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WEDGE: A Wide-area Efficiently Distributed Graph Engine

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Motivation

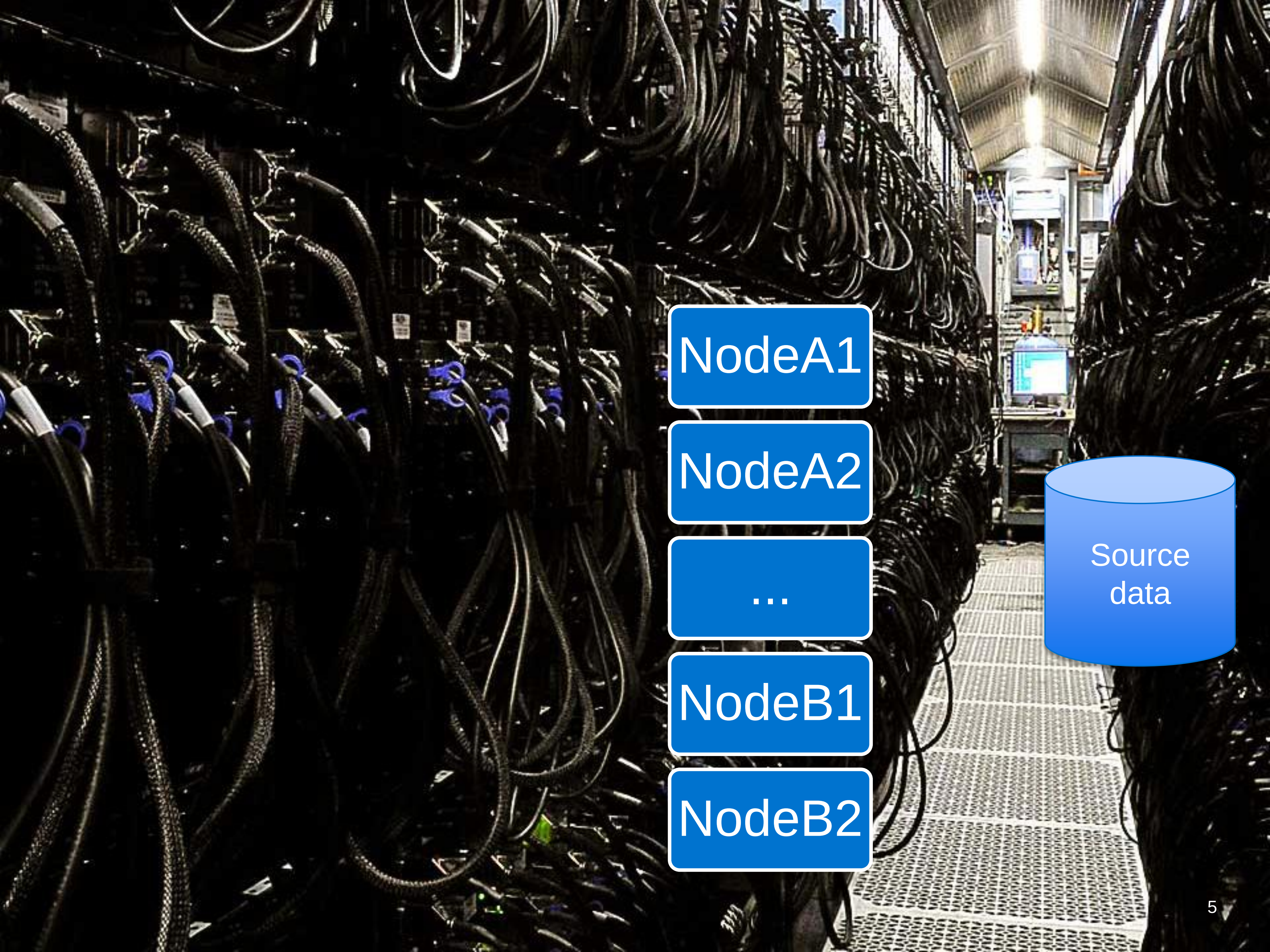
"Wide area" ***There are a variety of use cases for geographic dispersion of data:*** ***•Data may be generated globally*** ***•Want to take advantage of regional price differences in cloud computing services*** ***•Energy saving*** ***•Hybrid clouds*** ***HOWEVER current systems focus on single datacentre environments***	***"Graph processing"*** ***Many large datasets are graph-structured – e.g. The web graph, social networks, transport / traffic, recommendation networks, bioinformatic data.*** ***Users have a need to process this data in various ways (searching, ranking, clustering, etc).*** ***HOWEVER, the predominant map-reduce model is not well-suited to this.***

