Re-optimizing Data Parallel Computing

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A Data Parallel Job…

can be a collection of maps,

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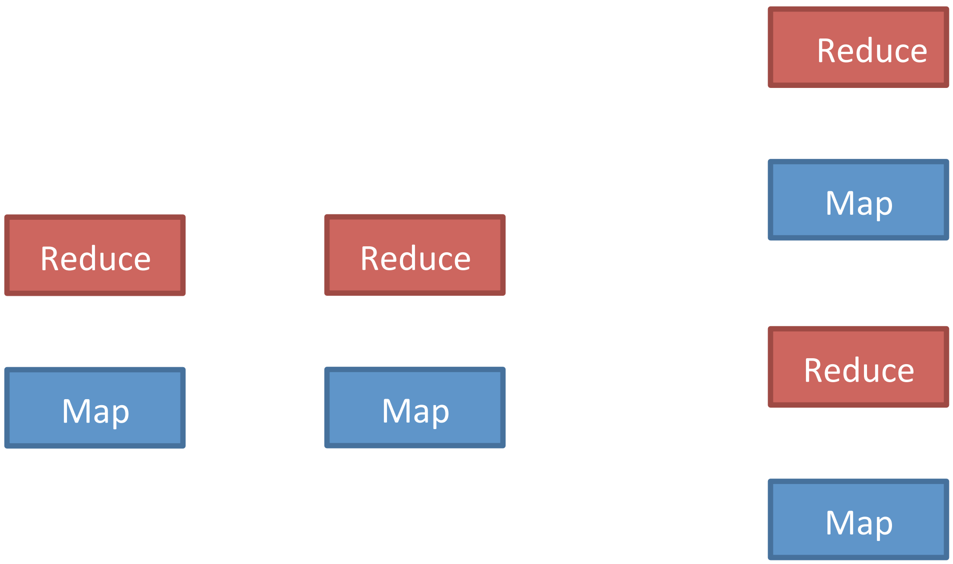
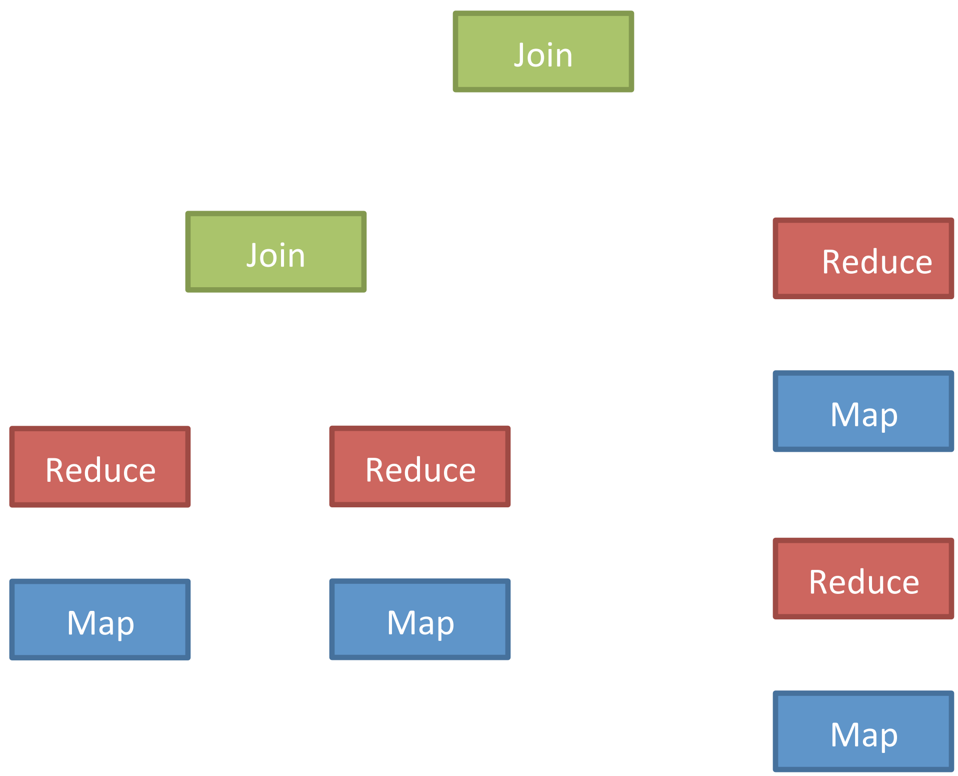


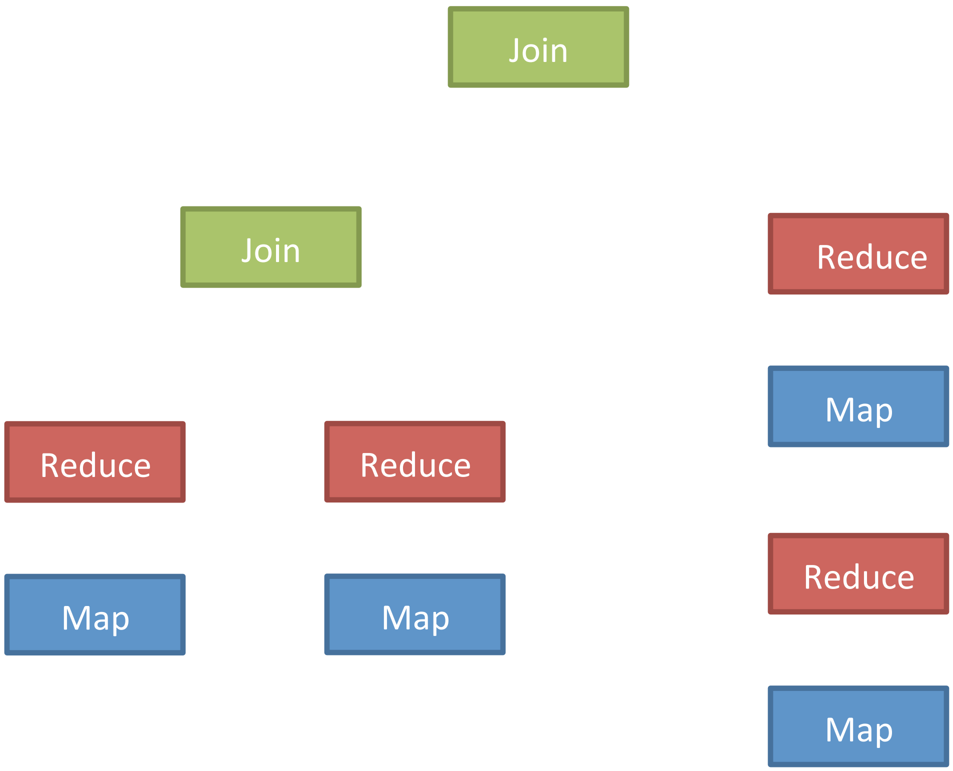
A Data Parallel Job…

can be a collection of maps, reduces, joins



A Data Parallel Job…

… and other framework dependent operations



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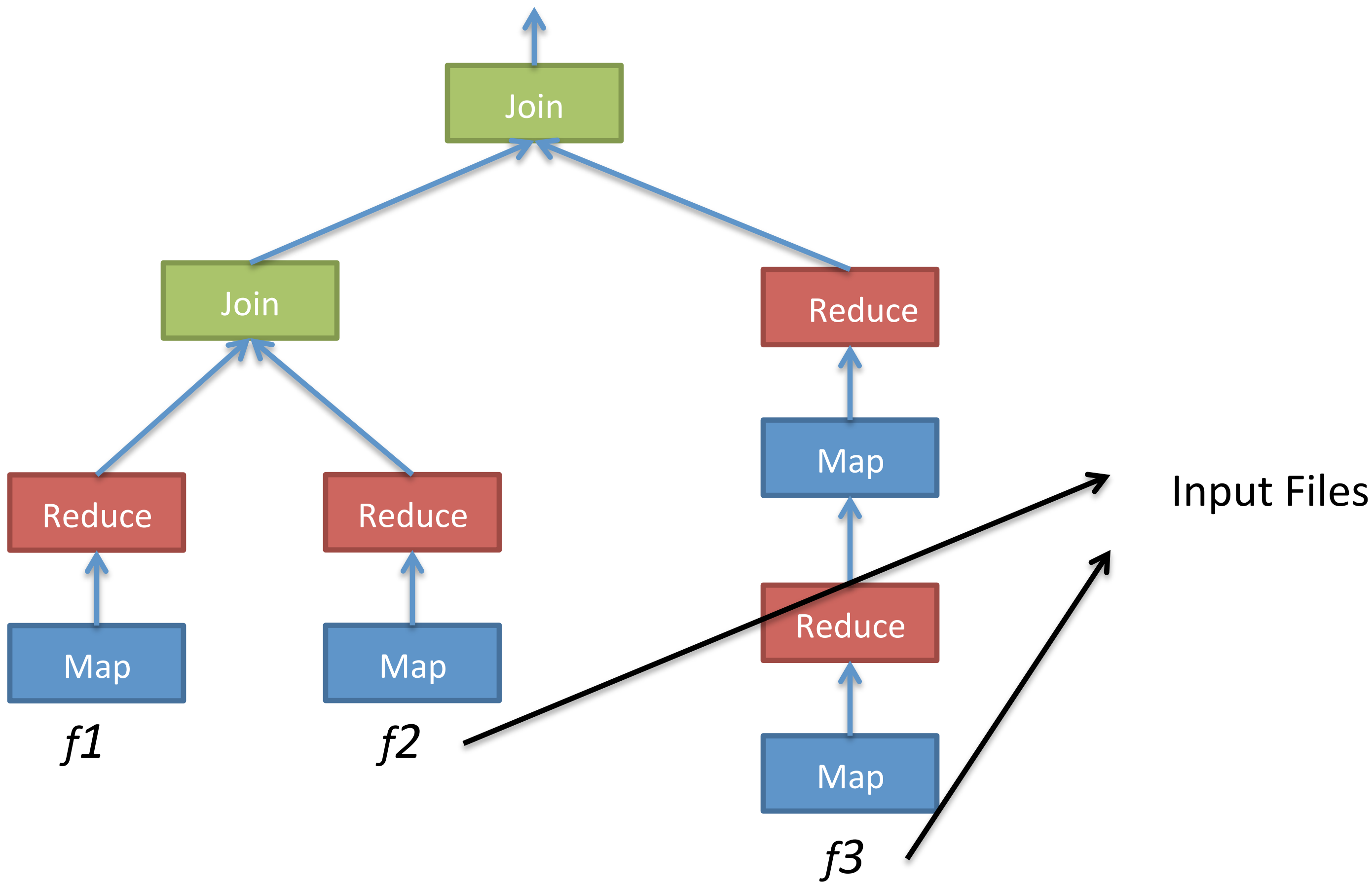

