Radically modular data ingestion APIs in Apache Beam

Eugene Kirpichov <kirpichov@google.com>
Staff Software Engineer

Google Cloud Platform

Plan

01 **Intro to Beam**
Unified, portable data processing

02 **IO — APIs for data ingestion**
What's the big deal

03 **Composable IO**
IO as data processing

04 **Splittable DoFn**
Missing piece for composable sources

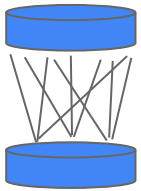
05 **Recap**
If you remember two things

01 Intro to Beam

Unified, portable data processing

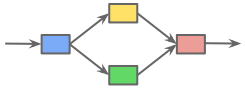
(2004) MapReduce

SELECT + GROUPBY



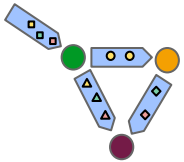
(2008) FlumeJava

High-level API



(2013) Millwheel

Deterministic streaming



(2014) Dataflow

Batch/streaming agnostic, Portable across languages & runners

(2016) Apache Beam

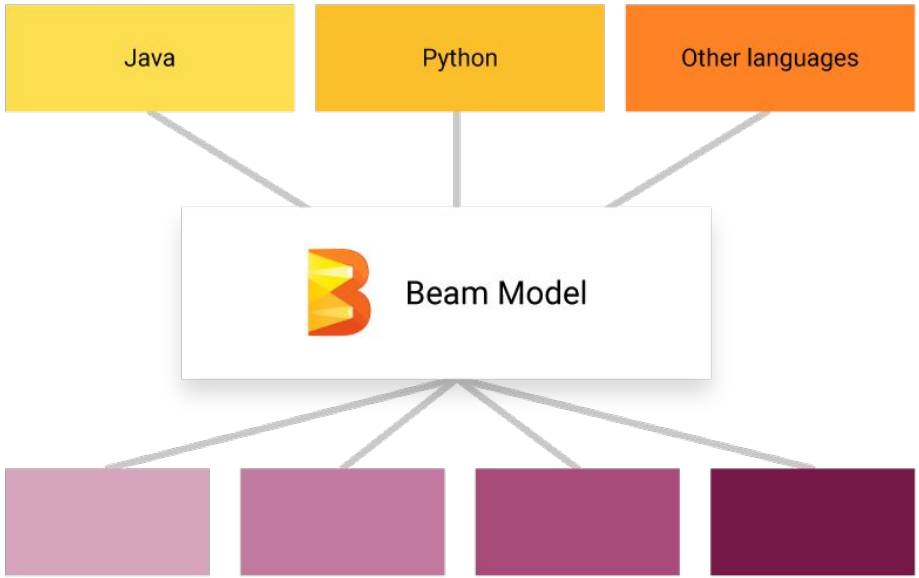
Open, Community-driven, Vendor-independent

Batch vs. streaming is moot

— Beam

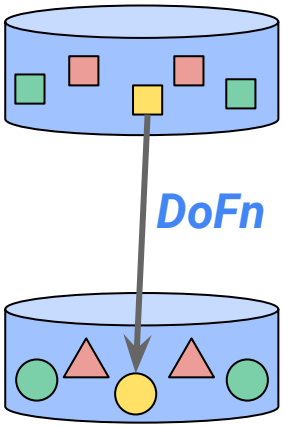
(Batch is nearly always part of higher-level streaming)

Choose your language...

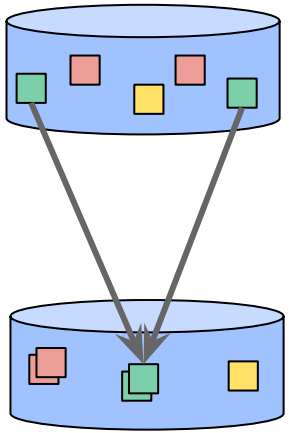


...and your runtime.

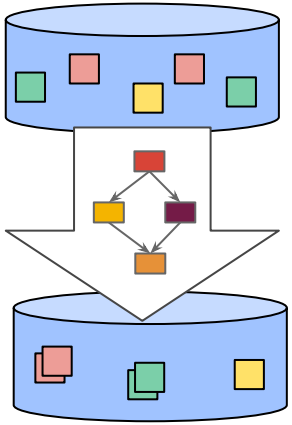
Beam PTransforms



ParDo
(good old FlatMap)



GroupByKey



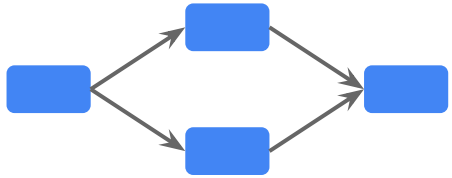
Composite

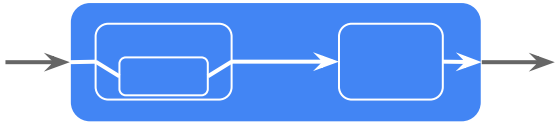
User code

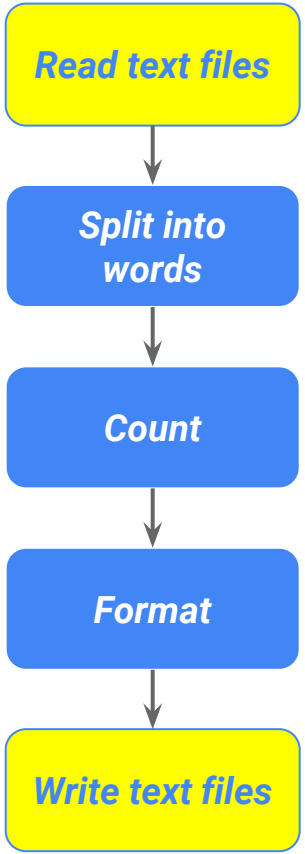
Libraries of PTransforms, IO

SDK (per language)

Runner








```
Pipeline p = Pipeline.create(options);

PCollection<String> lines = p.apply(
    TextIO.read().from("gs://.../*"));
PCollection<KV<String, Long>> wordCounts = lines
  .apply(FlatMapElements.via(word → word.split("\\W+")))
  .apply(Count.perElement());
wordCounts
  .apply(MapElements.via(
     count → count.getKey() + ": " + count.getValue()))
  .apply(TextIO.write().to("gs://.../..."));

p.run();
```