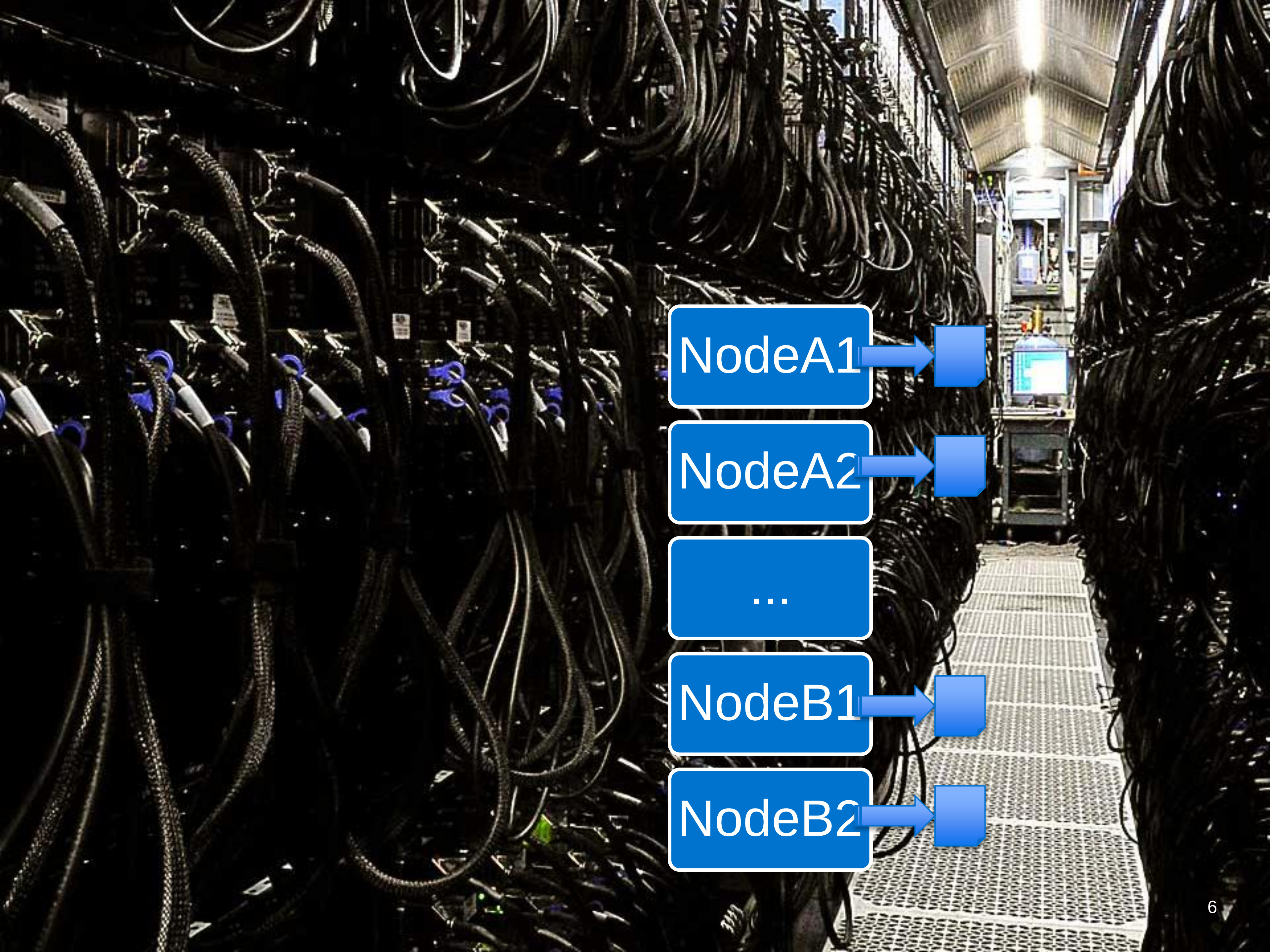
The Data Locality Challenge

- “Data-parallelism” is at the core of processing frameworks such as Hadoop.
  - We parallelise by splitting up data and processing with independent tasks. This is usually a local operation.
- The challenge arises from the need to collate the results (“reduction”). In the map-reduce model, this requires shuffling.

Brief overview of MapReduce

- map() takes an *input split* and produces zero or more *intermediate key-value pairs*.
- reduce() (or "fold") takes a set of intermediate key-values with a common key, and produces output.
- The framework arranges for source data to be distributed amongst a group of mappers, and then arranges for intermediate data to flow from mappers to one or more reducers


