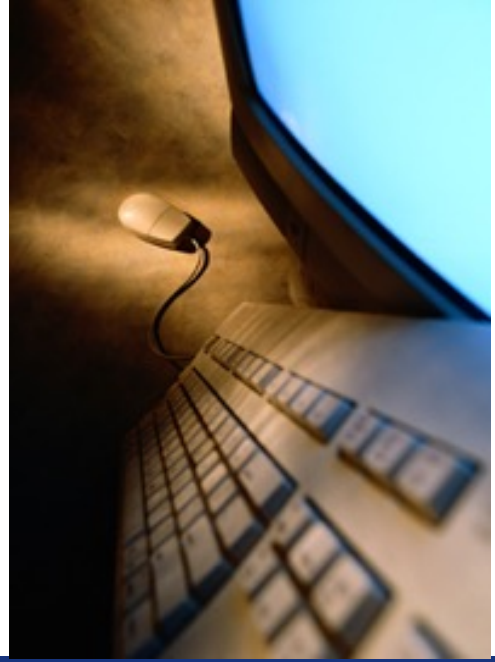
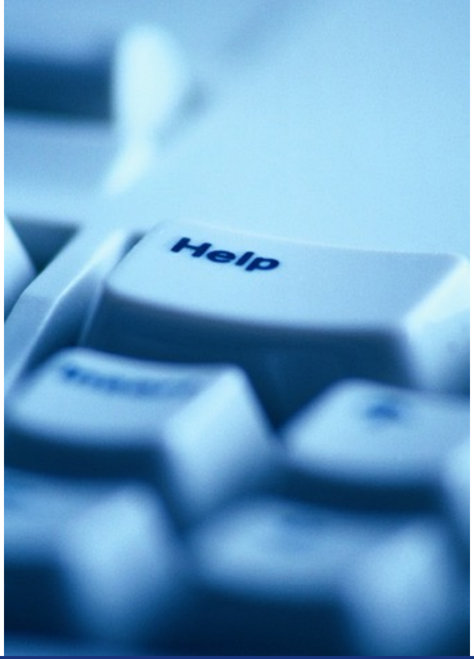

并行与分布式计算

Parallel & Distributed Computing

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Lecture 11 — Parallel Computing with MapReduce

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Outline:

- MapReduce Programming Model
- Typical Problems Solved by MapReduce
- MapReduce Examples
- A Brief History
- MapReduce Execution Overview
- Hadoop

Motivation: Large Scale Data Processing

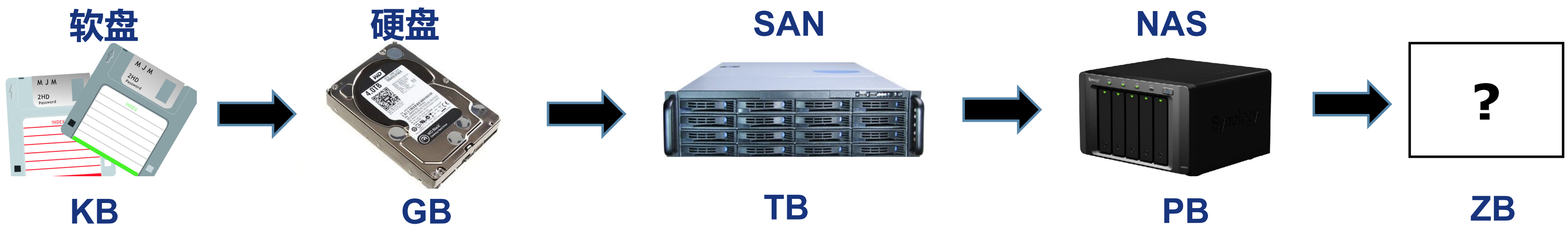
- 全社会数据产生的速度非常快

Internet上一分钟产生的数据有多大？

Motivation: Large Scale Data Processing

- 大数据的呈现出指数增长速度

全球数据存储量呈现爆炸式增长，企业及互联网数据以每年50%的速率在增长，据Gartner预测，到2020年，全球数据量将达到35ZB，等于80亿块4TB硬盘。



Motivation: Large Scale Data Processing

- Want to process lots of data (>1TB)
- Want to parallelize across hundreds/thousands of CPUs
- … Want to make this easy

MapReduce

- A simple and powerful interface that enables automatic parallelization and distribution of large-scale computations, combined with an implementation of this interface that achieves high performance on large clusters of commodity PCs.”

- More simply, MapReduce is A parallel programming model and associated implementation

Dean and Ghermawat, “MapReduce: Simplified Data Processing on Large Clusters”, OSDI 2004， Google Inc.

Some MapReduce Terminology

- Job–A “full program” -an execution of a Mapper and Reducer across a data set
- Task –An execution of a Mapper or a Reducer on a slice of data
  - a.k.a. Task-In-Progress (TIP)
- **Task Attempt** –A particular instance of an attempt to execute a task on a machine

Terminology Example

- Running “Word Count” across 20 files is one job
- 20 files to be mapped imply 20 map tasks+ some number of reduce tasks
- At least 20 map task attempts will be performed… more if a machine crashes, etc.

Task Attempts

- A particular task will be attempted at least once, possibly more times if it crashes
  - If the same input causes crashes over and over, that input will eventually be abandoned
- Multiple attempts at one task may occur in parallel with speculative execution turned on
  - Task ID from TaskInProgress is not a unique identifier

MapReduce Programming Model

- Process data using special map() and reduce() functions
    - The map() function is called on every item in the input and emits a series of intermediate key/value pairs
    - All values associated with a given key are grouped together
    - The reduce() function is called on every unique key, and its value list, and emits a value that is added to the output

Map

- Records from the data source (lines out of files, rows of a database, etc) are fed into the map function as key*value pairs: e.g., (filename, line)
- map() produces one or more intermediate values along with an output key from the input

```
– map  (in_key, in_value) ->
    (out_key, intermediate_value) list
```

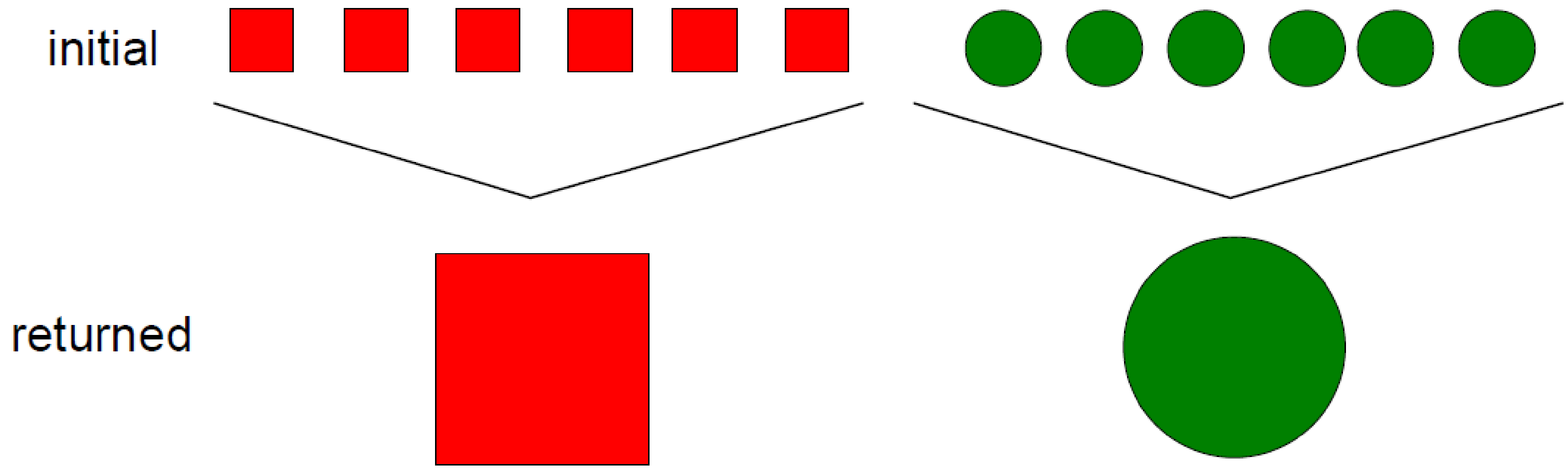
reduce

- After the map phase is over, all the intermediate values for a given output key are combined together into a list
- reduce() combines those intermediate values into one or more final values for that same output key

