
- Interoperable

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The Apache Arrow Project

- New Top-level Apache Software Foundation project
  - Announced Feb 17, 2016
- Focused on Columnar In-Memory Analytics
  1. 10-100x speedup on many workloads
  2. Common data layer enables companies to choose best of breed systems
  3. Designed to work with any programming language
  4. Support for both relational and complex data as-is
- Developers from 13+ major open source projects involved
  - A significant % of the world's data will be processed through Arrow!

Calcite
Cassandra
Deeplearning4j
Drill
Hadoop
HBase
Ibis
Impala
Kudu
Pandas
Parquet
Phoenix
Spark
Storm
R

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Interoperability and Ecosystem

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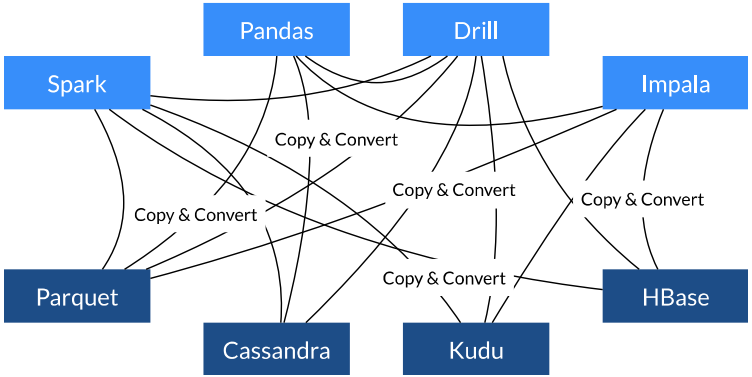
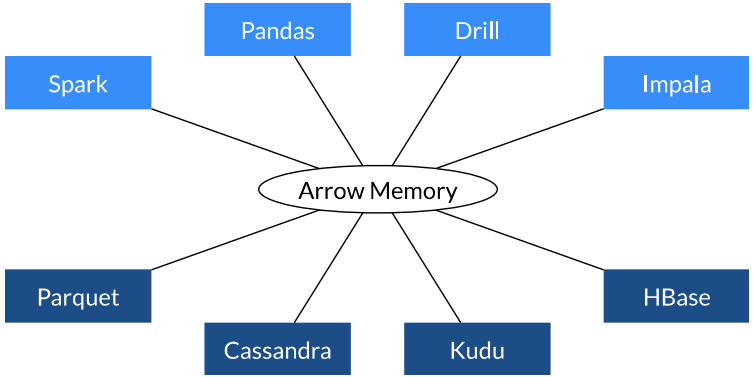
High Performance Sharing & Interchange

Today



- Each system has its own internal memory format
- 70-80% CPU wasted on serialization and deserialization
- Functionality duplication and unnecessary conversions

With Arrow



- All systems utilize the same memory format
- No overhead for cross-system communication
- Projects can share functionality (eg: Parquet-to-Arrow reader)

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Language Bindings

Parquet

- Target Languages
  - Java
  - CPP (underway)
  - Python & Pandas (underway)

Arrow

- Target Languages
  - Java (beta)
  - CPP (underway)
  - Python & Pandas (underway)
  - R
  - Julia
- Initial Focus
  - Read a structure
  - Write a structure
  - Manage Memory

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RPC & IPC

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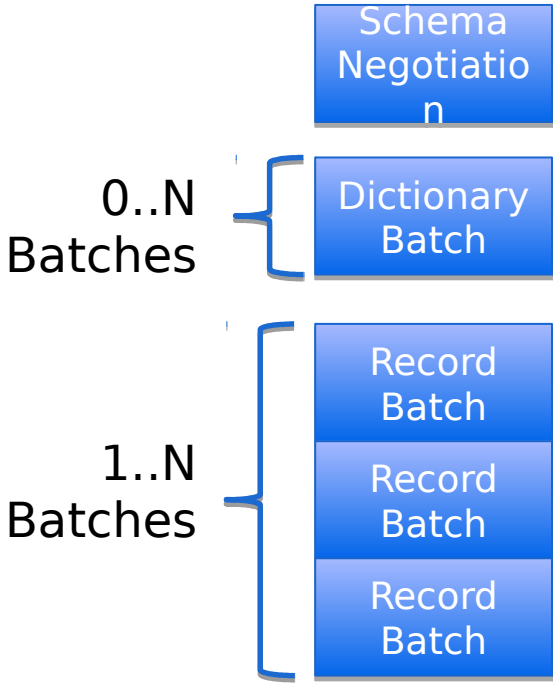
Common Message Pattern

- Schema Negotiation
  - Logical Description of structure
  - Identification of dictionary encoded Nodes
- Dictionary Batch
  - Dictionary ID, Values
- Record Batch
  - Batches of records up to 64K
  - Leaf nodes up to 2B values



