Hadoop Map/Reduce

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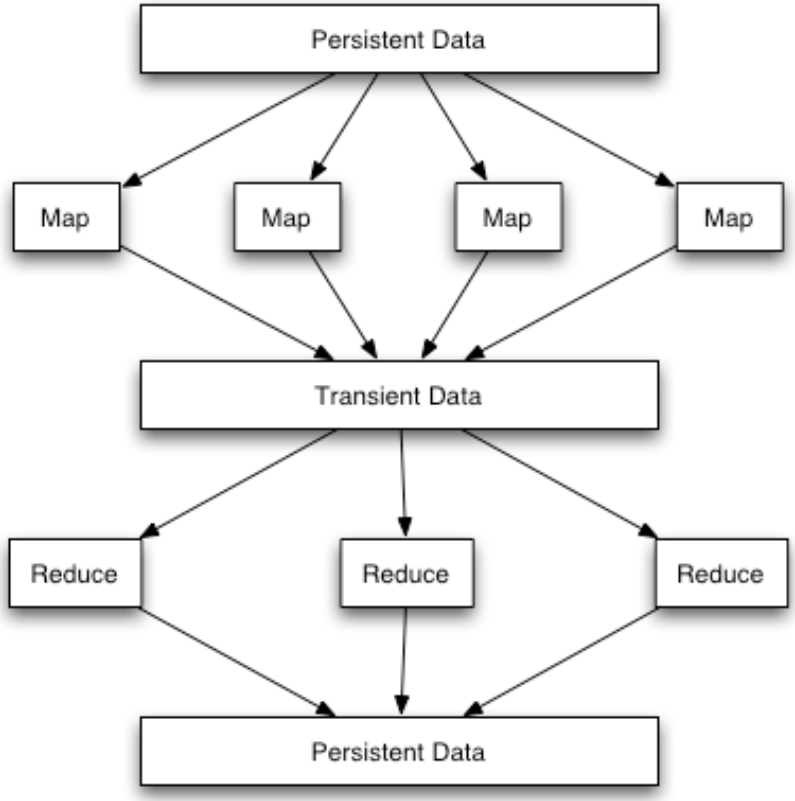
Map/Reduce Goals

- Distribution
  - The data is available where needed.
  - Application does not care how many computers are being used.
- Reliability
  - Application does not care that computers or networks may have temporary or permanent failures.

Application Perspective

- Define Mapper and Reducer classes and a "launching" program.
- Mapper
  - Is given a stream of key1,value1 pairs
  - Generates a stream of key2, value2 pairs
- Reducer
  - Is given a key2 and a stream of value2's
  - Generates a stream of key3, value3 pairs
- Launching Program
  - Creates a JobConf to define a job.
  - Submits JobConf to JobTracker and waits for completion.

Application Dataflow



Input & Output Formats

- The application also chooses input and output formats, which define how the persistent data is read and written. These are interfaces and can be defined by the application.
- InputFormat
  - Splits the input to determine the input to each map task.
  - Defines a RecordReader that reads key, value pairs that are passed to the map task
- OutputFormat
  - Given the key, value pairs and a filename, writes the reduce task output to persistent store.

Output Ordering

- The application can control the sort order and partitions of the output via OutputKeyComparator and Partitioner.
- OutputKeyComparator
  - Defines how to compare **serialized** keys.
  - Defaults to WritableComparable, but should be defined for any application defined key types.
    - key1.compareTo(key2)
- Partitioner
  - Given a map output key and the number of reduces, chooses a reduce.
  - Defaults to HashPartitioner
    - key.hashCode % numReduces

Combiners

- Combiners are an optimization for jobs with reducers that can merge multiple values into a single value.
- Typically, the combiner is the same as the reducer and runs on the map outputs before it is transferred to the reducer's machine.
- For example, WordCount's mapper generates (word, count) and the combiner and reducer generate the sum for each word.
  - Input: "hi Owen bye Owen"
  - Map output: ("hi", 1), ("Owen", 1), ("bye",1), ("Owen",1)
  - Combiner output: ("Owen", 2), ("bye", 1), ("hi", 1)