02 IO - APIs for data ingestion

What's the big deal

Beam IO

Files
Text/Avro/XML/…
HDFS, S3, GCS

Kafka

Kinesis

AMQP

Pubsub

JMS

Hadoop

MQTT

JDBC

MongoDb

Redis

Cassandra

HBase

Hive

Solr

Elasticsearch

BigQuery

BigTable

Datastore

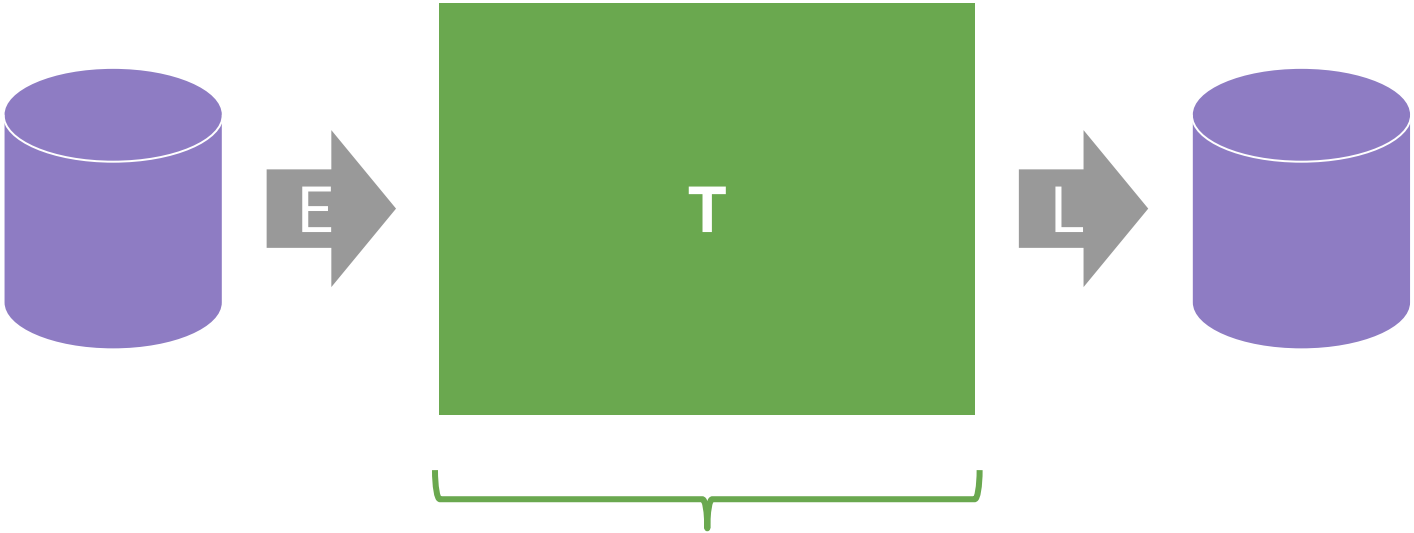
Spanner

IO is **essential**

Most pipelines move data from X to Y

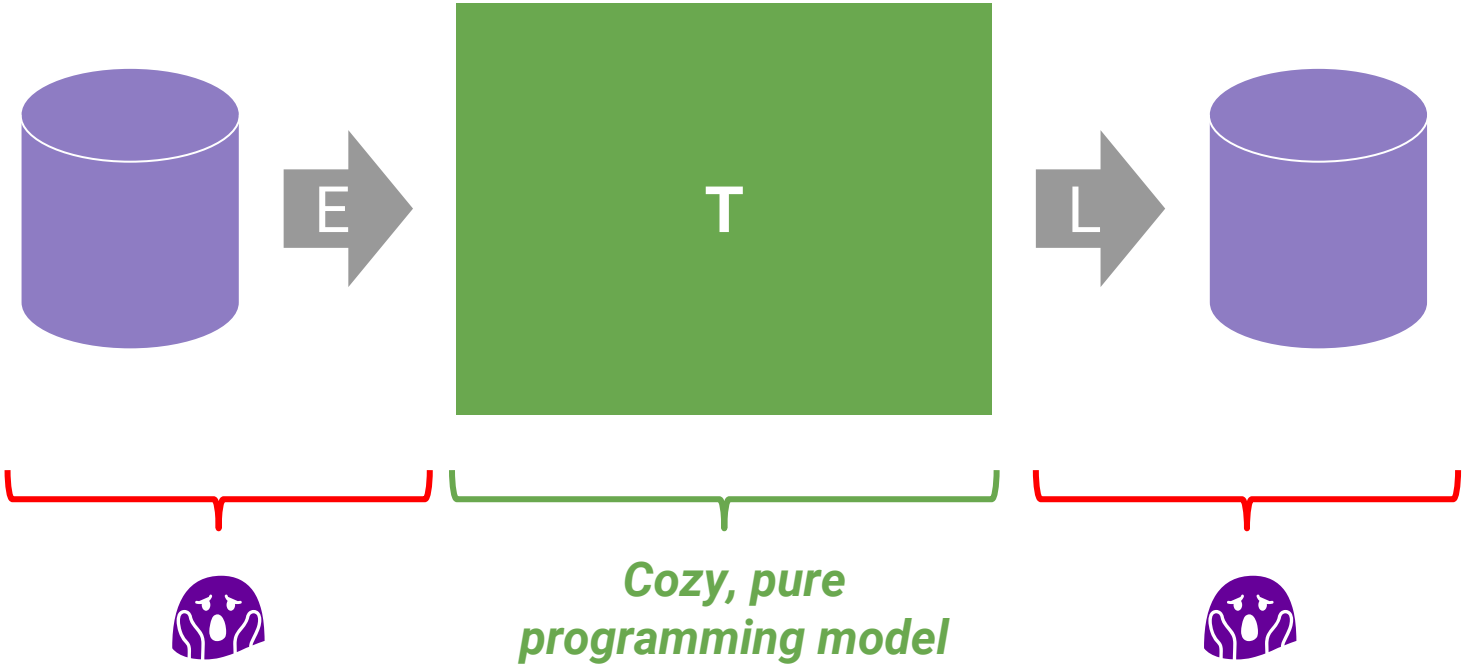
*ETL: **E**xtract, **T**ransform, **L**oad*

IO is **messy**



Cozy, pure programming model

IO is **messy**



IO is **messy**

Read via CSV dump

Clean up temp files

Preserve filenames

Route to different tables

Decompress ZIP

Dead-letter failed records

Read tons of small files

Skip headers

Write A, then write B

Write to A, then read B

Read multiple tables in tx

Stream new files

Quotas & size limits

Rate limiting / throttling

…

IO is **unified**

(batch/streaming agnostic)

Classic batch

Read files

Write files

Classic streaming

Read Kafka

Stream to Kafka

Reality

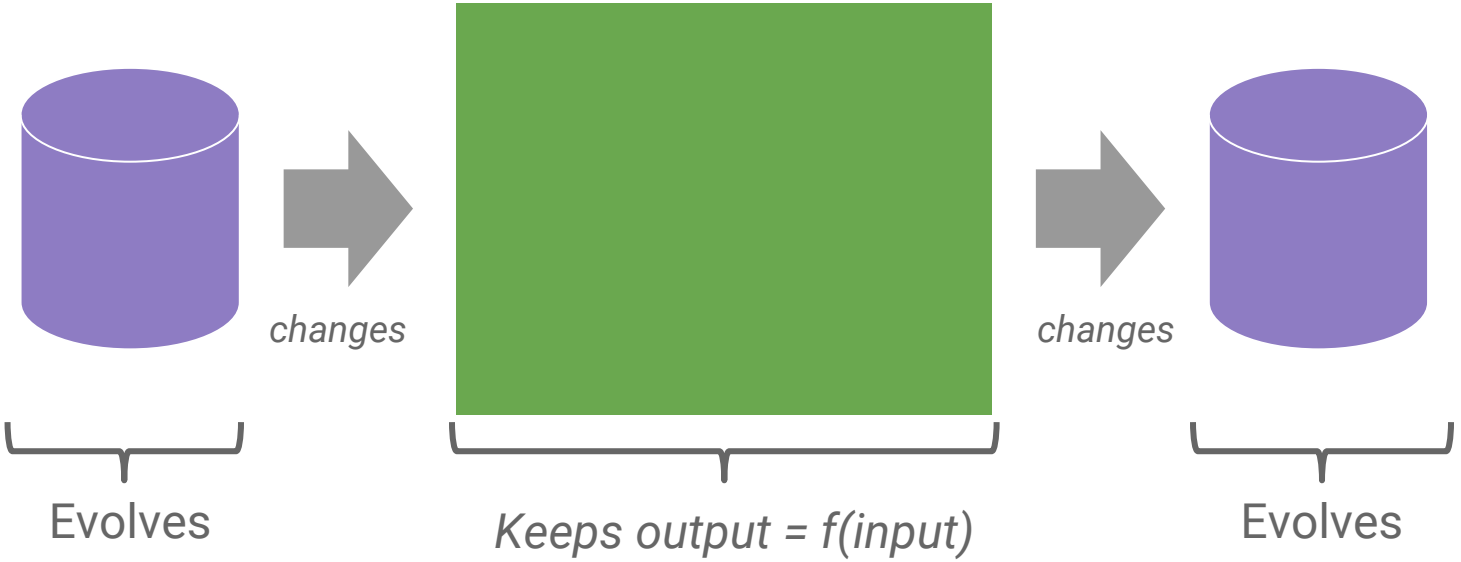
Read files + watch new files

Stream files

Read Kafka from start + tail

IO is **unified**

(batch/streaming agnostic)



https://www.infoq.com/presentations/beam-model-stream-table=theory

IO is **unforgiving**

Correctness

Any bug = data corruption

Fault tolerance

Exactly-once reads/writes

Error handling

Performance

Unexpected scale

Throughput, latency, memory, parallelism

IO is **a chance to do better**

Nobody writes a paper about their IO API.

