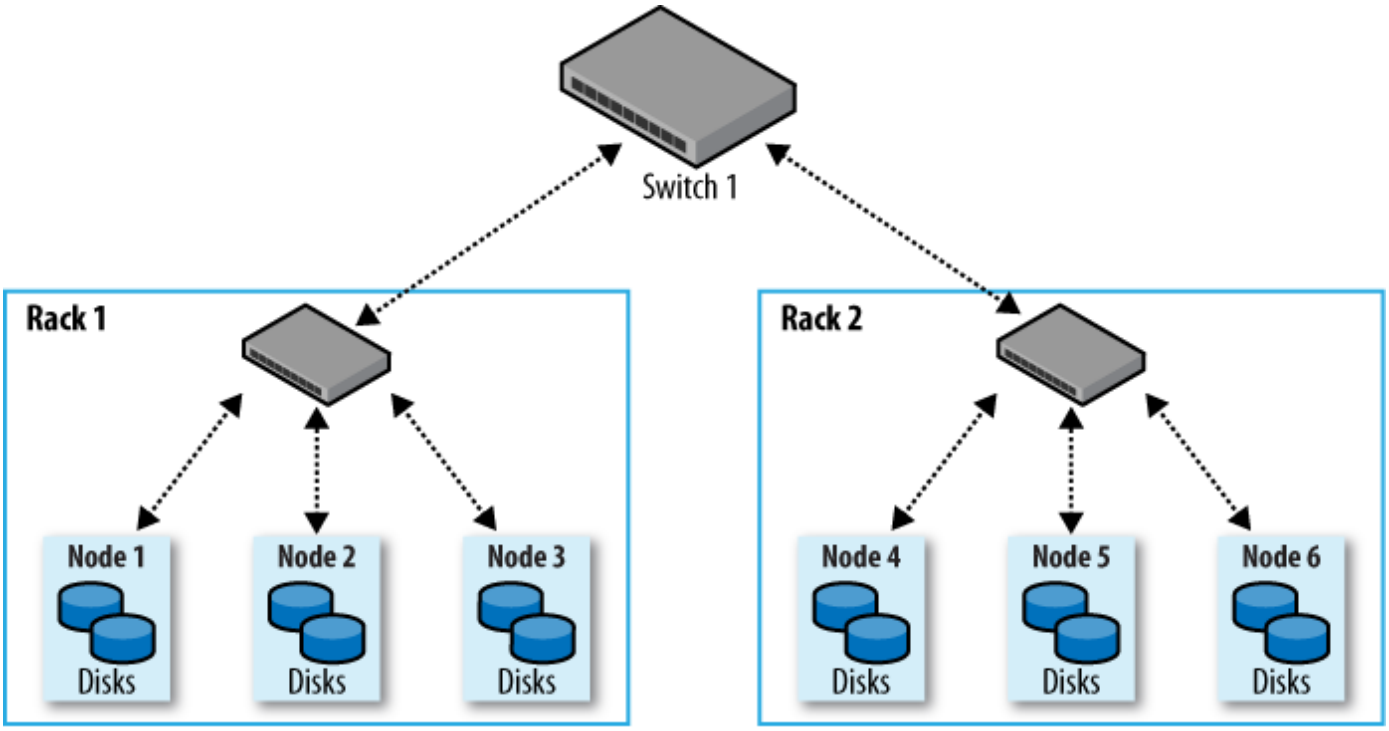
# Setting up a Hadoop Cluster

## Cluster specification

Hadoop uses "commodity hardware" that is easily available hardware (not low end). RAID is, however, not used for it's redundancy.

### Network Topology

Typically 30 servers per rack with 1 gb switch.




#### Rack awareness

If more than one rack is used, Hadoop must be configured to know the topology of the network (that is presented as a tree).

Hadoop conf must specify a map between node addresses and network locations described by the interface:

```
    public interface DNSToSwitchMapping {
        public List<String> resolve(List<String> names);
    }
```

The **names** is a list of IP addresses and the return is a list of corresponding network location strings. However most installations don't need to implement the interface since the default implementation is **ScriptBasedMapping** which is located in **topology.script.file.name**.

# Cluster Setup and Installation

Java 6 or later is needed. A Hadoop use is also a good practice and ssh password-less access between machines.

