Lab 7. Hadoop MapReduce

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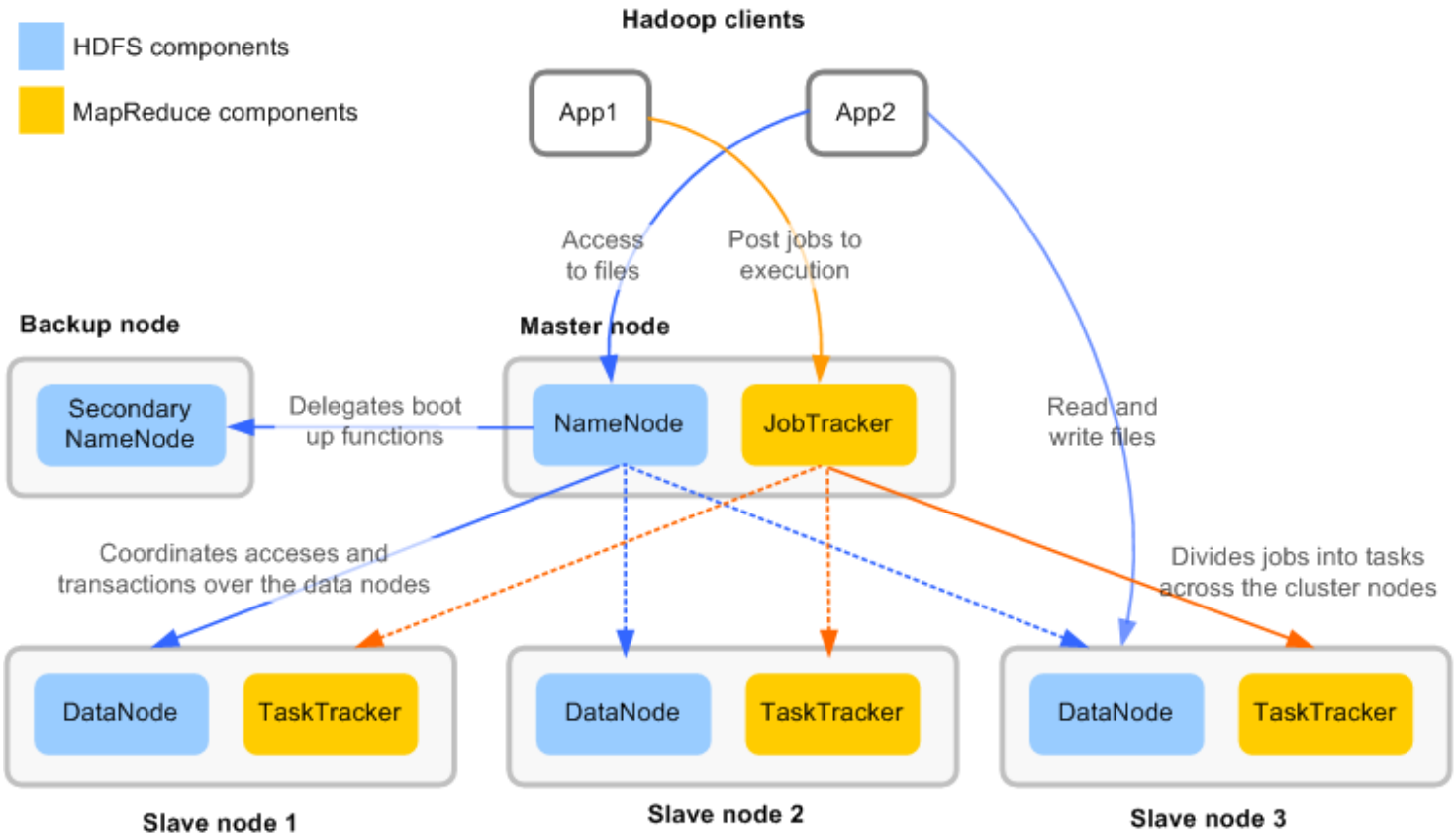
LAB 13-1)
HADOOP INSTALLATION

Entire System Overview

For more information visit me at
www.hadooper.blogspot.com

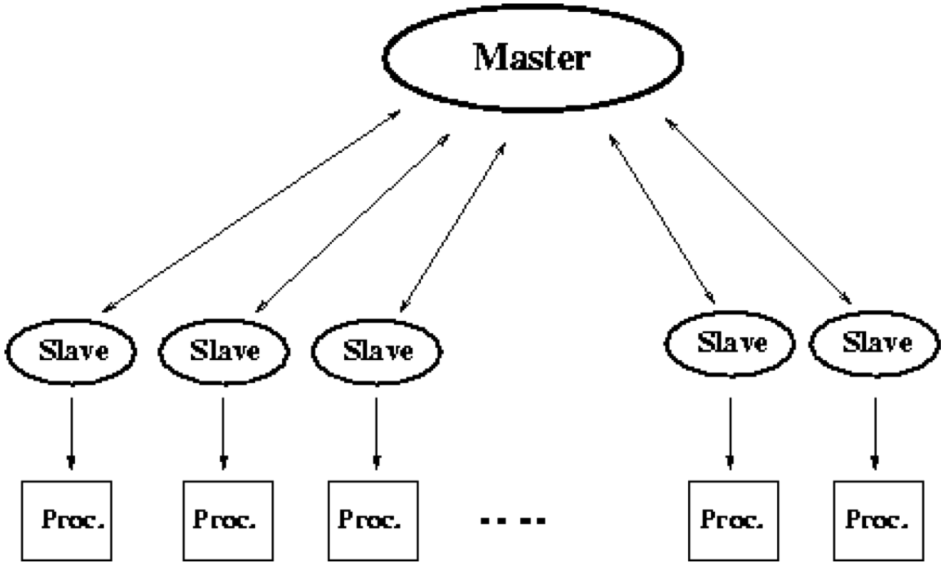
Fully-Distributed Mode

Hadoop base platform brief



Hadoop Architecture

- Master-Slave Model
  - In the master/slave (sometimes called boss/worker) model, a master entity receives one or more requests, then creates slave entities to execute them. Typically, the master controls the number of slaves and what each slave does.
  - The job of the master is to divide the work among the available slaves, keeping each of them busy without using too much communication
  - In slave, the most important aspect we have to deal with is the job handling



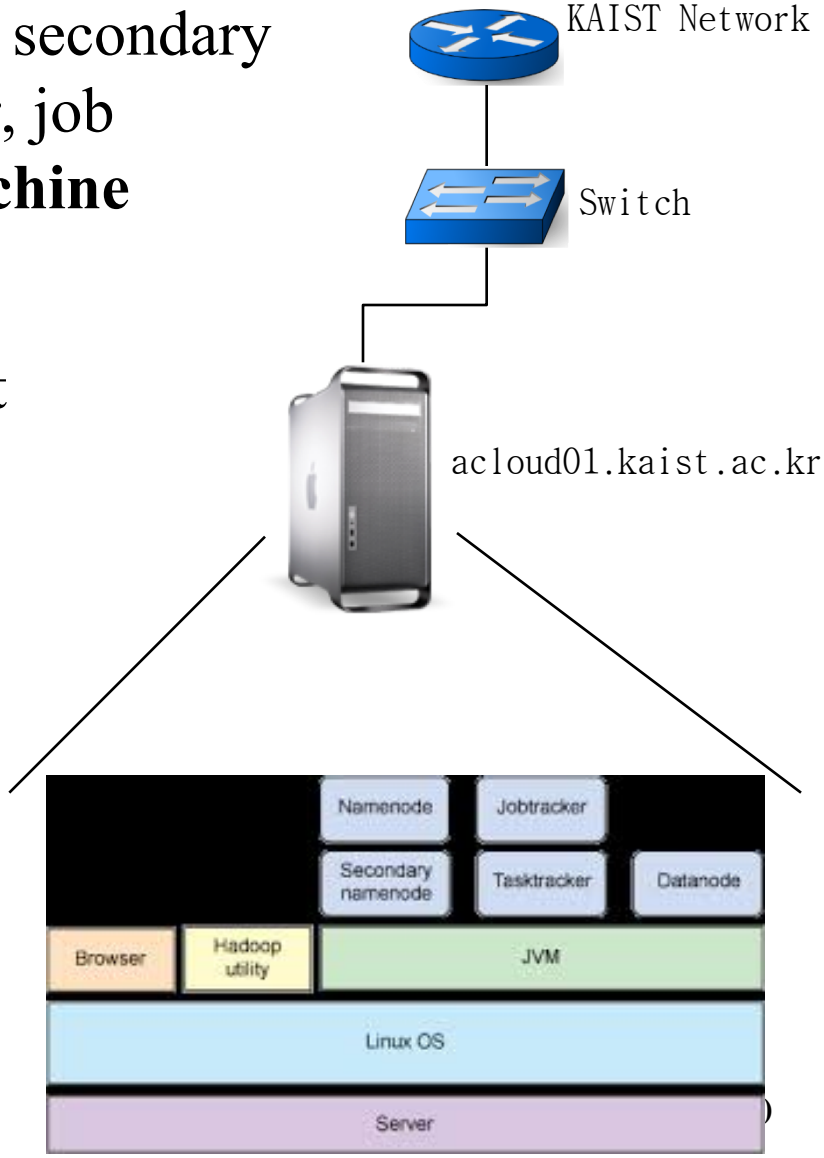
Hadoop Installation

- Supported Platforms
  - GNU/Linux as a development and production platform.
  - Win32 is supported as a *development platform*.
- Required Software
  - **JavaTM 1.6.x**, preferably from Sun, must be installed.
  - **SSH** must be installed and sshd must be running to use the Hadoop
- Supported modes
  - **Local (Standalone) Mode**
    - Used for debugging
  - **Pseudo-Distributed Mode**
    - All Hadoop process (namenode, secondary namenode, datanode, task tracker, job tracker) runs in **single linux machine**
  - **Fully-Distributed Mode**

