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Scalable Data Science

Lecture 18: Hadoop System

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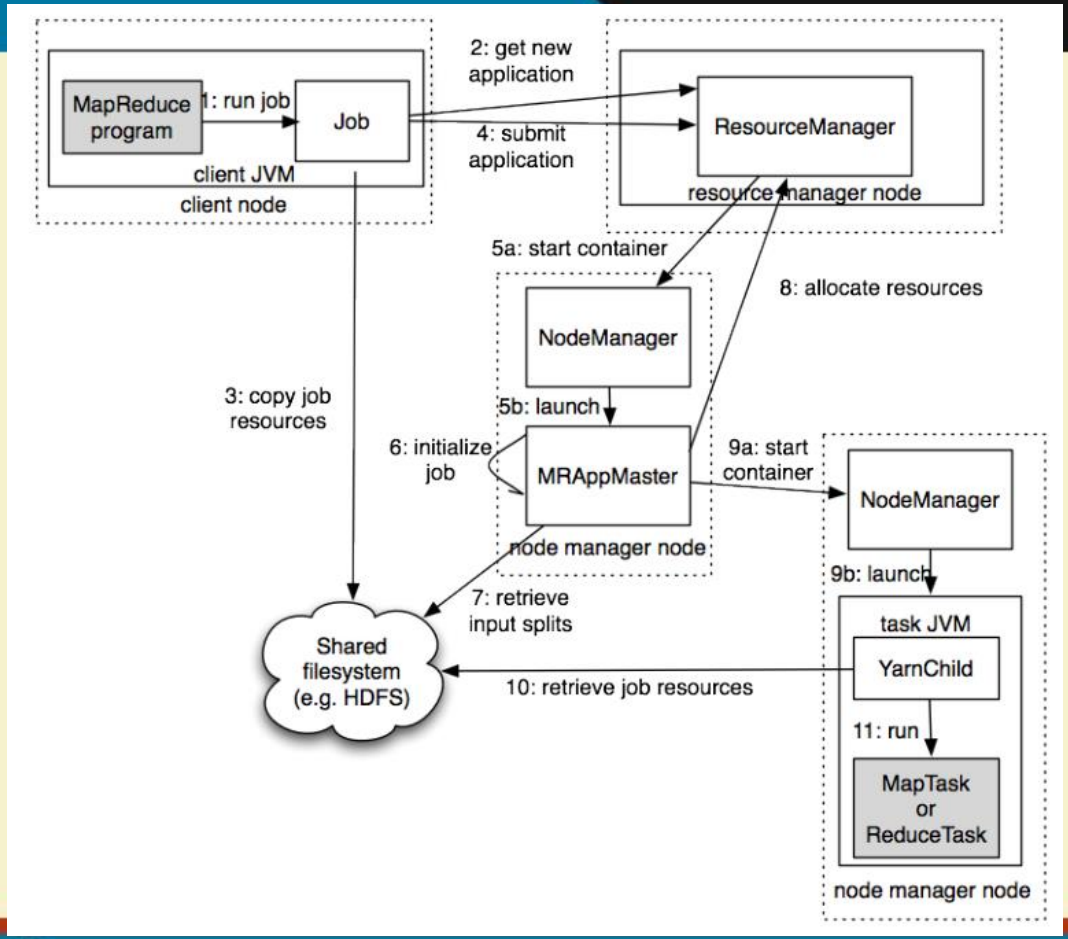
In the previous lectures:

- Outline:
  - What is Big Data and Hadoop?
  - What is Map Reduce ?
  - Example Map Reduce program.
  - HDFS – commands and internals.
  - Implementation of Map-reduce program
    - Java
    - Other languages through streaming API.

