

Hadoop Internals

Pietro Michiardi

Eurecom

Introduction and Recap

From Theory to Practice

● The story so far

- ▶ Principles behind the MapReduce Framework
- ▶ Programming model
- ▶ Algorithm design and patterns

● Hadoop implementation of MapReduce

- ▶ HDFS in details
- ▶ Hadoop MapReduce
 - ★ Implementation details
 - ★ Types and Formats
- ▶ Hadoop I/O

● Hadoop Deployments

- ▶ The BigFoot platform

Terminology

● MapReduce:

- ▶ **Job:** 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
- ▶ **Task Attempt:** instance of an attempt to execute a task
- ▶ **Example:**
 - ★ Running “Word Count” across 20 files is one job
 - ★ 20 files to be mapped = 20 map tasks + some number of reduce tasks
 - ★ At least 20 attempts will be performed... more if a machine crashes

● Task Attempts

- ▶ Task attempted at least once, possibly more
- ▶ Multiple crashes on input imply discarding it
- ▶ Multiple attempts may occur in parallel (a.k.a. speculative execution)
- ▶ Task ID from TaskInProgress is not a unique identifier

Hadoop Distributed File-System

Collocate data and computation!

- **As dataset sizes increase, more computing capacity is required for processing**
- **As compute capacity grows, the link between the compute nodes and the storage nodes becomes a bottleneck**
 - ▶ One could eventually think of special-purpose interconnects for high-performance networking
 - ▶ This is often a costly solution as cost does not increase linearly with performance
- **Key idea: abandon the separation between compute and storage nodes**
 - ▶ This is exactly what happens in current implementations of the MapReduce framework
 - ▶ A distributed filesystem is not mandatory, but highly desirable

The Hadoop Distributed Filesystem

- **Large dataset(s) outgrowing the storage capacity of a single physical machine**
 - ▶ Need to partition it across a number of separate machines
 - ▶ Network-based system, with all its complications
 - ▶ Tolerate failures of machines
- **Distributed filesystems are not new!**
 - ▶ HDFS builds upon previous results, tailored to the specific requirements of MapReduce
 - ▶ **Write once, read many workloads**
 - ▶ Does not handle concurrency, but allow replication
 - ▶ Optimized for throughput, not latency
- **Hadoop Distributed Filesystem[1, 2]**
 - ▶ Very large files
 - ▶ Streaming data access
 - ▶ Commodity hardware

HDFS Blocks

- **(Big) files are broken into block-sized chunks**

- ▶ Blocks are big! [64, 128] MB
- ▶ Avoids problems related to metadata management
- ▶ NOTE: A file that is smaller than a single block **does not** occupy a full block's worth of underlying storage

- **Blocks are stored on independent machines**

- ▶ Replicate across the local disks of nodes in the cluster
- ▶ Reliability and parallel access
- ▶ Replication is handled by storage nodes themselves (similar to **chain replication**)

- **Why is a block so large?**

- ▶ Make transfer times larger than seek latency
- ▶ E.g.: Assume seek time is 10ms and the transfer rate is 100 MB/s, if you want seek time to be 1% of transfer time, then the block size should be 100MB

NameNodes and DataNodes

● NameNode

- ▶ Keeps metadata in RAM
- ▶ Each block information occupies roughly 150 bytes of memory
- ▶ Without NameNode, the filesystem cannot be used
 - ★ Persistence of metadata: synchronous and atomic writes to NFS
- ▶ Maintains overall health of the file system

● Secondary NameNode

- ▶ Merges the namespace with the edit log
- ▶ A useful trick to recover from a failure of the NameNode is to use the NFS copy of metadata and switch the secondary to primary

● DataNode

- ▶ They store data and talk to clients
- ▶ They report periodically to the NameNode the list of blocks they hold

Architecture Illustration

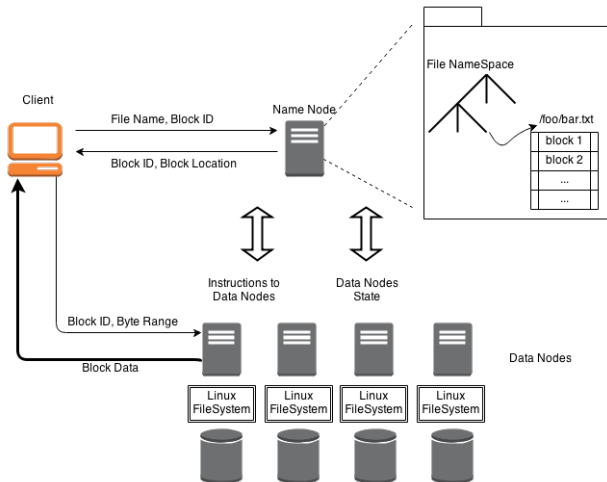


Figure : Architecture sketch of HDFS operations.