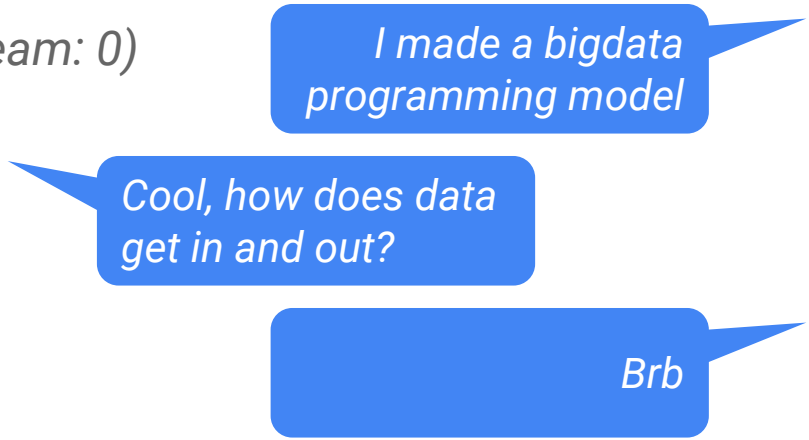
(MapReduce paper — 3 paragraphs; Spark, Flink, Beam: 0)

Requirements too diverse

to support everything out of the box

APIs too rigid

to let users do it themselves



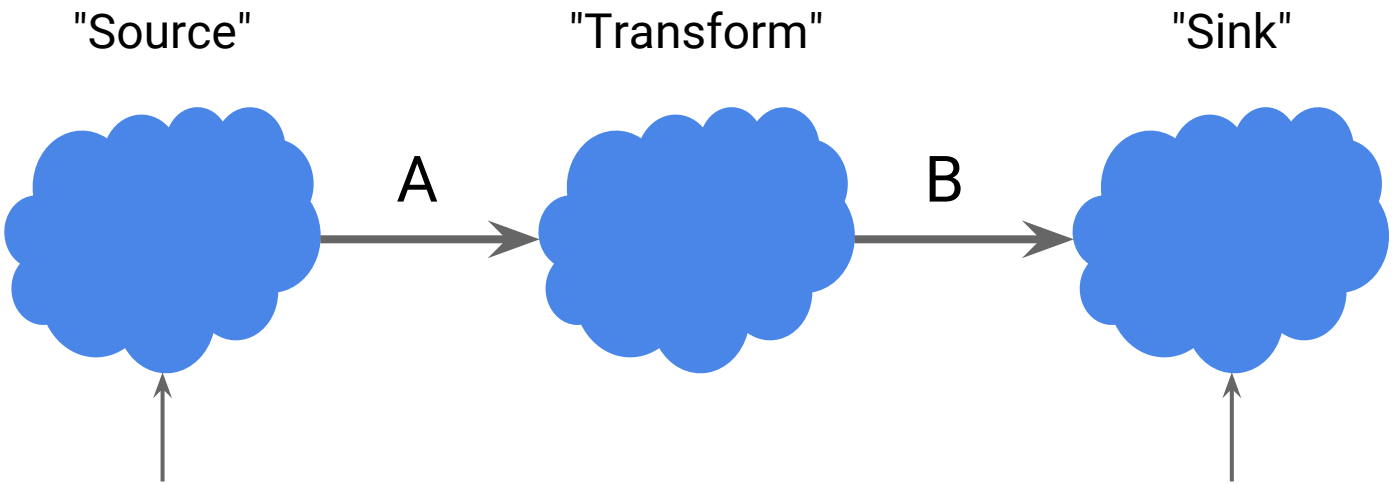
IO is essential, but messy and unforgiving.

It begs for good abstractions.

03 Composable IO

IO as data processing

Traditionally: ad-hoc API, at pipeline boundary



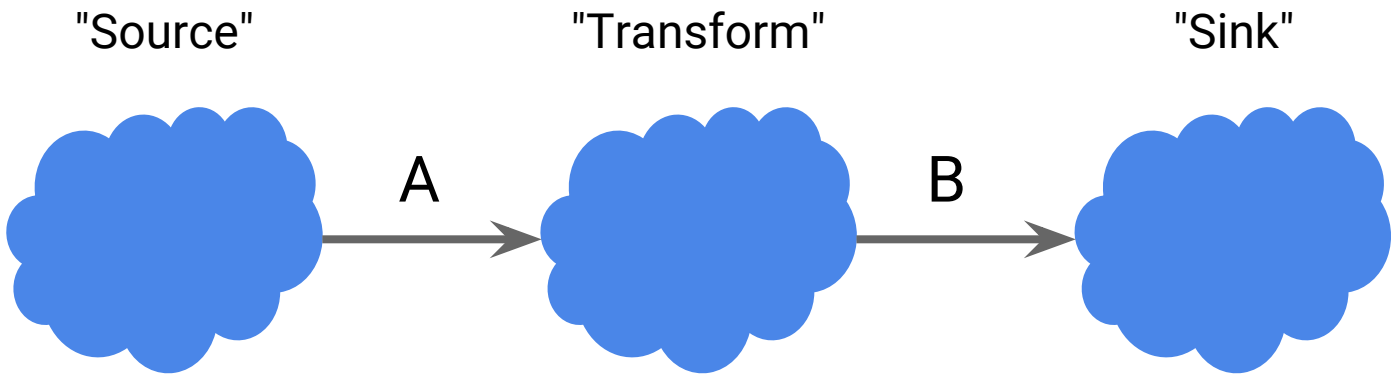
InputFormat / Receiver / SourceFunction / ...

Configuration:
Filepattern
Query string
Topic name
...

OutputFormat / Sink / SinkFunction / ...

Configuration:
Directory
Table name
Topic name
...

Traditionally: ad-hoc API, at pipeline boundary



My filenames come on a Kafka topic.

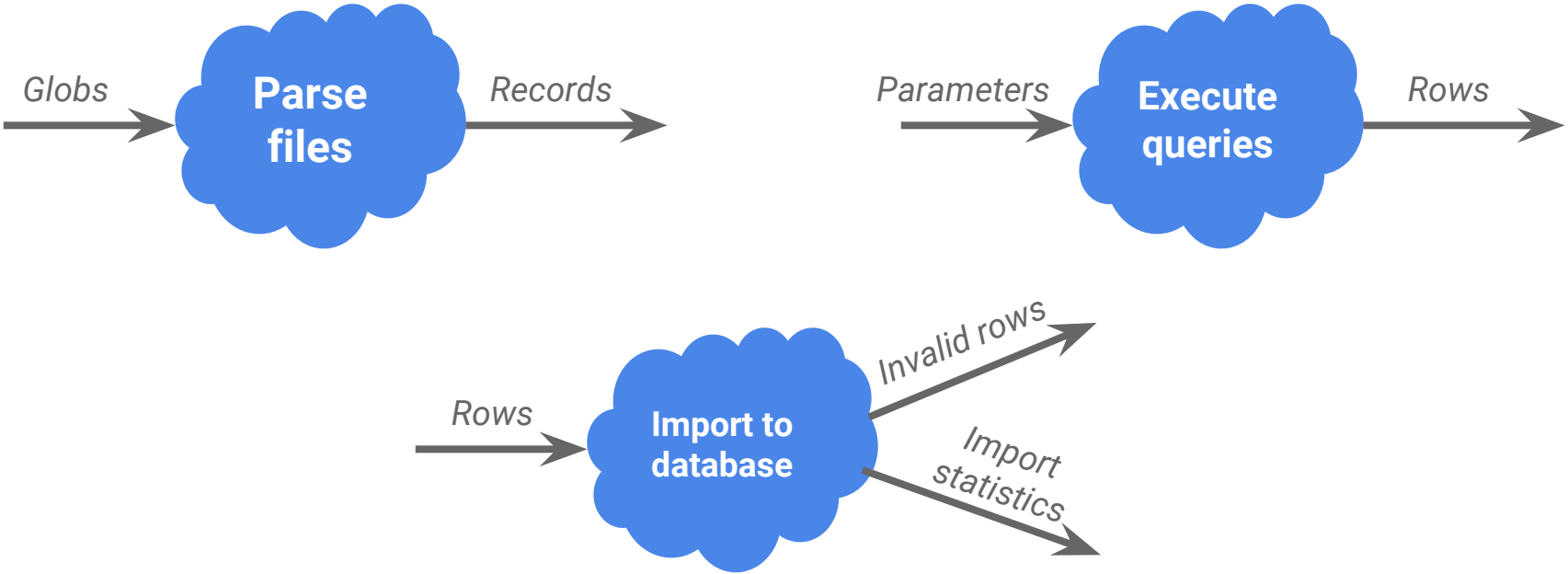
I have a table per client + table of clients