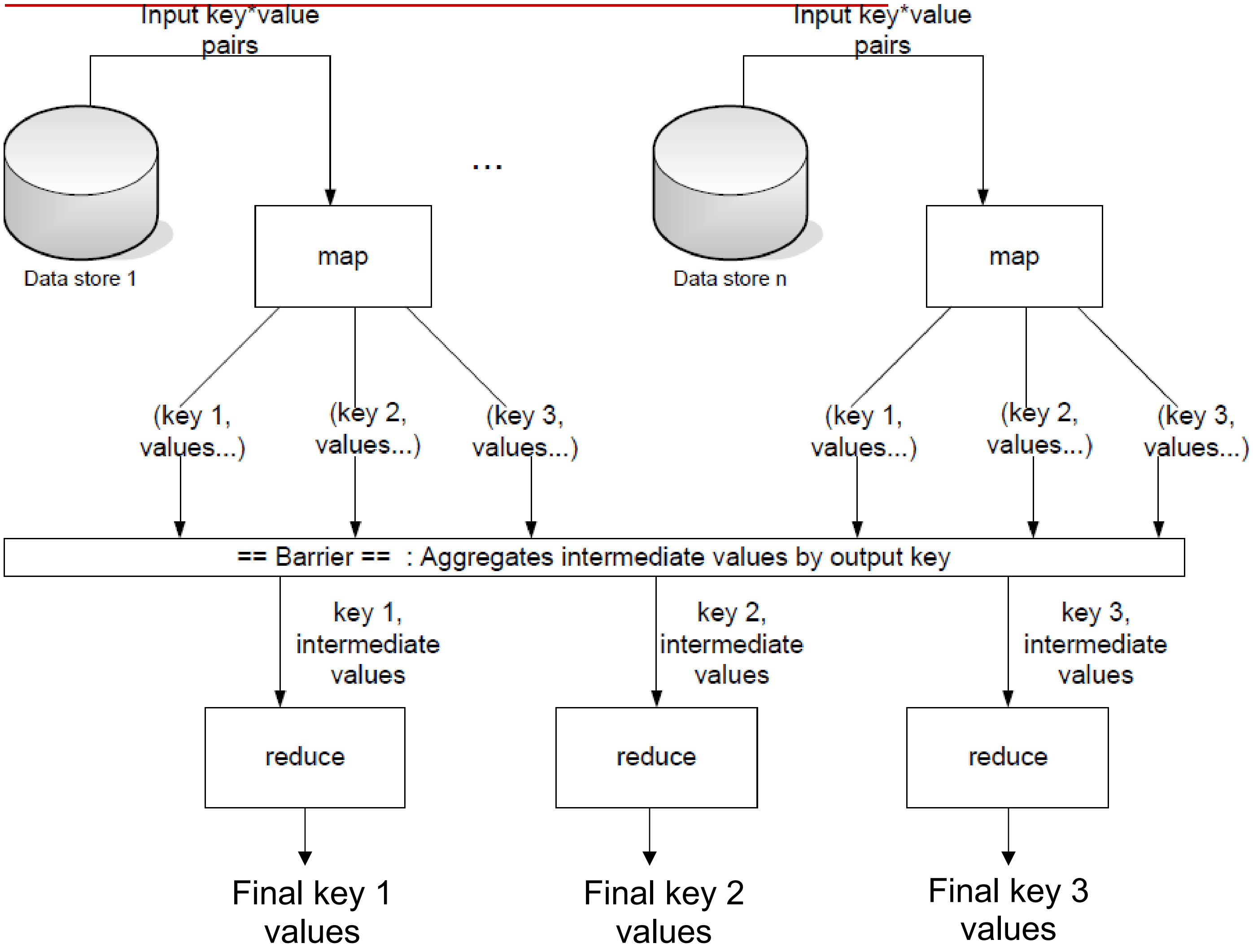
  – `reduce (out_key, intermediate_value list) -> out_value list`

reduce

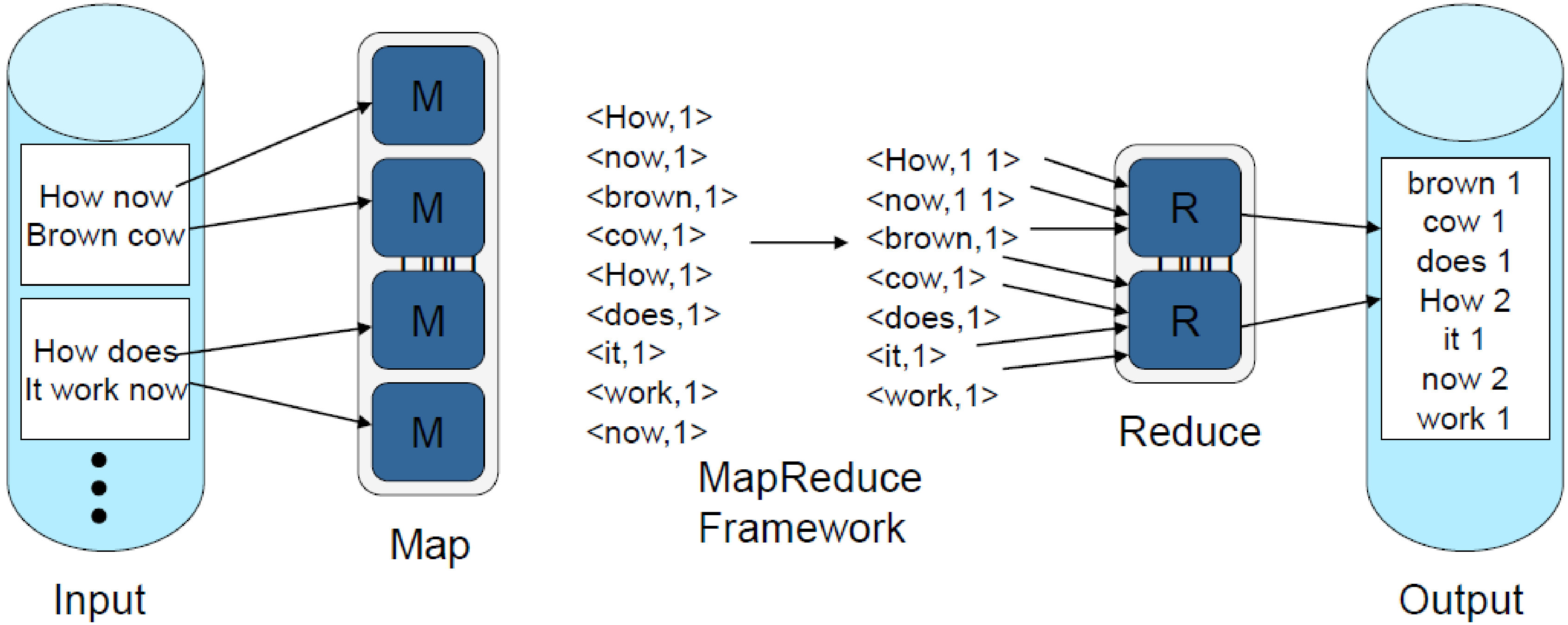
```
reduce (out_key, intermediate_value list) ->
        out_value list
```