*Table 9-1. Hadoop configuration files*

| 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 | Configuration settings for Hadoop Core, such as I/O settings that are common to HDFS and MapReduce. |
| *hdfs-site.xml* | Hadoop configuration XML | Configuration settings for HDFS daemons: the namenode, the secondary namenode, and the datanodes. |
| *mapred-site.xml* | Hadoop configuration XML | Configuration settings for MapReduce daemons: the jobtracker, and the tasktrackers. |
| *masters* | Plain text | A list of machines (one per line) that each run a secondary namenode. |
| *slaves* | Plain text | A list of machines (one per line) that each run a datanode and a tasktracker. |
| *hadoop-metrics.properties* | Java Properties | Properties for controlling how metrics are published in Hadoop (see "Metrics" on page 350). |
| *log4j.properties* | Java Properties | Properties for system logfiles, the namenode audit log, and the task log for the tasktracker child process ("Hadoop Logs" on page 173). |

## Configuration Management

Hadoop does not have a single file, global located, for conf info. Each node has its own set of conf files and the admins must sync them.

You'll need a *class* of machines because not all machines will have the same hardware nor the same configuration files.

### Control scripts

Hadoop slaves conf file can be anywhere setting the **HADOOP_SLAVES** in the *hadoop-env.sh*. Also **these files doesn't need to be distributed to worker nodes**.

You don't need to specify which machine the namenode and jobtracker runs on in the *masters* file as this is determined by the machine the scripts are run on.

Scripts:

- **start-dfs.sh**:

    - Starts a namenode on the local machine.
    - Starts a datanode in each *slave* file.
    - Starts a secondarynamenode in the *masters* file.

- **start-mapred.sh**:

    - Starts a Jobtracker on the local machine
    - Starts a TaskTracker on each machine listed in the slaves file.

### Master node scenarios

With more than 10 nodes it's convenient to put the Jobtracker, namenodes and secondarynamenodes on different machines. Namenode has high memory requirements, also the secondarynamenode (when not idle) because it keeps a copy of the latest checkpoint of the filesystem metadata. When the master daemons run on one or more nodes:

- Run HDFS control scripts from the namenode
- Run the MR control scripts from the JobTracker

## Environment Settings

### Memory

Hadoop alllocates 1gb of memory to each daemon it runs (**HADOOP_HEAPSIZE** in *hadoop-env.sh*). In addition the tasktracker also launches separate child JVMs to run map and reduce tasks. The memory given to each JVM is `-Xmx200m` or 200mb

The max number of map/reduce tasks are set in `mapred.tasktracker.map/reduce.tasks.maximum` (default to 2). They are also related to number of processors available in a 2:1 ratio (two processes per processor). For example, with 8 processors if you want 2 processes on each, the maximum map/reduce tasks could be 7 (because datanode and tasktracker each take one slot). With higher ( `-Xmx400m` ) the total memory usage would be 7600mb that will run or not, depending of the rest of the processes (like if you use Streaming or not).

Master node, each of the namenode, secondary namenode and jobtracker needs 1gb each one.

### System logfiles

Logfiles are store by default on **$HADOOP_INSTALL/logs** or in **HADOOP_LOG_DIR** within `hadoop-env.sh` file. The log4j is stored in a .log file and the combined standard output and error log and only the last five logs are retained.

Logfile names are a combination of the user, the daemon, the daemon name and the machine hostname.

### SSH Settings

**ConnectTimeout** can be used to avoid that control scripts hang waiting a response. **StrictHostKeyChecking** can be set to **no** to automatically add new host keys to the known hosts files.

To pass extra options to SSH, define the **HADOOP_SSH_OPTS** in `hadoop-env.sh`.

Hadopo control scripts **can distribute config files to all nodes** of the cluster using *rsync* but isn't enabled by default. To enable, a **HADOOP_MASTER** must be defined in the `hadoop-env.sh` to point the directory to *rsync* to the nodes. The HADOOP_MASTER directory will be sync to the **HADOOP_INSTAL** dir.