Anatomy of a File Read

- **NameNode is only used to get block location**

- ▶ Unresponsive `DataNode` are discarded by clients
- ▶ Batch reading of blocks is allowed

- **“External” clients**

- ▶ For each block, the `NameNode` returns a set of `DataNodes` holding a copy thereof
- ▶ `DataNodes` are sorted according to their proximity to the client

- **“MapReduce” clients**

- ▶ `TaskTracker` and `DataNodes` are **collocated**
- ▶ For each block, the `NameNode` usually¹ returns the local `DataNode`

¹Exceptions exist due to stragglers.

Anatomy of a File Write

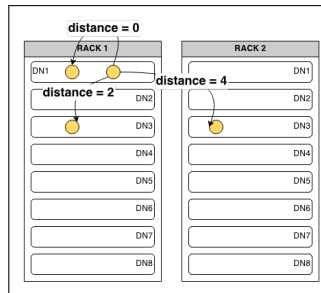
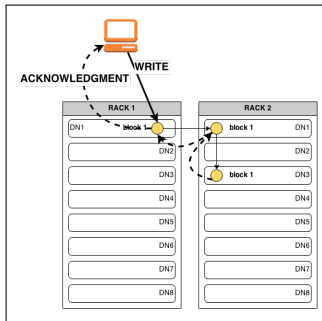
● Details on replication

- ▶ Clients ask `NameNode` for a list of suitable `DataNodes`
- ▶ This list forms a `pipeline`: first `DataNode` stores a copy of a block, then forwards it to the second, and so on

● Replica Placement

- ▶ **Tradeoff** between reliability and bandwidth
- ▶ Default placement:
 - ★ First copy on the “same” node of the client, second replica is **off-rack**, third replica is on the same rack as the second but on a different node
 - ★ Since Hadoop 0.21, replica placement can be customized

Chain Replication and Distance Metrics



HDFS Coherency Model

- **Read your writes is not guaranteed**

- ▶ The namespace is updated
- ▶ Block contents may not be visible after a write is finished
- ▶ Application design (other than MapReduce) should use `sync()` to force synchronization
- ▶ `sync()` involves some overhead: tradeoff between robustness/consistency and throughput

- **Multiple writers (for the **same** block) are not supported**

- ▶ Instead, different blocks can be written in parallel (using MapReduce)

Hadoop MapReduce

Disclaimer

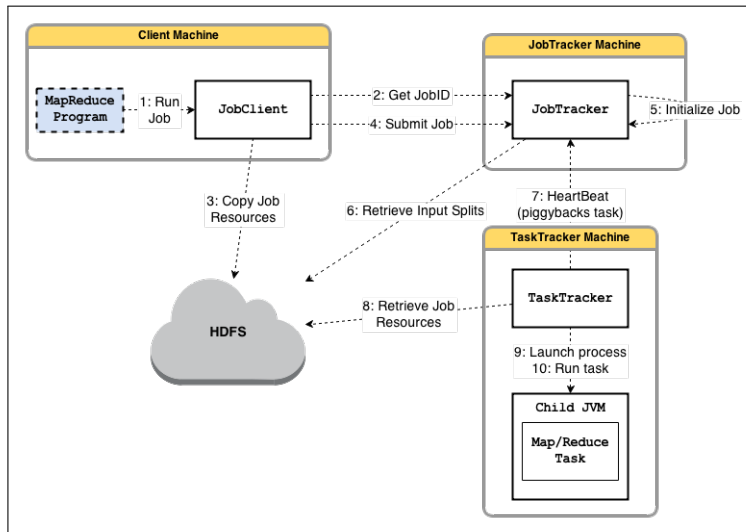
- **MapReduce APIs**

- ▶ Fast evolving
- ▶ Sometimes confusing

- **Do **NOT** rely on this slide deck as a reference**

- ▶ Use appropriate API docs
- ▶ Use Eclipse

Anatomy of a MapReduce Job Run



Job Submission

- **JobClient class**

- ▶ The `runJob()` method creates a new instance of a **JobClient**
- ▶ Then it calls the `submitJob()` on this class

- **Simple verifications on the Job**

- ▶ Is there an output directory?
- ▶ Are there any input splits?
- ▶ Can I copy the JAR of the job to HDFS?