Pseudo-Distributed Mode Installation

- **All Hadoop process** (namenode, secondary namenode, datanode, task tracker, job tracker) **runs in single linux machine**

1. Prepare linux machine with root authentication
2. Java Installation
3. Hadoop Download
4. SSH configuration
5. Hadoop Configuration



Pseudo-Distributed Mode Installation

1. Prepare linux machine with root authentication
   - Prepare user account ‘Hadoop’ with root authentication (some modifications are needed in /etc/sudoers file)

```
# User privilege specification
root    ALL=(ALL:ALL) ALL
hadoop  ALL=(ALL:ALL) ALL
```

   - To modify sudoers file, you might need root authentication. Use command ‘visudo’

   → $ sudo visudo

```
 GNU nano 2.2.6          File: /etc/sudoers.tmp

#
# This file MUST be edited with the 'visudo' command as root.
#
# Please consider adding local content in /etc/sudoers.d/ instead of
# directly modifying this file.
#
# See the man page for details on how to write a sudoers file.
#
Defaults        env_reset

# Host alias specification

# User alias specification

# Cmnd alias specification

# User privilege specification
root    ALL=(ALL:ALL) ALL
hadoop  ALL=(ALL:ALL) ALL

^G Get Help  ^O WriteOut  ^R Read File ^Y Prev Page ^K Cut Text  ^C Cur Pos
^X Exit      ^J Justify   ^W Where Is  ^V Next Page ^U UnCut Text^T To Spell
```

Pseudo-Distributed Mode Installation

- For Pseudo-Distributed mode installation, we will use **'localhost'** as hostname (Hostname is important in hadoop system. Hadoop manages every nodes with hostname like MPI)
- Can modify the local machine's hostname in **/etc/hostname** and can modify the remote machine's hostname in **/etc/hosts**

```
hadoop@acloud01:~$ cat /etc/hostname
acloud01
```

```
hadoop@acloud01:~$ cat /etc/hosts
127.0.0.1       localhost




143.248.152.16 acloud01.kaist.ac.kr     acloud01
143.248.152.17 acloud02.kaist.ac.kr     acloud02

143.248.6.161   anclabvm1.kaist.ac.kr   avm1

# The following lines are desirable for IPv6 capable hosts
::1     ip6-localhost ip6-loopback
fe00::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
```

Pseudo-Distributed Mode Installation

- After the modification of hostname, you should restart your network service

  → $ sudo /etc/init.d/networking restart

```
hadoop@acloud01:~$ sudo /etc/init.d/networking restart
 * Running /etc/init.d/networking restart is deprecated because it may not enabl
e again some interfaces
 * Reconfiguring network interfaces...
 * Disconnecting iSCSI targets
   ...done.
 * Stopping iSCSI initiator service
   ...done.
 * Disconnecting iSCSI targets
   ...done.
 * Stopping iSCSI initiator service
   ...done.

 * Starting iSCSI initiator service iscsid
   ...done.
 * Setting up iSCSI targets
   ...done.
ssh stop/waiting
ssh start/running, process 25566
 * Setting up iSCSI targets
   ...done.
ssh stop/waiting
ssh start/running, process 25649
                                                                    [ OK ]
```

Pseudo-Distributed Mode Installation

2. Java Installation

- Java which version is above the 1.6 is suggested

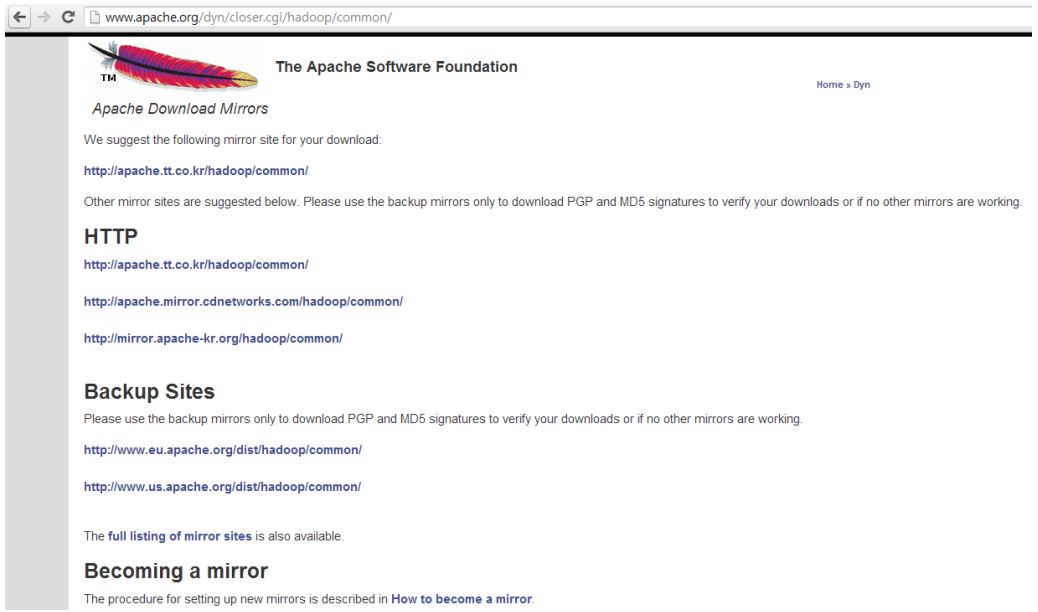
```
$ sudo apt-get update
$ sudo apt-get install openjdk-6-jdk
…
(installation process)
…
$ java –version
java version "1.6.0_27"
OpenJDK Runtime Environment (IcedTea6 1.12.3) (6b27-1.12.3-0ubuntu1~12.04.1)
OpenJDK 64-Bit Server VM (build 20.0-b12, mixed mode)
```

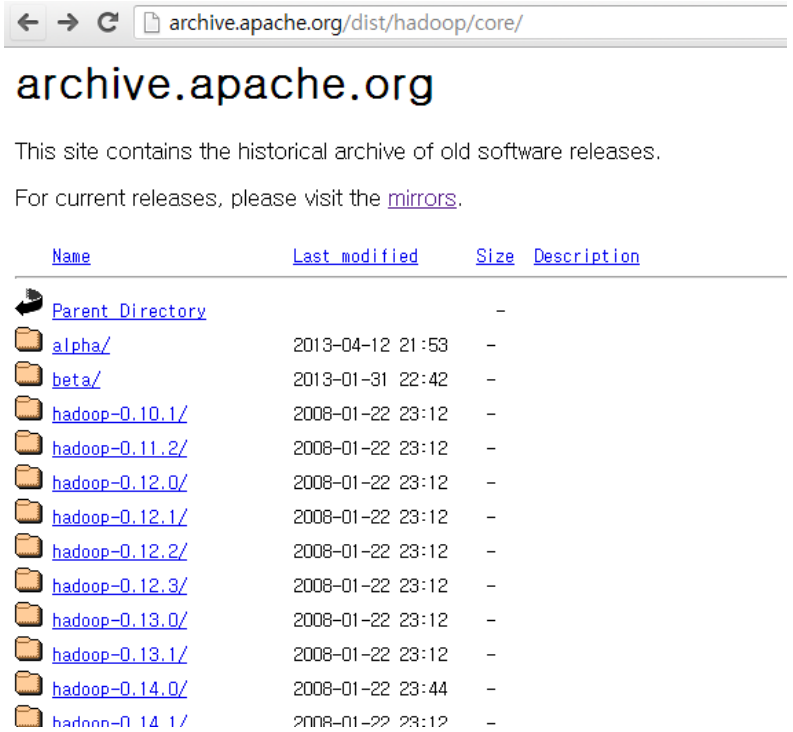
Java Location

→ /usr/lib/jvm/java-6-openjdk-amd64

Pseudo-Distributed Mode Installation

3. Hadoop Download
   - In this lab, we will use Hadoop 1.0.0
   - Download Hadoop at http://archive.apache.org/dist/hadoop/core/





Pseudo-Distributed Mode Installation

- Download with linux command

```
hadoop@acloud01:~$ wget http://archive.apache.org/dist/hadoop/core/hadoop-1.0.0/
hadoop-1.0.0.tar.gz
--2013-05-13 17:30:27--  http://archive.apache.org/dist/hadoop/core/hadoop-1.0.0
/hadoop-1.0.0.tar.gz
Resolving archive.apache.org (archive.apache.org)... 140.211.11.131, 192.87.106.
229, 2001:610:1:80bc:192:87:106:229
Connecting to archive.apache.org (archive.apache.org)|140.211.11.131|:80... conn
ected.
HTTP request sent, awaiting response... 200 OK
Length: 59468784 (57M) [application/x-gzip]
Saving to: `hadoop-1.0.0.tar.gz'

99% [=====================================> ] 59,395,576   135K/s  eta 2s
```