# Important Hadoop Daemon Properties

## HDFS

*Table 9-3. Important HDFS daemon properties*

| Property name | Type | Default value | Description |
|---|---|---|---|
| `fs.default.name` | URI | `file:///` | The default filesystem. The URI defines the hostname and port that the namenode's RPC server runs on. The default port is 8020. This property is set in *core-site.xml*. |
| `dfs.name.dir` | comma-separated directory names | `${hadoop.tmp.dir}/dfs/name` | The list of directories where the namenode stores its persistent metadata. The namenode stores a copy of the metadata in each directory in the list. |
| `dfs.data.dir` | comma-separated directory names | `${hadoop.tmp.dir}/dfs/data` | A list of directories where the datanode stores blocks. Each block is stored in only one of these directories. |
| `fs.checkpoint.dir` | comma-separated directory names | `${hadoop.tmp.dir}/dfs/namesecondary` | A list of directories where the secondary namenode stores checkpoints. It stores a copy of the checkpoint in each directory in the list. |

## MapReduce

*Table 9-4. Important MapReduce daemon properties*

| Property name | Type | Default value | Description |
|---|---|---|---|
| `mapred.job.tracker` | hostname and port | `local` | The hostname and port that the jobtracker's RPC server runs on. If set to the default value of `local`, then the jobtracker is run in-process on demand when you run a MapReduce job (you don't need to start the jobtracker in this case, and in fact you will get an error if you try to start it in this mode). |
| `mapred.local.dir` | comma-separated directory names | `${hadoop.tmp.dir}/mapred/local` | A list of directories where MapReduce stores intermediate data for jobs. The data is cleared out when the job ends. |
| `mapred.system.dir` | URI | `${hadoop.tmp.dir}/mapred/system` | The directory relative to `fs.default.name` where shared files are stored, during a job run. |
| `mapred.tasktracker.map.tasks.maximum` | `int` | `2` | The number of map tasks that may be run on a tasktracker at any one time. |
| `mapred.tasktracker.reduce.tasks.maximum` | `int` | `2` | The number of reduce tasks that may be run on a tasktracker at any one time. |
| `mapred.child.java.opts` | `String` | `-Xmx200m` | The JVM options used to launch the tasktracker child process that runs map and reduce tasks. This property can be set on a per-job basis, which can be useful for setting JVM properties for debugging, for example. |
| `mapreduce.map.java.opts` | `String` | `-Xmx200m` | The JVM options used for the child process that runs map tasks. From 0.21. |
| `mapreduce.reduce.java.opts` | `String` | `-Xmx200m` | The JVM options used for the child process that runs reduce tasks. From 0.21. |

## Hadoop Daemon Addresses and Ports

*Table 9-5. RPC server properties*

| Property name | Default value | Description |
|---|---|---|
| fs.default.name | file:/// | When set to an HDFS URI, this property determines the namenode's RPC server address and port. The default port is 8020 if not specified. |
| dfs.datanode.ipc.address | 0.0.0.0:50020 | The datanode's RPC server address and port. |
| mapred.job.tracker | local | When set to a hostname and port, this property specifies the jobtracker's RPC server address and port. A commonly used port is 8021. |
| mapred.task.tracker.report.address | 127.0.0.1:0 | The tasktracker's RPC server address and port. This is used by the tasktracker's child JVM to communicate with the tasktracker. Using any free port is acceptable in this case, as the server only binds to the loopback address. You should change this setting only if the machine has no loopback address. |

*Table 9-6. HTTP server properties*

| Property name | Default value | Description |
|---|---|---|
| mapred.job.tracker.http.address | 0.0.0.0:50030 | The jobtracker's HTTP server address and port. |
| mapred.task.tracker.http.address | 0.0.0.0:50060 | The tasktracker's HTTP server address and port. |
| dfs.http.address | 0.0.0.0:50070 | The namenode's HTTP server address and port. |
| dfs.datanode.http.address | 0.0.0.0:50075 | The datanode's HTTP server address and port. |
| dfs.secondary.http.address | 0.0.0.0:50090 | The secondary namenode's HTTP server address and port. |

# Other Hadoop Properties

## Cluster membership

A list of authorized machines are specified in the **dfs.hosts** for datanodes and **mapred.hosts** for tasktrackers as well as **dfs.hosts.exclude** and **mapred.hosts.exclude**.