- **NOTE: the JAR of the job is replicated 10 times**

Job Initialization

- **The JobTracker is responsible for:**

- ▶ Create an object for the job
- ▶ Encapsulate its tasks
- ▶ **Bookkeeping** with the tasks' status and progress

- **This is where the scheduling happens**

- ▶ JobTracker performs scheduling by maintaining a queue
- ▶ Queuing disciplines are pluggable

- **Compute mappers and reducers**

- ▶ JobTracker retrieves input splits (computed by JobClient)
- ▶ Determines the number of Mappers based on the number of input splits
- ▶ Reads the configuration file to set the number of Reducers

Scheduling

Task Assignment

● Heartbeat-based mechanism

- ▶ TaskTrackers periodically send heartbeats to the JobTracker
- ▶ TaskTracker is alive
- ▶ Heartbeat contains also information on availability of the TaskTrackers to execute a task
- ▶ JobTracker piggybacks a task if TaskTracker is available

● Selecting a task

- ▶ JobTracker first needs to select a job (*i.e.* Job scheduling)
- ▶ TaskTrackers have a fixed number of slots for map and reduce tasks
- ▶ JobTracker gives priority to map tasks (WHY?)

● Data locality

- ▶ JobTracker is topology aware
 - ★ Useful for map tasks
 - ★ Unused for reduce tasks (WHY?)

Task Execution

- **Task Assignment is done, now TaskTrackers can execute**

- ▶ Copy the JAR from HDFS
- ▶ Create a local working directory
- ▶ Create an instance of `TaskRunner`

- **TaskRunner launches a **child** JVM**

- ▶ This prevents bugs from stalling the `TaskTracker`
- ▶ A new child JVM is created per `InputSplit`
 - ★ Can be overridden by specifying JVM Reuse option, which is very useful for **custom, in-memory, combiners**

- **Streaming and Pipes**

- ▶ User-defined map and reduce methods need not to be in Java
- ▶ Streaming and Pipes allow C++ or python mappers and reducers
- ▶ NOTE: this feature is heavily used in industry, with some tricky downsides

Scheduling in detail

- **FIFO Scheduler (default in vanilla Hadoop)**

- ▶ First-come-first-served
 - ★ Long jobs monopolize the cluster

- **Fair Scheduler (default in Cloudera)**

- ▶ Every user gets a fair share of the cluster capacity over time
- ▶ Jobs are placed into pools, one for each user
 - ★ Users that submit more jobs have no more resources than others
 - ★ Can guarantee minimum capacity per pool

- **Capacity Scheduler (heavily used in Yahoo)**

- ▶ Hierarchical queues (mimic an organization)
- ▶ FIFO scheduling in each queue
- ▶ Supports priority

Failures

Handling Failures

In the real world, code is buggy, processes crash and machines fail

● Task Failure

- ▶ Case 1: map or reduce task throws a runtime exception
 - ★ The child JVM reports back to the parent `TaskTracker`
 - ★ `TaskTracker` logs the error and marks the `TaskAttempt` as failed
 - ★ `TaskTracker` frees up a slot to run another task
- ▶ Case 2: Hanging tasks
 - ★ `TaskTracker` notices no progress updates (timeout = 10 minutes)
 - ★ `TaskTracker` kills the child JVM²

● JobTracker is notified of a failed task

- ▶ Avoids rescheduling the task on the same `TaskTracker`
- ▶ If a task fails 4 times, it is not re-scheduled³
- ▶ **Default behavior:** if any task fails 4 times, the job fails

²With streaming, you need to take care of the orphaned process.

³Exception is made for speculative execution

Handling Failures

● TaskTracker Failure

- ▶ Types: crash, running very slowly
- ▶ Heartbeats will not be sent to `JobTracker`
- ▶ `JobTracker` waits for a timeout (10 minutes), then it removes the `TaskTracker` from its scheduling pool
- ▶ `JobTracker` needs to reschedule even *completed* tasks (WHY?)
- ▶ `JobTracker` needs to reschedule tasks in progress
- ▶ `JobTracker` may even blacklist a `TaskTracker` if too many tasks failed