Narrow APIs are not **hackable**

I want to know which records failed to write

I want to kick off another transform after writing

IO is just another data processing task



IO is just another data processing task

Composability
(aka hackability)

Unified batch/streaming

Transparent fault tolerance

Scalability
(read 1M files = process 1M elements)

Monitoring, debugging

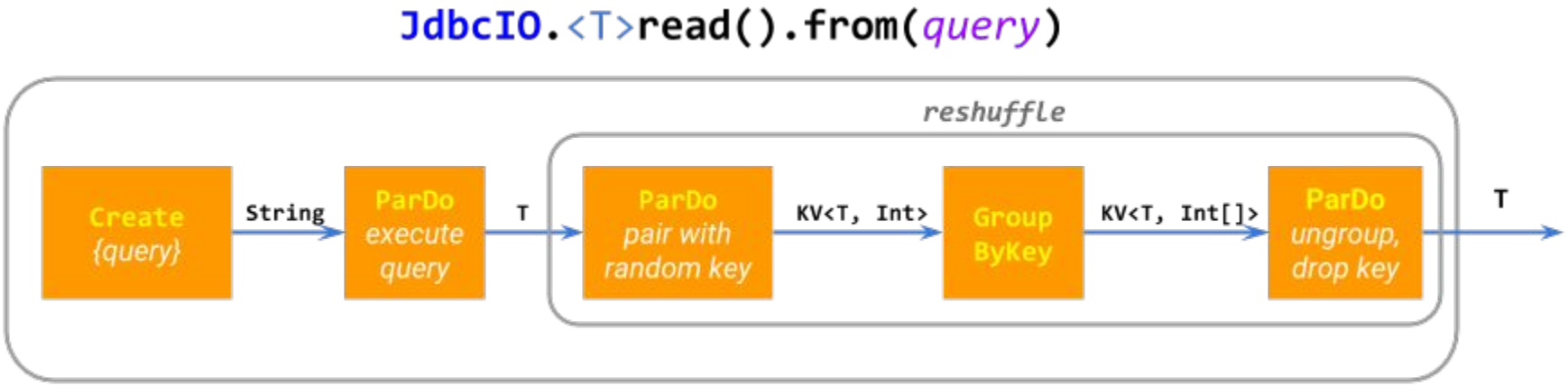
Orchestration
(do X, then read / write, then do Y)

Future features

The rest of the programming model has been getting this for free all along.

Join the party.

IO in Beam: just transforms



BigQueryIO.write():

(write to files, call import API)

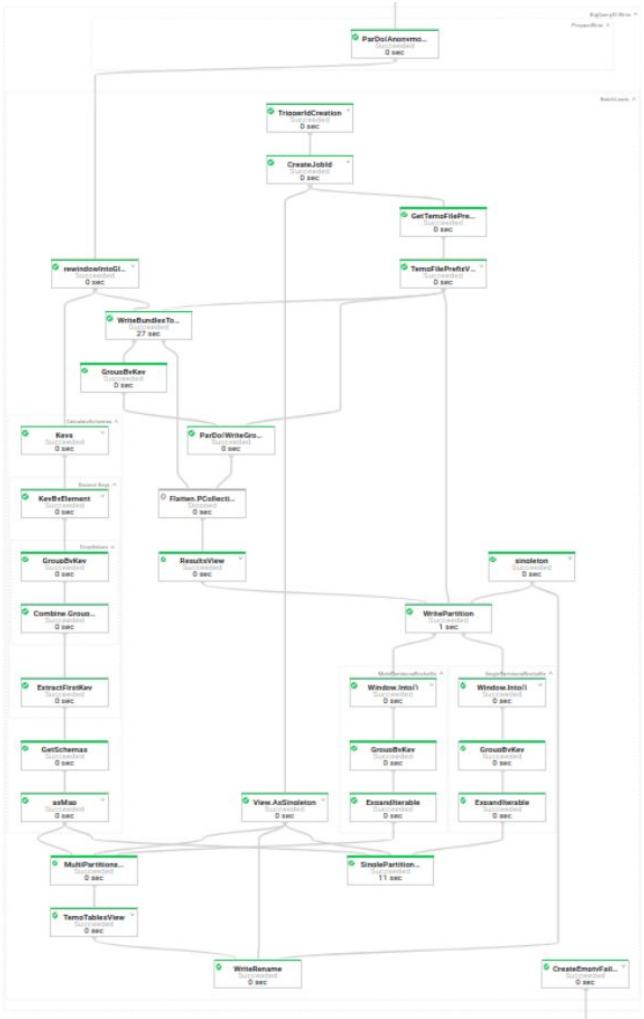
Dynamic routing

Cleanup

Sharding to fit under API limits

…

Pretty complex, but **arbitrarily** powerful



Composability ⇒ Modularity

What can be composed, can be decomposed.