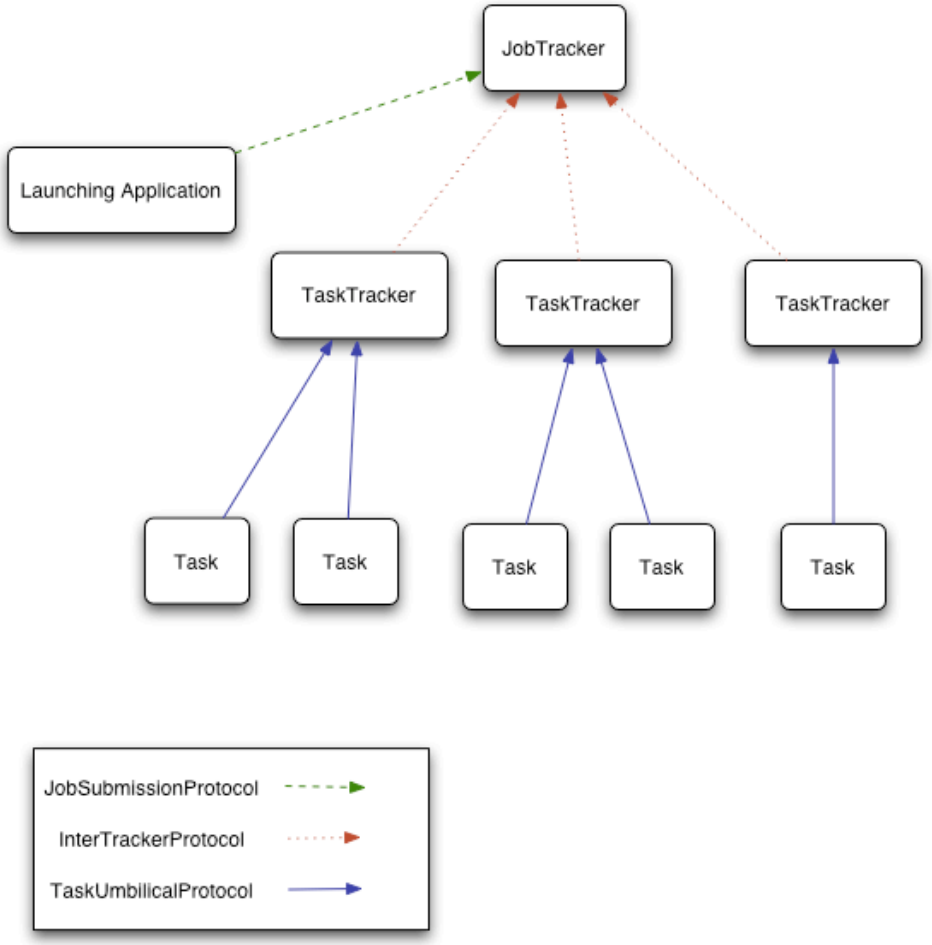
Process Communication

- Use a custom RPC implementation
  - Easy to change/extend
  - Defined as Java interfaces
  - Server objects implement the interface
  - Client proxy objects automatically created
- All messages originate at the client
  - Prevents cycles and therefore deadlocks
- Errors
  - Include timeouts and communication problems.
  - Are signaled to client via IOException.
  - Are **NEVER** signaled to the server.

Map/Reduce Processes

- Launching Application
  - User application code
  - Submits a specific kind of Map/Reduce job
- JobTracker
  - Handles all jobs
  - Makes all scheduling decisions
- TaskTracker
  - Manager for all tasks on a given node
- Task
  - Runs an individual map or reduce fragment for a given job
  - Forks from the TaskTracker

Process Diagram



Job Control Flow

- Application launcher creates and submits job.
- JobTracker initializes job, creates FileSplits, and adds tasks to queue.
- TaskTrackers ask for a new map or reduce task every 10 seconds or when the previous task finishes.
- As tasks run, the TaskTracker reports status to the JobTracker every 10 seconds.
- When job completes, the JobTracker tells the TaskTrackers to delete temporary files.
- Application launcher notices job completion and stops waiting.

Application Launcher

- Application code to create JobConf and set the parameters.
  - Mapper, Reducer classes
  - InputFormat and OutputFormat classes
  - Combiner class, if desired
- Writes JobConf and the application jar to DFS and submits job to JobTracker.
- Can exit immediately or wait for the job to complete or fail.

JobTracker

- Takes JobConf and creates an instance of the InputFormat. Calls the getSplits method to generate map inputs.
- Creates a JobInProgress object and a bunch of TaskInProgress “TIP” and Task objects.
  - **JobInProgress** is the status of the job.
  - **TaskInProgress** is the status of a fragment of work.
  - **Task** is an attempt to do a TIP.
- As TaskTrackers request work, they are given Tasks to execute.

TaskTracker

- All Tasks
  - Create the TaskRunner
  - Copy the job.jar and job.xml from DFS.
  - Localize the JobConf for this Task.
  - Call task.prepare() (details later)
  - Launch the Task in a new JVM under TaskTracker.Child.
  - Catch output from Task and log it at the info level.
  - Take Task status updates and send to JobTracker every 10 seconds.
  - If job is killed, kill the task.
  - If task dies or completes, tell the JobTracker.

TaskTracker for Reduces

- For Reduces, the task.prepare() fetches all of the relevant map outputs for this reduce.
- Files are fetched using http from the map's TaskTracker's Jetty.
- Files are fetched in parallel threads, but only 1 to each host.
- When fetches fail, a backoff scheme is used to keep from overloading TaskTrackers.
- Fetching accounts for the first 33% of the reduce's progress.

Map Tasks

- Use the InputFormat object to create a RecordReader from the FileSplit.
- Loop through the keys and values in the FileSplit and feed each to the mapper.
- For no combiner, a SequenceFile is written for the keys to each reduce.
- With a combiner, the frameworks buffers 100,000 keys and values, sorts, combines, and writes them to SequenceFile's for each reduce.

Reduce Tasks: Sort

- Sort
  - 33% to 66% of reduce's progress
  - Base
    - Read 100 (io.sort.mb) meg of keys and values into memory.
    - Sort the memory
    - Write to disk
  - Merge
    - Read 10 (io.sort.factor) files and do a merge into 1 file.
    - Repeat as many times as required (2 levels for 100 files, 3 levels for 1000 files, etc.)

Reduce Tasks: Reduce

- Reduce
  - 66% to 100% of reduce's progress
  - Use a SequenceFile.Reader to read sorted input and pass to reducer one key at a time along with the associated values.
  - Output keys and values are written to the OutputFormat object, which usually writes a file to DFS.
  - The output from the reduce is **NOT** resorted, so it is in the order and fragmentation of the map output keys.