● JobTracker Failure

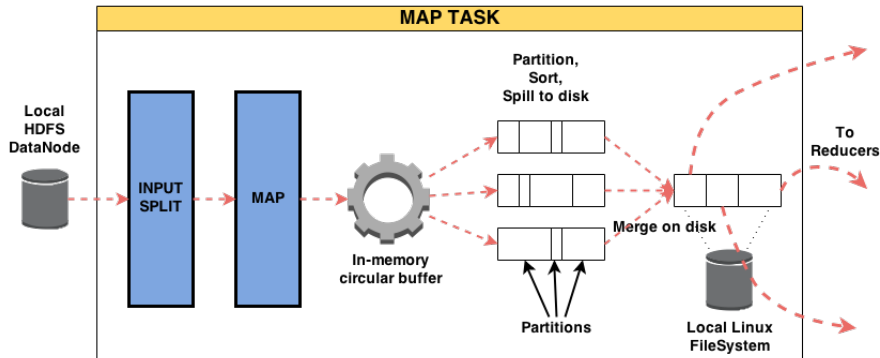
- ▶ Currently, Hadoop has no mechanism for this kind of failure
- ▶ In future (and commercial) releases:
 - ★ Multiple `JobTrackers`
 - ★ Use ZooKeeper as a coordination mechanisms
- High Availability

Internals

Shuffle and Sort

- **The MapReduce framework guarantees the input to every reducer to be sorted by key**
 - ▶ The process by which the system sorts and transfers map outputs to reducers is known as **shuffle**
- **Shuffle is the most important part of the framework, where the “magic” happens**
 - ▶ Good understanding allows optimizing both the framework and the execution time of MapReduce jobs
- **Subject to continuous refinements**

Shuffle and Sort: Map Side



Shuffle and Sort: the Map Side

- **The output of a map task is not simply written to disk**

- ▶ In memory buffering
- ▶ Pre-sorting

- **Circular memory buffer**

- ▶ 100 MB by default
- ▶ Threshold based mechanism to **spill** buffer content to disk
- ▶ Map output written to the buffer **while** spilling to disk
- ▶ If buffer fills up while spilling, the map task is **blocked**

- **Disk spills**

- ▶ Written in round-robin to a local dir
- ▶ Output data is partitioned corresponding to the reducers they will be sent to
- ▶ Within each partition, data is sorted (**in-memory**)
- ▶ Optionally, if there is a combiner, it is executed just after the sort phase (**WHY?**)

Shuffle and Sort: the Map Side

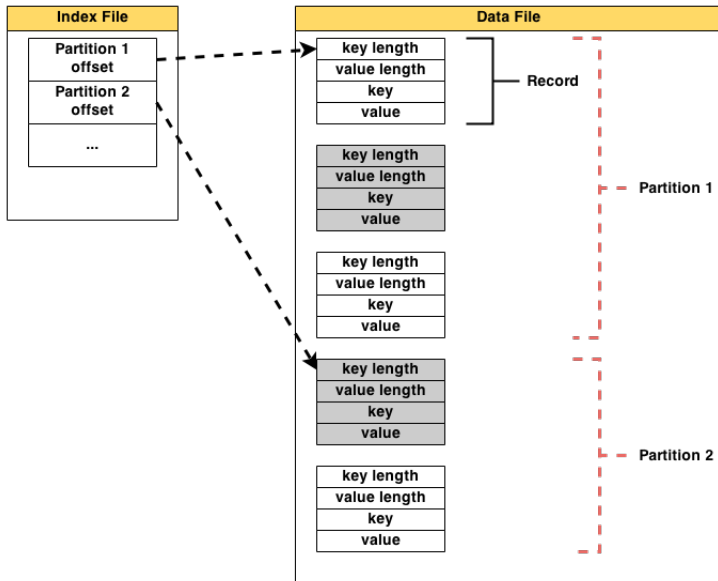
- **More on spills and memory buffer**

- ▶ Each time the buffer is full, a **new** spill is created
- ▶ Once the map task finishes, there are many spills
- ▶ Such spills are merged into a single partitioned and sorted output file

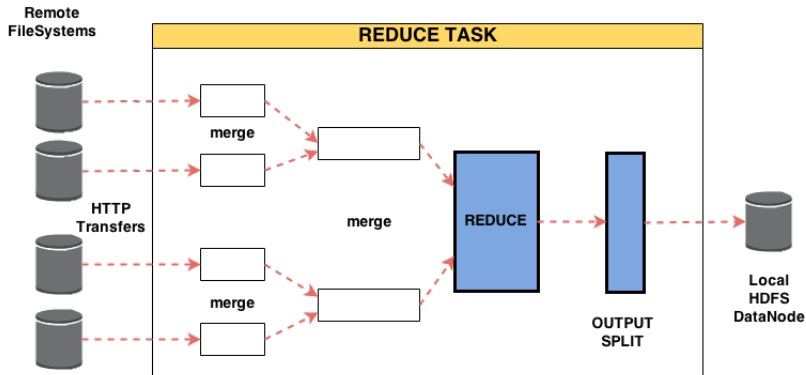
- **The output file partitions are made available to reducers over HTTP**