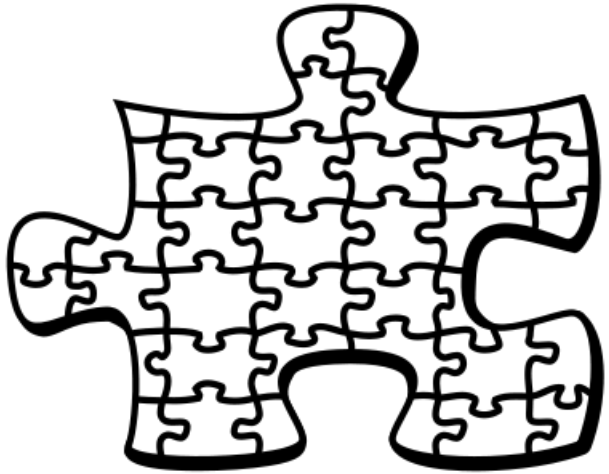
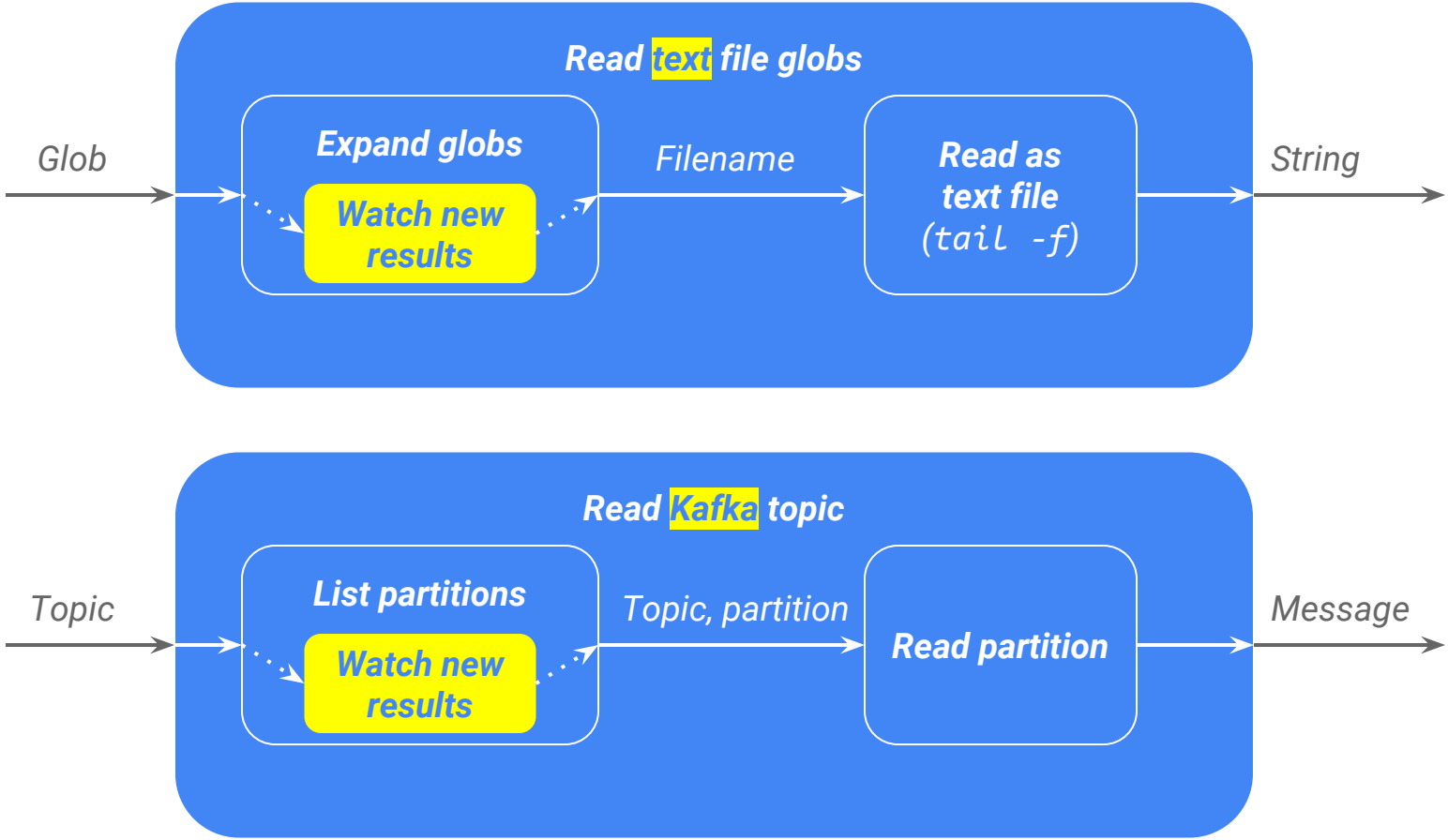
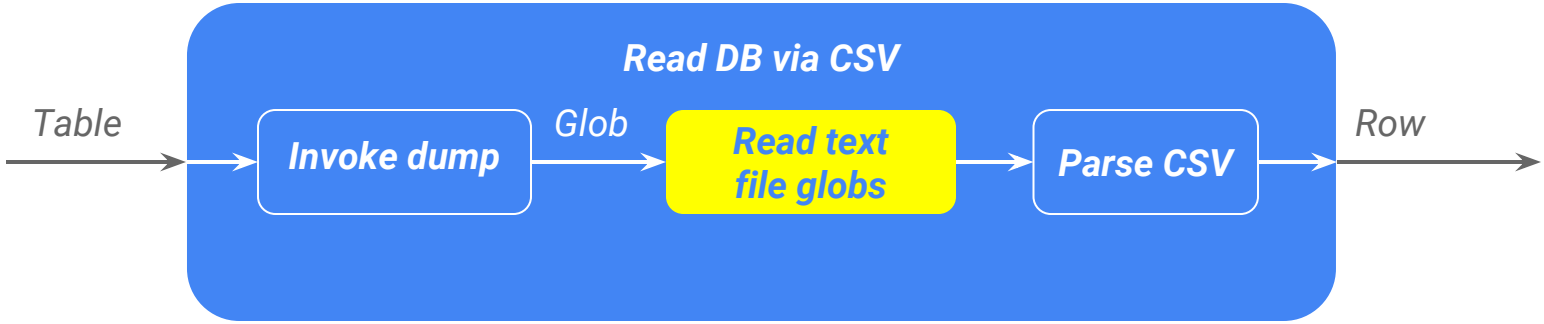
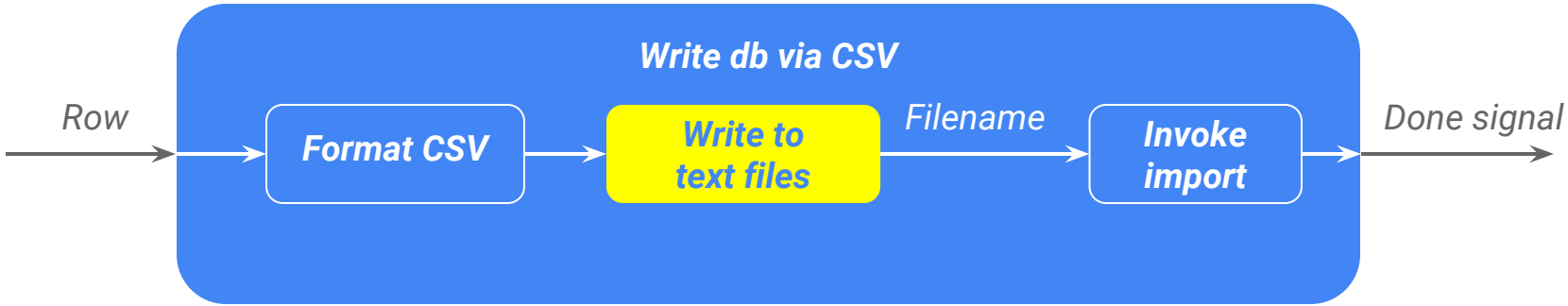
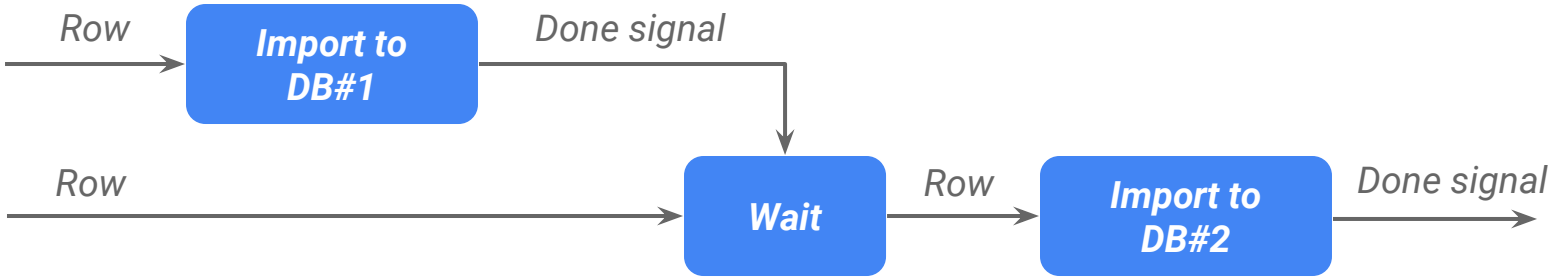


Image credit: Wikimedia


Read text file globs
Glob
Expand globs
Watch new results
Filename
Read as text file (tail -f)
String
Read Kafka topic
Topic
List partitions
Watch new results
Topic, partition
Read partition
Message


Read DB via CSV
Table
Invoke dump
Glob
Read text file globs
Parse CSV
Row


Write db via CSV
Row
Format CSV
Write to text files
Filename
Invoke import
Done signal



Consistent import into 2 databases

What can be composed, can be decomposed.

