Developing a MapReduce Application

Configuration API

A Configuration class is used to access the configuration XML and can be combined (if a var is repeteated, last is used). Variables can also be expanded using system properties.

Configuring the Development Environment

All JAR's from top level Hadoop directory must be added to the IDE. Also, you can have local and cluster file configurations.

GenericOptionsParser, Tool and ToolRunner

- **GenericOptionsParser** interprets Hadoop command-line options and sets them on a Configuration object
- **Tool** is an interface to use the above class

The `-D` option takes priority over Configuration files

Writing Unit Tests

Mapper Unit Test

Because Mapper and Reducers writes to Context files (instead of returning the result) a mock for the Context object is needed. We use Mockito as follows:

```
@Test
    public void processesValidRecord() throws IOException, InterruptedException {
        MaxTemperatureMapper mapper = new MaxTemperatureMapper();
        Text value = new Text(
```

```
            "00430119909999919500515180004+68750+023550FM-12+038299999V0203201N00261220001CN9999999
            );

        MaxTemperatureMapper.Context context = mock(MaxTemperatureMapper.Context.class);

        mapper.map(null, value, context);

        verify(context).write(new Text("1950"), new IntWritable(-11));
    }
}
```

We create the context object passing to the static `mock` method the class. Then we use it normally. Reducer unit test is similar.

Running locally and in a cluster on Test Data

- **Locally** Using the Tool interface you could write a driver to configure the local job.
- **Cluster** No code changes are needed, just to pack the Jar.

The MapReduce Web UI

Jobtracker Page

ip-10-250-110-47 Hadoop Map/Reduce Administration

Quick Links

State: RUNNING
Started: Sat Apr 11 08:11:53 EDT 2009
Version: 0.20.0, r763504
Compiled: Thu Apr 9 05:18:40 UTC 2009 by ndaley
Identifier: 200904110811

Cluster Summary (Heap Size is 53.75 MB/888.94 MB)

Maps	Reduces	Total Submissions	Nodes	Map Task Capacity	Reduce Task Capacity	Avg. Tasks/Node	Blacklisted Nodes
53	30	2	11	88	88	16.00	0

Scheduling Information

Queue Name	Scheduling Information
default	N/A

Filter (Jobid, Priority, User, Name)
Example: 'user:smith 3200' will filter by 'smith' only in the user field and '3200' in all fields

Running Jobs

Jobid	Priority	User	Name	Map % Complete	Map Total	Maps Completed	Reduce % Complete	Reduce Total	Reduces Completed	Job Scheduling Information
job_200904110811_0002	NORMAL	root	Max temperature	47.52%	101	48	15.25%	30	0	NA

Completed Jobs

Jobid	Priority	User	Name	Map % Complete	Map Total	Maps Completed	Reduce % Complete	Reduce Total	Reduces Completed	Job Scheduling Information
job_200904110811_0001	NORMAL	gonzo	word count	100.00%	14	14	100.00%	30	30	NA

Failed Jobs

none

Local Logs

Log directory, Job Tracker History

Hadoop, 2009.

1. Hadoop installation: version, compilation, jobtracker state...
2. Summary of the cluster: capacity, utilization, mr running, jobs, tasktrackers, slots, blacklisted Tasktrackers
3. Job Scheduler: Running and failed jobs with id's, owner, name...
4. Link to Jobtracker Logs: historic