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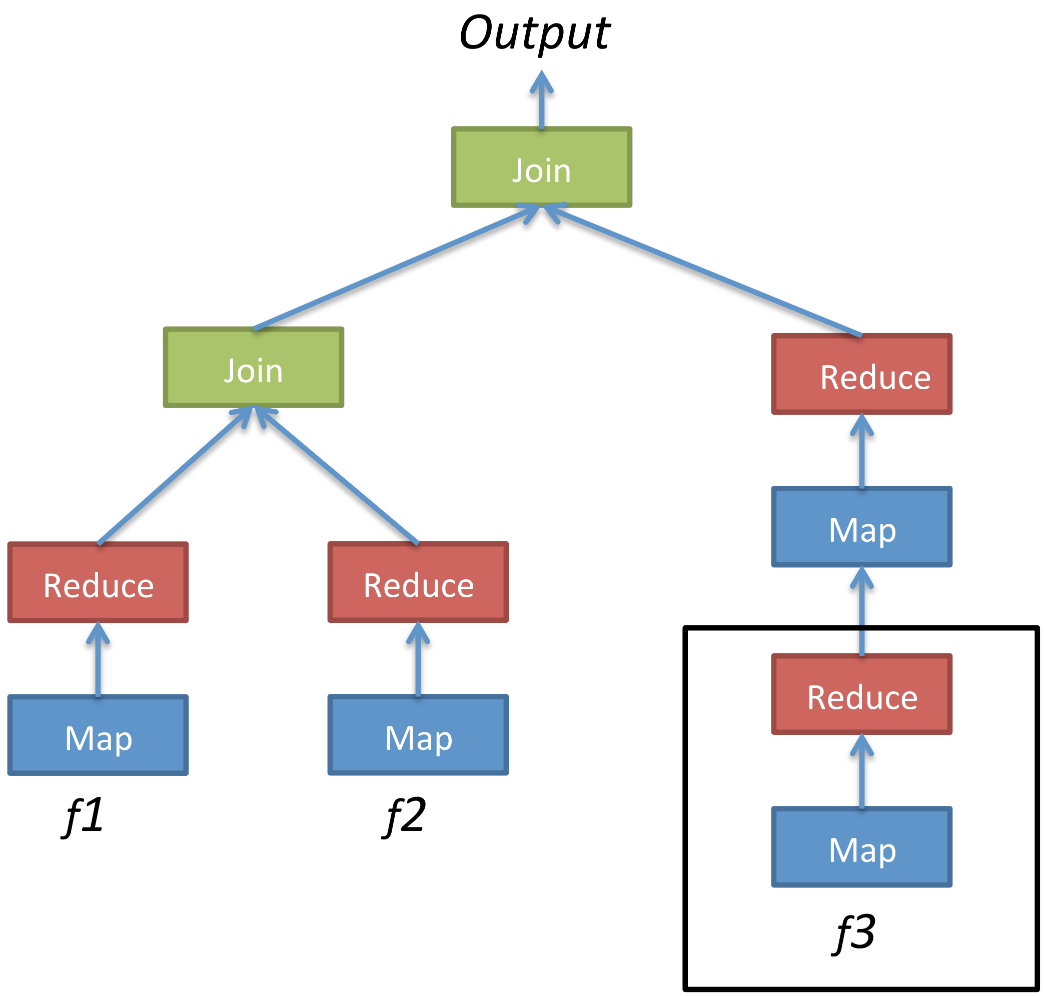

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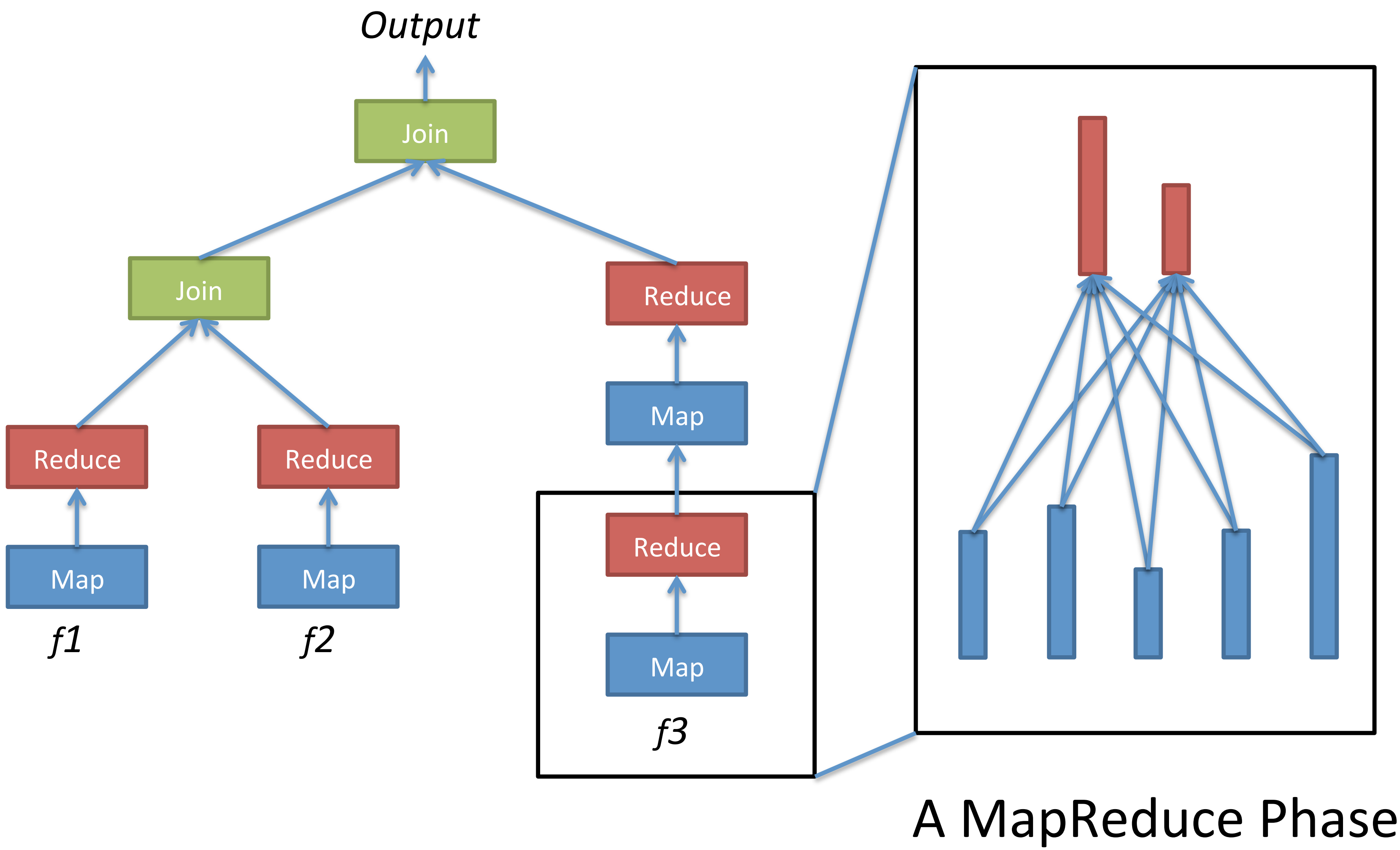