- ▶ There are 40 (default) threads dedicated to serve the file partitions to reducers

Details on local spill files



Shuffle and Sort: Reduce Side



Shuffle and Sort: the Reduce Side

- The map output file is located on the local disk of TaskTracker
- Another TaskTracker (in charge of a reduce task) requires input from many other TaskTracker (that finished their map tasks)
 - ▶ How do reducers know which TaskTrackers to fetch map output from?
 - ★ When a map task finishes it notifies the parent TaskTracker
 - ★ The TaskTracker notifies (with the heartbeat mechanism) the JobTracker
 - ★ A thread in the reducer polls periodically the JobTracker
 - ★ TaskTrackers do not delete local map output as soon as a reduce task has fetched them (WHY?)
- Copy phase: a pull approach
 - ▶ There is a small number (5) of copy threads that can fetch map outputs in parallel

Shuffle and Sort: the Reduce Side

- **The map output are copied to the the TraskTracker running the reducer in **memory** (if they fit)**
 - ▶ Otherwise they are copied to disk
- **Input consolidation**
 - ▶ A background thread merges all partial inputs into larger, **sorted** files
 - ▶ Note that if compression was used (for map outputs to save bandwidth), decompression will take place in memory
- **Sorting the input**
 - ▶ When all map outputs have been copied a merge phase starts
 - ▶ All map outputs are sorted maintaining their sort ordering, in rounds

Types and Formats

MapReduce Types

- **Recall: Input / output to mappers and reducers**

- ▶ $\text{map}: (k1, v1) \rightarrow [(k2, v2)]$
- ▶ $\text{reduce}: (k2, [v2]) \rightarrow [(k3, v3)]$

- **In Hadoop, a mapper is created as follows:**

- ▶ `void map(K1 key, V1 value, Context context)`

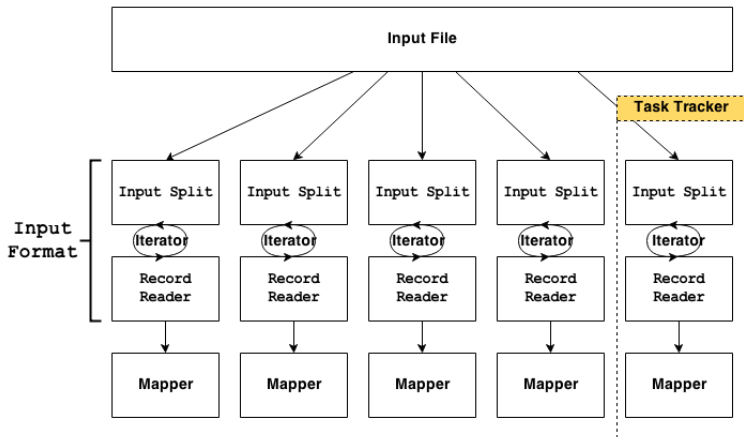
- **Types:**

- ▶ K types implement `WritableComparable`
- ▶ V types implement `Writable`

What is a `Writable`

- Hadoop defines its own classes for strings (`Text`), integers (`IntWritable`), etc...
- All keys are instances of `WritableComparable`
 - ▶ Why comparable?
- All values are instances of `Writable`

Getting Data to the Mapper



Reading Data

- **Datasets are specified by `InputFormats`**

- ▶ `InputFormats` define input data (e.g. a file, a directory)
- ▶ `InputFormats` is a factory for `RecordReader` objects to extract key-value records from the input source

- **`InputFormats` identify partitions of the data that form an `InputSplit`**

- ▶ `InputSplit` is a (**reference to a**) chunk of the input processed by a **single** map
 - ★ Largest split is processed first
- ▶ Each split is divided into records, and the map processes each record (a key-value pair) in turn
- ▶ Splits and records are **logical**, they are not physically bound to a file

InputFormat

- **TextInputFormat**

- ▶ Treats each `newline`-terminated line of a file as a value

- **KeyValueTextInputFormat**

- ▶ Maps `newline`-terminated text lines of “key” SEPARATOR “value”