- Untar the download file

  $ tar –zxvf hadoop-1.0.0.tar.gz

- Move the directory into /opt

  $ mv hadoop-1.0.0 /opt

```
hadoop@acloud01:/opt/hadoop-1.0.0$ ls
bin           docs                    ivy          NOTICE.txt
build.xml     hadoop-ant-1.0.0.jar    ivy.xml      README.txt
c++           hadoop-core-1.0.0.jar   lib          sbin
CHANGES.txt   hadoop-examples-1.0.0.jar libexec      share
conf          hadoop-test-1.0.0.jar   LICENSE.txt  src
contrib       hadoop-tools-1.0.0.jar  logs         webapps
```

Pseudo-Distributed Mode Installation

4. SSH Configuration (Refer the Lab 11)
   - Can access to the host named ‘localhost’ without password

```
$ ssh-keygen –t rsa –P “”
$ cd ~/.ssh
$ cat id_rsa.pub >> authorized_keys
$ cat authorized_keys
$ ssh localhost
```

Pseudo-Distributed Mode Installation

- Can access to the host named ‘localhost’ without password

```
hadoop@acloud01:~$ ssh-keygen -t rsa -P ""
Generating public/private rsa key pair.
Enter file in which to save the key (/home/hadoop/.ssh/id_rsa):
Your identification has been saved in /home/hadoop/.ssh/id_rsa.
Your public key has been saved in /home/hadoop/.ssh/id_rsa.pub.
The key fingerprint is:
                                                hadoop@acloud01
The key's randomart image is:
+--[ RSA 2048]----+
|                 |
|                 |
|                 |
|         .     .|
|                 |
|                 |
|                 |
|        . ..o Oo.|
|          o+= *+|
+-----------------+
```

```
hadoop@acloud01:~$ cd .ssh/
hadoop@acloud01:~/.ssh$ cat id_rsa.pub >> authorized_keys
hadoop@acloud01:~/.ssh$ cat authorized_keys
ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQDbJ4gUPxeAi9H2Ur2d9Ax2CjPwmFU717aFF0kvghLT


bbDsOAkR3mhScU2/H/f94YmnrFF1bgJAln9qcEkm7RmN5IyhHeeYUcOKcZsC6sOZjh3L9iWlZ6Lz+Hqg
KXYogukhaciF9HhlIq11EWDtj7Ah5Ginytd45JXM6CMW69IBVDdNUUprOcTf hadoop@acloud01
```

```
hadoop@acloud01:~/.ssh$ ssh localhost
Welcome to Ubuntu 12.04.2 LTS (GNU/Linux 3.2.0-40-generic x86_64)

 * Documentation:  https://help.ubuntu.com/

48 packages can be updated.
21 updates are security updates.

Last login: Mon May 13 16:48:33 2013 from localhost
```

Pseudo-Distributed Mode Installation

5. Hadoop Configuration

- The $HADOOP_INSTALL/hadoop/conf directory contains some configuration files for Hadoop.

```
hadoop@acloud01:/opt/hadoop-1.0.0/conf$ ls
capacity-scheduler.xml      hadoop-policy.xml      slaves
configuration.xsl           hdfs-site.xml          ssl-client.xml.example
core-site.xml               log4j.properties       ssl-server.xml.example
fair-scheduler.xml          mapred-queue-acls.xml  taskcontroller.cfg
hadoop-env.sh               mapred-site.xml
hadoop-metrics2.properties  masters
```

  - **hadoop-env.sh**: This file contains some environment variable settings used by Hadoop. You can use these to affect some aspects of Hadoop daemon behavior, such as where log files are stored, the maximum amount of heap used etc. The only variable you should need to change in this file is JAVA_HOME, which specifies the path to the Java 1.6.x installation used by Hadoop.

Pseudo-Distributed Mode Installation

- **masters:** This file specify the host, where the Secondary NameNode will run. By default this contains the single entry localhost
- **slaves**: This file lists the hosts, one per line, where the Hadoop slave daemons (datanodes and tasktrackers) will run. By default this contains the single entry localhost
- **core-site.xml**: This file contains site specific settings for Hadoop daemons and Map/Reduce jobs.
- **mapred-site.xml**: This file contains site specific settings for the Map/Reduce daemons and jobs.
- **hdfs-site.xml**: This file contains site specific settings for HDFS daemons.

Pseudo-Distributed Mode Installation

- Hadoop Configuration for Pseudo-Distributed Mode
  - masters, slaves

```
hadoop@acloud01:/opt/hadoop-1.0.0/conf$ cat masters
localhost
hadoop@acloud01:/opt/hadoop-1.0.0/conf$ cat slaves
localhost
```

    - To launch all hadoop modules in 'localhost' node, modify **conf/masters** and **conf/slaves** file
  - hadoop-env.sh

```
# The java implementation to use.  Required.
export JAVA_HOME=/usr/lib/jvm/java-6-openjdk-amd64/jre
```

    - Specify the location of Java installation in **conf/hadoop-env.sh**

Pseudo-Distributed Mode Installation

- Hadoop Configuration for Pseudo-Distributed Mode
  - conf/core-site.xml:

```
<configuration>
  <property>
    <name>hadoop.tmp.dir</name>
    <value>/opt/hdfs</value>
  </property>
  <property>
    <name>fs.default.name</name>
    <value>hdfs://localhost:9000</value>
  </property>
</configuration>
```

    - Above configuration define the local file system directory for HDFS storage
    - Also define the namenode and its port for RPC

Pseudo-Distributed Mode Installation

- Hadoop Configuration for Pseudo-Distributed Mode
  - conf/hdfs-site.xml:

```
<configuration>
   <property>
      <name>dfs.replication</name>
      <value>1</value>
   </property>
</configuration>
```

    - Above configuration define the number of replication for failure control
  - conf/mapred-site.xml:

```
<configuration>
   <property>
      <name>mapred.job.tracker</name>
      <value>localhost:9001</value>
   </property>
</configuration>
```

    - Above configuration define the JobTracker node and its port for RPC

Detail options:
http://hadoop.apache.org/docs/stable/cluster_setup.html

Pseudo-Distributed Mode Launch

- HDFS (namenode) format

  $ bin/hadoop namenode -format

```
hadoop@acloud01:/opt/hadoop-1.0.0$ bin/hadoop namenode -format
Warning: $HADOOP_HOME is deprecated.

13/05/13 23:34:50 INFO namenode.NameNode: STARTUP_MSG:
/************************************************************
STARTUP_MSG: Starting NameNode
STARTUP_MSG:   host = acloud01/143.248.152.16
STARTUP_MSG:   args = [-format]
STARTUP_MSG:   version = 1.0.0
STARTUP_MSG:   build = https://svn.apache.org/repos/asf/hadoop/common/branches/b
ranch-1.0 -r 1214675; compiled by 'hortonfo' on Thu Dec 15 16:36:35 UTC 2011
************************************************************/
13/05/13 23:34:50 INFO util.GSet: VM type       = 64-bit
13/05/13 23:34:50 INFO util.GSet: 2% max memory = 17.77875 MB
13/05/13 23:34:50 INFO util.GSet: capacity      = 2^21 = 2097152 entries
13/05/13 23:34:50 INFO util.GSet: recommended=2097152, actual=2097152
13/05/13 23:34:50 INFO namenode.FSNamesystem: fsOwner=hadoop
13/05/13 23:34:50 INFO namenode.FSNamesystem: supergroup=supergroup
13/05/13 23:34:50 INFO namenode.FSNamesystem: isPermissionEnabled=true
13/05/13 23:34:50 INFO namenode.FSNamesystem: dfs.block.invalidate.limit=100
13/05/13 23:34:50 INFO namenode.FSNamesystem: isAccessTokenEnabled=false accessK
eyUpdateInterval=0 min(s), accessTokenLifetime=0 min(s)
13/05/13 23:34:50 INFO namenode.NameNode: Caching file names occuring more than
10 times
13/05/13 23:34:50 INFO common.Storage: Image file of size 112 saved in 0 seconds
.
13/05/13 23:34:51 INFO common.Storage: Storage directory /opt/hdfs/dfs/name has
been successfully formatted.
13/05/13 23:34:51 INFO namenode.NameNode: SHUTDOWN_MSG:
/************************************************************
SHUTDOWN_MSG: Shutting down NameNode at acloud01/143.248.152.16
************************************************************/
```

Pseudo-Distributed Mode Launch

- The $HADOOP_INSTALL/hadoop/bin directory contains some scripts used to launch Hadoop DFS and Hadoop Map/Reduce daemons
  - **start-dfs.sh**: Starts the Hadoop DFS daemons, the namenode and datanodes. Use this before start-mapred.sh
  - **stop-dfs.sh**: Stops the Hadoop DFS daemons.
  - **start-mapred.sh**: Starts the Hadoop Map/Reduce daemons, the jobtracker and tasktrackers.