NodeA1
NodeA2
...
NodeB1
NodeB2
Source data


NodeA1
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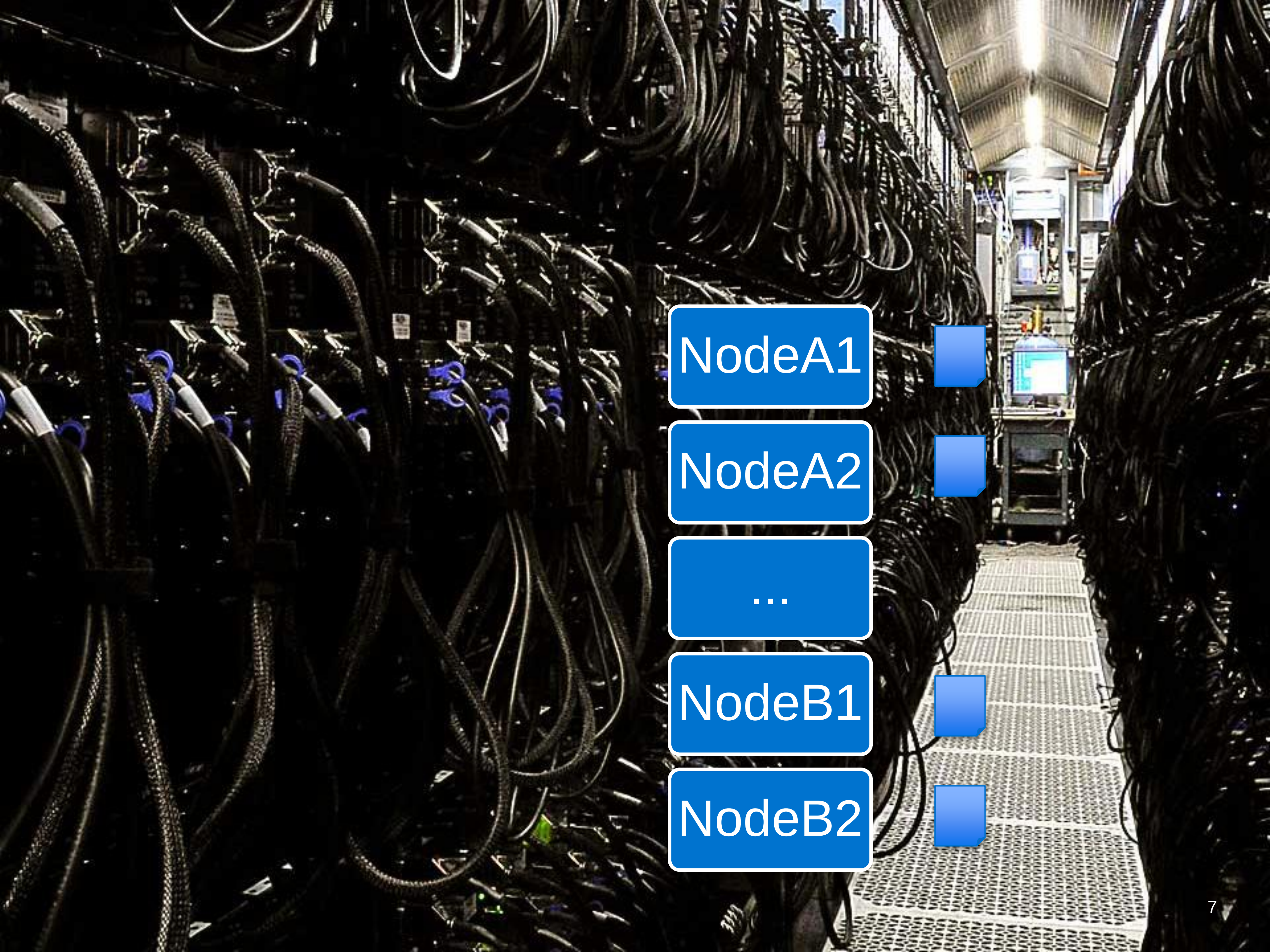
NodeA1
NodeA2