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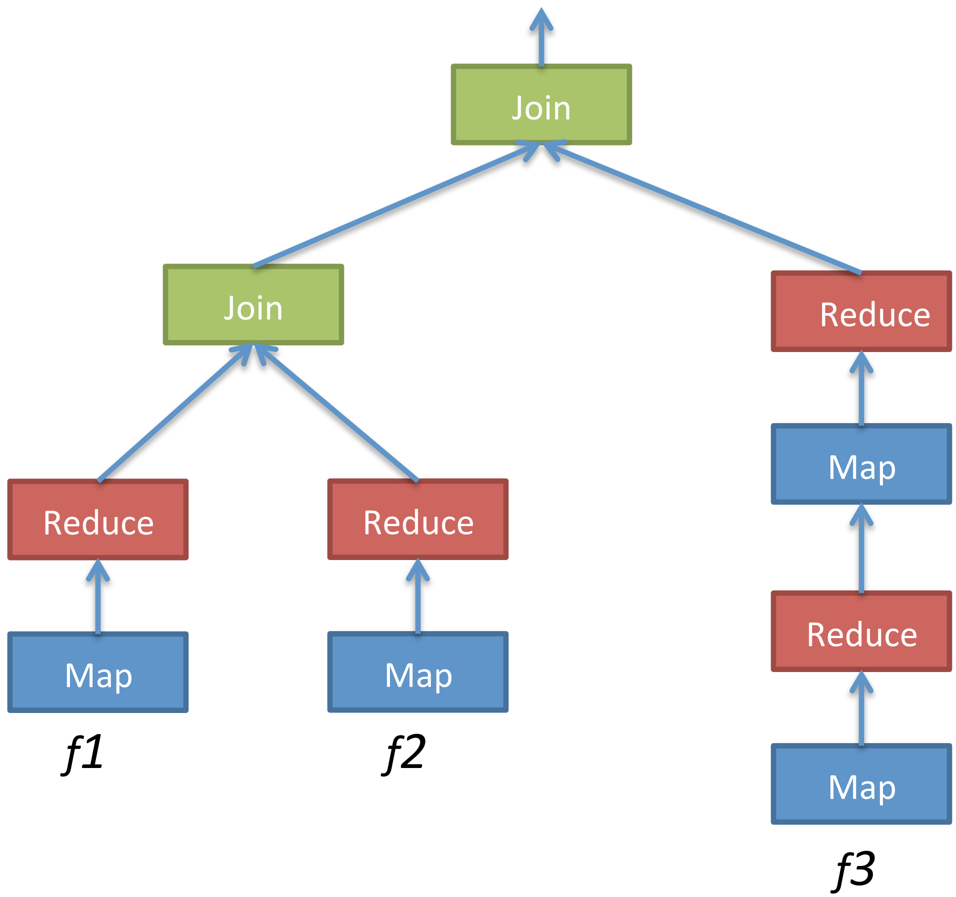
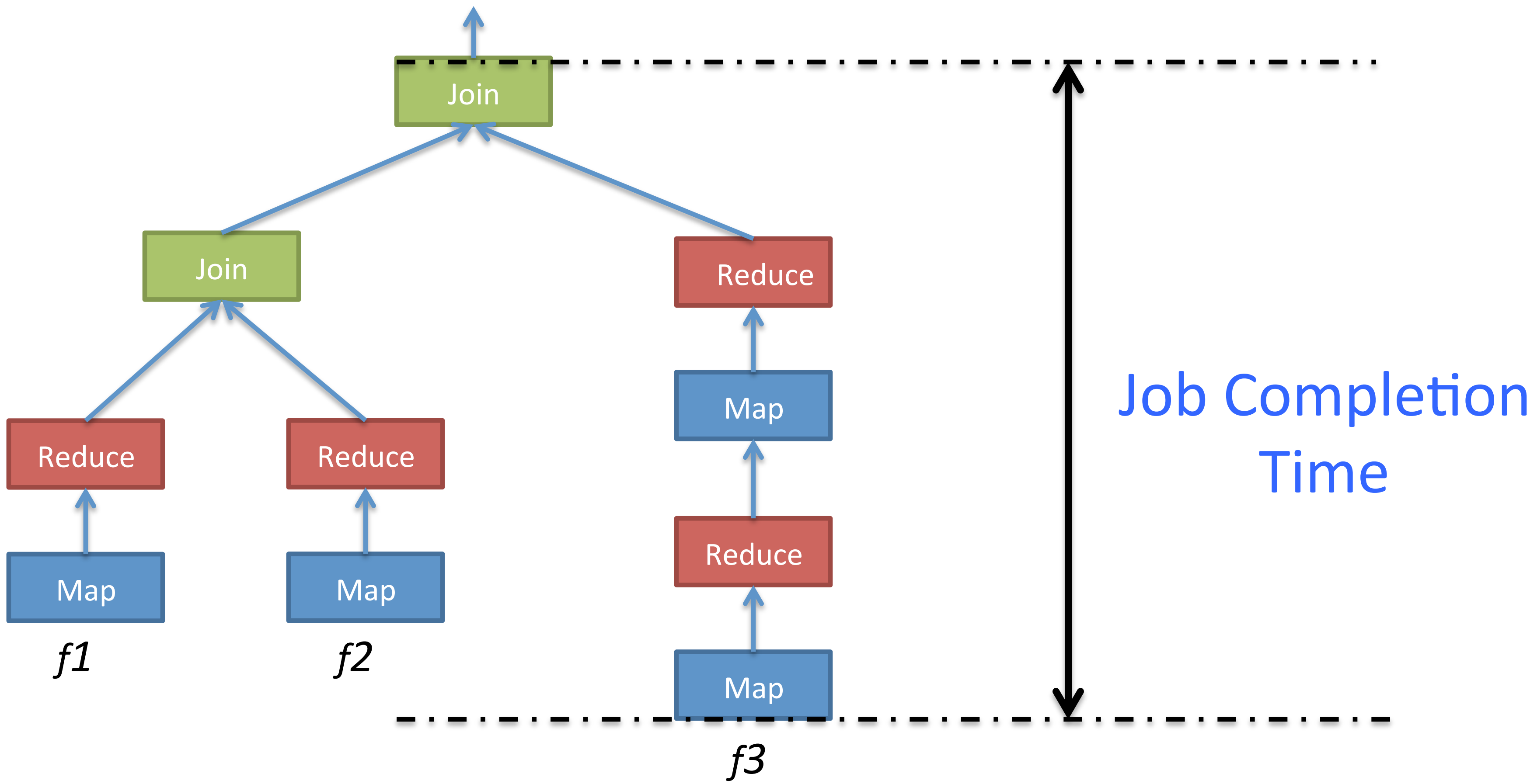


Runs on Large Clusters

Batched Jobs (Dryad/Hadoop)

Key Metrics


Join
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Reduce
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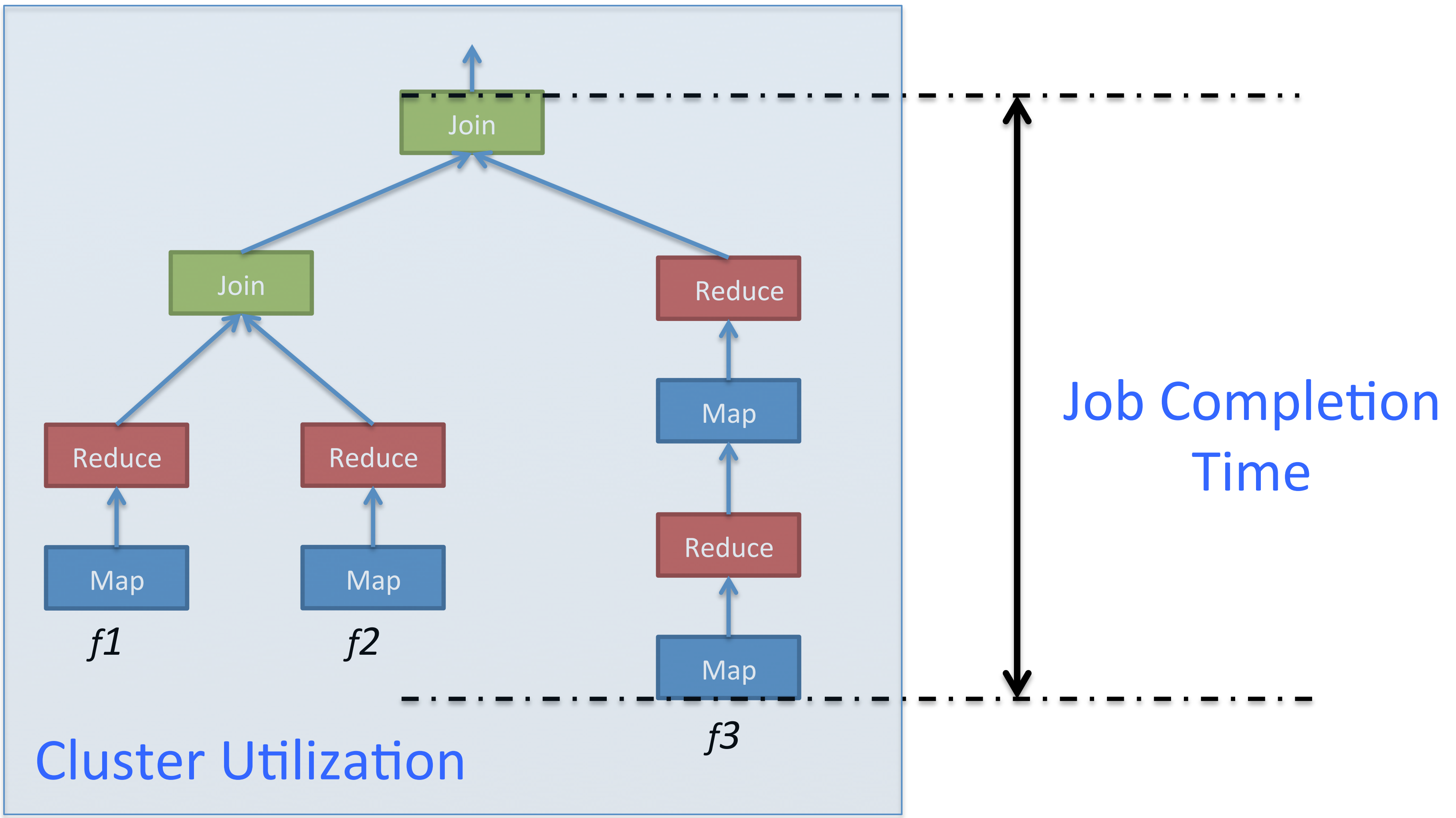
Map
Map
Map
Reduce
Map
f1
f2
f3
Job Completion
Time