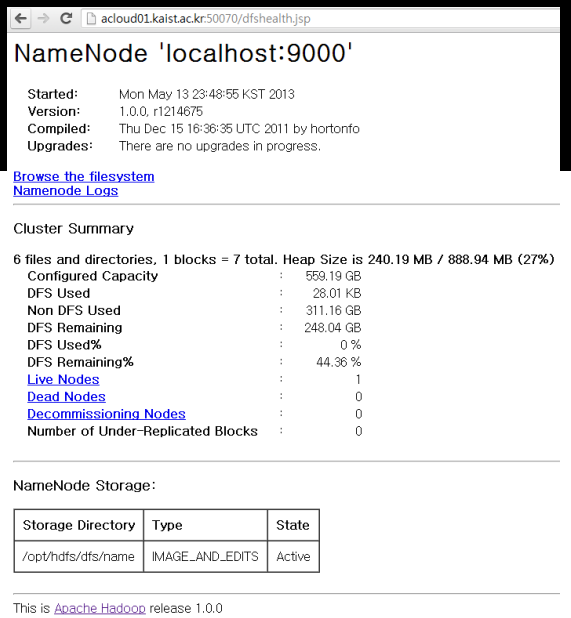
Pseudo-Distributed Mode Launch

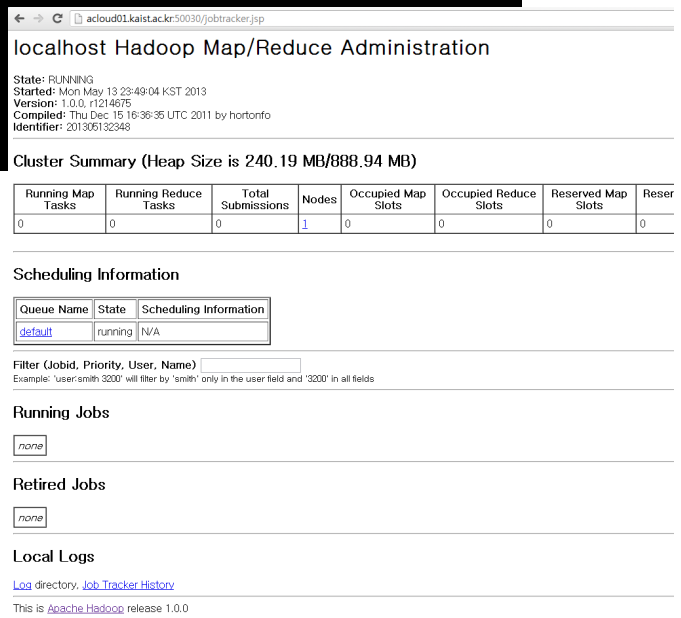
- The $HADOOP_INSTALL/hadoop/bin directory contains some scripts used to launch Hadoop DFS and Hadoop Map/Reduce daemons
  - **stop-mapred.sh**: Stops the Hadoop Map/Reduce daemons.
  - **start-all.sh**: Starts all Hadoop daemons, the namenode, datanodes, the jobtracker and tasktrackers. Deprecated; use start-dfs.sh then start-mapred.sh
  - **stop-all.sh**: Stops all Hadoop daemons. Deprecated; use stop-mapred.sh then stop-dfs.sh

Pseudo-Distributed Mode Launch

- Hadoop Launch command
  - $ bin/start-all.sh
- Can verify the operation of hadoop with
  - jps (Java Virtual Machine Process Status Tool) command
  - http://acloud01.kaist.ac.kr:50070: Namenode web interface
  - http://acloud01.kaist.ac.kr:50030: JobTracker web interface

```
hadoop@acloud01:/opt/hadoop-1.0.0$ bin/start-all.sh
Warning: $HADOOP_HOME is deprecated.

starting namenode, logging to /opt/hadoop-1.0.0/libexec/../logs/hadoop-hadoop-namenode-acloud01.out
localhost: starting datanode, logging to /opt/hadoop-1.0.0/libexec/../logs/hadoop-hadoop-datanode-acloud01.out
localhost: starting secondarynamenode, logging to /opt/hadoop-1.0.0/libexec/../logs/hadoop-hadoop-secondarynamenode-acloud01.out
starting jobtracker, logging to /opt/hadoop-1.0.0/libexec/../logs/hadoop-hadoop-jobtracker-acloud01.out
localhost: starting tasktracker, logging to /opt/hadoop-1.0.0/libexec/../logs/hadoop-hadoop-tasktracker-acloud01.out
hadoop@acloud01:/opt/hadoop-1.0.0$ jps
20816 SecondaryNameNode
21248 Jps
20329 NameNode
20566 DataNode
21168 TaskTracker
20918 JobTracker
```





Pseudo-Distributed Mode Launch

NameNode 'localhost:9000'

Started: Mon May 13 23:48:55 KST 2013
Version: 1.0.0, r1214675
Compiled: Thu Dec 15 16:36:35 UTC 2011 by hortonfo
Upgrades: There are no upgrades in progress.

Browse the filesystem
Namenode Logs
Go back to DFS home

Live Datanodes : 1

Node	Last Contact	Admin State	Configured Capacity (GB)	Used (GB)	Non DFS Used (GB)	Remaining (GB)	Used (%)	Used (%)	Remaining (%)	Blocks
acloud01	0	In Service	559.19	0	311.17	248.02	0		44.35	1

This is Apache Hadoop release 1.0.0

localhost Hadoop Machine List

Active Task Trackers

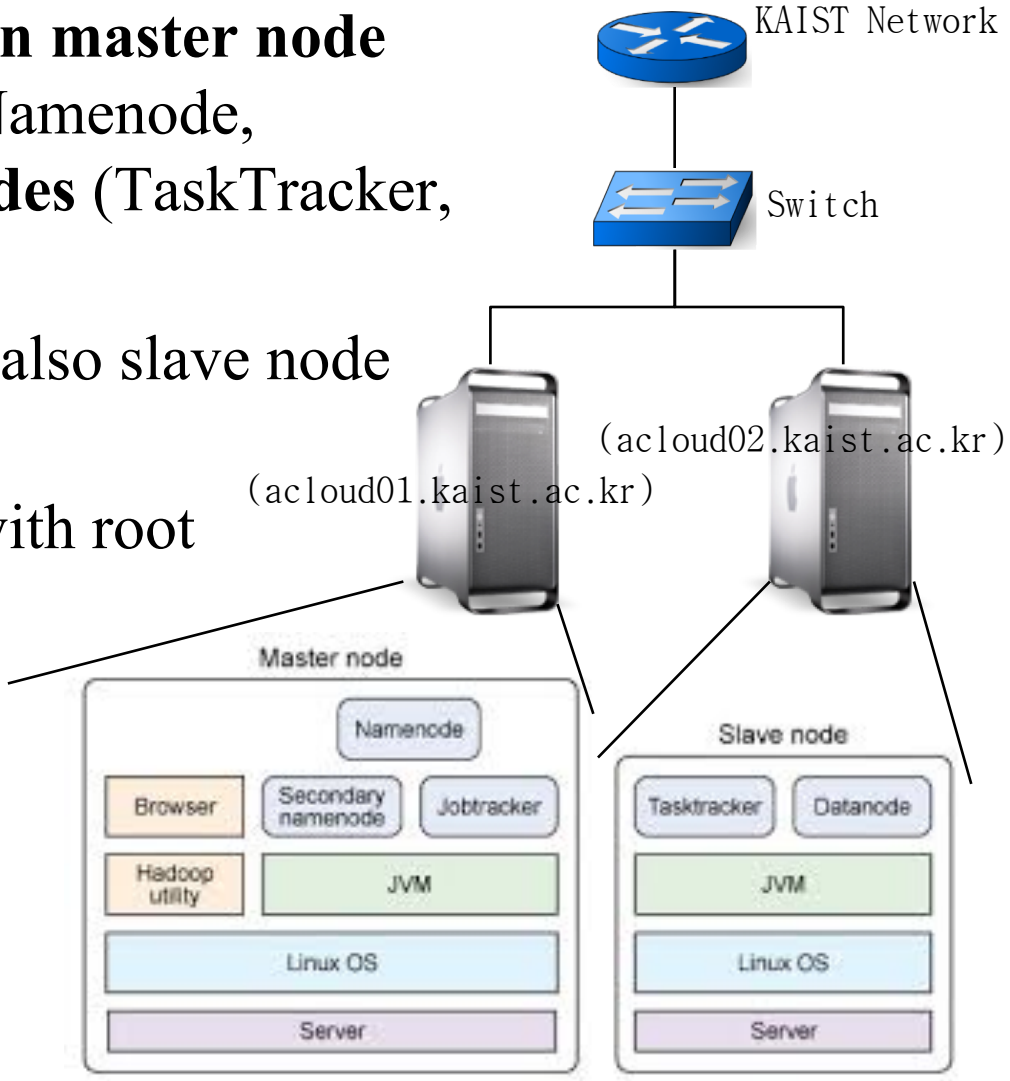
Task Trackers															
Name	Host	# running tasks	Max Map Tasks	Max Reduce Tasks	Failures	Node Health Status	Seconds Since Node Last Healthy	Total Tasks Since Start	Succeeded Tasks Since Start	Total Tasks Last Day	Succeeded Tasks Last Day	Total Tasks Last Hour	Succeeded Tasks Last Hour	Seconds since heartbeat
tracker_acloud01.kaist.ac.kr:localhost/127.0.0.1:55112	acloud01.kaist.ac.kr	0	2	2	0	N/A	0	0	0	0	0	0	0	0

This is Apache Hadoop release 1.0.0

Fully-Distributed Mode Installation

- **Hadoop processes runs in master node** (JobTracker, Secondary Namenode, Namenode) **and slave nodes** (TaskTracker, Datanode) **dispersedly**
- We will use acloud01 as also slave node (resource waste)

1. Prepare linux machine with root authentication
2. Java Installation
3. Hadoop Download
4. SSH configuration
5. Hadoop Configuration



Fully-Distributed Mode Installation

1. Prepare linux machine with root authentication for every node
   - Prepare user account ‘Hadoop’ with root authentication

```
# User privilege specification
root    ALL=(ALL:ALL) ALL
hadoop  ALL=(ALL:ALL) ALL
```