In this Lecture:

- Outline:
  - Map-reduce implementation details
    - Coordination
    - Fault- tolerance
    - Pipelining
    - Refinements

Hadoop(v2) MR job



Source: Hadoop: The Definitive Guide

Coordination: Master

- **Master node takes care of coordination:**
  - **Task status:** (idle, in-progress, completed)
  - **Idle tasks** get scheduled as workers become available
  - When a map task completes, it sends the master the location and sizes of its *R* intermediate files, one for each reducer
  - Master pushes this info to reducers
- Master pings workers periodically to detect failures

Fault tolerance

- Comes from scalability and cost effectiveness
- HDFS:
  - Replication
- Map Reduce
  - Restarting failed tasks: map and reduce
  - Writing map output to FS
  - Minimizes re-computation

Failures

- Task failure
  - Task has failed – report error to node manager, appmaster, client.
  - Task not responsive, JVM failure – Node manager restarts tasks.
- Application Master failure
  - Application master sends heartbeats to resource manager.
  - If not received, the resource manager retrieves job history of the run tasks.
- Node manager failure

Dealing with Failures

- **Map worker failure**
  - Map tasks completed or in-progress at worker are reset to idle
  - Reduce workers are notified when task is rescheduled on another worker
- **Reduce worker failure**
  - Only in-progress tasks are reset to idle
  - Reduce task is restarted
- **Master failure**
  - MapReduce task is aborted and client is notified

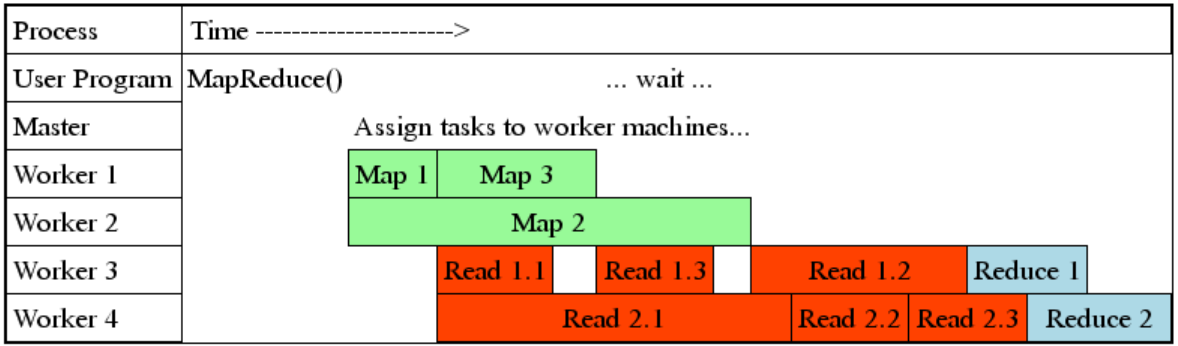
How many Map and Reduce jobs?

- *M* map tasks, *R* reduce tasks
- **Rule of a thumb:**
  - Make *M* much larger than the number of nodes in the cluster
  - One DFS chunk per map is common
  - Improves dynamic load balancing and speeds up recovery from worker failures

- **Usually *R* is smaller than *M***
  - Because output is spread across *R* files

Task Granularity & Pipelining

- **Fine granularity tasks:** map tasks >> machines
  - Minimizes time for fault recovery
  - Can do pipeline shuffling with map execution
  - Better dynamic load balancing