### Buffer size

Hadoop uses a 4kb buffer size for its I/O operations which is conservative and increasing to 128kb will give an improved performance in **io.file.buffer.size** in *core-site.xml*.

### Reserved storage space

To reserve some space on the datanodes set **dfs.datanode.du.reserved** to the amount of bytes to reserve.

### Trash

Minimum period a deleted file in HDFS is retain until ultimate deletion (**fs.trash.interval** defaults to 0 which is disable)

### Reduce Slow Start

Reducers wait until 5% of the map tasks in a jab have completed before scheduling reduce tasks. For large jobs this will take slots while waiting. **mapred.reduce.slowstart.completed.maps** can be set to a higher value (like 0.8 = 80%)

### Task memory limits

With *ulimit* or **mapred.child.ulimit** a limit for tasks is set

# YARN Configuration

- **yarn-env.sh**: Environment variables
- **yarn-site.xml**: Configuration settings for YARN daemons: resourcemanager, jobhistory, webapp and node managers.

## Important YARN Daemon Properties

*mapred-site.xml* is still used for general MapReduce properties.

*Table 9-9. Important YARN daemon properties*

| Property name | Type | Default value | Description |
|---|---|---|---|
| `yarn.resourceman ager.address` | hostname and port | `0.0.0.0:8040` | The hostname and port that the resource manager's RPC server runs on. |
| `yarn.nodeman ager.local-dirs` | comma-separated directory names | `/tmp/nm-local-dir` | A list of directories where node managers allow containers to store intermediate data. The data is cleared out when the application ends. |
| `yarn.nodeman ager.aux-services` | comma-separated service names | | A list of auxiliary services run by the node manager. A service is implemented by the class defined by the property `yarn.nodemanager.aux-services.`*`service-name`*`.class`. By default no auxiliary services are specified. |
| `yarn.nodeman ager.resource.mem ory-mb` | `int` | `8192` | The amount of physical memory (in MB) which may be allocated to containers being run by the node manager. |





| Property name | Type | Default value | Description |
|---|---|---|---|
| `yarn.nodeman ager.vmem-pmem-ratio` | `float` | `2.1` | The ratio of virtual to physical memory for containers. Virtual memory usage may exceed the allocation by this amount. |

### Memory

YARN allows to request an arbitrary amount of memory (within limits) for a task instead of the fixed slot-way of Hadoop v1. **yarn.nodemanager.resource.memory-mb** can be set to a limit that can't be trespassed.

Also in map and reduce the physical memory limits can be set with **mapreduce.map/reduce.memory.mb**

## Yarn Daemon Addresses and Ports

*Table 9-10. YARN RPC server properties*

| Property name | Default value | Description |
|---|---|---|
| yarn.resourceman ager.address | 0.0.0.0:8040 | The resource manager's RPC server address and port. This is used by the client (typically outside the cluster) to communicate with the resource manager. |
| yarn.resourceman ager.admin.address | 0.0.0.0:8141 | The resource manager's admin RPC server address and port. This is used by the admin client (invoked with `yarn rmadmin`, typically run outside the cluster) to communicate with the resource manager. |
| yarn.resourceman ager.scheduler.address | 0.0.0.0:8030 | The resource manager scheduler's RPC server address and port. This is used by (in-cluster) application masters to communicate with the resource manager. |
| yarn.resourceman ager.resource-tracker.address | 0.0.0.0:8025 | The resource manager resource tracker's RPC server address and port. This is used by the (in-cluster) node managers to communicate with the resource manager. |
| yarn.nodeman ager.address | 0.0.0.0:0 | The node manager's RPC server address and port. This is used by (in-cluster) application masters to communicate with node managers. |
| yarn.nodemanager.local izer.address | 0.0.0.0:4344 | The node manager localizer's RPC server address and port. |
| mapreduce.jobhis tory.address | 0.0.0.0:10020 | The job history server's RPC server address and port. This is used by the client (typically outside the cluster) to query job history. This property is set in *mapred-site.xml*. |