   - For Fully-Distributed mode installation, we will use ‘acloud01’ and ‘acloud02’ as hostname respectively

Fully-Distributed Mode Installation

1. Prepare linux machine with root authentication for every node
   - Can modify the local machine's hostname in /etc/hostname and can modify the remote machine's hostname in /etc/hosts

```
hadoop@acloud01:~$ cat /etc/hostname
acloud01
```

```
hadoop@acloud02:~$ cat /etc/hostname
acloud02
```

```
hadoop@acloud01:~$ cat /etc/hosts
127.0.0.1       localhost



143.248.152.16 acloud01.kaist.ac.kr     acloud01
143.248.152.17 acloud02.kaist.ac.kr     acloud02

143.248.6.161   anclabvm1.kaist.ac.kr   avm1

# The following lines are desirable for IPv6 capable hosts
::1     ip6-localhost ip6-loopback
fe00::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
```

```
hadoop@acloud02:~$ cat /etc/hosts
127.0.0.1       localhost



143.248.152.16 acloud01.kaist.ac.kr     acloud01
143.248.152.17 acloud02.kaist.ac.kr     acloud02


# The following lines are desirable for IPv6 capable hosts
::1     ip6-localhost ip6-loopback
fe00::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
```

Fully-Distributed Mode Installation

2. Same as Pseudo-Distributed Mode Installation
3. Same as Pseudo-Distributed Mode Installation
4. SSH Configuration (Refer the Lab 11)
   - Can access to the hosts named ‘acloud01’ and ‘acloud02’ without password
   - Get the ‘id_rsa.pub’ file’s contents from every node and append the contents to ‘authorized_keys’ under ~/.ssh directory
   - Copy ‘authorized_keys’ to every node

Fully-Distributed Mode Installation

- Hadoop Configuration for Pseudo-Distributed Mode
  - masters, slaves

```
hadoop@acloud01:/opt/hadoop-1.0.0/conf$ cat masters
acloud01
hadoop@acloud01:/opt/hadoop-1.0.0/conf$ cat slaves
acloud01
acloud02
```

    - To launch Secondary Namenode module in acloud01 node and to launch slave modules in acloud01/acloud02, modify **conf/masters** and **conf/slaves** file
  - hadoop-env.sh

```
# The java implementation to use.  Required.
export JAVA_HOME=/usr/lib/jvm/java-6-openjdk-amd64/jre
```

    - Specify the location of Java installation in **conf/hadoop-env.sh**

Fully-Distributed Mode Installation

- Hadoop Configuration for Pseudo-Distributed Mode
  - conf/core-site.xml:

```
<configuration>
  <property>
    <name>hadoop.tmp.dir</name>
    <value>/opt/hdfs</value>
  </property>
  <property>
    <name>fs.default.name</name>
    <value>hdfs://acloud01:9000 </value>
  </property>
</configuration>
```

    - Above configuration define the local file system directory for HDFS storage
    - Also define the namenode and its port for RPC

Fully-Distributed Mode Installation

- Hadoop Configuration for Pseudo-Distributed Mode
  - conf/hdfs-site.xml:

```
<configuration>
  <property>
    <name>dfs.replication</name>
    <value>2</value>
  </property>
</configuration>
```

    - Above configuration define the number of replication for failure control
  - conf/mapred-site.xml:

```
<configuration>
  <property>
    <name>mapred.job.tracker</name>
    <value>acloud01:9001</value>
  </property>
</configuration>
```

    - Above configuration define the JobTracker node and its port for RPC

Detail options:
http://hadoop.apache.org/docs/stable/cluster_setup.html

Fully-Distributed Mode Launch

- HDFS (namenode) format

  $ bin/hadoop namenode -format

```
hadoop@acloud01:/opt/hadoop-1.0.0$ bin/hadoop namenode -format
Warning: $HADOOP_HOME is deprecated.

13/05/14 00:46:43 INFO namenode.NameNode: STARTUP_MSG:
/************************************************************
STARTUP_MSG: Starting NameNode
STARTUP_MSG:   host = acloud01/143.248.152.16
STARTUP_MSG:   args = [-format]
STARTUP_MSG:   version = 1.0.0
STARTUP_MSG:   build = https://svn.apache.org/repos/asf/hadoop/common/branches/b
ranch-1.0 -r 1214675; compiled by 'hortonfo' on Thu Dec 15 16:36:35 UTC 2011
************************************************************/
13/05/14 00:46:43 INFO util.GSet: VM type       = 64-bit
13/05/14 00:46:43 INFO util.GSet: 2% max memory = 17.77875 MB
13/05/14 00:46:43 INFO util.GSet: capacity      = 2^21 = 2097152 entries
13/05/14 00:46:43 INFO util.GSet: recommended=2097152, actual=2097152
13/05/14 00:46:44 INFO namenode.FSNamesystem: fsOwner=hadoop
13/05/14 00:46:44 INFO namenode.FSNamesystem: supergroup=supergroup
13/05/14 00:46:44 INFO namenode.FSNamesystem: isPermissionEnabled=true
13/05/14 00:46:44 INFO namenode.FSNamesystem: dfs.block.invalidate.limit=100
13/05/14 00:46:44 INFO namenode.FSNamesystem: isAccessTokenEnabled=false accessK
eyUpdateInterval=0 min(s), accessTokenLifetime=0 min(s)
13/05/14 00:46:44 INFO namenode.NameNode: Caching file names occuring more than
10 times
13/05/14 00:46:44 INFO common.Storage: Image file of size 112 saved in 0 seconds
.
13/05/14 00:46:44 INFO common.Storage: Storage directory /opt/hdfs/dfs/name has
been successfully formatted.
13/05/14 00:46:44 INFO namenode.NameNode: SHUTDOWN_MSG:
/************************************************************
SHUTDOWN_MSG: Shutting down NameNode at acloud01/143.248.152.16
************************************************************/
```

Fully-Distributed Mode Launch

- Hadoop Launch command
  - $ bin/start-all.sh
  - Slave nodes also launched with command master node using SSH remote command
- Can verify the operation of hadoop with
  - jps (Java Virtual Machine Process Status Tool) command
    - acloud01: Secondary Namenode, JobTracker, Namenode, TaskTraker, Datanode
    - acloud02: TaskTracker, Datanode

```
hadoop@acloud01:/opt/hadoop-1.0.0$ bin/start-all.sh
Warning: $HADOOP_HOME is deprecated.

starting namenode, logging to /opt/hadoop-1.0.0/libexec/../logs/hadoop-hadoop-na
menode-acloud01.out
acloud01: starting datanode, logging to /opt/hadoop-1.0.0/libexec/../logs/hadoop
-hadoop-datanode-acloud01.out
acloud02: starting datanode, logging to /opt/hadoop-1.0.0/libexec/../logs/hadoop
-hadoop-datanode-acloud02.out
acloud01: starting secondarynamenode, logging to /opt/hadoop-1.0.0/libexec/../lo
gs/hadoop-hadoop-secondarynamenode-acloud01.out
starting jobtracker, logging to /opt/hadoop-1.0.0/libexec/../logs/hadoop-hadoop-
jobtracker-acloud01.out
acloud01: starting tasktracker, logging to /opt/hadoop-1.0.0/libexec/../logs/had
oop-hadoop-tasktracker-acloud01.out
acloud02: starting tasktracker, logging to /opt/hadoop-1.0.0/libexec/../logs/had
oop-hadoop-tasktracker-acloud02.out
hadoop@acloud01:/opt/hadoop-1.0.0$ jps
880 SecondaryNameNode
1252 TaskTracker
988 JobTracker
370 NameNode
1351 Jps
617 DataNode
```

```
hadoop@acloud02:/opt$ jps
8516 TaskTracker
8390 DataNode
8593 Jps
```

Fully-Distributed Mode Launch

NameNode 'acloud01.kaist.ac.kr:9000'

Started: Tue May 14 01:12:11 KST 2013
Version: 1.0.0, r1214675
Compiled: Thu Dec 15 16:36:35 UTC 2011 by hortonfo
Upgrades: There are no upgrades in progress.