Key Metrics



Join
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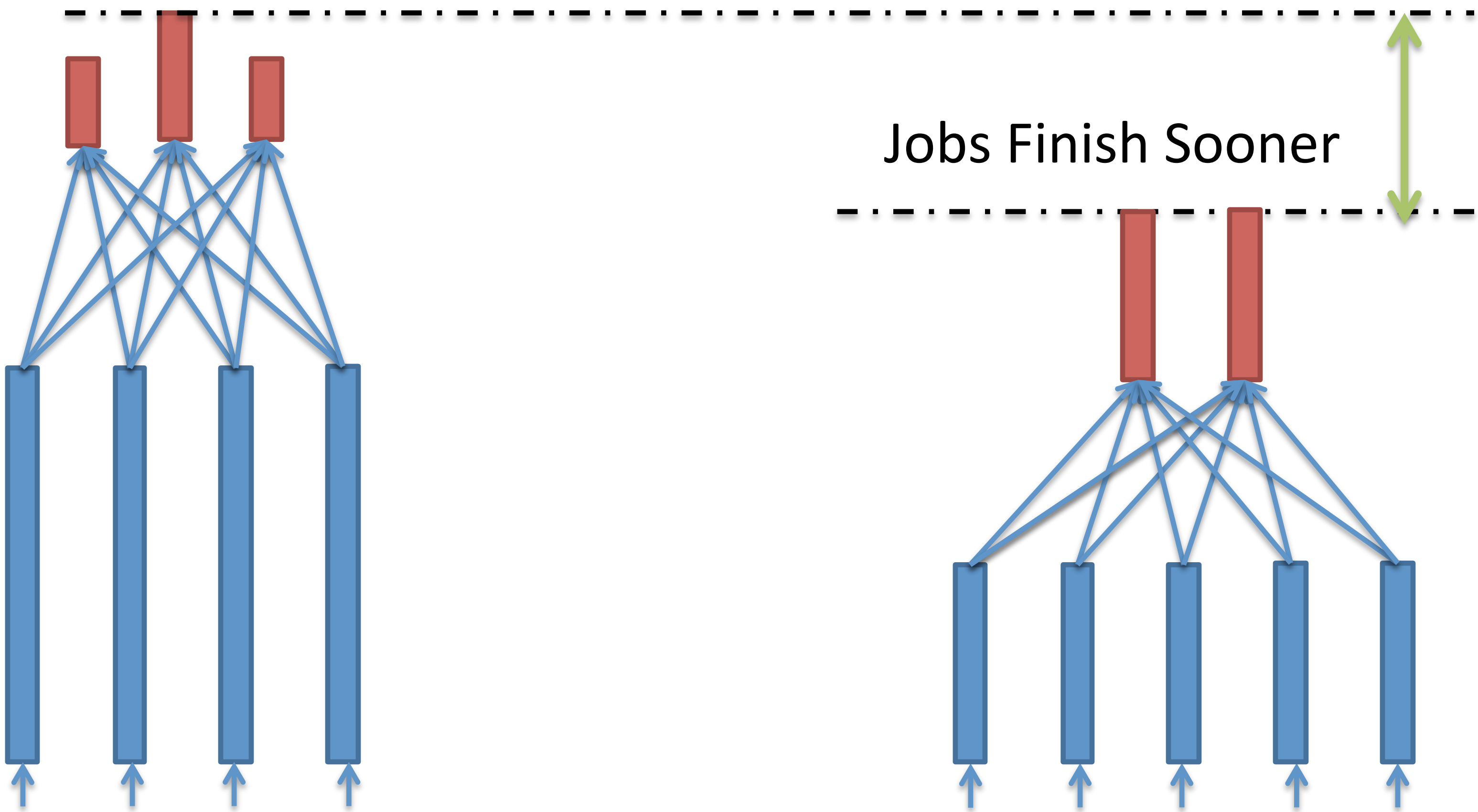
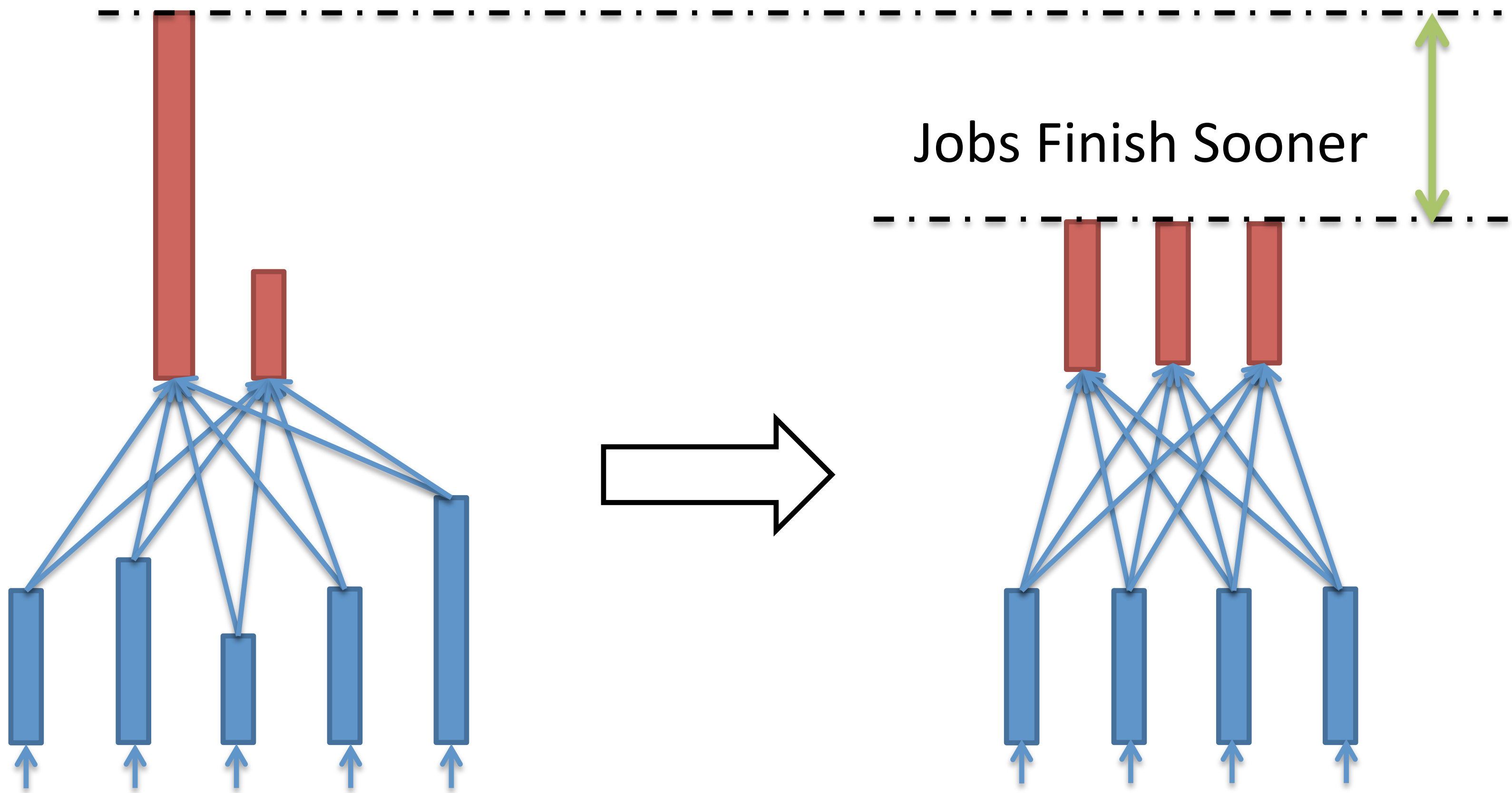
f1
f2
f3
Cluster Utilization
Job Completion Time

Imbalance



Different Work is being done at Every Stage (Data + Complexity)

Data Skews



Data is not independent and uniformly distributed

These problems are real!

Imbalance ~ Avg. Task time per Stage

Most stages take < 10 seconds

Top 4% (1%) take > 100 (1000) seconds

These problems are real!

$$\text{Skew} = \frac{\text{Maximum Partition Size}}{\text{Average Partition Size}}$$

Most stages have skew < 2

But, 5% have > 10

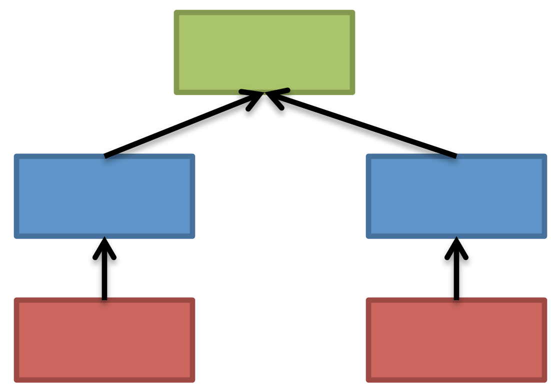
These problems are real!