MapReduce Architecture

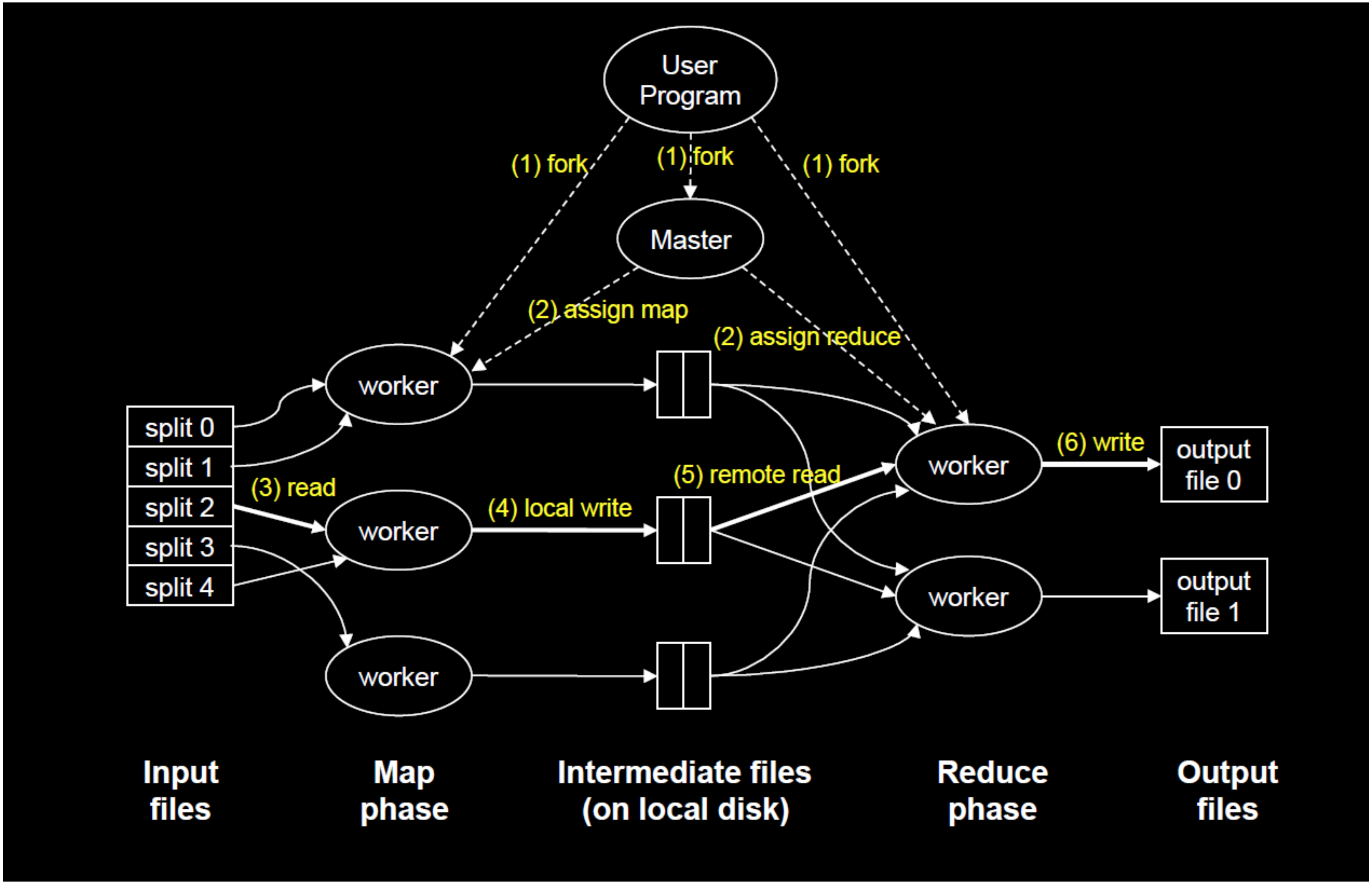


MapReduce Programming Model

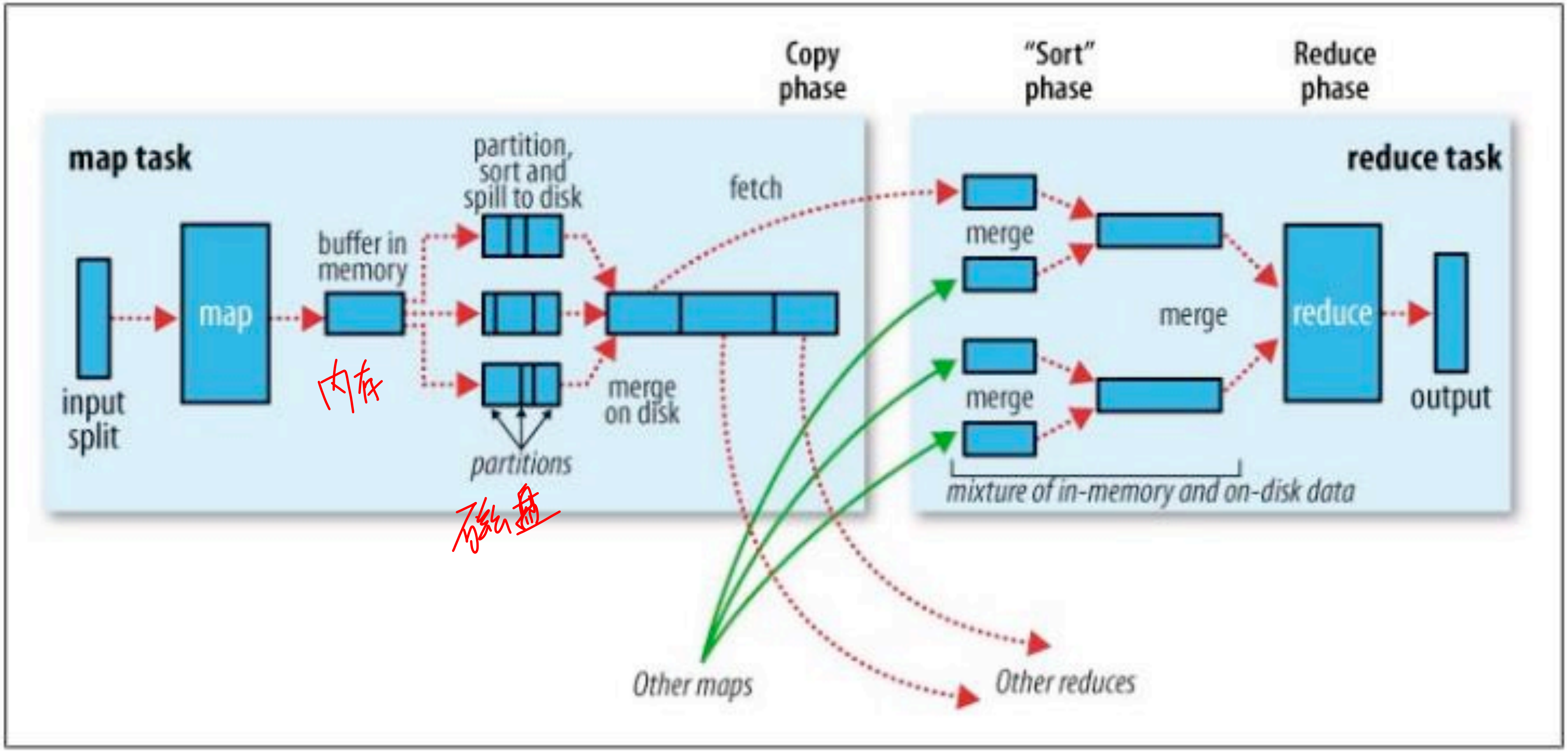


- More formally,
  - Map(k1,v1) --> list(k2,v2)
  - Reduce(k2, list(v2)) --> list(v2)

MapReduce Execution Flow



MapReduce in One Picture



MapReduce Runtime System

- Partitions input data

  Partition and distribute data amongst different nodes

- Schedules executions across a set of machines

  Yarn – (Resource Manager), FIFO. (**Many Research work**)

- Handles machine failure

  Reschedule tasks when the machine fails.

- Manages interprocess communication

Parallelism

- map() functions run in parallel, creating different **intermediate values** from different input data sets
- reduce() functions also run in parallel, each working on a different output key
- All values are processed independently
- **Bottleneck**: reduce phase can't start until map phase is completely finished

Locality

- Master program divides up tasks based on location of data: tries to have map() tasks on the same machine **as physical file data, or at least same rack**
- map() task inputs are divided into 64 MB blocks: same size as **Google File System** chunks

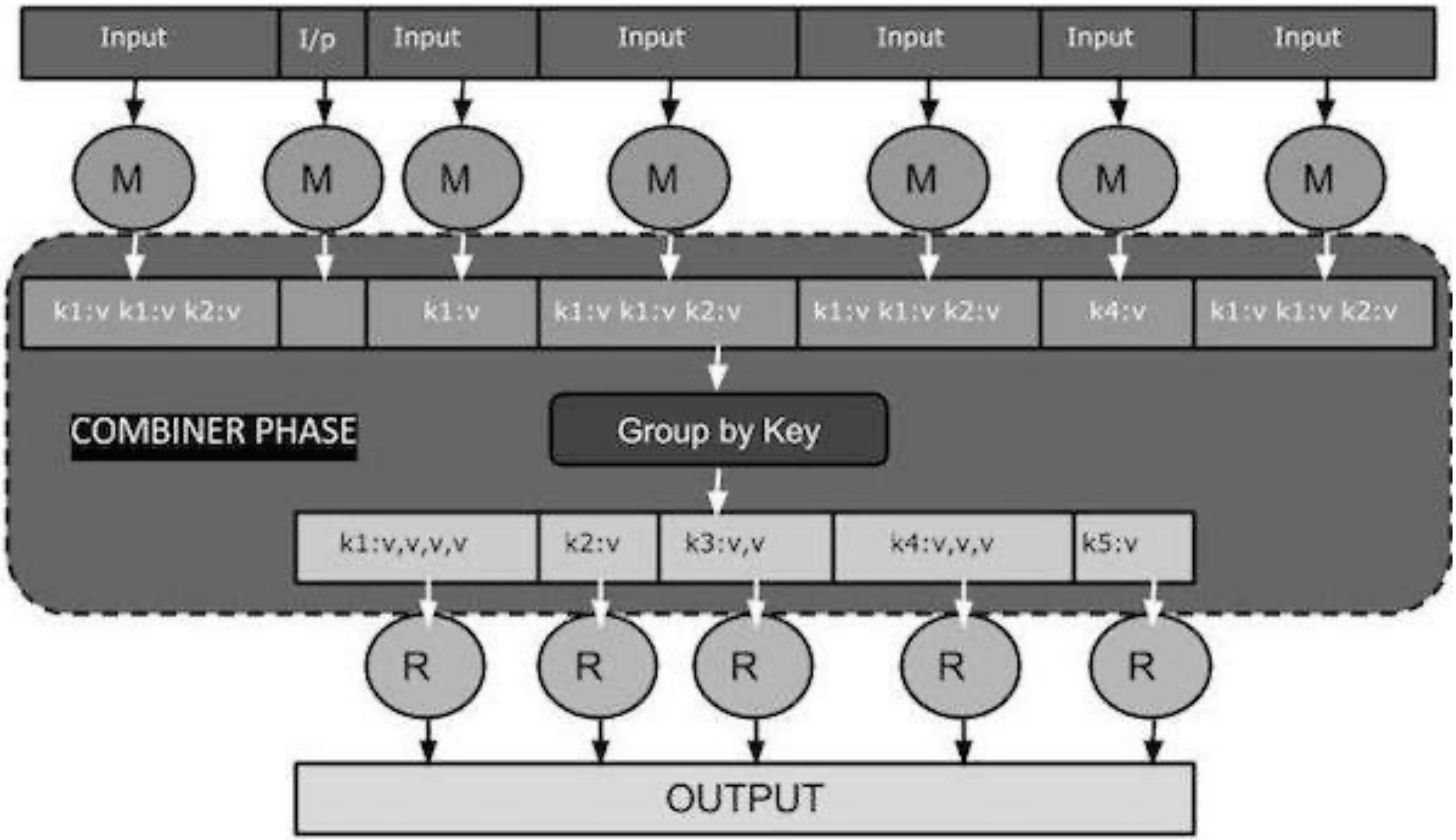
Fault Tolerance

- Master detects worker failures
  - Re-executes completed & in-progress map() tasks
  - Re-executes in-progress reduce() tasks
- Master notices particular input key/values cause crashes in map(), and skips those values on re-execution
  - Effect: Can work around bugs in third-party libraries!