Browse the filesystem
Namenode Logs
Go back to DFS home

http://acloud01.kaist.ac.kr:50070: Namenode web interface
http://acloud01.kaist.ac.kr:50030: JobTracker web interface

Live Datanodes : 2

Node	Last Contact	Admin State	Configured Capacity (GB)	Used (GB)	Non DFS Used (GB)	Remaining (GB)	Used (%)	Used (%)	Remaining (%)	Blocks
acloud01	1	In Service	559.19	0	311.35	247.85	0		44.32	2
acloud02	0	In Service	174.27	0	120.6	53.68	0		30.8	1

This is Apache Hadoop release 1.0.0

acloud01 Hadoop Machine List

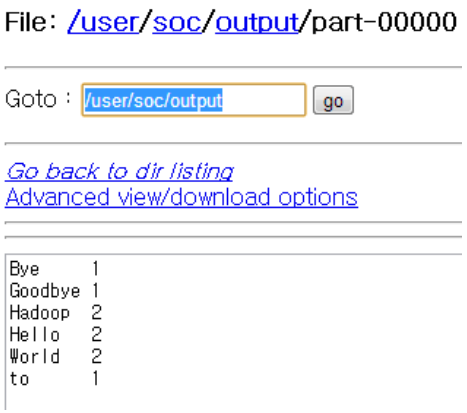
Active Task Trackers

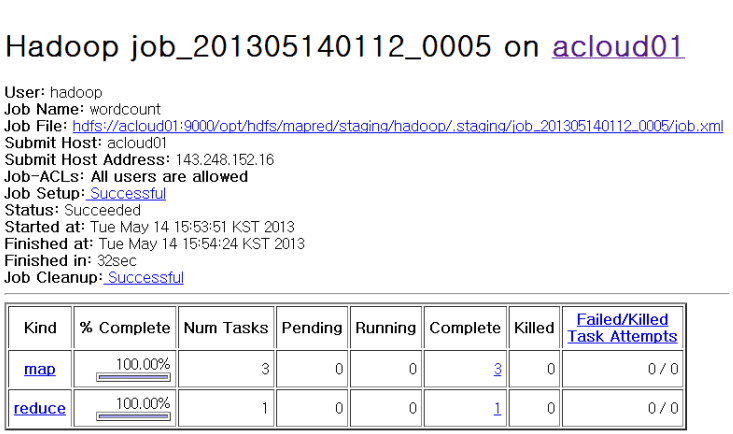
Task Trackers														
Name	Host	# running tasks	Max Map Tasks	Max Reduce Tasks	Failures	Node Health Status	Seconds Since Node Last Healthy	Total Tasks Since Start	Succeeded Tasks Since Start	Total Tasks Last Day	Succeeded Tasks Last Day	Total Tasks Last Hour	Succeeded Tasks Last Hour	Seconds since heartbeat
tracker_acloud01.kaist.ac.kr:localhost/127.0.0.1:46498	acloud01.kaist.ac.kr	0	2	2	0	N/A	0	0	0	0	0	0	0	1
tracker_acloud02.kaist.ac.kr:localhost/127.0.0.1:33005	acloud02.kaist.ac.kr	0	2	2	0	N/A	0	0	0	0	0	0	0	1

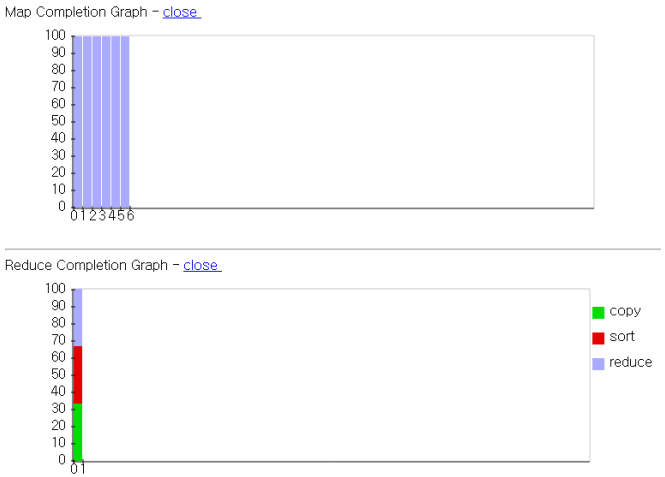
This is Apache Hadoop release 1.0.0

Hadoop Web Interface

- HDFS: http://acloud01.kaist.ac.kr:50070/dfshealth.jsp
- JobTracker: http://acloud01.kaist.ac.kr:50030/jobtracker.jsp
- Can see the status of HDFS, MapReduce and their nodes
- Can browse the HDFS file system
- Also can see the job processing status







HDFS Commands

HDFS commands

- http://hadoop.apache.org/docs/r1.1.2/file_system_shell.html
  - Try each listed command
- Each student gets a home directory in HDFS
  - /user/your_account_name
- Examples:
  - hadoop fs –ls HDFS_directory
  - hadoop fs –put local_file HDFS_file
  - hadoop fs –get HDFS_file local_file
  - Other: -cat, -mkdir, -rm, -rmr

Hadoop Distributed File System (HDFS)

- HDFS-shell guide

Comm.	Descriptions	examples
mkdir	Takes path uri's as argument and creat es directories	hadoop fs -mkdir /user/hadoop/dir1
cp	Copy files from source to destination	hadoop fs -cp /user/hadoop/file1 /user/hadoop/file2
count	Copy files from source to destination	hadoop fs -cp /user/hadoop/file1 /user/hadoop/file2
get	Copy files to the local file system.	hadoop fs -get /user/hadoop/file localfile
put	Copy single src, or multiple srcs from local file system to the destination file system	hadoop fs -put localfile /user/hadoop/hadoopfile
cat	Copies source paths to stdout	hadoop fs -cat hdfs://nn1.example.com/file1
ls (lsr)	For a file returns	hadoop fs –ls /user
rm (rmr)	Delete files specified as args	hadoop fs -rm hdfs://nn.example.com/file

HDFS commands

- **mkdir**

  `Usage: hadoop fs -mkdir <paths>`

  Takes path uri's as argument and creates directories. The behavior is much like unix mkdir -p creating parent directories along the path.

  - Example:

    `hadoop fs -mkdir /user/hadoop/dir1 /user/hadoop/dir2`

    `hadoop fs -mkdir hdfs://nn1.example.com/user/hadoop/dir hdfs://nn2.example.com/user/hadoop/dir`

  - Exit Code:

    `Returns 0 on success and -1 on error.`

```
hadoop@acloud01:/opt/hadoop-1.0.0/bin$ hadoop fs -mkdir /user/soc7011
hadoop@acloud01:/opt/hadoop-1.0.0/bin$ hadoop fs -ls /user
Found 3 items
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 15:06 /user/hadoop
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 17:00 /user/soc
drwxr-xr-x   - hadoop supergroup          0 2013-05-16 01:50 /user/soc7011
```

HDFS commands

- **ls**

  `Usage: hadoop fs -ls <args>`

  - For a file returns stat on the file with the following format:

    `permissions number_of_replicas userid groupid filesize modification_date modification_time filename`

  - For a directory it returns list of its direct children as in unix.A directory is listed as:

    `permissions userid groupid modification_date modification_time dirname`

  - Example:

    `hadoop fs -ls /user/hadoop/file1`

  - Exit Code:

    `Returns 0 on success and -1 on error.`

```
hadoop@acloud01:/opt/hadoop-1.0.0/bin$ hadoop fs -ls /user/soc/input
Found 2 items
-rw-r--r--   2 hadoop supergroup         22 2013-05-14 15:51 /user/soc/input/file0
-rw-r--r--   2 hadoop supergroup         31 2013-05-14 15:51 /user/soc/input/file1
```

HDFS commands

- **lsr**

  `Usage: hadoop fs -lsr <args>`

  Recursive version of `ls`. Similar to Unix `ls -R`.

```
hadoop@acloud01:~/temp$ hadoop fs -lsr /user/soc
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 17:00 /user/soc/ii_output
-rw-r--r--   2 hadoop supergroup          0 2013-05-14 17:00 /user/soc/ii_output/
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 17:00 /user/soc/ii_output/
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 17:00 /user/soc/ii_output/
-rw-r--r--   2 hadoop supergroup      19337 2013-05-14 17:00 /user/soc/ii_output/
-rw-r--r--   2 hadoop supergroup      19923 2013-05-14 17:00 /user/soc/ii_output/
-rw-r--r--   2 hadoop supergroup         91 2013-05-14 17:00 /user/soc/ii_output/p
drwxr-xr-x   - hadoop supergroup          0 2013-05-16 02:10 /user/soc/input
-rw-r--r--   2 hadoop supergroup         22 2013-05-16 02:10 /user/soc/input/file0
-rw-r--r--   2 hadoop supergroup         31 2013-05-14 15:51 /user/soc/input/file1
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 15:54 /user/soc/output
-rw-r--r--   2 hadoop supergroup          0 2013-05-14 15:54 /user/soc/output/_SUC
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 15:53 /user/soc/output/_log
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 15:53 /user/soc/output/_log
-rw-r--r--   2 hadoop supergroup      19332 2013-05-14 15:53 /user/soc/output/_log
-rw-r--r--   2 hadoop supergroup      20228 2013-05-14 15:53 /user/soc/output/_log
-rw-r--r--   2 hadoop supergroup         46 2013-05-14 15:54 /user/soc/output/part
```

HDFS commands

- **count**

```
Usage: hadoop fs -count [-q] <paths>
```

Count the number of directories, files and bytes under the paths that match the specified file pattern.

- The output columns with `-count` are:

```
DIR_COUNT, FILE_COUNT, CONTENT_SIZE FILE_NAME
```

- The output columns with `-count -q` are:

```
QUOTA, REMAINING_QUATA, SPACE_QUOTA,
REMAINING_SPACE_QUOTA, DIR_COUNT, FILE_COUNT,
CONTENT_SIZE, FILE_NAME
```

- Example:

```
hadoop fs -count hdfs://nn1.example.com/file1
hdfs://nn2.example.com/file2
hadoop fs -count -q hdfs://nn1.example.com/file1
```

- Exit Code:

```
Returns 0 on success and -1 on error.
```

```
hadoop@acloud01:/opt/hadoop-1.0.0/bin$ hadoop fs -count /user/soc
           8               10                 79010 hdfs://acloud01:9000/user/soc
```

HDFS commands

- **get**

  `Usage: hadoop fs -get [-ignorecrc] [-crc] <src> <localdst>`

  Copy files to the local file system. Files that fail the CRC check may be copied with the `-ignorecrc` option. Files and CRCs may be copied using the `-crc` option.