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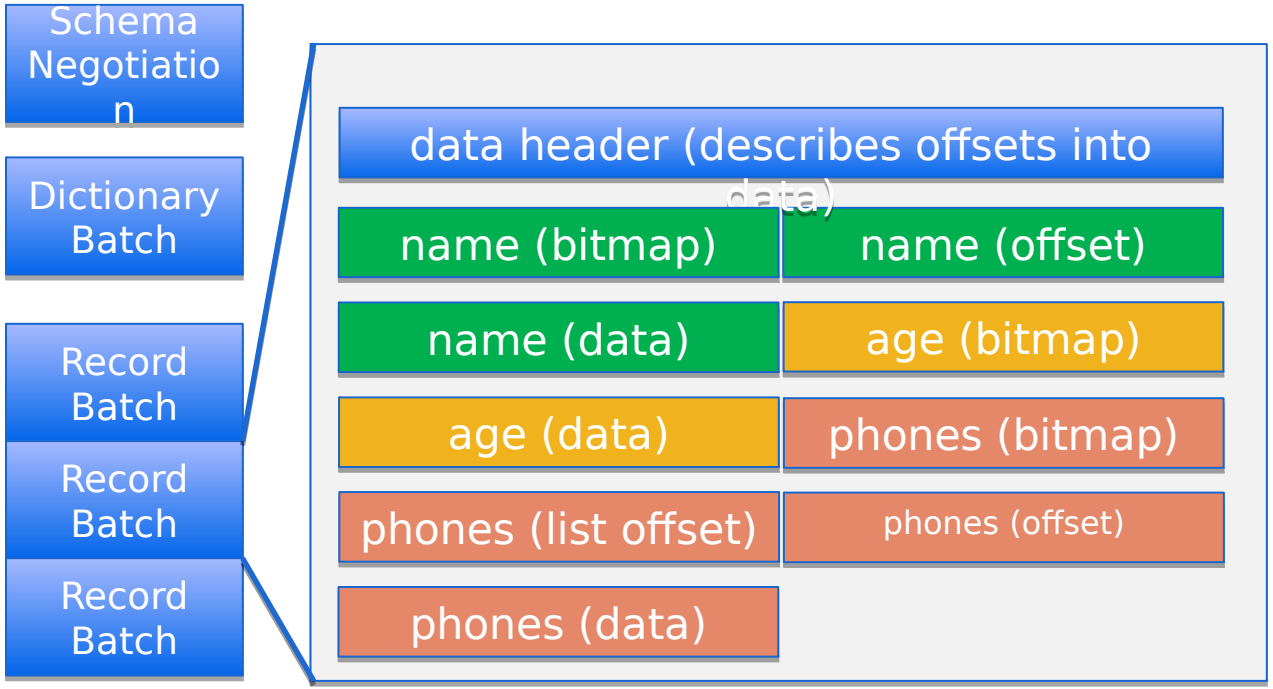
Record Batch Construction



Each box (vector) is contiguous memory
The entire record batch is contiguous on wire

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Moving Data Between Systems

RPC

- Avoid Serialization & Deserialization
- Layer TBD: Focused on supporting vectored io
  - Scatter/gather reads/writes against socket

IPC

- Alpha implementation using memory mapped files
  - Moving data between Python and Drill
- Working on shared allocation approach
  - Shared reference counting and well-defined ownership semantics

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Example data exchanges:

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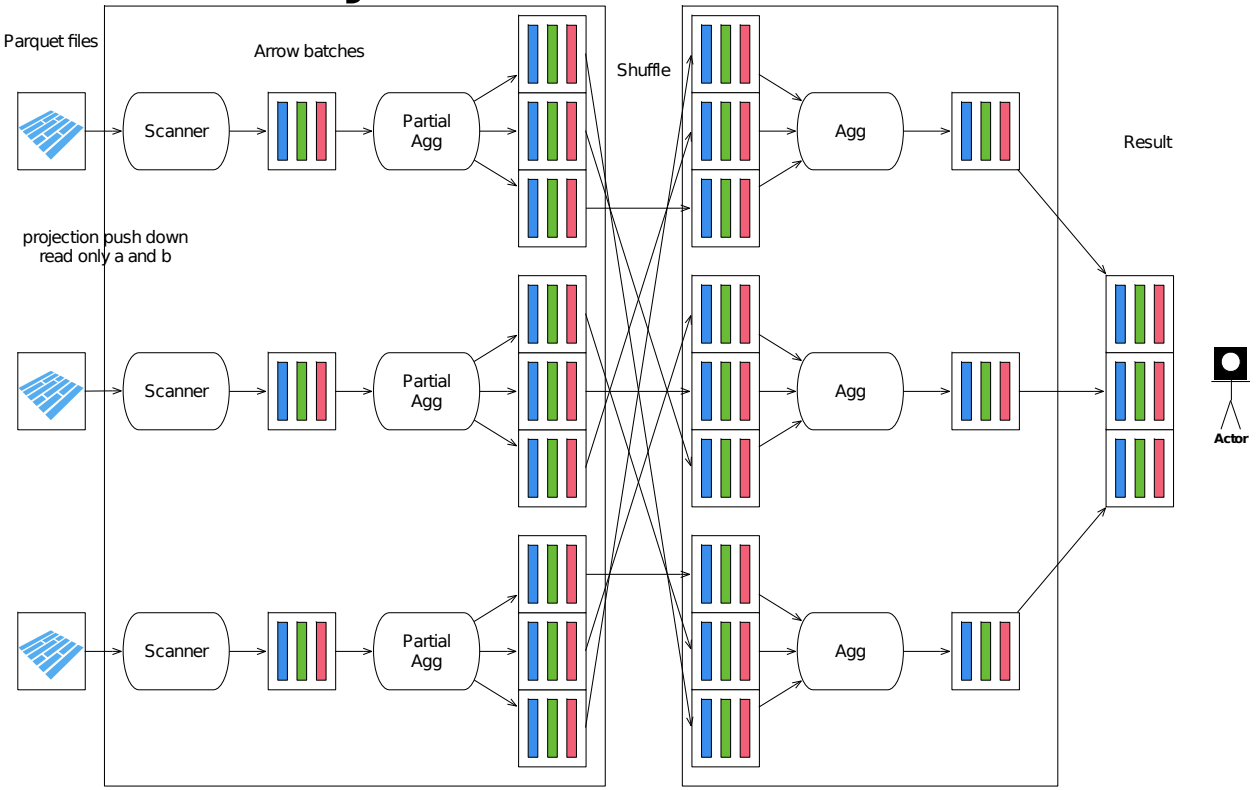
RPC: Query execution