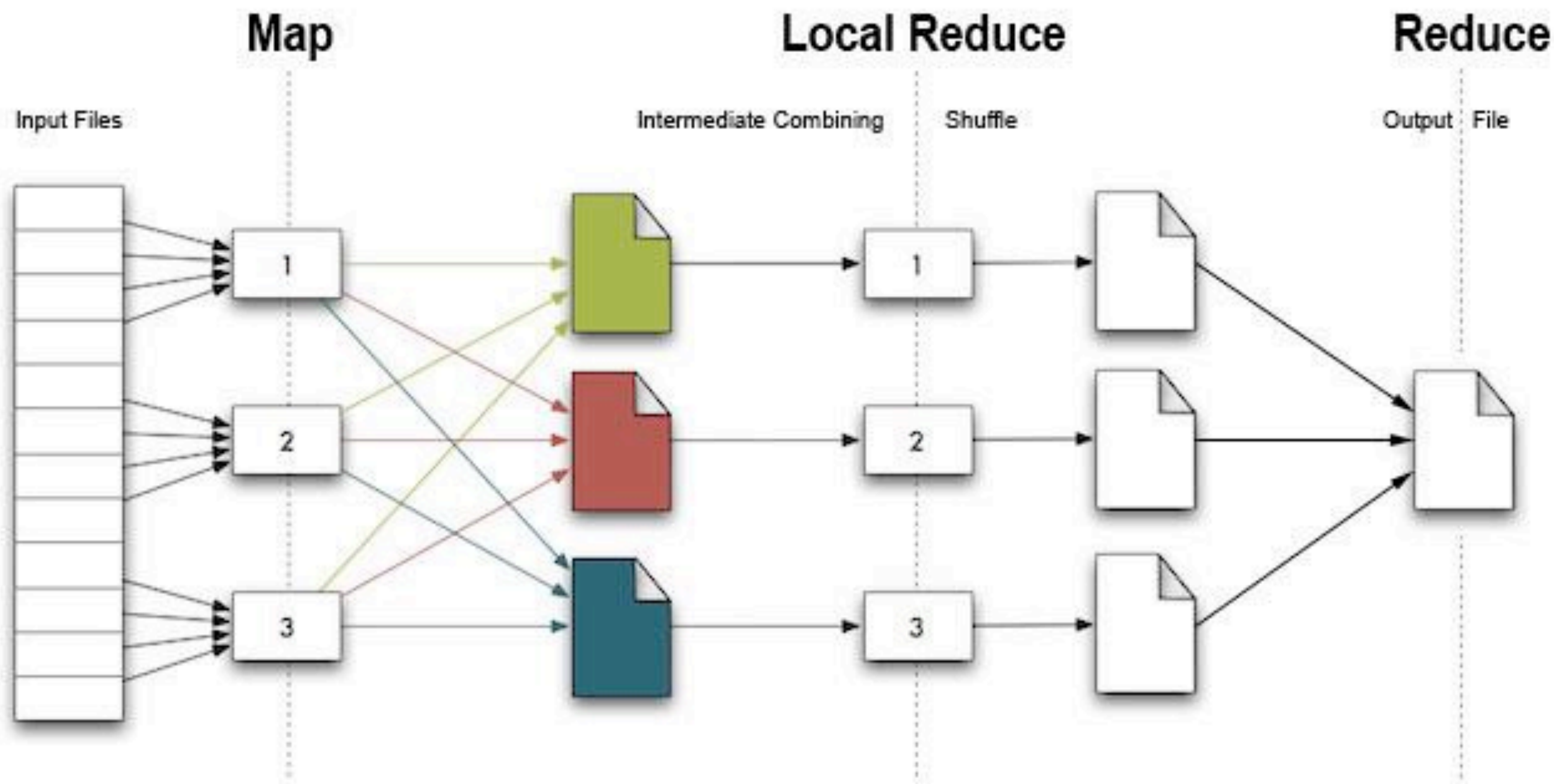
Optimizations

- **No reduce can start until map is complete**
  - A single slow disk controller can rate-limit the whole process
- Master redundantly executes “slow-moving” map tasks; uses results of first copy to finish
- “Combiner” functions can run on same machine as a mapper
- Causes a mini-reduce phase to occur before the real reduce phase, to save bandwidth

Combiner


Input
I/p
Input
Input
Input
Input
Input
M
M
M
M
M
M
M
k1:v k1:v k2:v
k1:v
k1:v k1:v k2:v
k1:v k1:v k2:v
k4:v
k1:v k1:v k2:v
COMBINER PHASE
Group by Key
k1:v,v,v,v
k2:v
k3:v,v
k4:v,v,v
k5:v
R
R
R
R
R
OUTPUT

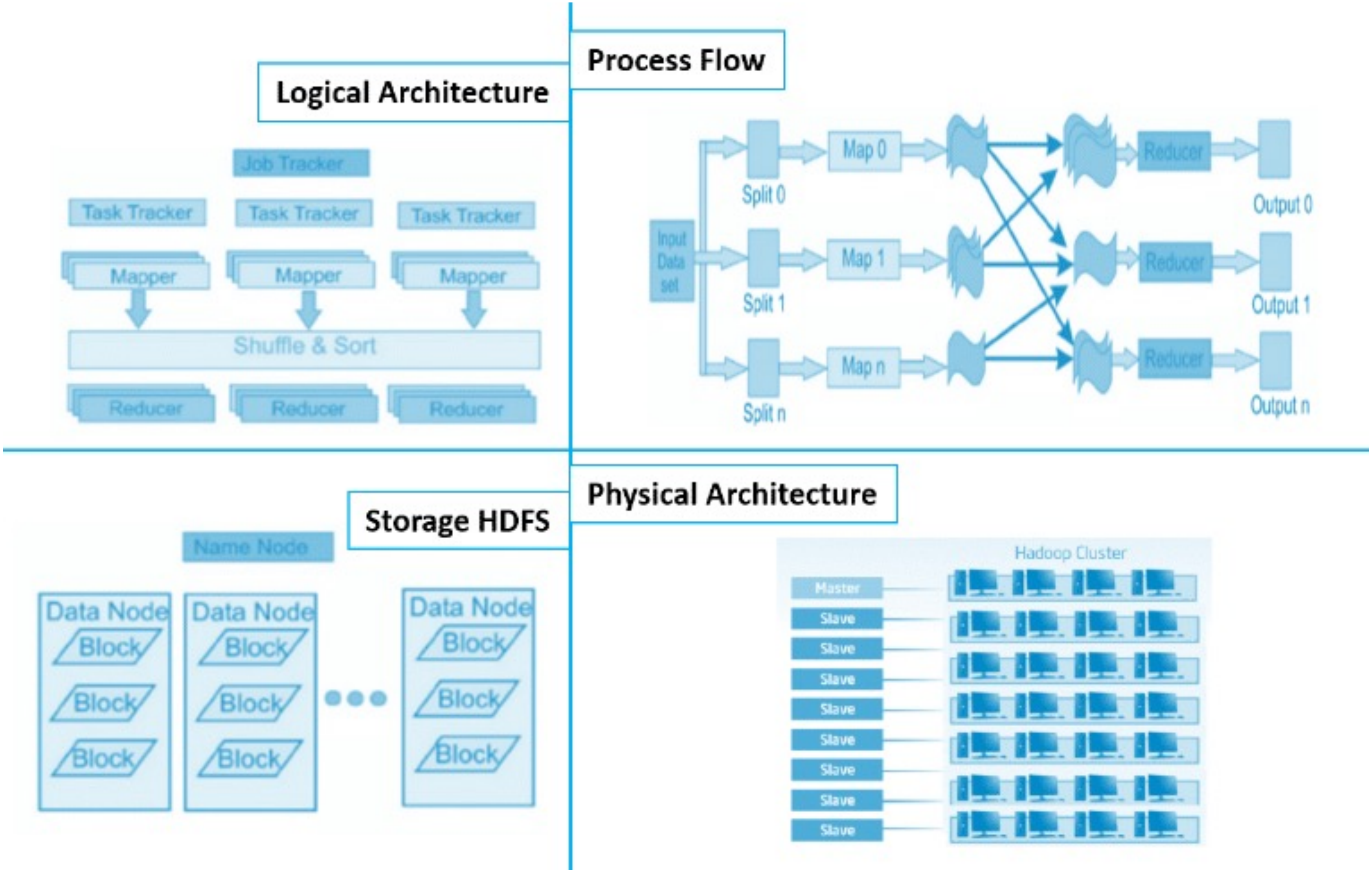
Optimizations



MapReduce Benefits

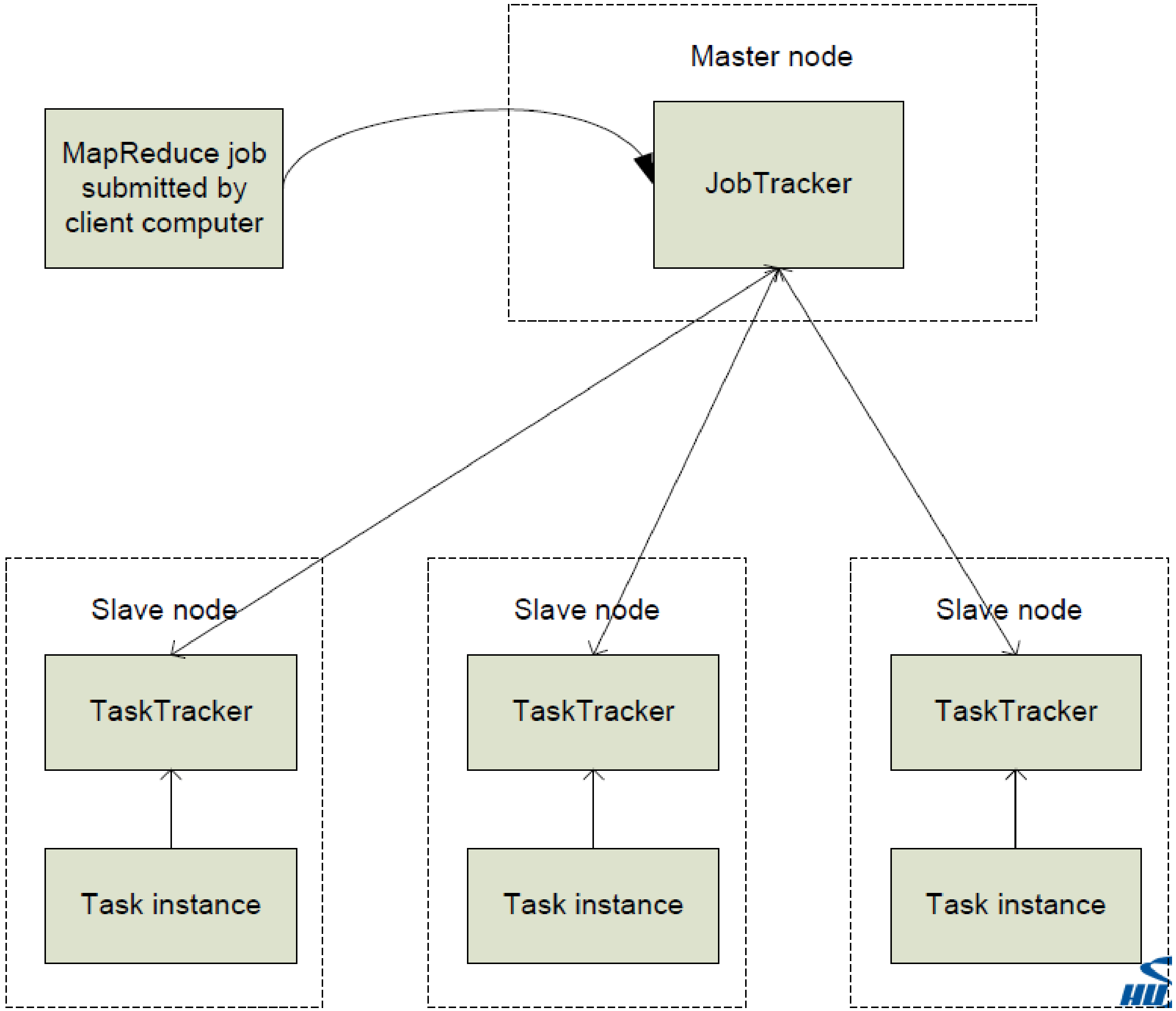
- Greatly reduces parallel programming complexity
  - Reduces synchronization complexity
  - Automatically partitions data
  - Provides failure transparency
  - Handles load balancing