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NodeB1
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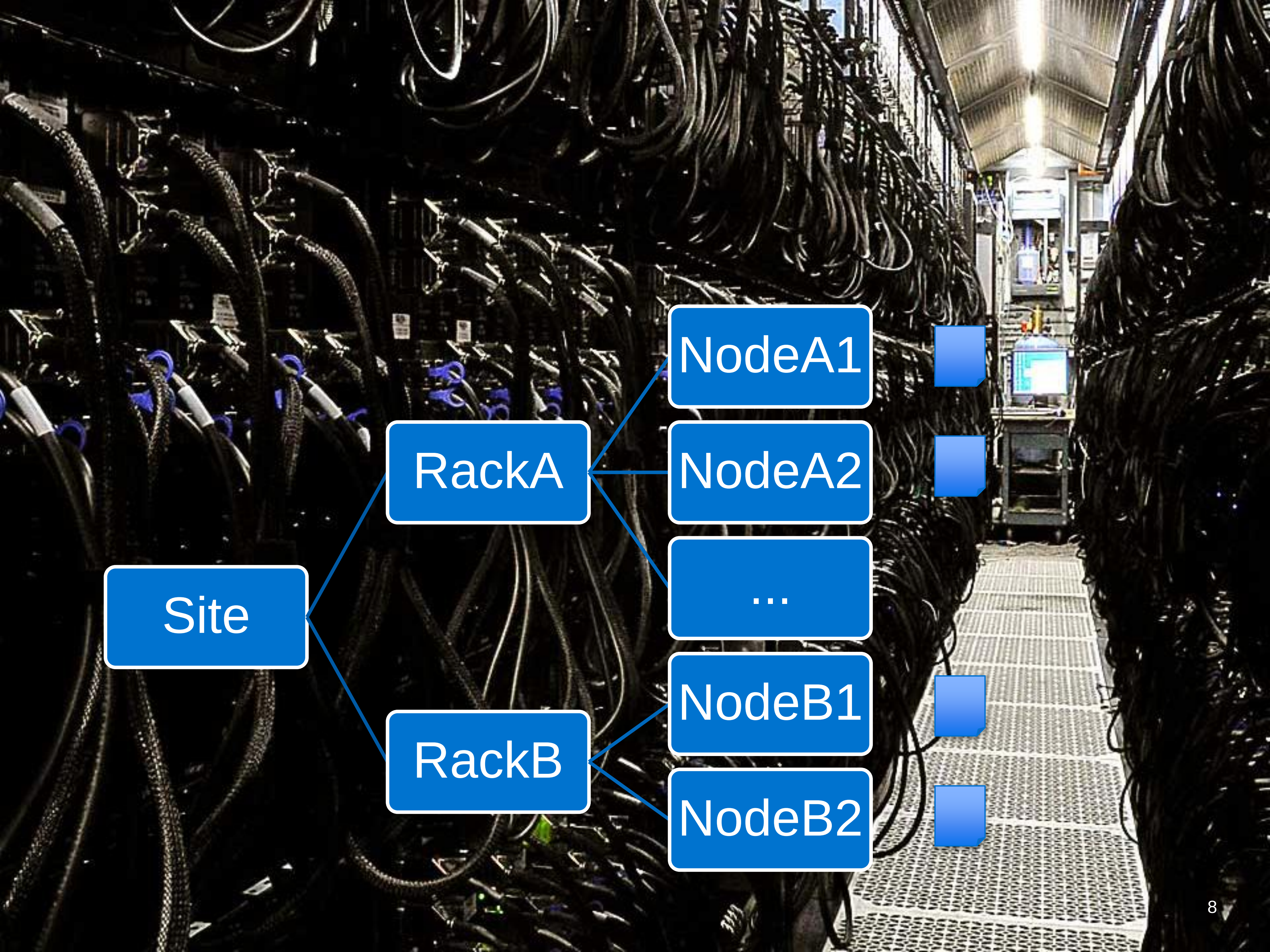
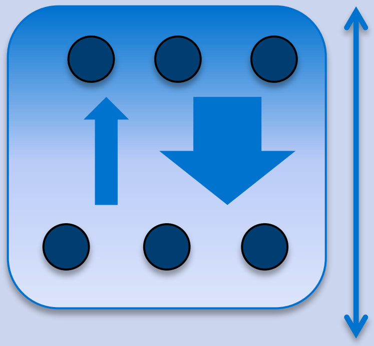