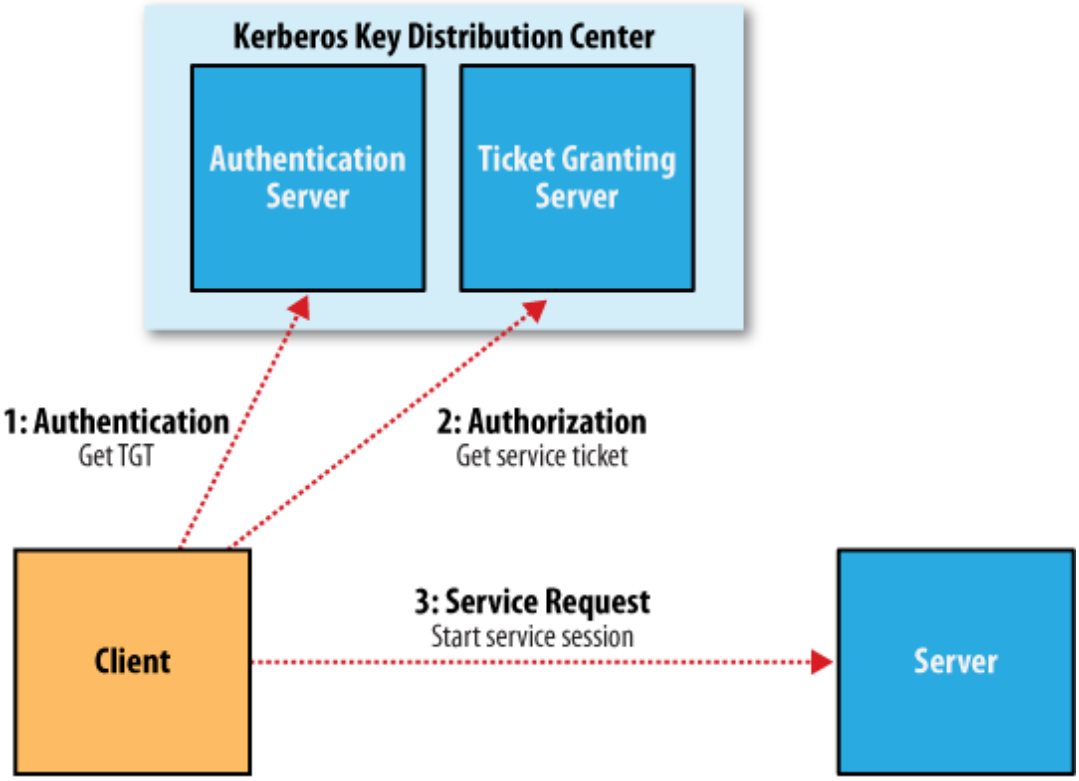
*Table 9-11. YARN HTTP server properties*

| Property name | Default value | Description |
|---|---|---|
| yarn.resourceman ager.webapp.address | 0.0.0.0:8088 | The resource manager's HTTP server address and port. |
| yarn.nodeman ager.webapp.address | 0.0.0.0:9999 | The node manager's HTTP server address and port. |
| yarn.web-proxy.address | | The web app proxy server's HTTP server address and port. If not set (the default) then the web app proxy server will run in the resource manager process. |
| mapreduce.jobhis tory.webapp.address | 0.0.0.0:19888 | The job history server's HTTP server address and port. This property is set in *mapred-site.xml*. |
| mapreduce.shuffle.port | 8080 | The shuffle handler's HTTP port number. This is used for serving map outputs, and is not a user-accessible web UI. This property is set in *mapred-site.xml*. |

# Security

## Kerberos and Hadoop

1. *Authentication*: Client authenticates itself to the Authentication Server and receives a timestamped Ticket-Granting Ticket (TGT)
2. *Authorization*: The client uses the TGT to request a service ticket from the Ticket Granting Server
3. *Service Request*: The client uses the service ticket to authenticate itself to the server that is providing the service the client is using (namenode or jobtracker).




Kerberos is enabled with **hadoop.security.authentication** in *core-site.xml* and **hadoop.security.authorization** to true to enable service level auth. You may configure Access Control Lists (ACLs) in the *hadoop-policy.xml* file.

## Delegation Token

Delegation tokes are used transparently by Hadoop, it is like a shared secret between the client and the server. They are generated by the server: it uses Kerberos on the first call and it will get a Delegation Token which the namenode can verify.