Hadoop architecture from different views



Typical Problems Solved by MapReduce

MapReduce: High Level



Nodes, Trackers, Tasks

- Master node runs **JobTracker (ResourceManager)** instance, which accepts Job requests from clients
- **TaskTracker (NodeManager)** instances run on slave nodes
- TaskTracker forks separate Java process for task instances

Typical Problems Solved by MapReduce

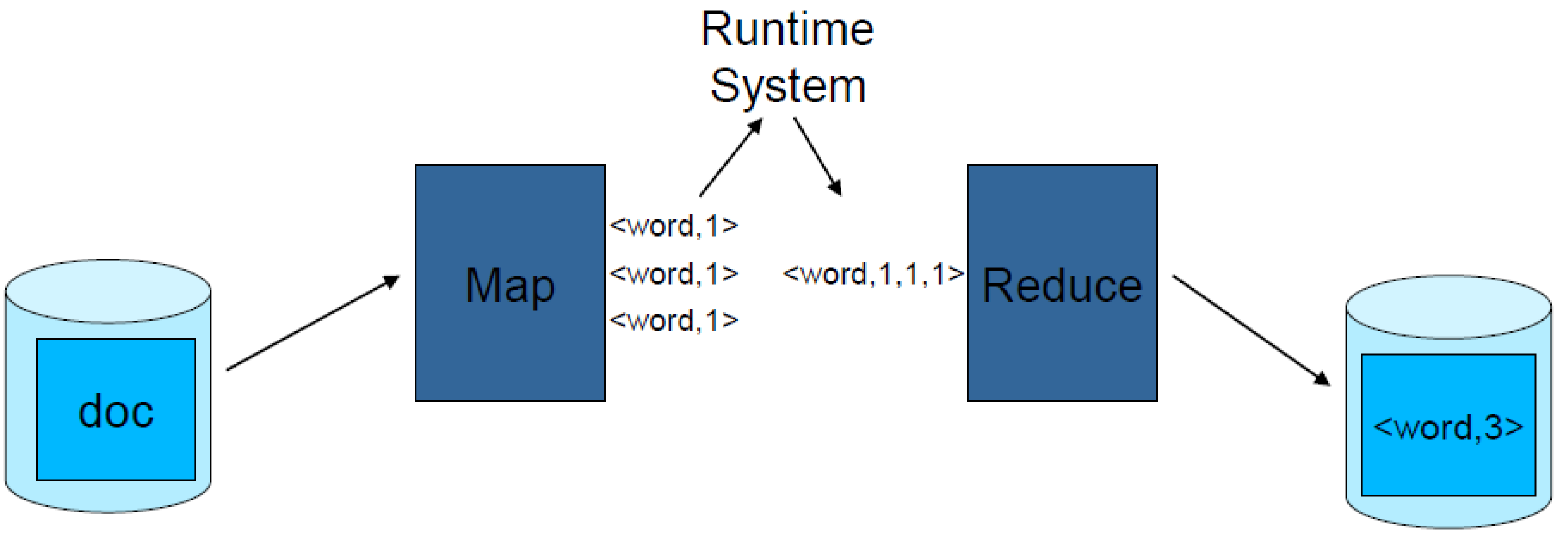
- Read a lot of data
- Map: extract something you care about from each record
- Shuffle and Sort
- Reduce: aggregate, summarize, filter, or transform
- Write the results

- Outline stays the same, but **map** and **reduce** change to fit the problem

MapReduce Examples

MapReduce Examples

- Word frequency

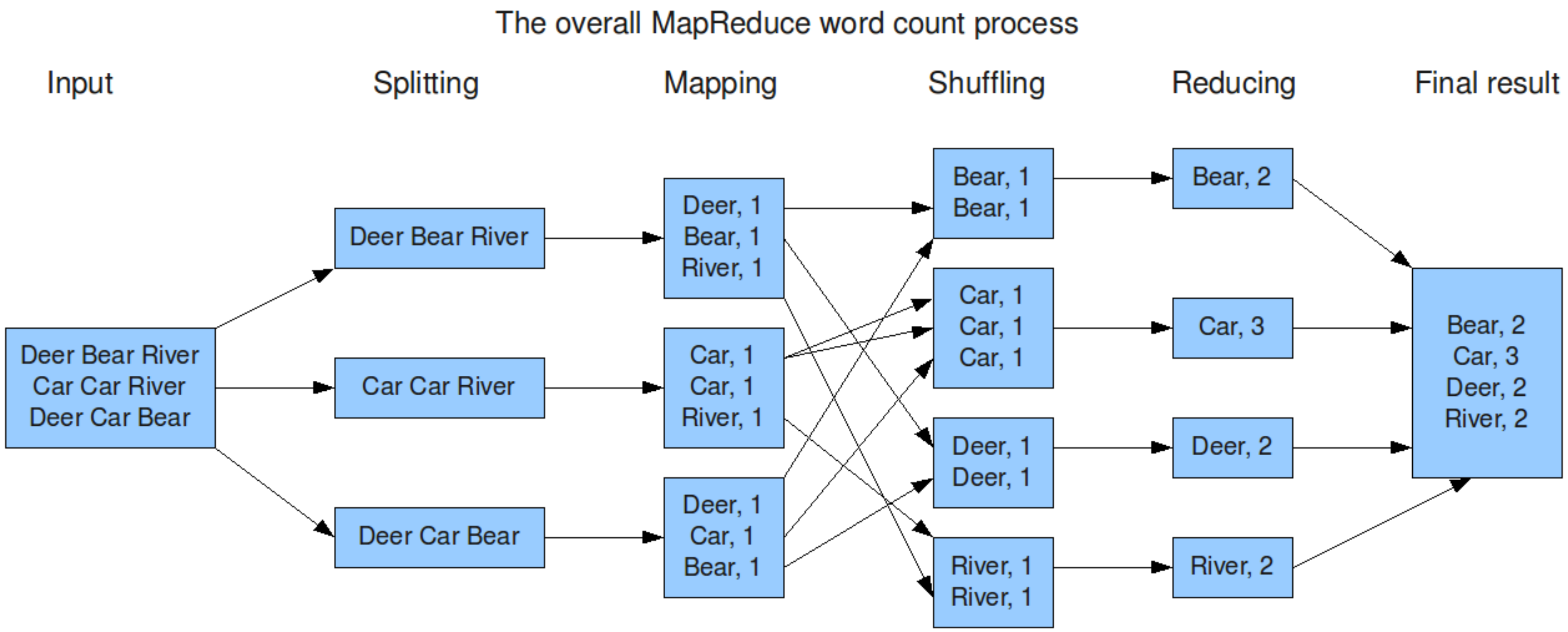


Example: Count Word Occurrences

```
map(String input_key, String input_value):
  // input_key: document name
  // input_value: document contents
  for each word w in input_value:
    EmitIntermediate(w, "1");


reduce(String output_key, Iterator
  intermediate_values):
  // output_key: a word
  // output_values: a list of counts
  int result = 0;
  for each v in intermediate_values:
    result += ParseInt(v);
 Emit(AsString(result));
```

Example: Count Word Occurrences



MapReduce Examples

- Distributed grep
  - Map function emits <word, line_number> if word matches search criteria
  - Reduce function is the identity function
- URL access frequency
  - Map function processes web logs, emits <url, 1>
  - Reduce function sums values and emits <url, total>

A Brief History

A Brief History

MapReduce is a new use of an old idea in Computer Science

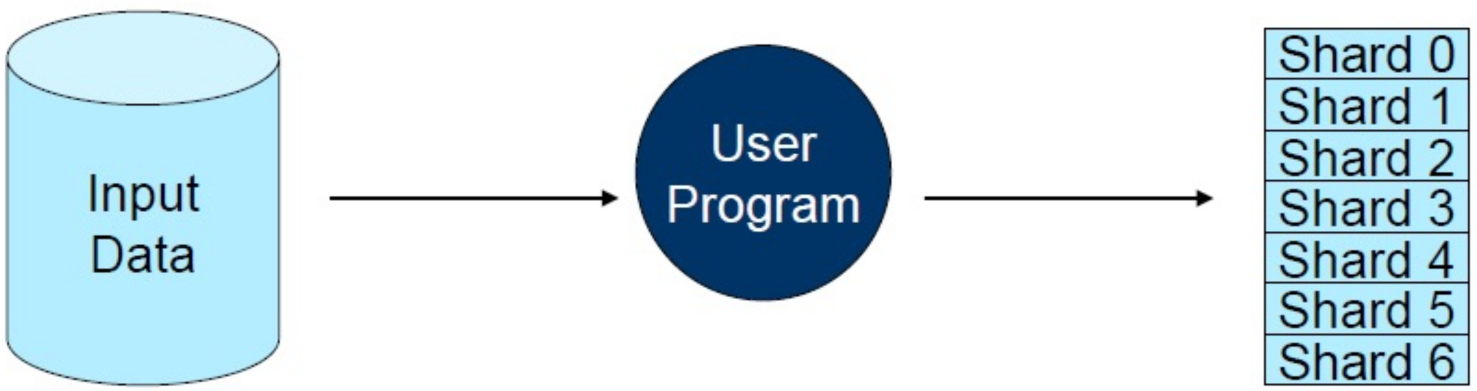
- **Map**: Apply a function to every object in a list
  - Each object is independent
    - Order is unimportant
    - Maps can be done in parallel
  - The function produces a result
- **Reduce**: Combine the results to produce a final result