- **SequenceFileInputFormat**

- ▶ Binary file of key-value pairs with some additional metadata

- **SequenceFileAsTextInputFormat**

- ▶ Same as before but, maps `(k.toString(), v.toString())`

InputSplit

- **FileInputFormat divides large files into chunks**

- ▶ Exact size controlled by `mapred.min.split.size`

- **Record readers receive file, offset, and length of chunk**

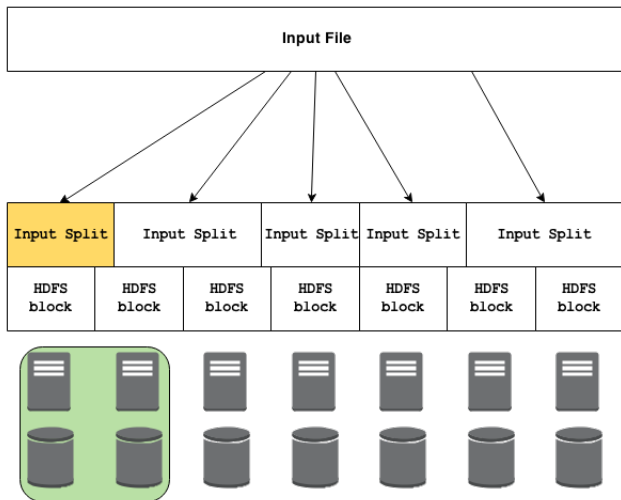
- ▶ Example

On the top of the Crumpetty Tree→
The Quangle Wangle sat,→
But his face you could not see,→
On account of his Beaver Hat.→

(0, On the top of the Crumpetty Tree)
(33, The Quangle Wangle sat,)
(57, But his face you could not see,)
(89, On account of his Beaver Hat.)

- **Custom InputFormat implementations may override split size**

The relationship between an `InputSplit` and an HDFS block



Record Readers

- **Each `InputFormat` provides its own `RecordReader` implementation**
- **`LineRecordReader`**
 - ▶ Reads a line from a text file
- **`KeyValueRecordReader`**
 - ▶ Used by `KeyValueTextInputFormat`

Sending Data to Reducers

- **Map function receives Context object**
 - ▶ `Context.write()` receives key-value elements
- **Any (WritableComparable, Writable) can be used**
- **By default, mapper output type assumed to be the same as the reducer output type**

WritableComparator

- **Compares WritableComparable data**

- ▶ Will call the `WritableComparable.compare()` method
- ▶ Can provide fast path for serialized data

- **Configured through:**

`JobConf.setOutputValueGroupingComparator()`

Partitioner

- **`int getPartition(key, value, numPartitions)`**
 - ▶ Outputs the partition number for a given key
 - ▶ One partition == all values sent to a single reduce task
- **HashPartitioner used by default**
 - ▶ Uses `key.hashCode()` to return partition number
- **JobConf used to set Partitioner implementation**

The Reducer

- `void reduce(k2 key, Iterator<v2> values, Context context)`
- **Keys and values sent to one partition all go to the same reduce task**
- **Calls are sorted by key**
 - ▶ “Early” keys are reduced and output before “late” keys

Writing the Output

- **Analogous to `InputFormat`**
- **`TextOutputFormat` writes “key value <newline>” strings to output file**
- **`SequenceFileOutputFormat` uses a binary format to pack key-value pairs**
- **`NullOutputFormat` discards output**

Hadoop I/O

I/O operations in Hadoop

- **Reading and writing data**

- ▶ From/to HDFS
- ▶ From/to local disk drives
- ▶ Across machines (inter-process communication)

- **Customized tools for large amounts of data**

- ▶ Hadoop does not use Java native classes
- ▶ Allows flexibility for dealing with custom data (e.g. binary)

- **What's next**

- ▶ Overview of what Hadoop offers
- ▶ For an in depth knowledge, use [2]

Data Integrity

- **Every I/O operation on disks or the network may corrupt data**
 - ▶ Users expect data not to be corrupted during storage or processing
 - ▶ Data integrity usually achieved with a simple **checksum** mechanism
- **HDFS transparently checksums all data during I/O**
 - ▶ HDFS makes sure that storage overhead is roughly 1%
 - ▶ `DataNodes` are in charge of checksumming
 - ★ With replication, the last replica performs the check
 - ★ Checksums are timestamped and logged for **statistics on disks**
 - ▶ Checksumming is also run periodically in a separate thread
 - ★ Note that thanks to replication, **error correction** is possible in addition to detection

Compression

- **Why using compression**

- ▶ Reduce storage requirements
- ▶ Speed up data transfers (across the network or from disks)

- **Compression and Input Splits**

- ▶ IMPORTANT: use compression that supports **splitting** (e.g. bzip2)