SELECT SUM(a) FROM t GROUP BY b

The memory representation is sent over the wire.

No serialization overhead.

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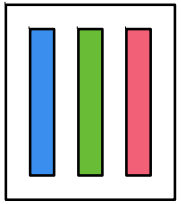
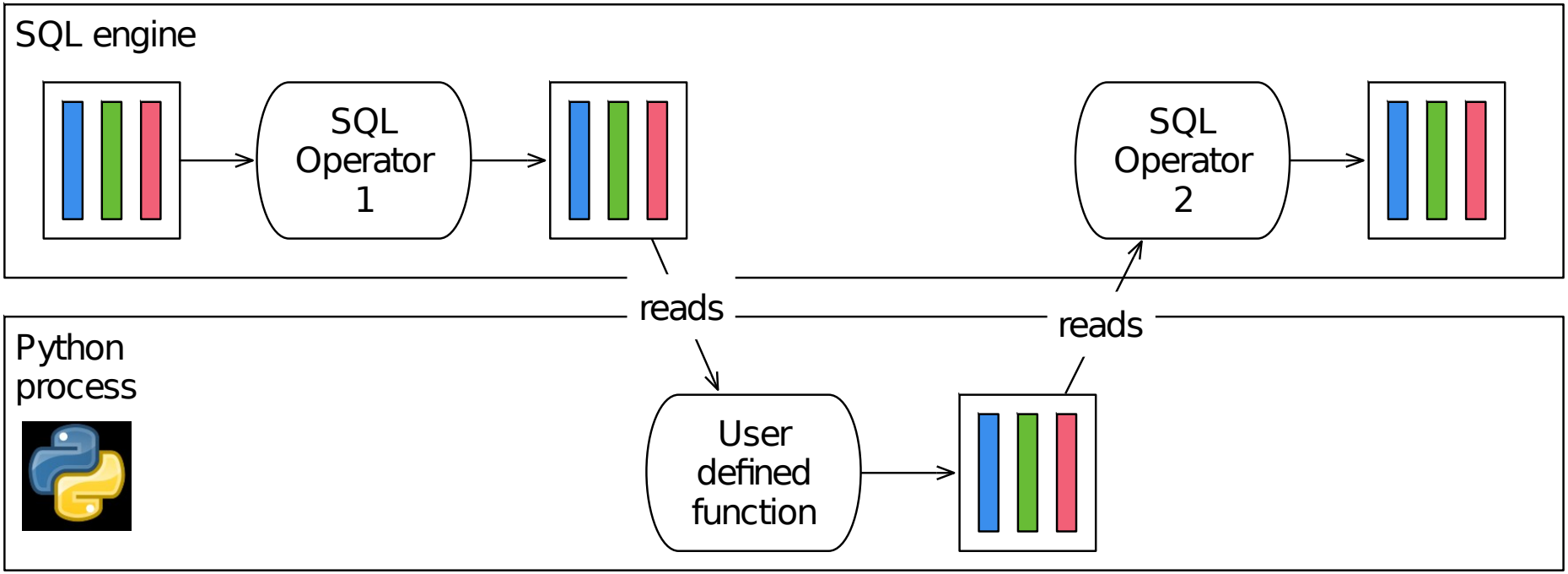
IPC: Python with Spark or Dri



Immutable Arrow Batch



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What's Next

- Parquet – Arrow conversion for Python & C++
- Arrow IPC Implementation
- Apache {Spark, Drill} to Arrow Integration
  - Faster UDFs, Storage interfaces
- Support for integration with Intel's Persistent Memory library via Apache

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Get Involved

- Join the community
  - dev@arrow.apache.org, dev@parquet.apache.org
  - Slack: https://apachearrowslackin.herokuapp.com/
  - http://arrow.apache.org http://parquet.apache.org

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