You may have seen this in a Lisp or functional programming course

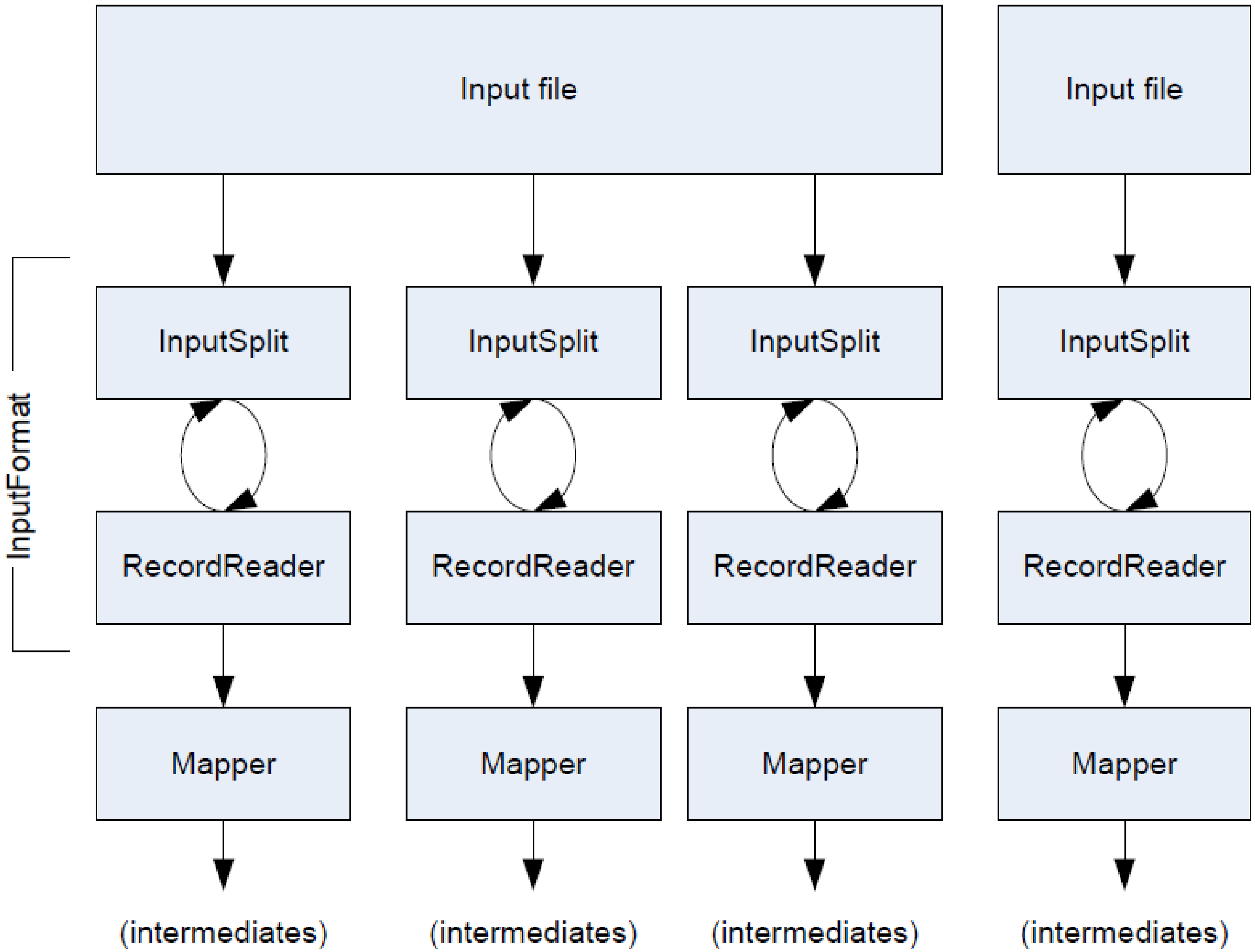
MapReduce Execution Overview

MapReduce Execution Overview

- The user program, via the MapReduce library, shards the input data

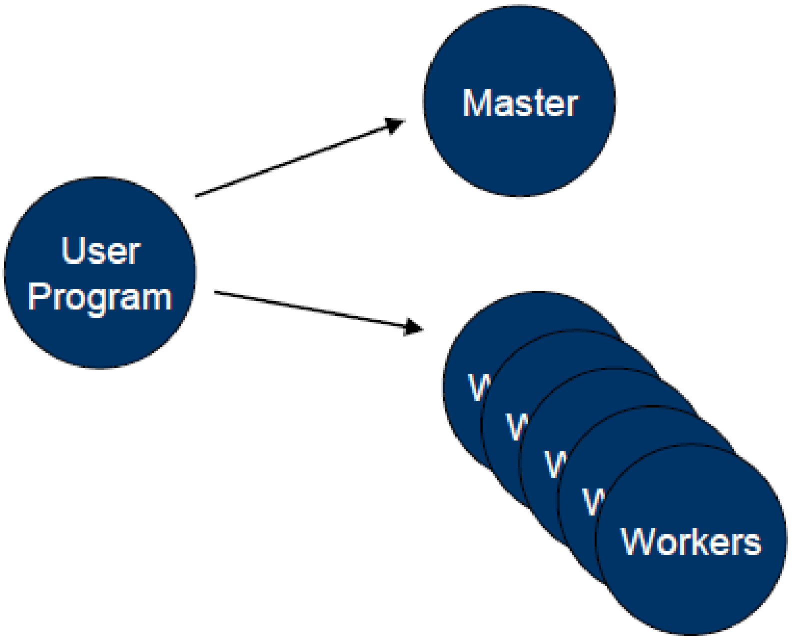


Getting Data To The Mapper



Getting Data To The Mapper

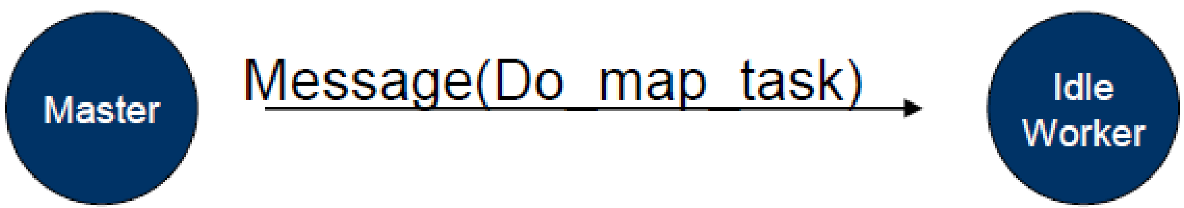
- The user program creates process copies distributed on a machine cluster. One copy will be the “master” and the others will be worker threads



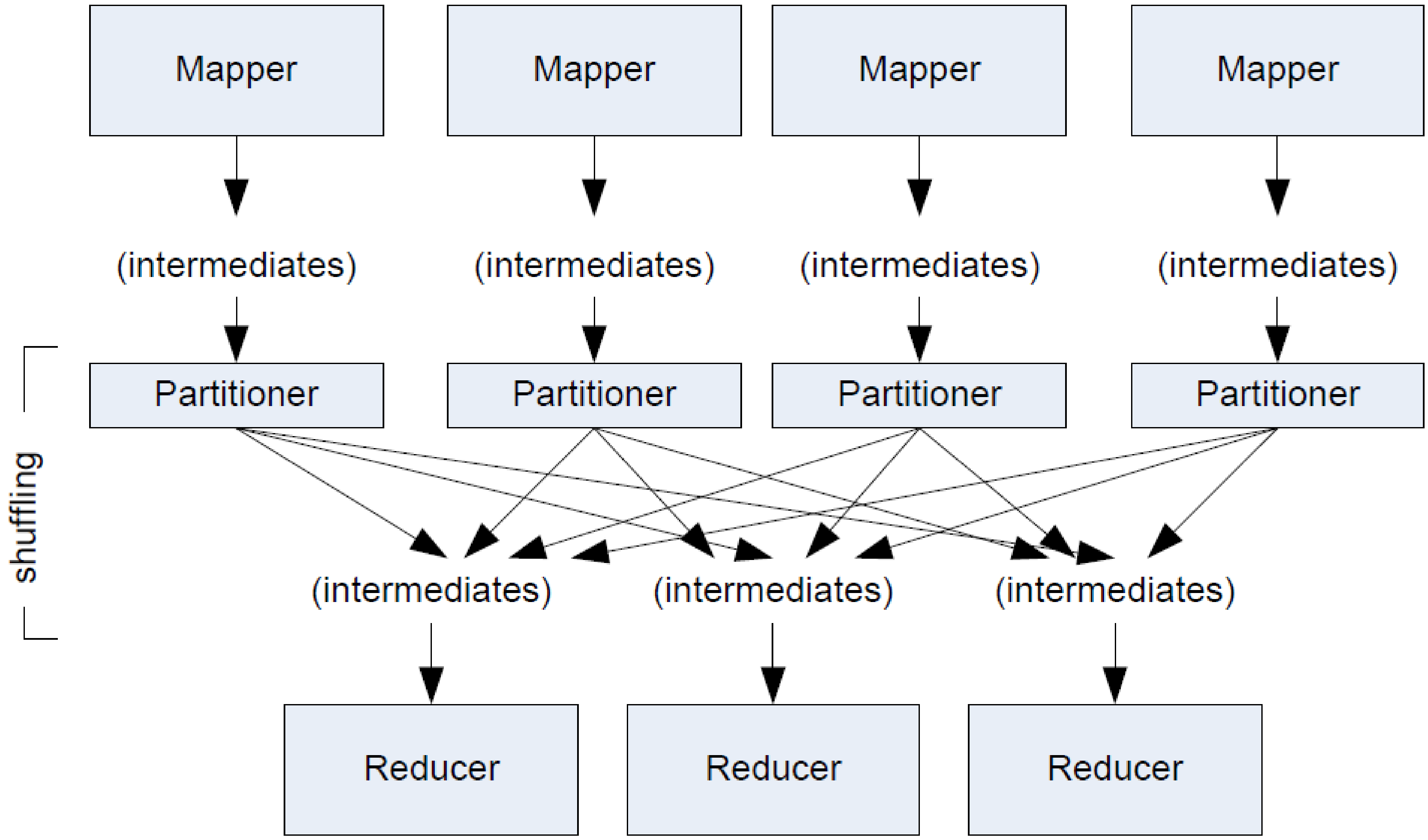
MapReduce Execution Overview

The master distributes *M* map and *R* reduce tasks to idle workers

- *M* == number of shards
- *R* == the intermediate key space is divided into R parts