- **Splittable files, Example 1**

- ▶ Consider an uncompressed file of 1GB
- ▶ HDFS will split it in 16 blocks, 64MB each, to be processed by separate Mappers

Compression

- **Unsplittable files, Example 2 (gzip)**

- ▶ Consider a compressed file of 1GB
- ▶ HDFS will split it in 16 blocks of 64MB each
- ▶ Creating an `InputSplit` for each block will not work, since it is not possible to read at an arbitrary point

- **What's the problem?**

- ▶ This forces MapReduce to treat the file as a **single split**
- ▶ Then, a single Mapper is fired by the framework
- ▶ For this Mapper, only 1/16-th is local, the rest comes from the network

- **Which compression format to use?**

- ▶ Use `bzip2`
- ▶ Otherwise, use `SequenceFiles`
- ▶ See Chapter 4 [2]

Serialization

- **Transforms structured objects into a byte stream**
 - ▶ For transmission over the network: **Hadoop uses RPC**
 - ▶ For persistent storage on disks
- **Hadoop uses its own serialization format, `Writable`**
 - ▶ Comparison of types is crucial (Shuffle and Sort phase): Hadoop provides a custom `RawComparator`, which avoids deserialization
 - ▶ Custom `Writable` for having full control on the binary representation of data
 - ▶ Also “external” frameworks are allowed: enter **Avro**
- **Fixed-length or variable-length encoding?**
 - ▶ Fixed-length: when the distribution of values is uniform
 - ▶ Variable-length: when the distribution of values is not uniform

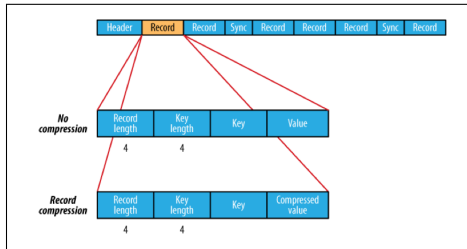
Sequence Files

- **Specialized data structure to hold custom input data**

- ▶ Using blobs of binaries is not efficient

- **SequenceFiles**

- ▶ Provide a persistent data structure for binary key-value pairs
- ▶ Also work well as containers for smaller files so that the framework is more happy (remember, better few large files than lots of small files)
- ▶ They come with the `sync()` method to introduce sync points to help managing `InputSplits` for MapReduce



Hadoop Deployments

Setting up a Hadoop Cluster

- **Cluster deployment**

- ▶ Private cluster
- ▶ Cloud-based cluster
- ▶ AWS Elastic MapReduce

- **Outlook:**

- ▶ Cluster specification
 - ★ Hardware
 - ★ Network Topology
- ▶ Hadoop Configuration
 - ★ Memory considerations

Cluster Specification

● Commodity Hardware

- ▶ Commodity \neq Low-end
 - ★ False economy due to failure rate and maintenance costs
- ▶ Commodity \neq High-end
 - ★ High-end machines perform better, which would imply a smaller cluster
 - ★ A single machine failure would compromise a large fraction of the cluster

● A 2012 specification:

- ▶ Dual socket, Two exacore
- ▶ 128 GB ECC RAM
- ▶ 8×1 TB disks⁴
- ▶ {1,10} Gigabit Ethernet

⁴Why not using RAID instead of JBOD?

Cluster Specification

● Example:

- ▶ Assume your data grows by 1 TB per week
- ▶ Assume you have three-way replication in HDFS
- You need additional 3TB of raw storage per week
- ▶ Allow for some overhead (temporary files, logs)
- **This is a new machine per week**

● How to dimension a cluster?

- ▶ Obviously, you won't buy a machine per week!!
- ▶ The idea is that the above back-of-the-envelope calculation is that you can project over a 2 year life-time of your system
- You would need a 100-machine cluster

● Where should you put the various components?

- ▶ Small cluster: NameNode and JobTracker can be **collocated**
- ▶ Large cluster: requires more RAM at the NameNode

Cluster Specification

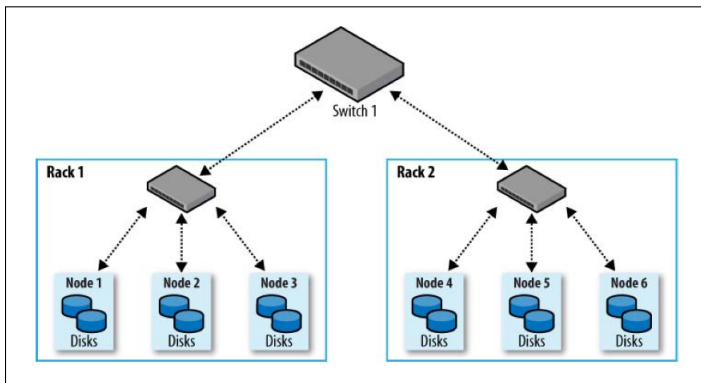
- **Should we use 64-bit or 32-bit machines?**