Site
RackA
RackB
NodeA1
NodeA2
...
NodeB1
NodeB2

Example

"Unbalanced Reduction"

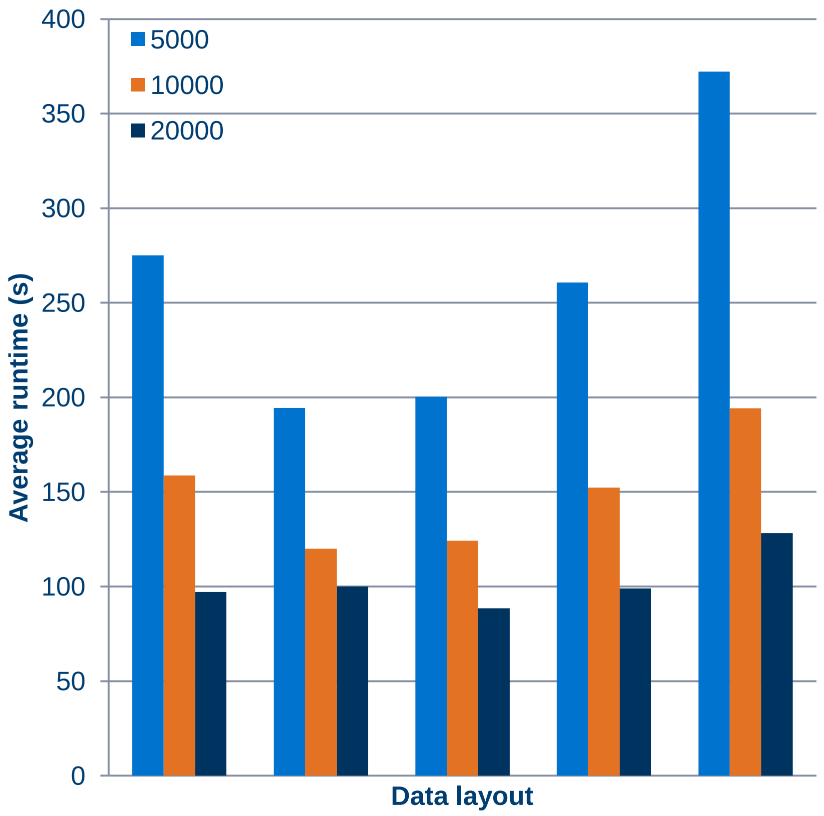
Increased traffic to remote reducers

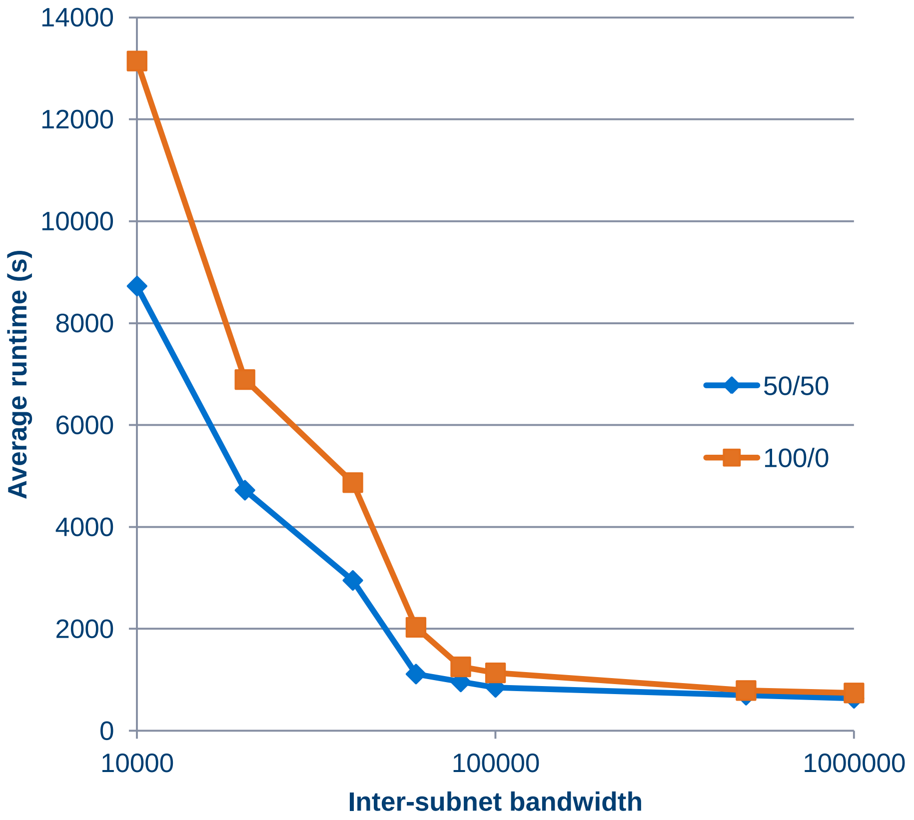


Uneven distribution

- Trade-off between work distribution and data locality
- How to partition key-values?
- *Programming constraint: all instances of a key map to single reducer*
- Attempts to improve locality may affect the functionality of the task