Job page

Hadoop job_200904110811_0002 on ip-10-250-110-47

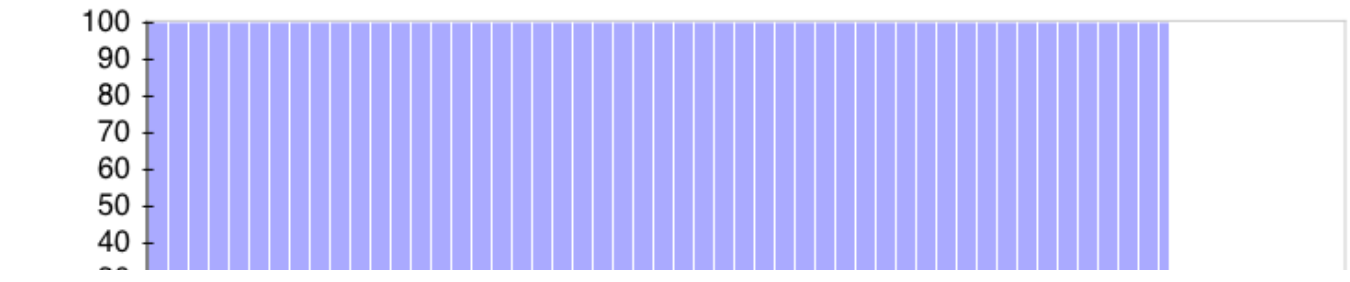
User: root

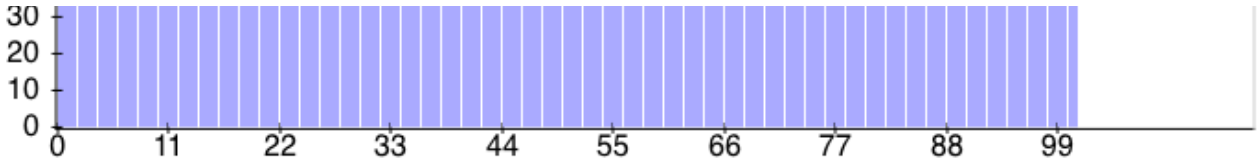
Job Name: Max temperature
Job File: hdfs://ip-10-250-110-47.ec2.internal/mnt/hadoop/mapred/system/job_200904110811_0002/job.xml
Job Setup: Successful
Status: Running
Started at: Sat Apr 11 08:15:53 EDT 2009
Running for: 5mins, 38sec
Job Cleanup: Pending

Kind	% Complete	Num Tasks	Pending	Running	Complete	Killed	Failed/Killed Task Attempts
map	100.00%	101	0	0	101	0	0 / 26
reduce	70.74%	30	0	13	17	0	0 / 0

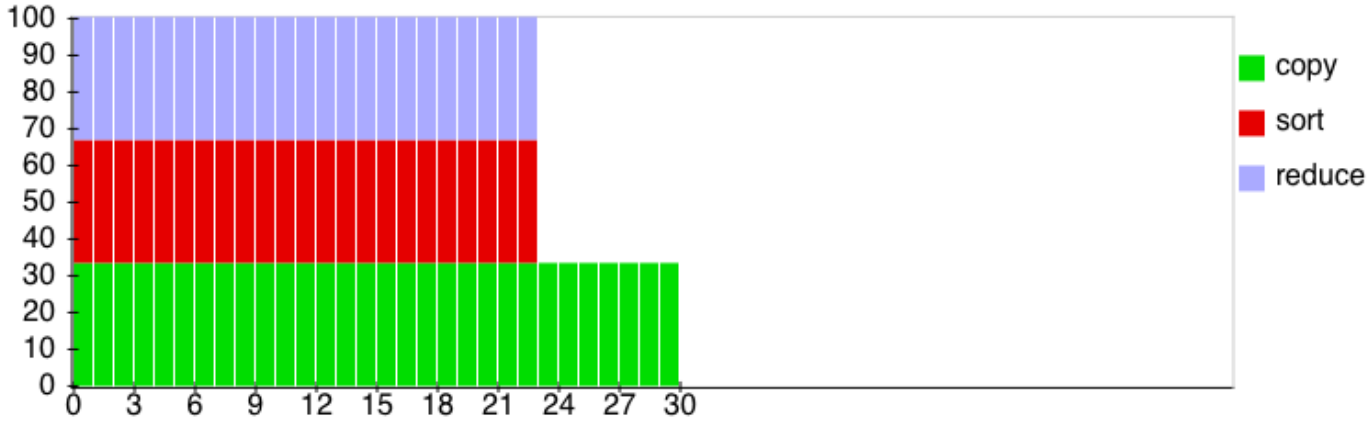
	Counter	Map	Reduce	Total
Job Counters	Launched reduce tasks	0	0	32
	Rack-local map tasks	0	0	82
	Launched map tasks	0	0	127
	Data-local map tasks	0	0	45
FileSystemCounters	FILE_BYTES_READ	12,665,901	564	12,666,465
	HDFS_BYTES_READ	33,485,841,275	0	33,485,841,275
	FILE_BYTES_WRITTEN	988,084	564	988,648
	HDFS_BYTES_WRITTEN	0	360	360
Map-Reduce Framework	Reduce input groups	0	40	40
	Combine output records	4,489	0	4,489
	Map input records	1,209,901,509	0	1,209,901,509
	Reduce shuffle bytes	0	18,397	18,397
	Reduce output records	0	40	40
	Spilled Records	9,378	42	9,420
	Map output bytes	10,282,306,995	0	10,282,306,995
	Map input bytes	274,600,205,558	0	274,600,205,558
	Map output records	1,142,478,555	0	1,142,478,555
	Combine input records	1,142,482,941	0	1,142,482,941
	Reduce input records	0	42	42

Map Completion Graph - close





Reduce Completion Graph - close



Go back to JobTracker

Hadoop, 2009.

- Job progress
- Owner
- Name
- Running time
- Completion graphs

Retrieving the results

Each map will write a single file. The `-getmerge` option of `hadoop fs` gets all files in a folder and merges the into a single local file.