- ▶ NameNode should run on a 64-bit machine: this avoids the 3GB Java heap size limit on 32-bit machines

- **What's the role of Java?**

- ▶ Recent releases (Java6) implement some optimization to eliminate large pointer overhead
- A cluster of 64-bit machines has no downside

Network Topology



Network Topology

- **Two-level network topology**

- ▶ Switch redundancy is not shown in the figure

- **Typical configuration**

- ▶ 30-40 servers per rack
- ▶ 10 GB switch TOR
- ▶ Core switch or router with 10GB or better

- **Features**

- ▶ Aggregate bandwidth between nodes on the same rack is much larger than for nodes on different racks
- ▶ **Rack awareness**
 - ★ Hadoop should know the cluster topology
 - ★ Benefits both HDFS (data placement) and MapReduce (locality)

Hadoop Configuration

- **There are a handful of files for controlling the operation of an Hadoop Cluster**
 - ▶ Hundreds of parameters!!
 - ▶ See next slide for a summary table
- **Managing the configuration across several machines**
 - ▶ All machines of an Hadoop cluster must be in sync!
 - ▶ What happens if you dispatch an update and some machines are down?
 - ▶ What happens when you add (new) machines to your cluster?
 - ▶ What if you need to patch MapReduce?
- **Common practice: use configuration management tools**
 - ▶ Chef, Puppet, ...
 - ▶ Declarative language to specify configurations
 - ▶ Allow also to install software

Hadoop Configuration

Filename	Format	Description
hadoop-env.sh	Bash script	Environment variables that are used in the scripts to run Hadoop.
core-site.xml	Hadoop configuration XML	I/O settings that are common to HDFS and MapReduce.
hdfs-site.xml	Hadoop configuration XML	Namenode, the secondary namenode, and the datanodes.
mapred-site.xml	Hadoop configuration XML	Jobtracker, and the tasktrackers.
masters	Plain text	A list of machines that each run a secondary namenode.
slaves	Plain text	A list of machines that each run a datanode and a tasktracker.

Table : Hadoop Configuration Files

Hadoop Configuration: memory utilization

- **Hadoop uses a lot of memory**

- ▶ Default values, for a typical cluster configuration
 - ★ DataNode: 1 GB
 - ★ TaskTracker: 1 GB
 - ★ Child JVM map task: $2 \times 200\text{MB}$
 - ★ Child JVM reduce task: $2 \times 200\text{MB}$

- **All the moving parts of Hadoop (HDFS and MapReduce) can be individually configured**

- ▶ This is true for cluster configuration but also for **job specific** configurations

- **Hadoop is fast when using RAM**

- ▶ Generally, MapReduce Jobs **are not** CPU-bound
- ▶ Avoid I/O on disk as much as you can
- ▶ Minimize network traffic
 - ★ Customize the partitioner
 - ★ Use compression (\rightarrow decompression is in RAM)

Elephants in the cloud!

- **Many organizations run Hadoop in private clusters**
 - ▶ Pros and cons
- **Cloud based Hadoop installations (Amazon biased)**
 - ▶ Use Cloudera + {Whirr, boto, ...}
 - ▶ Use Elastic MapReduce

Hadoop on EC2

- **Launch instances of a cluster on demand, paying by hour**
 - ▶ CPU, in general bandwidth is used from within a datacenter, hence it's free
- **Apache Whirr project**
 - ▶ Launch, terminate, modify a running cluster
 - ▶ Requires AWS credentials
- **Example**
 - ▶ Launch a cluster `test-hadoop-cluster`, with one master node (JobTracker and NameNode) and 5 worker nodes (DataNodes and TaskTrackers)
 - `hadoop-ec2 launch-cluster test-hadoop-cluster 5`
 - ▶ See Chapter 9 [2]

AWS Elastic MapReduce

- **Hadoop as a service**

- ▶ Amazon handles everything, which becomes transparent
- ▶ How this is done remains a mystery

- **Focus on What not How**

- ▶ All you need to do is to package a MapReduce Job in a JAR and upload it using a Web Interface
- ▶ Other Jobs are available: python, pig, hive, ...
- ▶ **Test your jobs locally!!!**

References

References I

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- [2] Tom White.
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