Effects of imbalance





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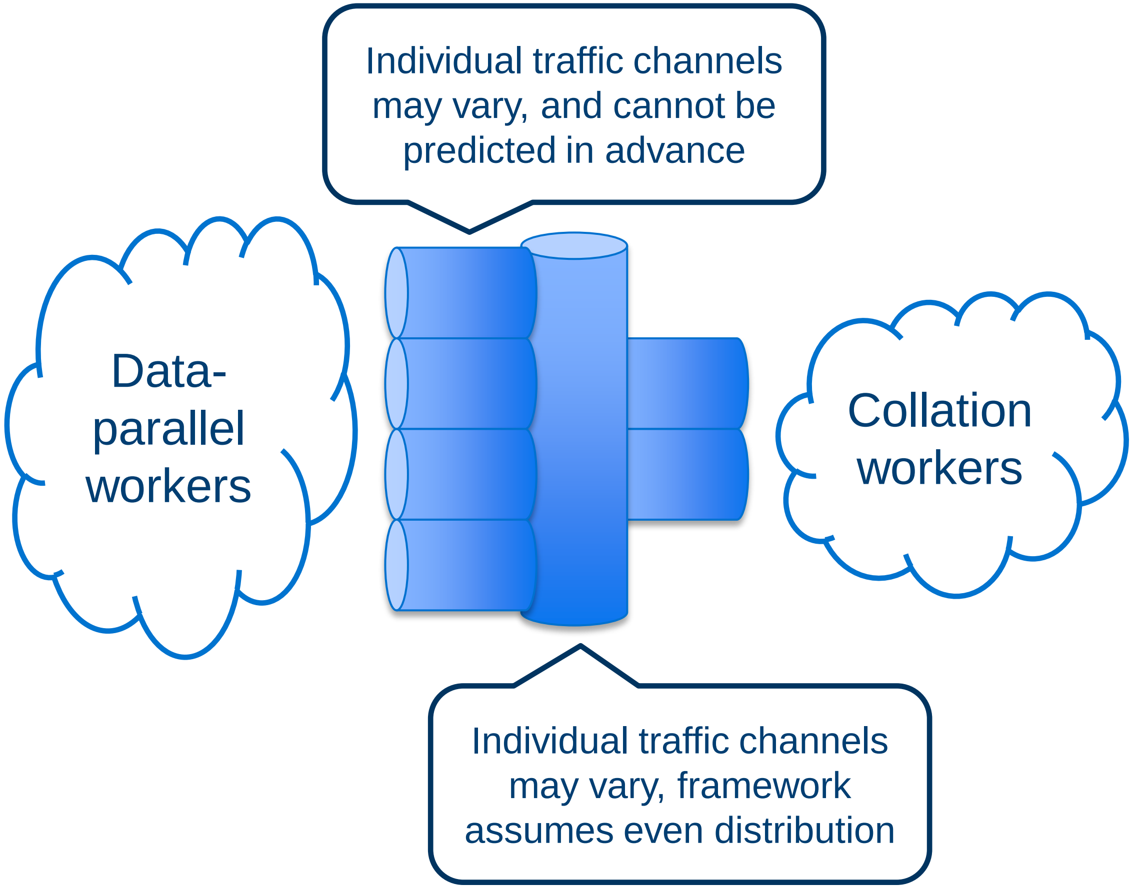
Current mitigation strategies

- Framework tuning
  - Problematic due to large parameter space; may be counterproductive (requires trial and error)
- Programmatic
  - Custom partitioning; custom combiners; domain-specific optimisation
- Reactive scheduling
  - Straggler detection (LATE etc)
  - Speculative execution

But the core problem remains...



Unwieldy for the wide-area: we can't identify individual traffic flows.