Debugging a Job: The tasks page

It is often useful to use a counter in the MR. Write a MR to read logs or write info to map output that can be check on the tasks page in the "status" column. The Action column allows to kill a task if `webinterface.private.actions` is set to true.

Hadoop Logs

Logs	Primary audience	Description
System daemon logs	Administrators	Each Hadoop daemon produces a logfile (using log4j) and another file that combines standard out and error. Written in the directory defined by the HADOOP_LOG_DIR environment variable
HDFS audit logs	Administrators	A log of all HDFS requests, turned off by default. Written to the namenode's log, although this is configurable
MapReduce job history logs	Users	A log of the events (such as task completion) that occur in the course of running a job.Saved centrally on the jobtracker, and in the job's output directory in a _logs/history subdirectory
MapReduce task logs	Users	Each tasktracker child process produces a logfile using log4j (called syslog), a file for data sent to standard out (stdout), and a file for standard error (stderr). Written in the userlogs subdirectory of the directory defined by the HADOOP_LOG_DIR environment variable

Logfiles can be found on the local fs of each TaskTracker and if JVM reuse is enabled, each log accumulates the entire JVM run.

Anything written to standard output or error is directed to the relevant logfile.

Remote debugging

No direct ways. Options:

- **Reproduce the failure locally** Download the fail that makes the task to fail.
- **Use JVM debugging options** -XX:-HeapDumpOnOutOfMemoryError -XX:HeapDumpPath=/path/to/dumps to log Java out of memory errors.
- **Use task profiling** Mechanism to profile a subset of the task

Sometimes is useful to keep intermediate files for a failed task setting `keep.failed.task.files` to *true* that will store the files in the `mapred.local.dir` of the node.

Tuning a Job to improve performance

| Area | Best Practice | | ---------- + ---------- | | Number of mappers | How long are your mappers running for? If they are only running for a few seconds on average, then you should

see if there's a way to have fewer mappers and make them all run longer, a minute or so, as a rule of thumb. The extent to which this is possible depends on the input format you are using | | Number of Reducers | For maximum performance, the numberof reducers should be slightly less than the number of reduce slots in the cluster. This allows the reducers to finish in one wave and fully utilizes the cluster during the reduce phase | | Combiners | Can your job take advantage of a combiner to reduce the amount of data in passing through the shuffle? | | Intermediate Compression | Job execution time can almost always benefit from enabling map output compression | | Custom serialization | If you are using your own custom Writable objects, or custom comparators, then make sure you have implemented RawComparator | | Shuffle Tweaks | The MapReduce shuffle exposes around a dozen tuning parameters for memory management, which may help you eke out the last bit of performance |

Profiling tasks

HPROF is enabled in JobConf:

```
Configuration conf = getConf();
conf.setBoolean("mapred.task.profile", true);   // Enable profiling
conf.set("mapred.task.profile.params", "-agentlib:hprof=cpu=samples," +
    "heap=sites,depth=6,force=n,thread=y,verbose=n,file=%s");   //Params
conf.set("mapred.task.profile.maps", "0-2"); // Tasks to profile
conf.set("mapred.task.profile.reduces", ""); // no reduces
Job job = new Job(conf, "Max temperature");
```

MapReduce Workflows, job control

For a linear chain, use JobClient like `JobClient.runJob(conf1)`, `JobClient.runJob(conf2)`, etc. If a job fails will throw an IOException. You could also use JobControl from the client machine to represents a graph of jobs.

Apache Oozie

1. **Workflow engine**: Stores and runs workflows composed of Hadoop jobs.
2. **Coordinator engine**: Run workflows jobs based on predefined schedules and data availability

Oozie runs as a service in the cluster receiving workflows (DAG) of **action nodes** (moving files in HDFS, running MR, Pig...) and **control flow nodes** (flow between action nodes).

- **Workflow**
    - One **start** and **one** end node.

- `Kill` nodes finished a workflow as failed and reports the message specified
- A **map-reduce** action
  - **job-tracker** Specifies jobtracker to submit
  - **name-node** URI for input/output data
  - A **configuration** element to specofy key/value pairs
- A **prepare** action is executed before the map-reduce

Running an Oozie workflow job

```
$ export OOZIE_URL="http://localhost:11000/oozie"
$ oozie job -config [*.properties] -run
```

`-config` defines local Java properties in the workflow XML as well as `oozie.wf.application.path` which tells Oozie workflow app. `-info` gives info about the workflow job. A properties file:

```
nameNode=hdfs://localhost:8020
jobTracker=localhost:8021
oozie.wf.application.path=${nameNode}/user/${user.name}/max-temp-workflow
```