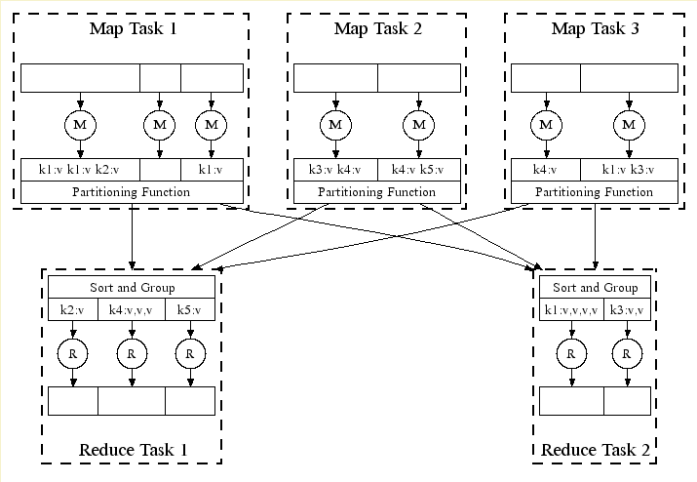
Refinements: Backup Tasks

- **Problem**
  - Slow workers significantly lengthen the job completion time:
    - Other jobs on the machine
    - Bad disks
    - Weird things
- **Solution**
  - Near end of phase, spawn backup copies of tasks
    - Whichever one finishes first “wins”
- **Effect**
  - Dramatically shortens job completion time

Refinement: Combiners

- Often a Map task will produce many pairs of the form $(k,v_1), (k,v_2), \ldots$ for the same key k
  - E.g., popular words in the word count example

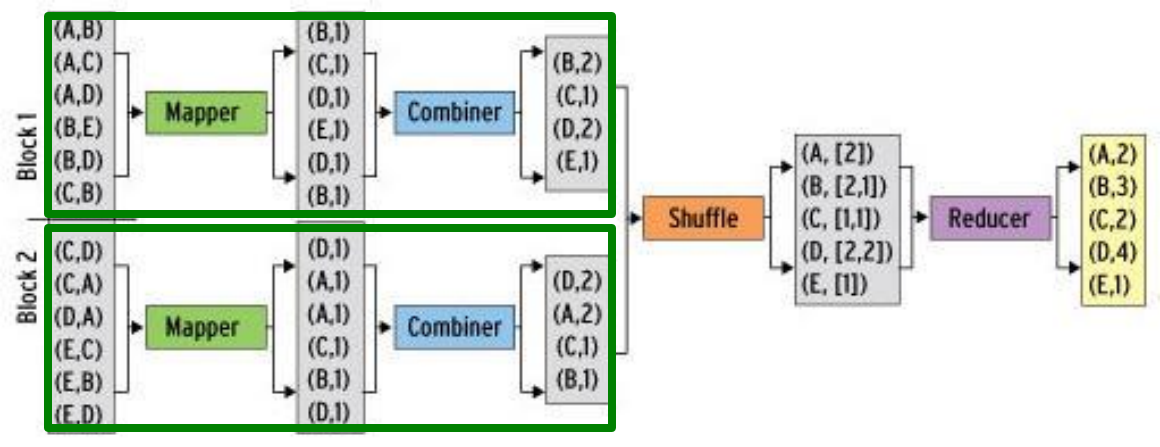
- **Can save network time by pre-aggregating values in the mapper:**
  - combine(k, list(v_1)) → v_2
  - Combiner is usually same as the reduce function



- Works only if reduce function is commutative and associative

Refinement: Combiners

- **Back to our word counting example:**
  - Combiner combines the values of all keys of a single mapper (single machine):



  - Much less data needs to be copied and shuffled!

Refinement: Partition Function

- **Want to control how keys get partitioned**
  - Inputs to map tasks are created by contiguous splits of input file
  - Reduce needs to ensure that records with the same intermediate key end up at the same worker

- **System uses a default partition function:**
  - **hash(key) mod *R***

- **Sometimes useful to override the hash function:**
  - E.g., **hash(hostname(URL)) mod *R*** ensures URLs from a host end up in the same output file

Conclusion:

- We have seen:
  - The structure of HDFS.
  - The shell commands.
  - The architecture of HDFS system.
  - Internal functioning of HDFS.

References:

- Jure Leskovec, Anand Rajaraman, Jeff Ullman. **Mining of Massive Datasets.** *2nd edition. - Cambridge University Press.* *http://www.mmds.org/*

- Tom White. **Hadoop: The definitive Guide.** Oreilly Press.

Thank You!!