What this means for you

Library authors

- Ignore native IO APIs if possible
- Unify batch & streaming
- Decompose ruthlessly

Users

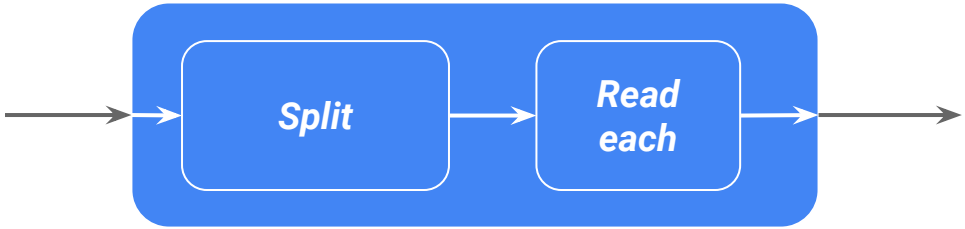
- Ignore native IO APIs if possible
- Assemble what you need from powerful primitives

04 Splittable DoFn

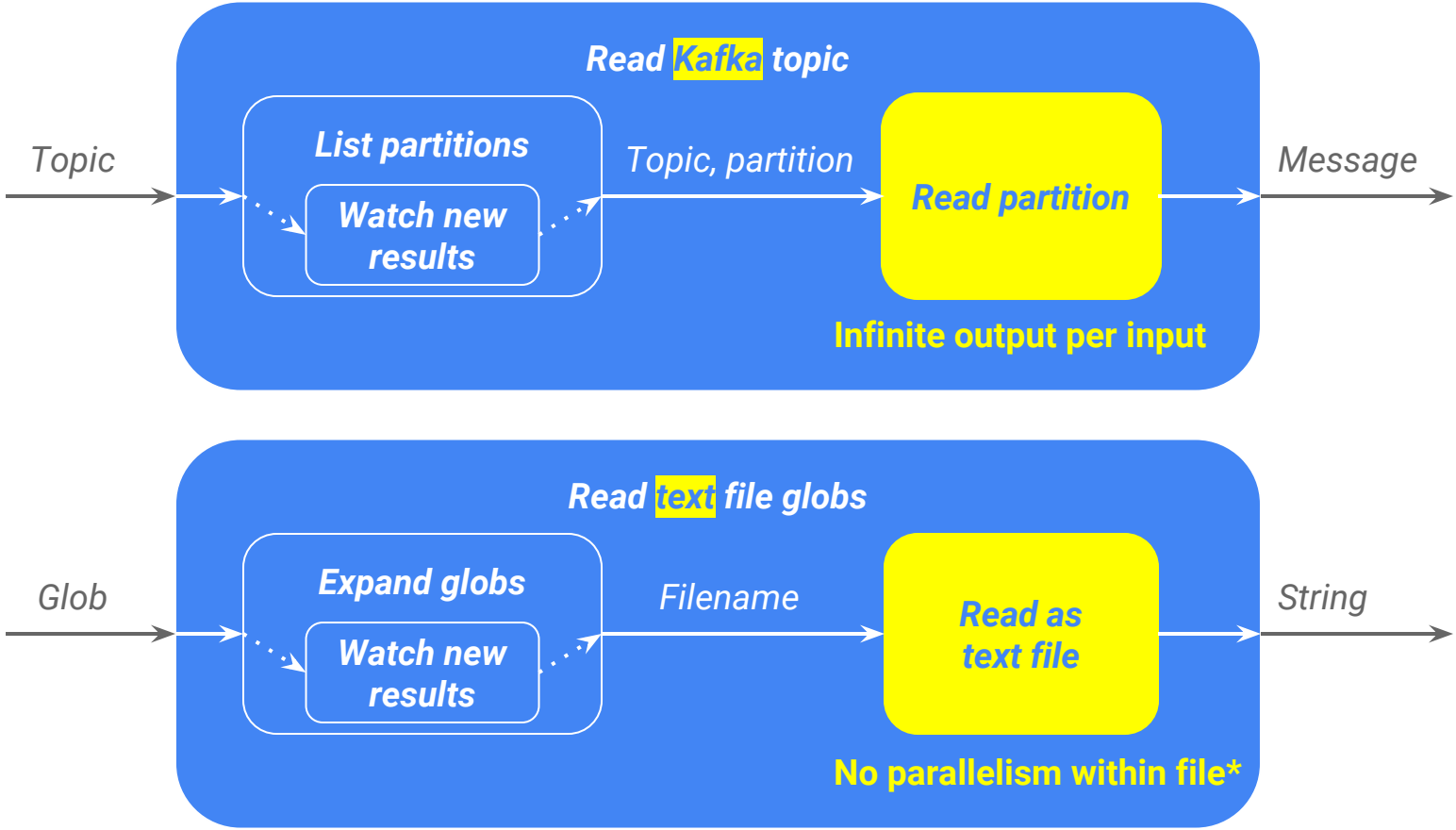
Missing piece for composable sources

Typical IO transforms

Read



Write



*No Shard Left Behind: Straggler-free data processing in Cloud Dataflow

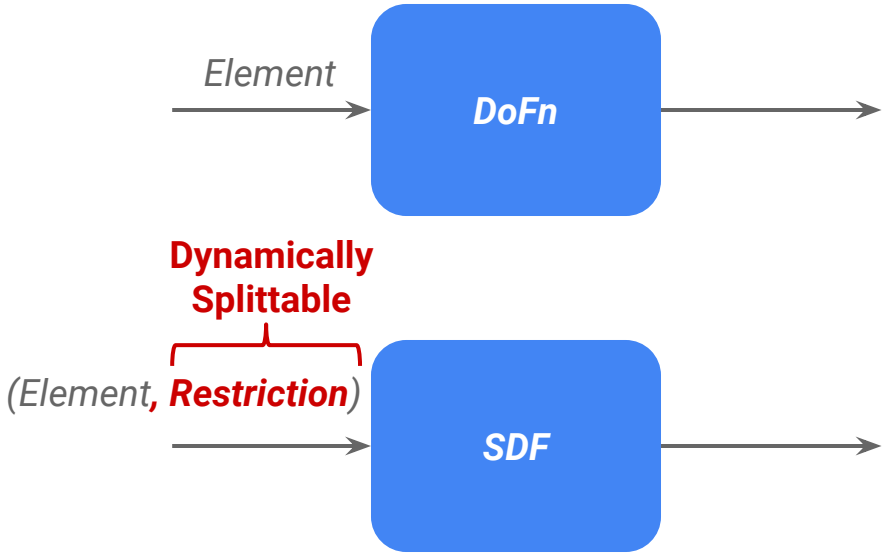
What ParDo can't do

Per-element work is **indivisible black box**

⇒ can't be **infinite**

⇒ can't be **parallelized further**

Splittable DoFn (SDF): Partial work via restrictions



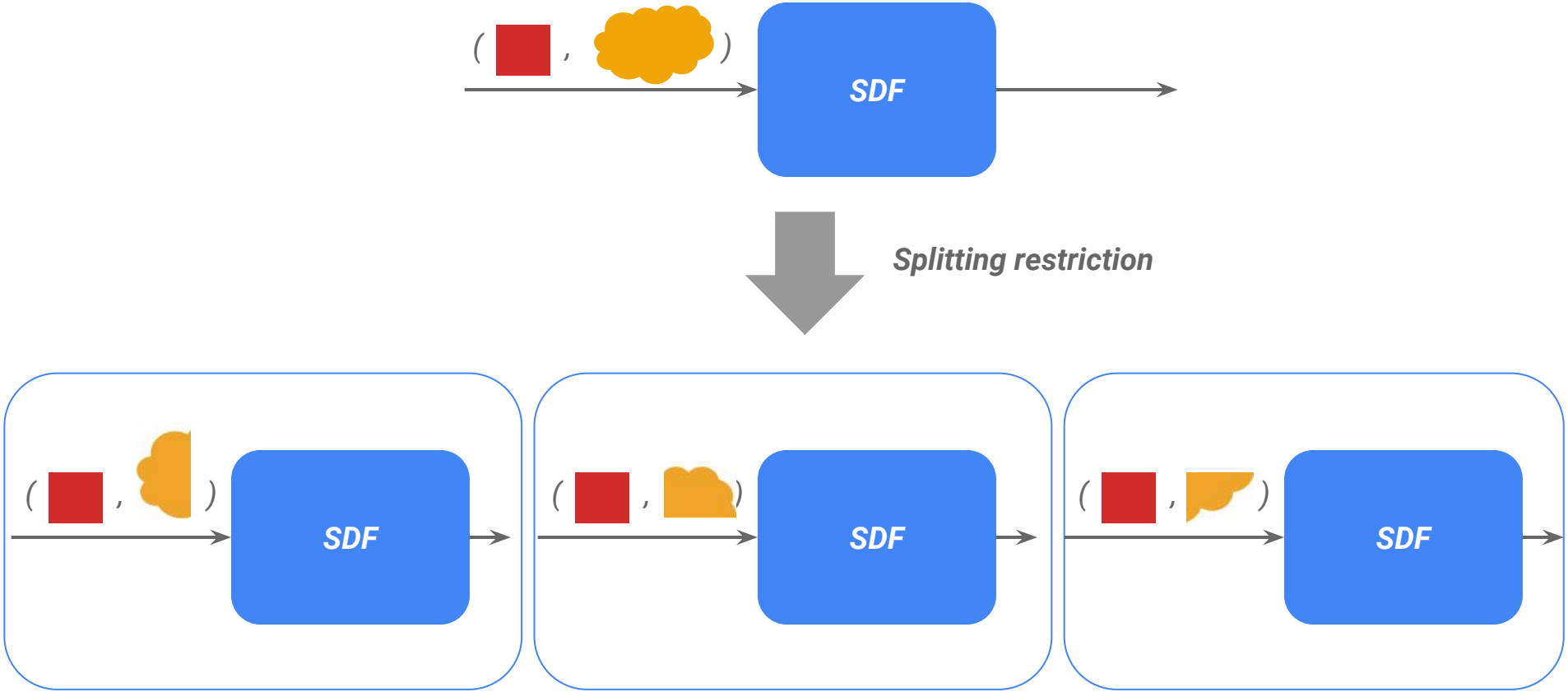
Element: what work