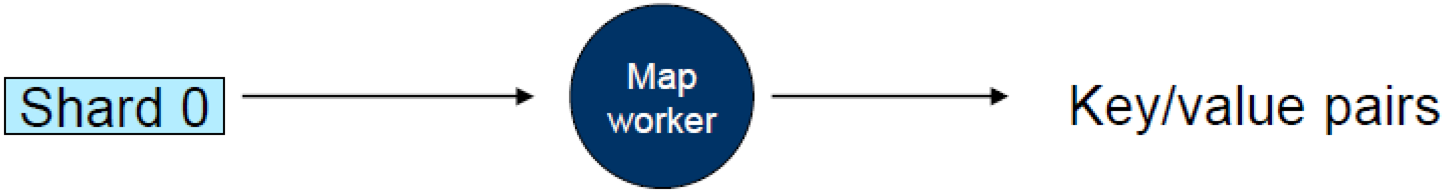


Partition and Shuffle



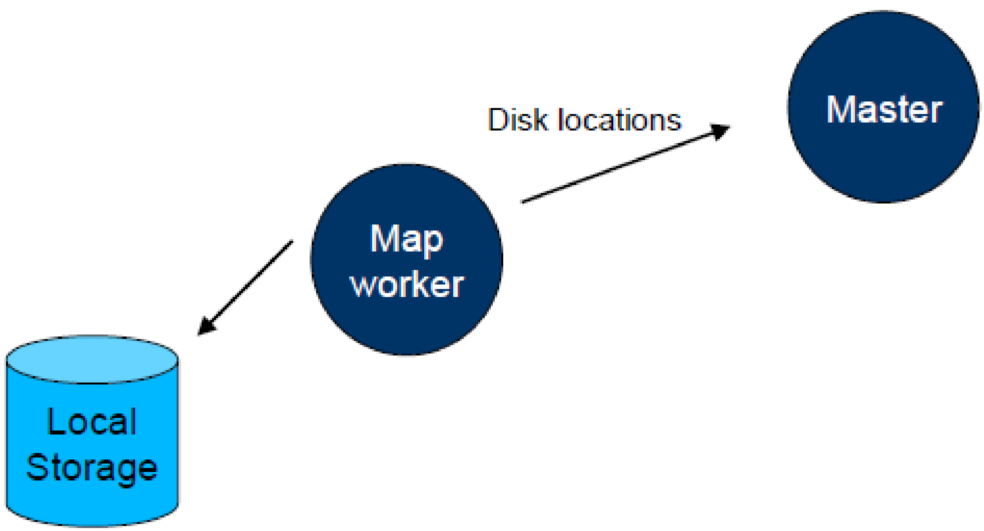
MapReduce Execution Overview

- Each map-task worker reads assigned input shard and outputs intermediate key/value pairs
  - Output buffered in RAM



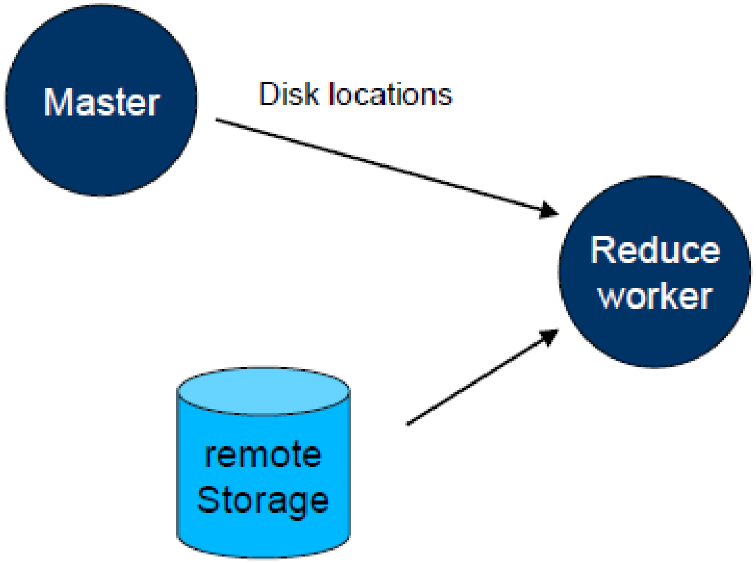
MapReduce Execution Overview

- Each worker flushes intermediate values, partitioned into *R* regions, to disk and notifies the Master process.



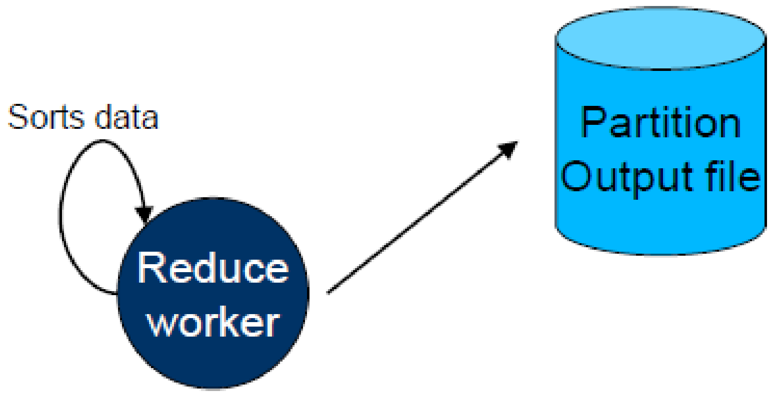
MapReduce Execution Overview

- Master process gives disk locations to an available reduce-task worker who reads all associated intermediate data.



MapReduce Execution Overview

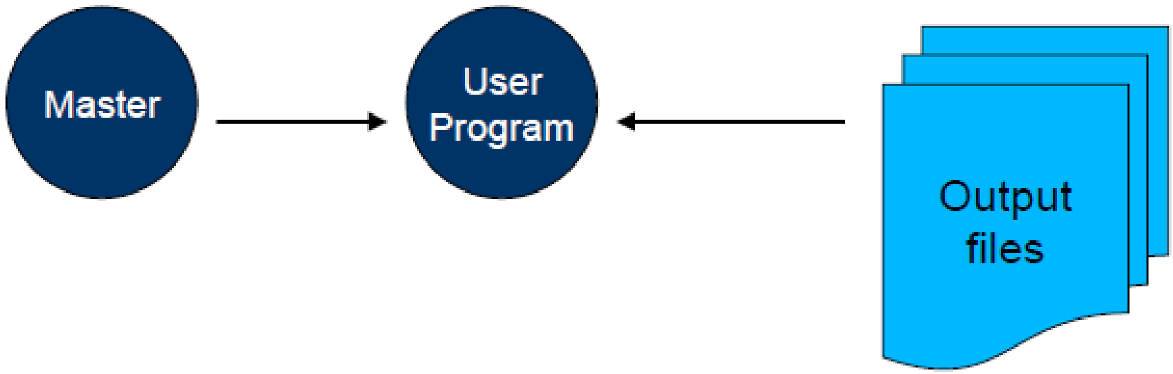
- Each reduce-task worker sorts its intermediate data. Calls the reduce function, passing in unique keys and associated key values. Reduce function output appended to reduce-task's partition output file



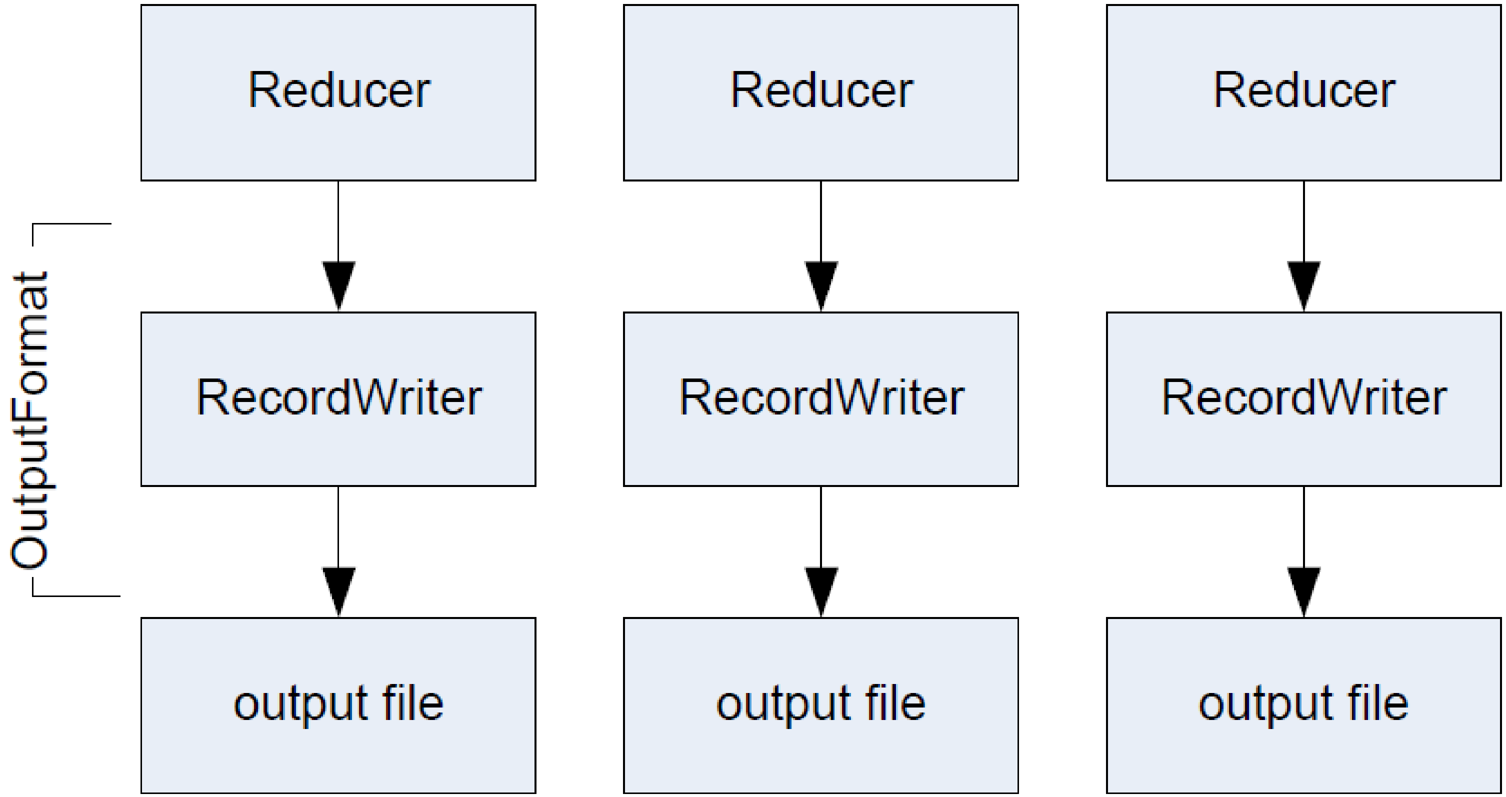
MapReduce Execution Overview

- Master process wakes up user process when all tasks have completed.