  - Example:

    ```
    hadoop fs -get /user/hadoop/file localfile
    hadoop fs -get hdfs://nn.example.com/user/hadoop/file
    localfile
    ```

  - Exit Code:

    `Returns 0 on success and -1 on error.`

```
hadoop@acloud01:~/temp$ ls
hadoop@acloud01:~/temp$ hadoop fs -get /user/soc/input/file0 file0
hadoop@acloud01:~/temp$ ls
file0
```

HDFS commands

- **put**

```
Usage: hadoop fs -put <localsrc> ... <dst>
```

Copy single src, or multiple srcs from local file system to the destination file system. Also reads input from stdin and writes to destination file system.

- Example:

```
hadoop fs -put localfile /user/hadoop/hadoopfile
hadoop fs -put localfile1 localfile2
/user/hadoop/hadoopdir
hadoop fs -put localfile
hdfs://nn.example.com/hadoop/hadoopfile
```

- Exit Code:

Returns 0 on success and -1 on error.

```
hadoop@acloud01:~/temp$ hadoop fs -ls /user/soc/input
Found 1 items
-rw-r--r--   2 hadoop supergroup         31 2013-05-14 15:51 /user/soc/input/file1
hadoop@acloud01:~/temp$ ls
file0
hadoop@acloud01:~/temp$ hadoop fs -put file0 /user/soc/input
hadoop@acloud01:~/temp$ hadoop fs -ls /user/soc/input
Found 2 items
-rw-r--r--   2 hadoop supergroup         22 2013-05-16 02:10 /user/soc/input/file0
-rw-r--r--   2 hadoop supergroup         31 2013-05-14 15:51 /user/soc/input/file1
```

HDFS commands

- **rm**

  `Usage: hadoop fs -rm [-skipTrash] URI [URI …]`

  Delete files specified as args. Only deletes non empty directory and files. If the `-skipTrash` option is specified, the trash, if enabled, will be bypassed and the specified file(s) deleted immediately. This can be useful when it is necessary to delete files from an over-quota directory. Refer to rmr for recursive deletes.

  - Example:

    ```
    hadoop fs -rm hdfs://nn.example.com/file
    /user/hadoop/emptydir
    ```

  - Exit Code:

    `Returns 0 on success and -1 on error.`

```
hadoop@acloud01:~/temp$ hadoop fs -ls /user/soc/input
Found 2 items
-rw-r--r--   2 hadoop supergroup         22 2013-05-14 15:51 /user/soc/input/file0
-rw-r--r--   2 hadoop supergroup         31 2013-05-14 15:51 /user/soc/input/file1
hadoop@acloud01:~/temp$ hadoop fs -rm /user/soc/input/file0
Deleted hdfs://acloud01:9000/user/soc/input/file0
hadoop@acloud01:~/temp$ hadoop fs -ls /user/soc/input
Found 1 items
-rw-r--r--   2 hadoop supergroup         31 2013-05-14 15:51 /user/soc/input/file1
```

HDFS commands

- **rmr**

```
Usage: hadoop fs -rmr [-skipTrash] URI [URI …]
```

Recursive version of delete. If the `-skipTrash` option is specified, the trash, if enabled, will be bypassed and the specified file(s) deleted immediately. This can be useful when it is necessary to delete files from an over-quota directory.

- Example:

```
hadoop fs -rmr /user/hadoop/dir
hadoop fs -rmr hdfs://nn.example.com/user/hadoop/dir
```

- Exit Code:

```
Returns 0 on success and -1 on error.
```

```
hadoop@acloud01:~/temp$ hadoop fs -ls /user
Found 3 items
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 15:06 /user/hadoop
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 17:00 /user/soc
drwxr-xr-x   - hadoop supergroup          0 2013-05-16 01:50 /user/soc7011
hadoop@acloud01:~/temp$ hadoop fs -rmr /user/soc7011
Deleted hdfs://acloud01:9000/user/soc7011
hadoop@acloud01:~/temp$ hadoop fs -ls /user
Found 2 items
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 15:06 /user/hadoop
drwxr-xr-x   - hadoop supergroup          0 2013-05-14 17:00 /user/soc
```

Execution of MapReduce Example

Execution of MapReduce Example

- Hadoop gives example MapRecude source code and execution file
  - hadoop-examples-1.0.0.jar
  - src/examples/org/apache/hadoop/examples

```
hadoop@acloud01:/opt/hadoop-1.0.0$ ls
bin           conf                hadoop-core-1.0.0.jar      ivy      LICENSE.txt  sbin
build.xml     contrib             hadoop-examples-1.0.0.jar  ivy.xml  logs         share
c++           docs                hadoop-test-1.0.0.jar      lib      NOTICE.txt   src
CHANGES.txt   hadoop-ant-1.0.0.jar hadoop-tools-1.0.0.jar     libexec  README.txt   webapps
```

```
hadoop@acloud01:/opt/hadoop-1.0.0$ cd src/examples/org/apache/hadoop/examples/
hadoop@acloud01:/opt/hadoop-1.0.0/src/examples/org/apache/hadoop/examples$ ls
AggregateWordCount.java      Grep.java                RandomTextWriter.java  terasort
AggregateWordHistogram.java  Join.java                RandomWriter.java      WordCount.java
dancing                      MultiFileWordCount.java  SecondarySort.java
DBCountPageView.java         package.html             SleepJob.java
ExampleDriver.java           PiEstimator.java         Sort.java
```

Execution of MapReduce Example

- Hadoop gives number of examples listed below

  $ hadoop jar hadoop-examples-1.0.0.jar

```
hadoop@acloud01:/opt/hadoop-1.0.0$ hadoop jar hadoop-examples-1.0.0.jar
An example program must be given as the first argument.
Valid program names are:
  aggregatewordcount: An Aggregate based map/reduce program that counts the words in the input files.
  aggregatewordhist: An Aggregate based map/reduce program that computes the histogram of the words in the input files.
  dbcount: An example job that count the pageview counts from a database.
  grep: A map/reduce program that counts the matches of a regex in the input.
  join: A job that effects a join over sorted, equally partitioned datasets
  multifilewc: A job that counts words from several files.
  pentomino: A map/reduce tile laying program to find solutions to pentomino problems.
  pi: A map/reduce program that estimates Pi using monte-carlo method.
  randomtextwriter: A map/reduce program that writes 10GB of random textual data per node.
  randomwriter: A map/reduce program that writes 10GB of random data per node.
  secondarysort: An example defining a secondary sort to the reduce.
  sleep: A job that sleeps at each map and reduce task.
  sort: A map/reduce program that sorts the data written by the random writer.
  sudoku: A sudoku solver.
  teragen: Generate data for the terasort
  terasort: Run the terasort
  teravalidate: Checking results of terasort
  wordcount: A map/reduce program that counts the words in the input files.
```

Execution of MapReduce Example

- Hadoop jar execution command

  $ hadoop jar [local jar file] [execution class with package name] [arguments]

  $ hadoop jar hadoop-examples-1.0.0.jar pi

```
hadoop@acloud01:/opt/hadoop-1.0.0$ hadoop jar hadoop-examples-1.0.0.jar pi
Usage: org.apache.hadoop.examples.PiEstimator <nMaps> <nSamples>
Generic options supported are
-conf <configuration file>     specify an application configuration file
-D <property=value>            use value for given property
-fs <local|namenode:port>      specify a namenode
-jt <local|jobtracker:port>    specify a job tracker
-files <comma separated list of files>    specify comma separated files to be copied to the map reduce cluster
-libjars <comma separated list of jars>    specify comma separated jar files to include in the classpath.
-archives <comma separated list of archives>    specify comma separated archives to be unarchived on the compute machines.

The general command line syntax is
bin/hadoop command [genericOptions] [commandOptions]
```

Needs more argument <nMaps> <nSamples>

Execution of MapReduce Example

- Hadoop jar execution command

  $ hadoop jar [local jar file] [execution class with package name] [arguments]

  $ hadoop jar hadoop-examples-1.0.0.jar pi 4 10000

```
hadoop@acloud01:/opt/hadoop-1.0.0$ hadoop jar hadoop-examples-1.0.0.jar pi 4 10000
Number of Maps  = 4
Samples per Map = 10000
Wrote input for Map #0
Wrote input for Map #1
Wrote input for Map #2
Wrote input for Map #3
Starting Job
13/05/16 02:34:25 INFO mapred.FileInputFormat: Total input paths to process : 4
13/05/16 02:34:25 INFO mapred.JobClient: Running job: job_201305160148_0001
13/05/16 02:34:26 INFO mapred.JobClient:  map 0% reduce 0%
13/05/16 02:34:41 INFO mapred.JobClient:  map 100% reduce 0%
13/05/16 02:34:54 INFO mapred.JobClient:  map 100% reduce 100%
13/05/16 02:34:59 INFO mapred.JobClient: Job complete: job 201305160148 0001
```

```
Job Finished in 33.686 seconds
Estimated value of Pi is 3.14140000000000000000
```

Execution of MapReduce Example

- Job Status Monitoring with web interface

  http://acloud01.kaist.ac.kr:50030/jobtracker.jsp

Hadoop job_201305160148_0001 on acloud01

User: hadoop
Job Name: PiEstimator
Job File: hdfs://acloud01:9000/opt/hdfs/mapred/staging/hadoop/.staging/job_201305160148_0001/job.xml
Submit Host: acloud01
Submit Host Address: 143.248.152.16
Job-ACLs: All users are allowed
Job Setup: Successful
Status: Succeeded
Started at: Thu May 16 02:34:25 KST 2013
Finished at: Thu May 16 02:34:58 KST 2013
Finished in: 32sec
Job Cleanup: Successful