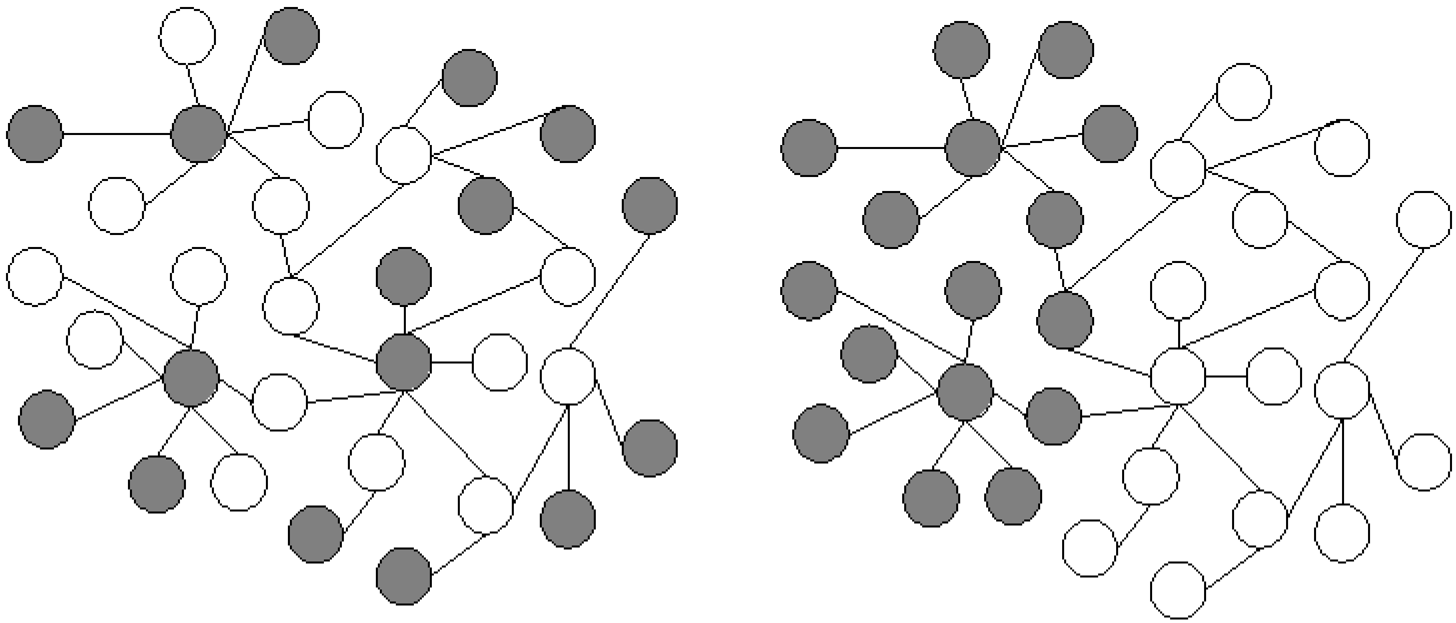
Unwieldy for graph processing: need to pass state between iterations

Bulk Synchronous Parallel

- BSP offers an alternative approach for graph processing (as used by Pregel)
- Step 1: For each vertex in the graph, we process local data in parallel.
- Step 2: Each vertex then generates updates to be passed to immediate neighbours in the graph.
- Step 3: We impose a synchronisation barrier to ensure all updates are propagated.
- Step 4: Iterate.

Insight: shuffling becomes message passing

- How can we minimise the amount of message passing in this model?
- Answer: re-partition the graph



Approaches to graph partitioning

- In HDFS-style systems, typically a background process is responsible for rebalancing data.
- In WEDGE, a similar process would operate on the graph, by identifying optimal partitions and re-organising data.
  - Could use minimal/balanced cut approaches (such as ParMETIS). These produce well-partitioned graphs, but are computationally expensive.
  - Community detection methods offer a heuristic approach based on modularity maximisation. Less overhead, but possibly lower yield.
  - Could offer a range of strategies to the user.

WEDGE: The broader framework

- Three desirable properties:
  - Algorithmic flexibility
    - CIEL offers the building blocks.
  - Partition-tolerance
    - Need to re-fashion CIEL to deal with the wide area
  - Locality optimisation (graph partitioning)
    - Need to integrated with existing resource-management capability

Summary

- There are a range of motivating factors for wide-area graph processing
- Hadoop is neither well-suited to graphs nor the wide area
- We need to explore alternative programming models – BSP is one possibility.
- We can optimise message passing in the BSP model by re-partitioning the graph.
- Community-structured partitions should also facilitate efficient graph processing in other programming models.