Others in paper…

Optimizing the Job Execution

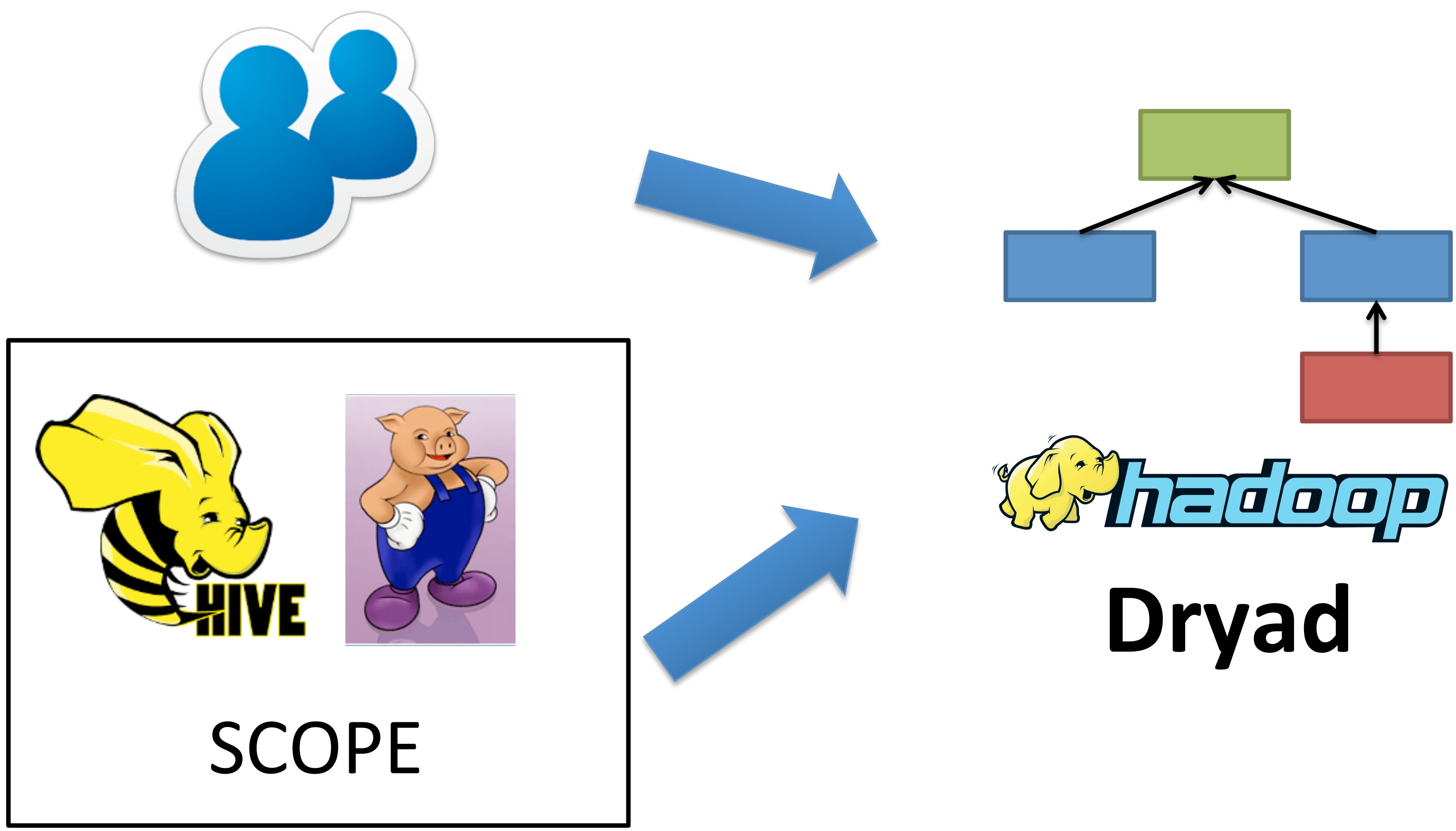
To optimize the completion time and cluster utilization, ideally you need to control:

- Parallelism
- Partition Sizes
- Operator Sequence
- Operator Implementation



The *Execution Plan* lets you control these knobs

Who generates execution plans?



High Level Abstractions

Hadoop	Hive	Pig/Scope	Database

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Want automatic control of all four knobs

- Based on the data and computation
- Robust for User Defined Functions (UDFs)

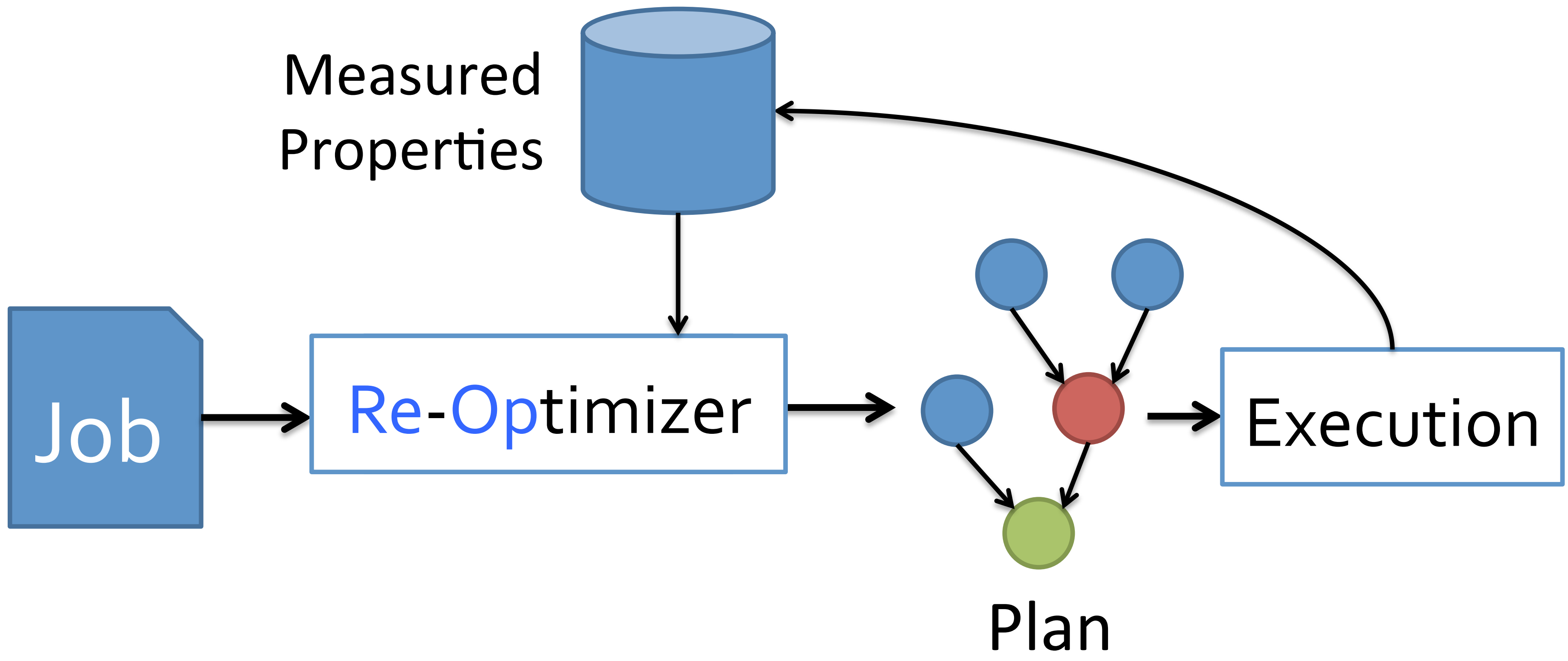
RoPE: Re-optimizer for Parallel Executions

Data & Computation Information

- Degree of Parallelism at every operation
- Data Partitions for each operation
- Implementations for each operation
- Sequence of operations

Cost-based query optimizer

+ information about code and data

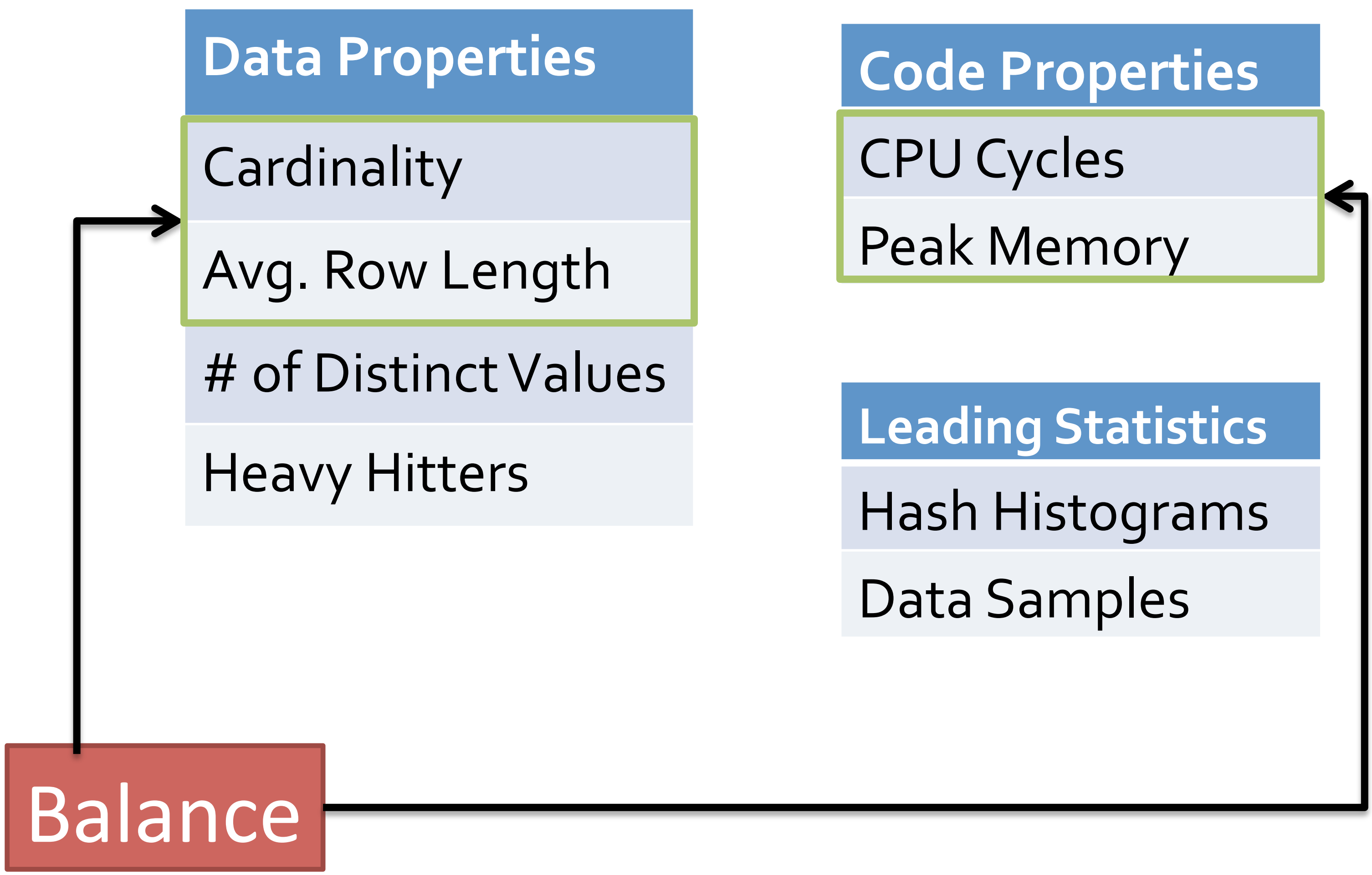


Usage Scenarios:

Better Execution Plans For

1. Recurring Jobs
   - Same “code” runs hourly on new data
   - Data properties are stable
2. “Similar” Jobs
   - e.g., jobs with identical parts
3. Future parts of this Job
   - e.g., after a barrier

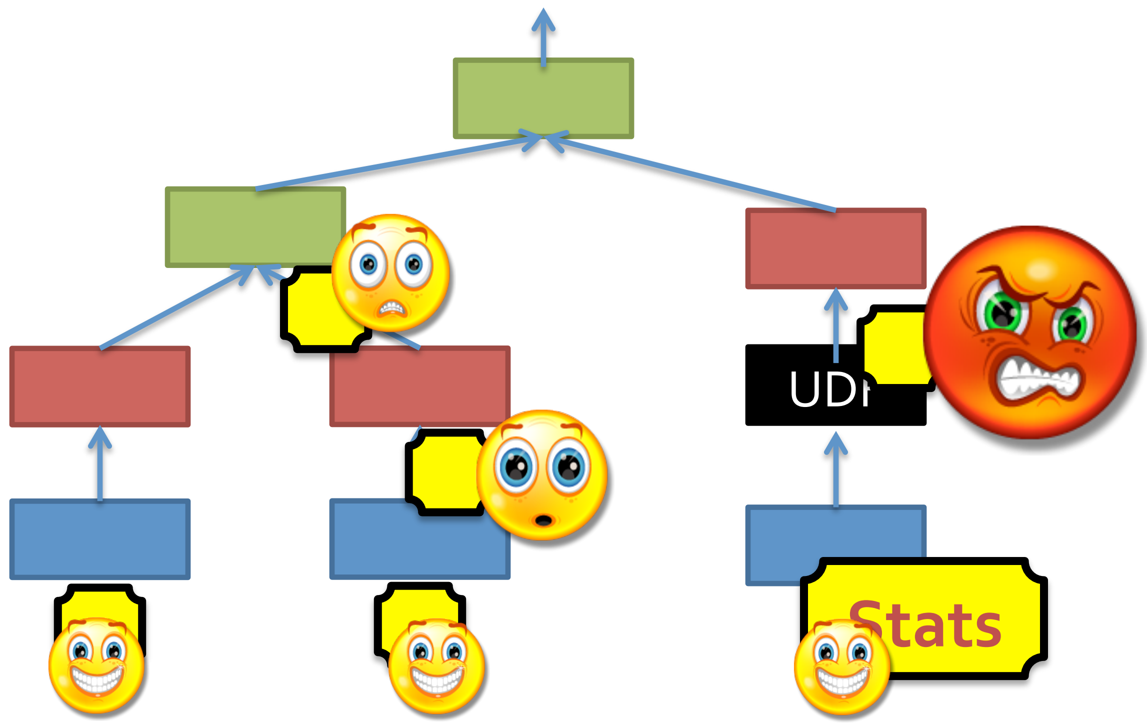
Information collected



Efficiently collecting this information is Challenging

Collecting Information

Option 1: Measure Input Properties, Propagate over operations



Collecting Information

Option 1: Measure Input Properties, Propagate over operations

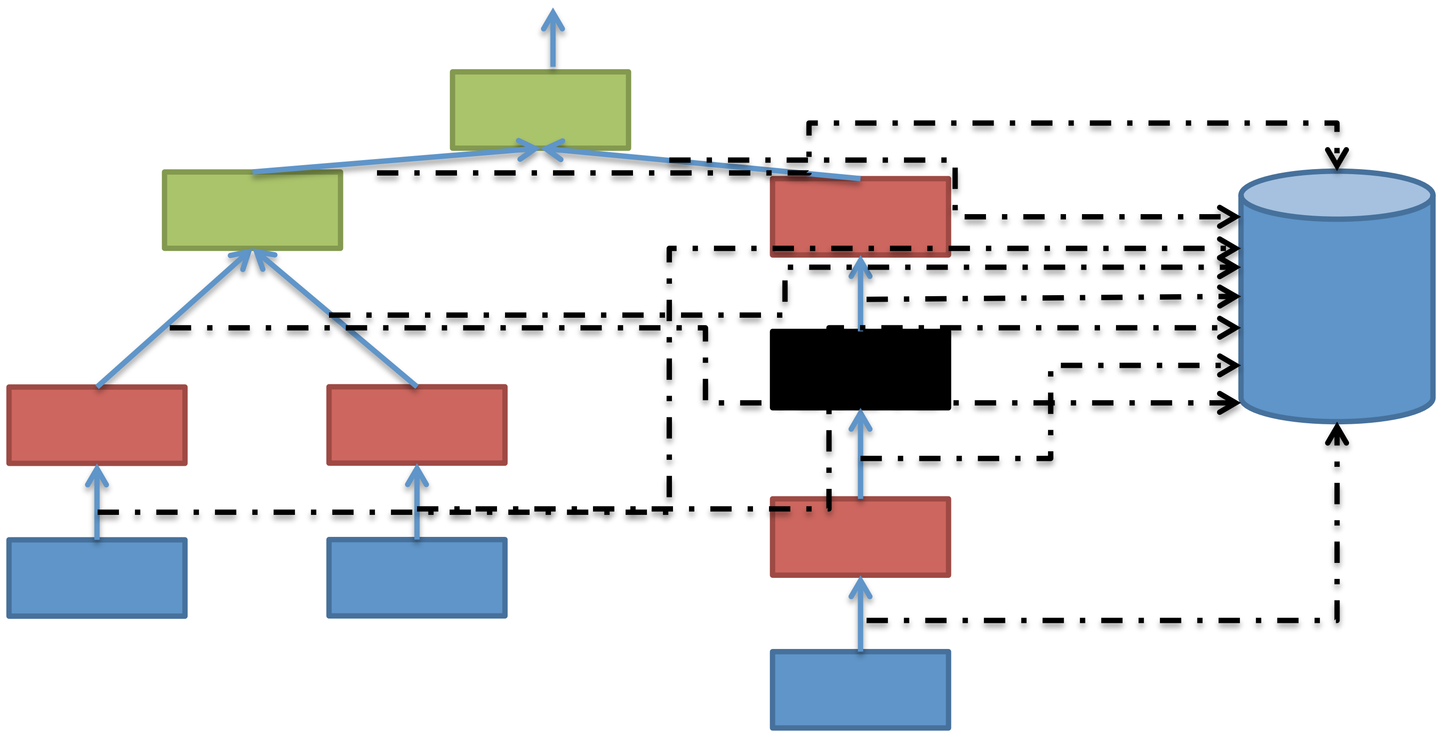
Low Overhead

Bad Accuracy

- Estimation error increases exponentially with #operations [Rio]
- Hard to reason about user defined functions

Collecting Information

Option 2: Store all intermediate data, analyze offline



Collecting Information

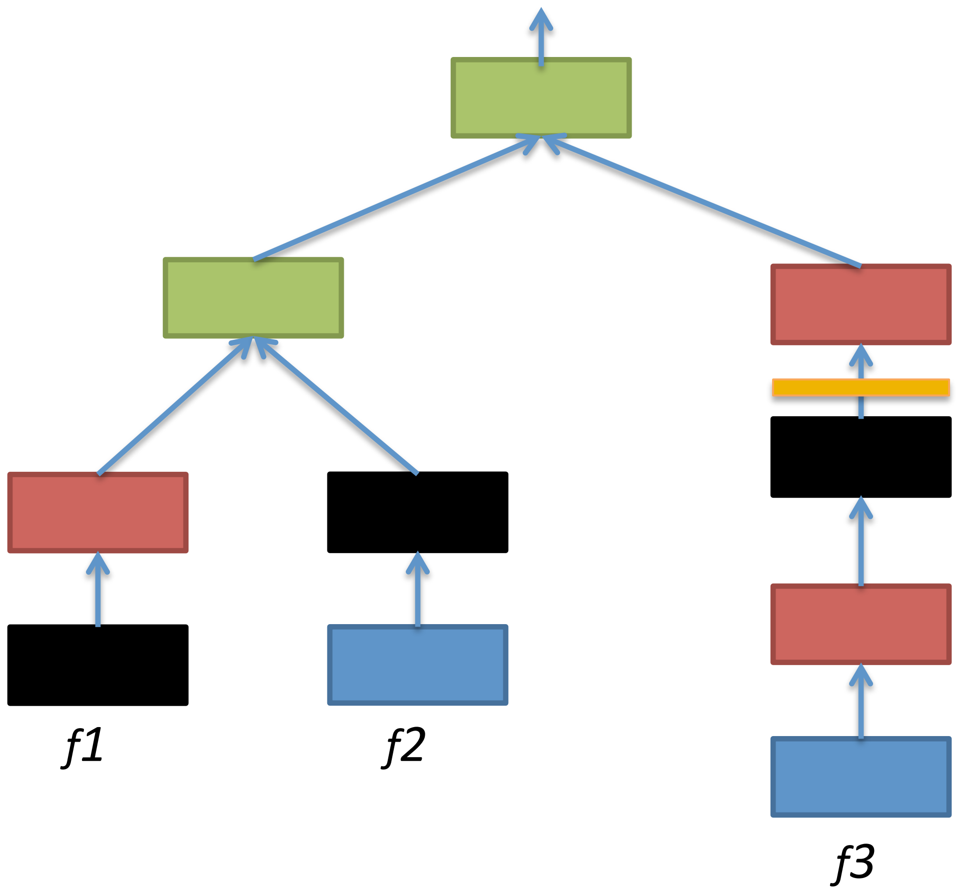
Option 2: Store all intermediate data, analyze offline