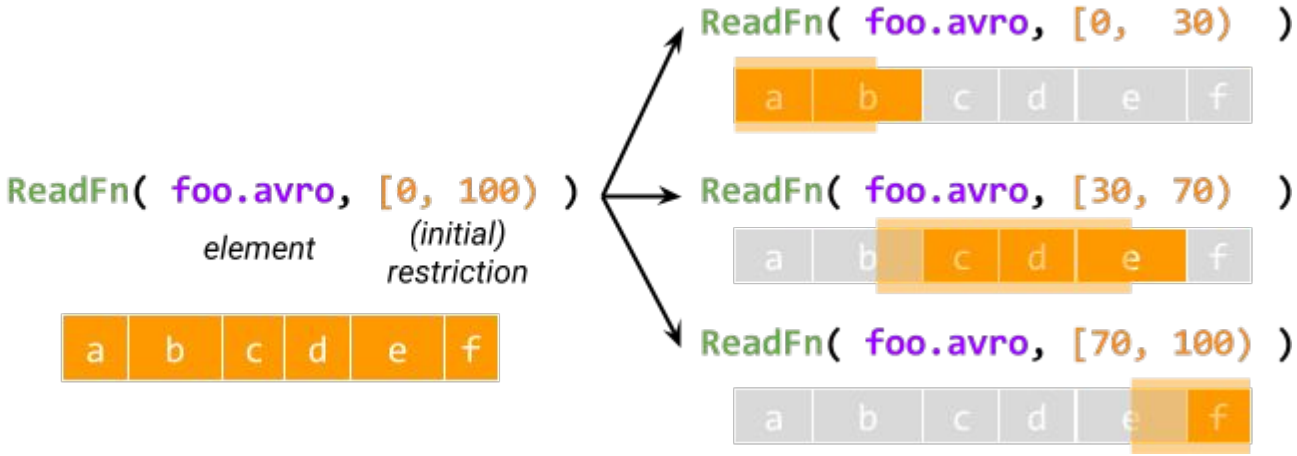
Restriction: what **part** of the work

Design: s.apache.org/splittable-do-fn

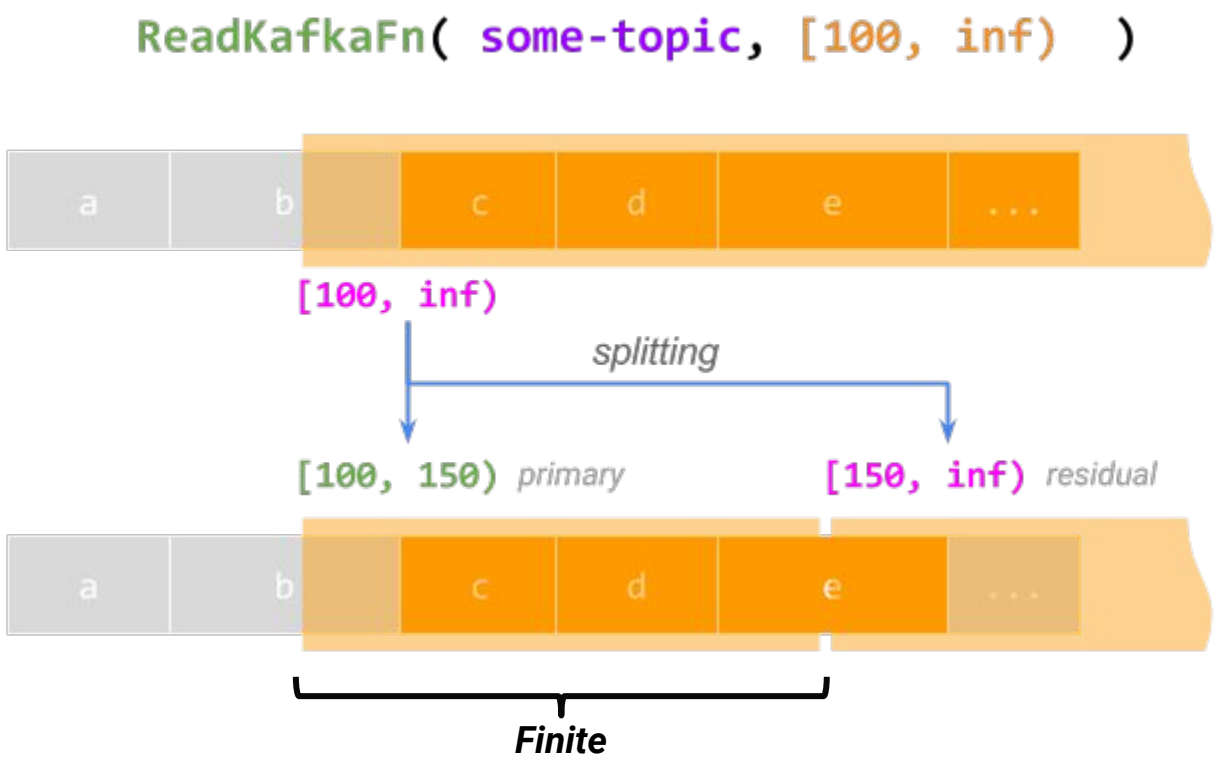
Example restrictions

	Element	Restriction
Reading splittable files	*filename*	*start offset, end offset*
Reading Bigtable	*(table, filter, columns)*	*start key, end key*
Reading Kafka	*(topic, partition)*	*start offset, end offset*


SDF
Splitting restriction
SDF
SDF
SDF


ReadFn(foo.avro, [0, 100))
element
(initial) restriction
a b c d e f
ReadFn(foo.avro, [0, 30))
a b c d e f
ReadFn(foo.avro, [30, 70))
a b c d e f
ReadFn(foo.avro, [70, 100))
a b c d e f

Unbounded work per element



Anatomy of an SDF

How to process 1 element?

Read a text file: `(String filename) → records`

How to do it in parts?