  Output contained in *R* output files



Writing The Output



MapReduce Execution Overview

- Fault Tolerance
  - Master process periodically pings workers
    - Map-task failure
      - Re-execute
        - All output was stored locally
    - Reduce-task failure
      - Only re-execute partially completed tasks
        - All output stored in the global file system

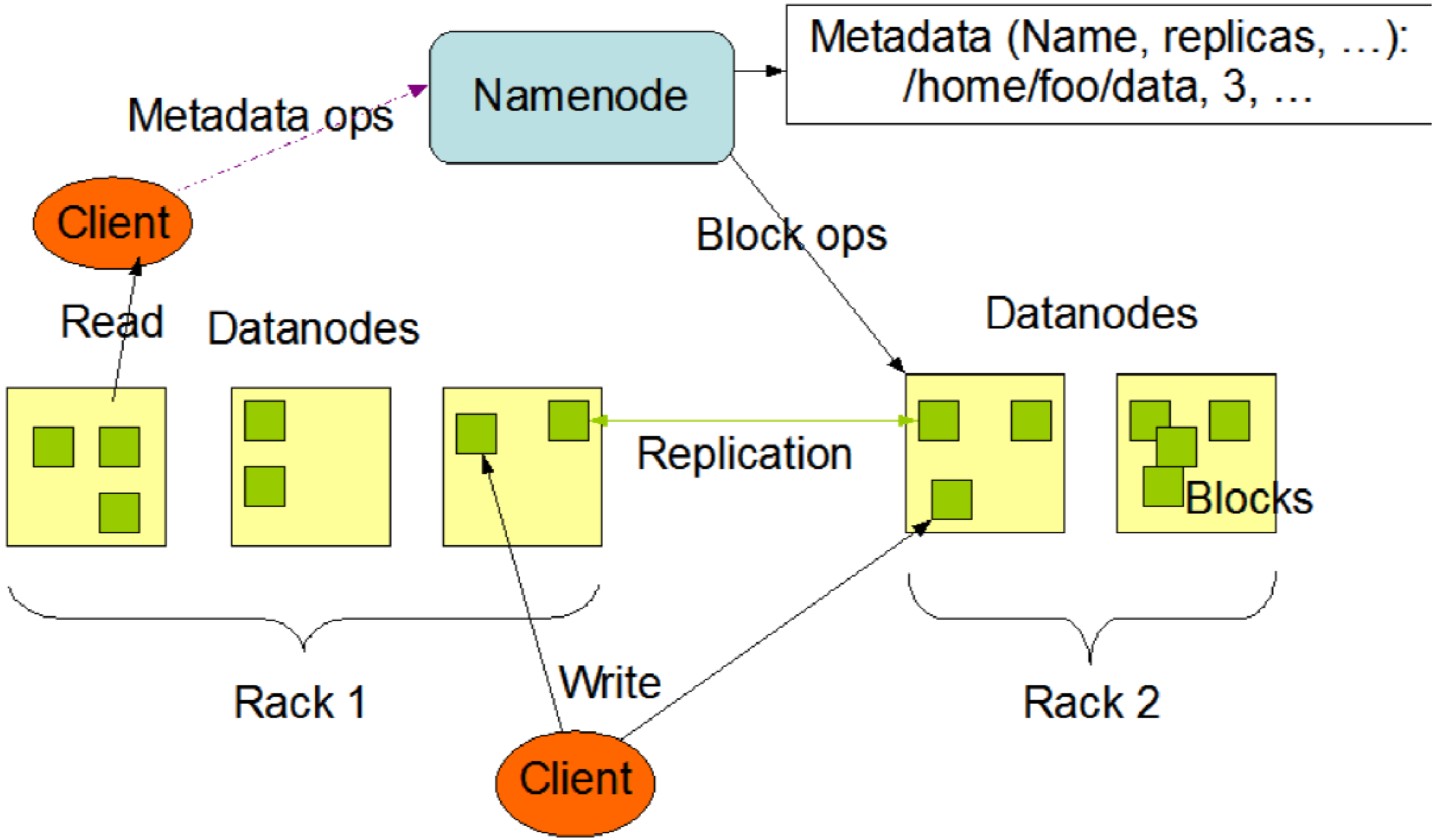
Hadoop

MapReduce Execution Overview

- Open source MapReduce implementation
  - http://hadoop.apache.org/core/index.html

Google calls it	Hadoop equivalent
MapReduce	Hadoop
GFS	HDFS
Bigtable	HBase
Chubby	(nothing yet… but planned)

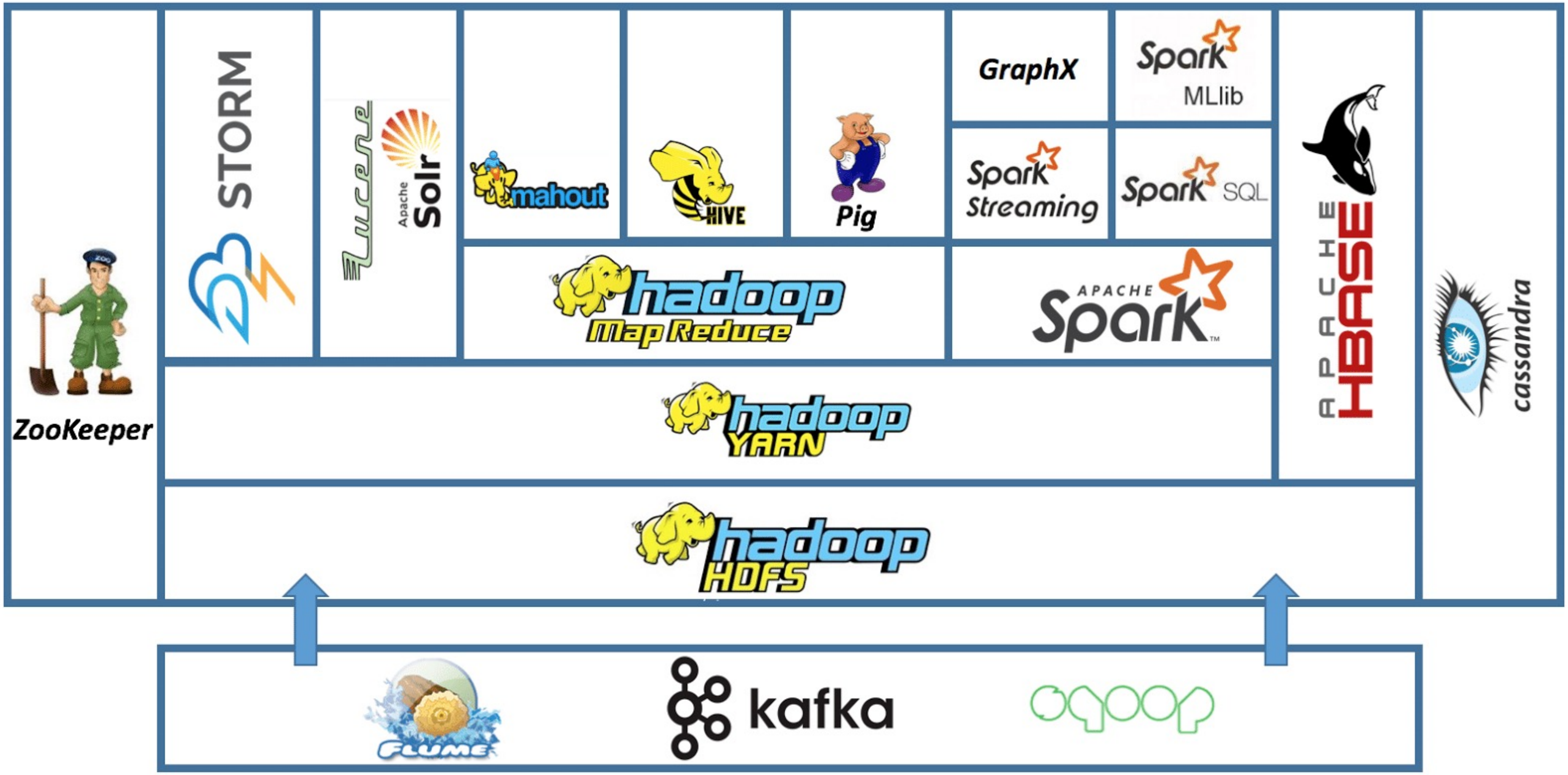
HDFS Architecture



Hadoop Related Projects

- **Ambari:** A web-based tool for provisioning, managing, and monitoring Apache Hadoop clusters which includes support for Hadoop HDFS, Hadoop MapReduce Hive, HCatalog, HBase, ZooKeeper, Oozie, Pig and Sqoop. Ambari also provides a dashboard for viewing cluster health such as heat maps and ability to view MapReduce, Pig and Hive applications visually along with features to diagnose their performance characteristics in a user-friendly manner
- **Avro:** A data serialization system
- **Cassandra:** A scalable multi-master database with no single points of failure
- **Chukwa:** A data collection system for managing large distributed systems
- **HBase:** A scalable, distributed database that supports structured data storage for large tables (NoSQL)
- **Hive:** A data warehouse infrastructure that provides data summarization and ad hoc querying
- **Mahout:** A Scalable machine learning and data mining library
- **Pig:** A high-level data-flow language and execution framework for parallel computation
- **ZooKeeper:** A high-performance coordination service for distributed applications

Hadoop Ecosystem



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- Hadoop
  - http://hadoop.apache.org/core/

Thank You！