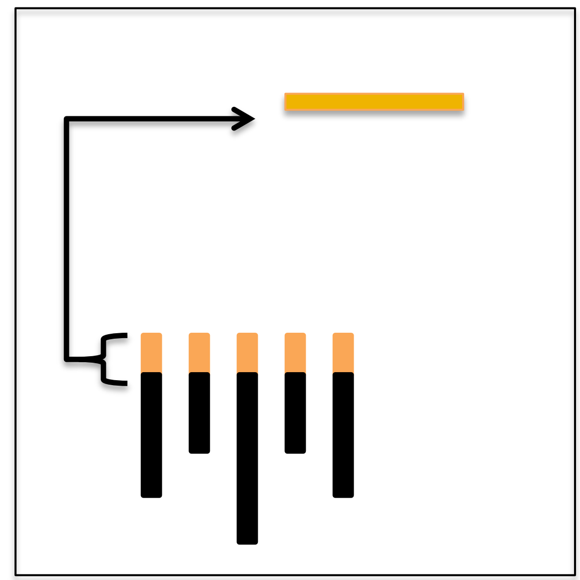
High Overhead

Good Accuracy

- Lots of Intermediate Data
- Job latencies and resource requirements went up ~10x

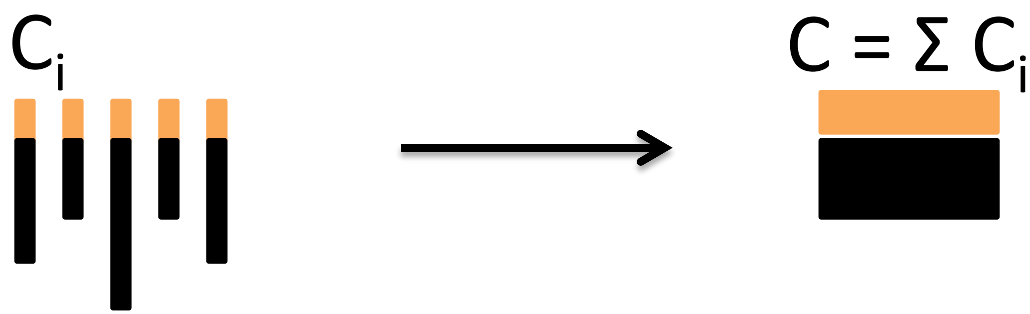
RoPE's Distributed Stats Collection





- Composable
- Light (single pass, sub-linear state)

Composing statistics with Resource constraints



- Trivial for some … e.g., cardinality
- Doable for some … e.g., heavy hitters, #distinct values
- Open problem for others … e.g., equi-width histograms

Related Work

Implementing Execution Plans Well

- Placing Tasks to maximize locality (Quincy, Delay Scheduling)
- Dealing with Outliers (LATE, Mantri)
- Orchestrating Network Transfers (Orchestra, Camdoop, SUDO)

RoPE finds better execution plans

Related Work

Re-optimization in Databases

- Single Machine/Short Queries (Kabra/Dewitt)
- Creating Robust plans given uncertainty in properties (Rio)
- Parametric Query optimization

RoPE reasons about Parallel Plans and deals with User-Defined Functions

Does it work?

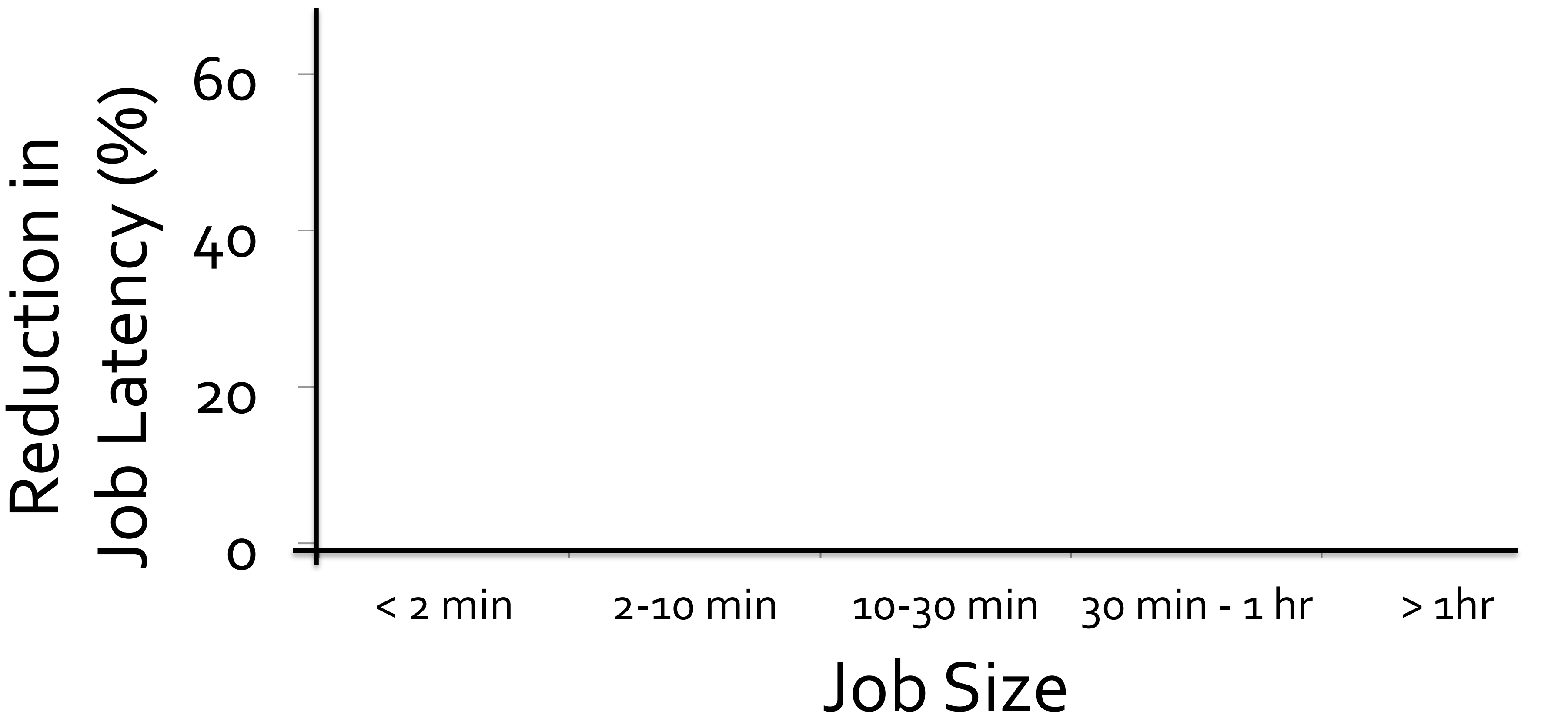
Evaluation

- We evaluated RoPE on a large production cluster
- Our workload suite consisted of hundreds of production jobs from a wide range of users during March 2012.
- **Baseline**: Production Scope (State-of-Art-QO)
- **Metrics**: Completion Time & Cluster Utilization

Highlights

- **2x** improvements across job latency for production jobs at **75th** percentile while using **1.5x** fewer resources
  - Better Execution Plans
  - Reduction in terabytes of Intermediate data and cross-rack shuffles
  - Better Parallelism
- 2-5% overhead incurred by our distributed statistics collection framework