Reading byte sub-ranges

How to describe 1 part? *(**restriction**)*

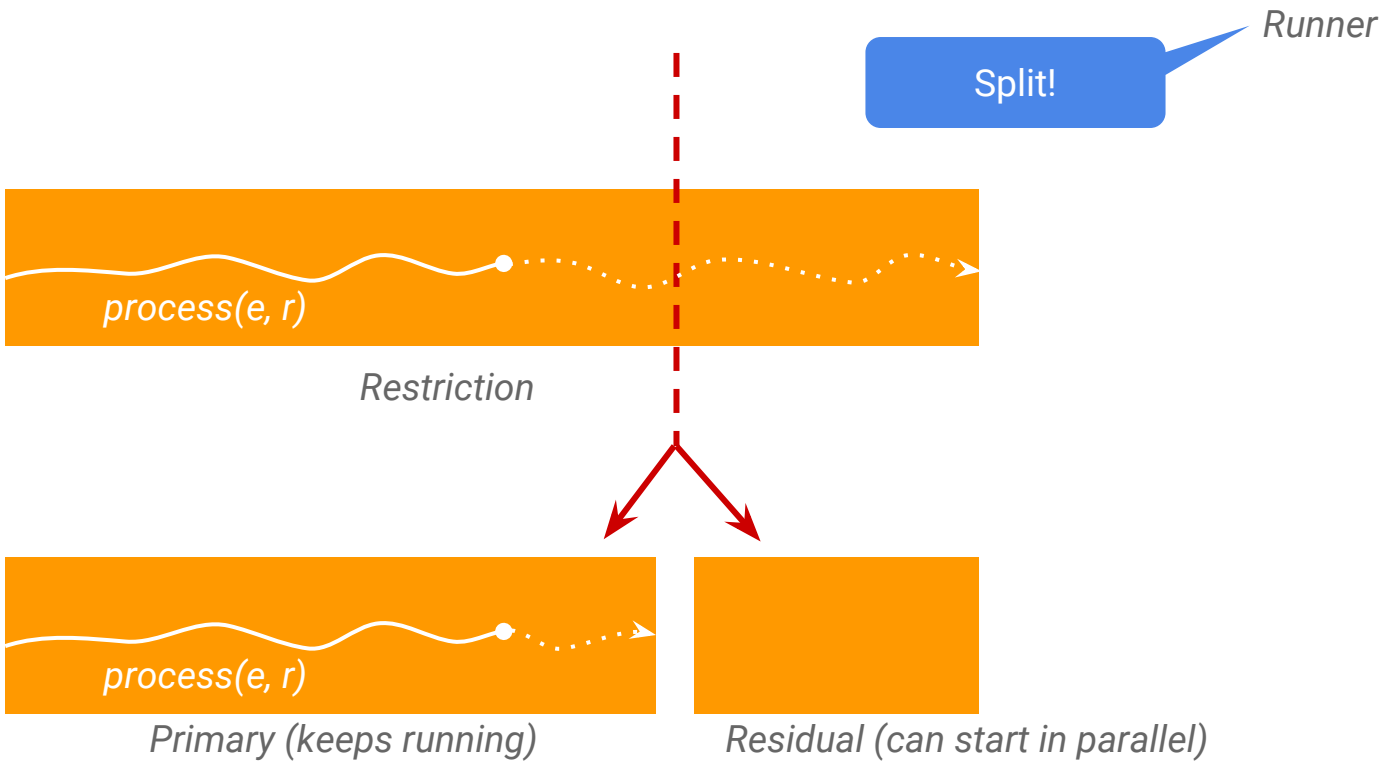
```
{long start, long end}
```

How to do this part of this element?

```
f = open(element);
f.seek(start);
while(f.tell() < end) {
    yield f.readLine();
}
```

Dynamic splitting of restrictions

(basically work stealing)



```
class ReadAvroFn extends DoFn<Filename, AvroRecord> {
  void processElement(ProcessContext c, OffsetRange range) {

    try (AvroReader r = Avro.open(c.element())) {
      for (r.seek(range.start());
           r.currentBlockOffset() < range.end();
           r.readNextBlock()) {
        for (AvroRecord record : r.currentBlock()) {
          c.output(record);
        }
      }
    }

  }
}
```

```
class ReadAvroFn extends DoFn<Filename, AvroRecord> {
  void processElement(ProcessContext c, OffsetRange range) {

    try (AvroReader r = Avro.open(c.element())) {
      for (r.seek(range.start());
           r.currentBlockOffset() < range.end();
           r.readNextBlock()) {
        for (AvroRecord record : r.currentBlock()) {
          c.output(record);
        }
      }
    }

  }
}
```

range can change concurrently

Concurrent splitting

Runner: Avoid **returning** something **already done**

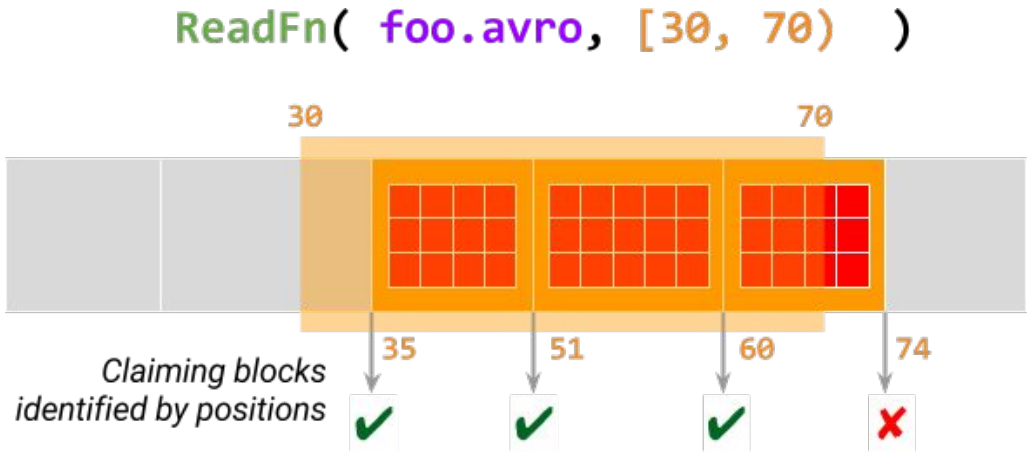
`process()` call: Avoid **doing** something **already returned**

Idea: Claiming

Contract: `process()` **claims** work before doing it

Split off only **unclaimed** work

Restriction trackers, Blocks and Positions

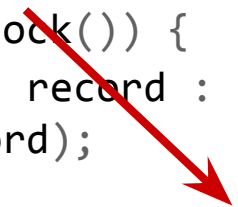


RestrictionTracker *{ restriction, what part is claimed }*

Block Unit of claiming *(indivisible portion of work within restriction)*

Position Identifies a block within restriction

```
void processElement(ProcessContext c, OffsetRangeTracker tracker) {
  try (AvroReader r = Avro.open(c.element())) {
    for (r.seek(tracker.start());
         tracker.tryClaim(r.currentBlockOffset());
         r.readNextBlock()) {
      for (AvroRecord record : r.currentBlock()) {
        c.output(record);
      }
    }
  }
}
```



true ⇒ safe to process *(won't be split off)*

false ⇒ stop — hit end of restriction

Role in Beam APIs

Fundamental building block for splittable work *(primarily, reading data)*

- **Unbounded** *(checkpoints)*
- **Dynamically splittable**

Enables library authors to create higher-level building blocks

- Matching globs, reading files, reading topics, …

05 Recap

If you remember two things

Recap: Context

Batch vs. streaming is moot *(including IO)*

IO is essential, messy, unforgiving

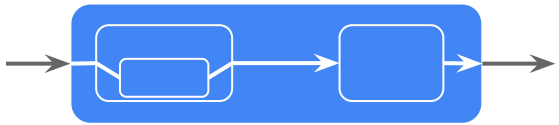
Traditionally: special APIs, neglected, inflexible

Begs for better abstractions

If you remember two things

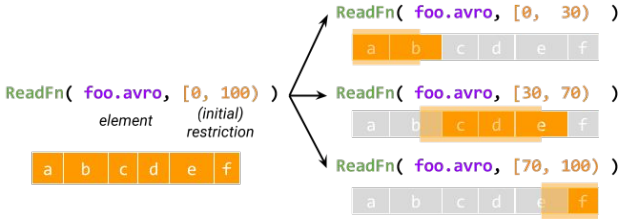
Composable IO = data processing

- Full power of programming model
- Boycott native APIs
- Composable = decomposable
  - *(smaller building blocks)*



Splittable DoFn

- **Element:** what work
- **Restriction:** what part of work.
- Enables composable IO for sources



Q&A