When it performs operations on HDFS, client uses a *block access token* that the namenode passes to the client in response to a metadata request. Client uses the block to access itself to datanodes. This closes the security hole where only the Job ID was needed to access to a block (by default enabled in **dfs.block.access.token.enable**)

When the job is finished, the delegation token are invalidated

## Other Security Enhancements

- Tasks can be run using the OS user rather thatn the tasktracker's user (**mapred.task.tracker.task-controller** to **org.apache.hadoop.mapred.LinuxTaskController**)

- When tasks are run as the user who submitted the job, the distributed cache is secure.
- Users can view and modify only their own jobs (**mapred.acls.enabled** to **true**)
- Shuffle is secure but not encrypted
- It's no longer possible for a malicious user to run a rogue node that can join the cluster. Daemons must authenticate against the namenode
- A datanode may be run on a privileged port (under 1024) so a client may be reasonably sure that it was started securetly.
- A task may only communicate with its parent tasktracker.

# Benchmarking a Hadoop Cluster

## Hadoop Benchmarks

### Benchmarking HDFS with TestDFSIO

**TestDFSIO** tests I/O performance of HDFS by reading or writing files. For example, to write 10 files of 1000 mb each:

```
$ hadoop jar $HADOOP_INSTALL/hadoop-*-test.jar TestDFSIO -write -nrFiles 10 -fileSize 1000
```

A read benchmark

```
$ hadoop jar $HADOOP_INSTALL/hadoop-*-test.jar TestDFSIO -read -nrFiles 10 -fileSize 1000
```

### Benchmarking MapReduce with Sort

Good for testing because it sends a full input dataset through the shuffle.

1. Generate some random data: `hadoop jar $HADOOP_INSTALL/hadoop-*-examples.jar randomwriter random-data`
2. Run the sort: `hadoop jar $HADOOP_INSTALL/hadoop-*-examples.jar sort random-data sorted-data`
3. Validate:
   `hadoop jar $HADOOP_INSTALL/hadoop-*-test.jar testmapredsort -sortInput random-data -sortOutput sorted-data`

### Other benchmarks

- **MRBench**: runs a small job a number of times
- **NNBench**: load testing namenode hardware
- **Gridmix**: suite of benchmarks to model a realistic cluster overload

# Hadoop In The Cloud

# Hadoop on Amazon EC2

Use **Whirr** telling it the credentials and for launching. An example:

```
bin/whirr launch-cluster --config recipes/hadoop-ec2.properties --private-key-file ~/.ssh/id_rsa_whirr
```

## Configuration

Configuration is passed as bundles in a conf file with the **--config** option:

```
whirr.cluster-name=hadoop
whirr.instance-templates=1 hadoop-namenode+hadoop-jobtracker, 5 hadoop-datanode+hadoop-tasktracker
whirr.provider=aws-ec2
whirr.identity=${env:AWS_ACESS_KEY_ID}
whirr.credential=${env:AWS_SECRET_ACESS_KEY}
whirr.hardware-id=c1.xlarge
whirr.image-id=us-east-1/ami-da0cf8b3
whirr.location-id=us-east-1
```

All the options are self explanatory. The identity and credential uses environment variables set with `export` in bash. You can also override any of this properties passing them (without the whirr prefix) throught the command line.

## Running a proxy

To set up the proxy:

```
$ . ~/.whirr/hadoop/hadoop-proxy.sh
```

## Running a MapReduce Job

You can run a MR job from within the cluster or from an external machine.

Whirr conf files are in ~/.whirr/hadoop and can be used to connect to the cluster by setting the **HADOOP_CONF_DIR** in *hadoop-env.sh* to it.

Then we need to populate the cluster with data from, for example, S3:

```
$ hadoop distcp \
    -Dfs.s3n.awsAccessKeyId='...' \
    -Dfs.s3n.awsSecretAccessKey='...' \
    s3n://hadoopbook/ncdc/all input/ncdc/all
```

The the job is run as usual. To write the output to S3 the command is as follows:

```
$ hadoop jar hadoop-examples.jar MyJob /input s3n://mybucket/output
```

## Shutting Down a Cluster

```
$ bin/whirr destroy-cluster --config recipes/hadoop-ec2.properties
```