Job Completion Time



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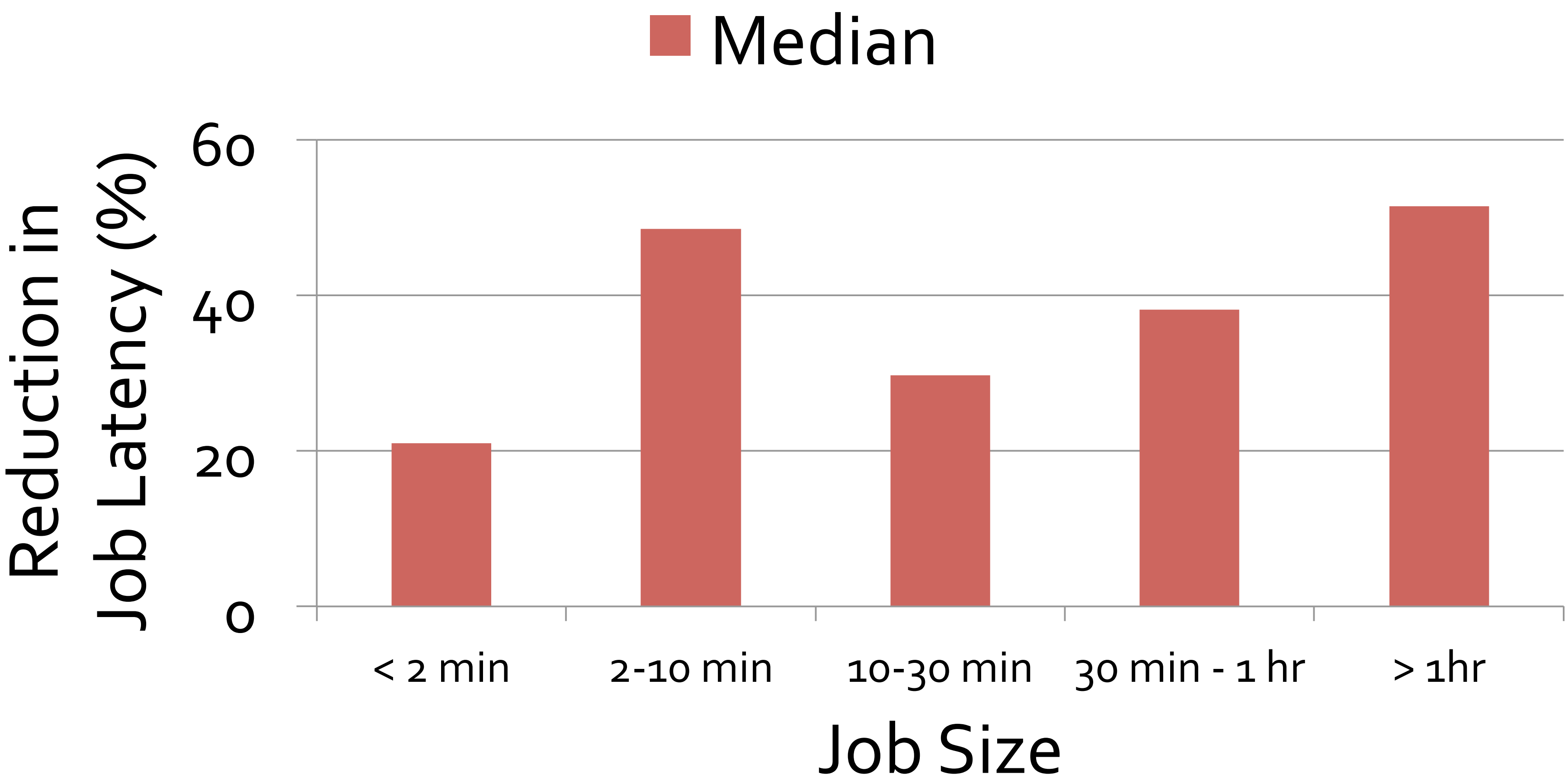
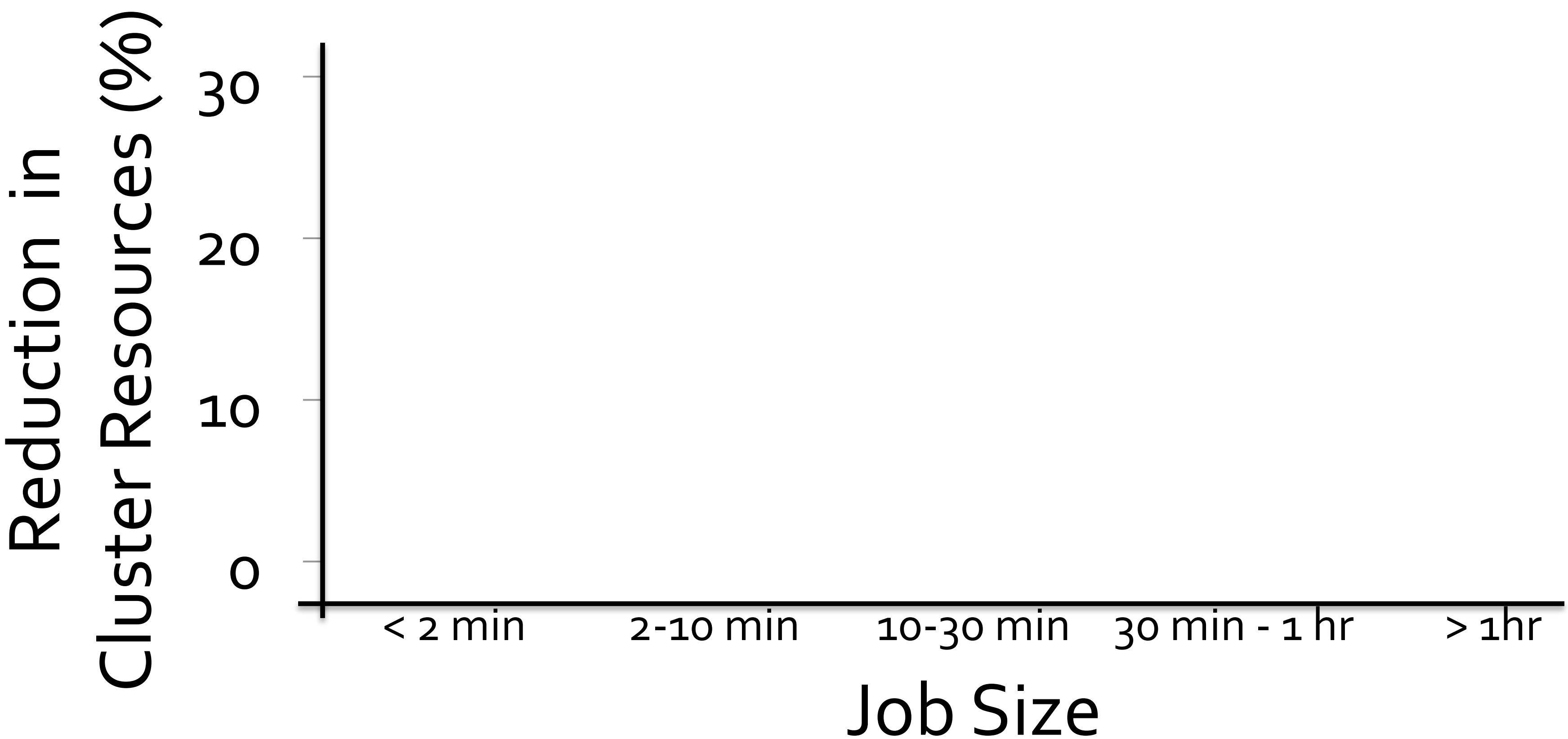


Cluster Utilization



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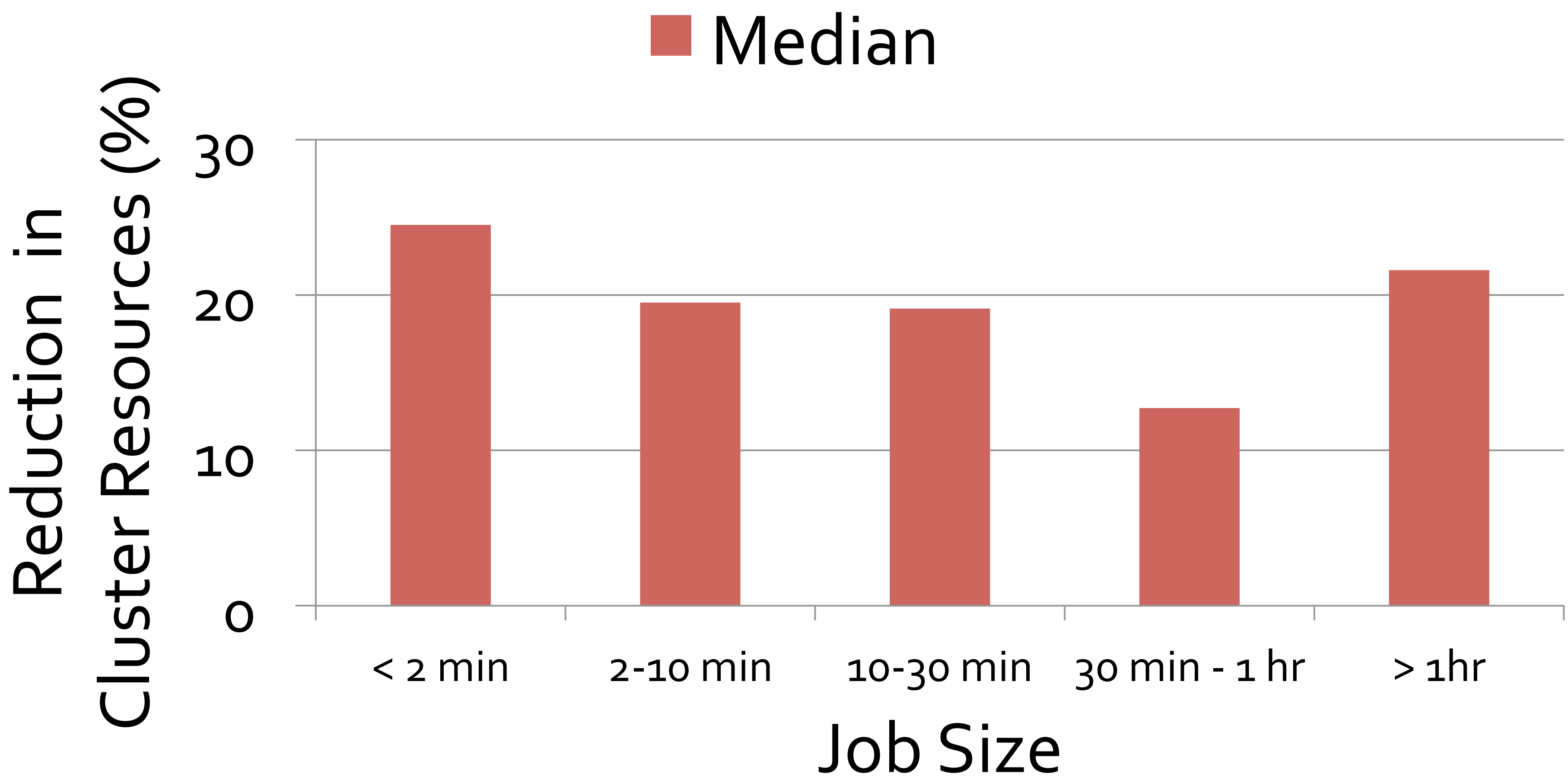

RoPE improves execution plans for data-parallel jobs

- Measurements identify novel problems and opportunities
- To leverage, built RoPE, a re-optimizer, that learns/ uses code- and data- properties
- Running live in Bing Production Clusters since December 2011

Thank you