Kind	% Complete	Num Tasks	Pending	Running	Complete	Killed	Failed/Killed Task Attempts
map	100.00%	4	0	0	4	0	0 / 0
reduce	100.00%	1	0	0	1	0	0 / 0

Map Completion Graph - close

Reduce Completion Graph - close

Lab 13-1 Requirements

- Please install hadoop framework in VM environment with Fully-Distributed Mode Installation configuration
  - Refer the page 24
- Please compare the distributed computing frameworks. Figure out the differences between MPI framework and Hadoop framework (PiEstimator example using monte-carlo method will be helpful)

Lab 13-1 Requirements

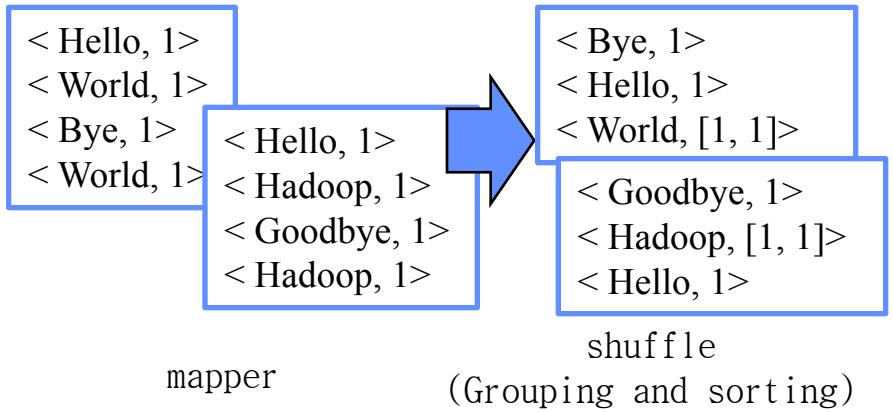
- Please explain the all job status metrics which is shown in right figure. Also analysis specific MapReduce example using the metrics

	Counter	Map	Reduce	Total
Job Counters	SLOTS_MILLIS_MAPS	0	0	15,539
	Launched reduce tasks	0	0	1
	Total time spent by all reduces waiting after reserving slots (ms)	0	0	0
	Total time spent by all maps waiting after reserving slots (ms)	0	0	0
	Launched map tasks	0	0	2
	Data-local map tasks	0	0	2
	SLOTS_MILLIS_REDUCES	0	0	9,955
File Output Format Counters	Bytes Written	0	46	46
File Input Format Counters	Bytes Read	53	0	53
FileSystemCounters	FILE_BYTES_READ	0	88	88
	HDFS_BYTES_READ	265	0	265
	FILE_BYTES_WRITTEN	43,080	21,550	64,630
	HDFS_BYTES_WRITTEN	0	46	46
Map-Reduce Framework	Map output materialized bytes	94	0	94
	Map input records	2	0	2
	Reduce shuffle bytes	0	0	0
	Spilled Records	7	7	14
	Map output bytes	89	0	89
	CPU time spent (ms)	360	800	1,160
	Total committed heap usage (bytes)	369,295,360	200,998,912	570,294,272
	Combine input records	9	0	9
	SPLIT_RAW_BYTES	212	0	212
	Reduce input records	0	7	7
	Reduce input groups	0	6	6
	Combine output records	7	0	7
	Physical memory (bytes) snapshot	396,623,872	112,578,560	509,202,432
	Reduce output records	0	6	6
	Virtual memory (bytes) snapshot	4,646,756,352	2,628,759,552	7,275,515,904
	Map output records	9	0	9

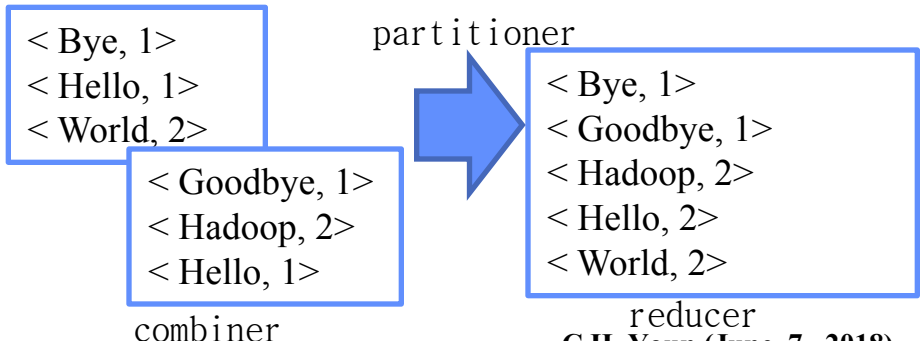
LAB 13-2)
HADOOP PROGRAMING

WordCount

```
public static class Map extends MapReduceBase implements Mapper<LongWritable, Text, Text, IntWritable>{
        private final static IntWritable one = new IntWritable(1);
        private Text word = new Text();

        public void map(LongWritable key, Text value, OutputCollector<Text, IntWritable> output, Reporter reporter) throws
IOException{
                String line = value.toString();
                StringTokenizer tokenizer = new StringTokenizer(line);
                while (tokenizer.hasMoreTokens()){
                        word.set(tokenizer.nextToken());
                        output.collect(word, one);
                }
        }
}
```




```
public static class Reduce extends MapReduceBase implements Reducer<Text, IntWritable, Text, IntWritable>{
        public void reduce(Text key, Iterator<IntWritable> values, OutputCollector<Text, IntWritable> output, Reporter
reporter) throws IOException {
                int sum=0;
                while (values.hasNext()){
                        sum += values.next().get();
                }
                output.collect(key, new IntWritable(sum));
        }
}
```

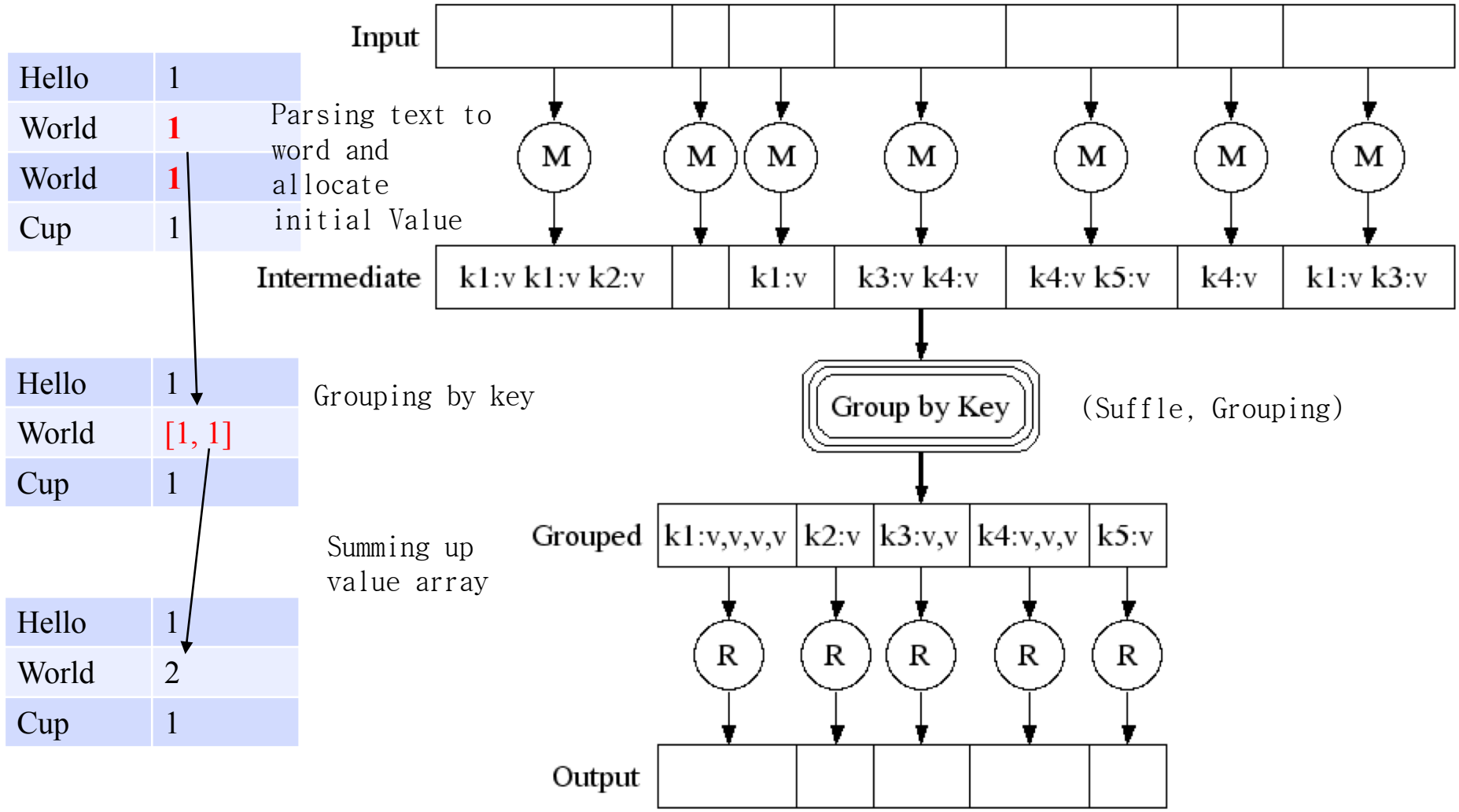


WordCount

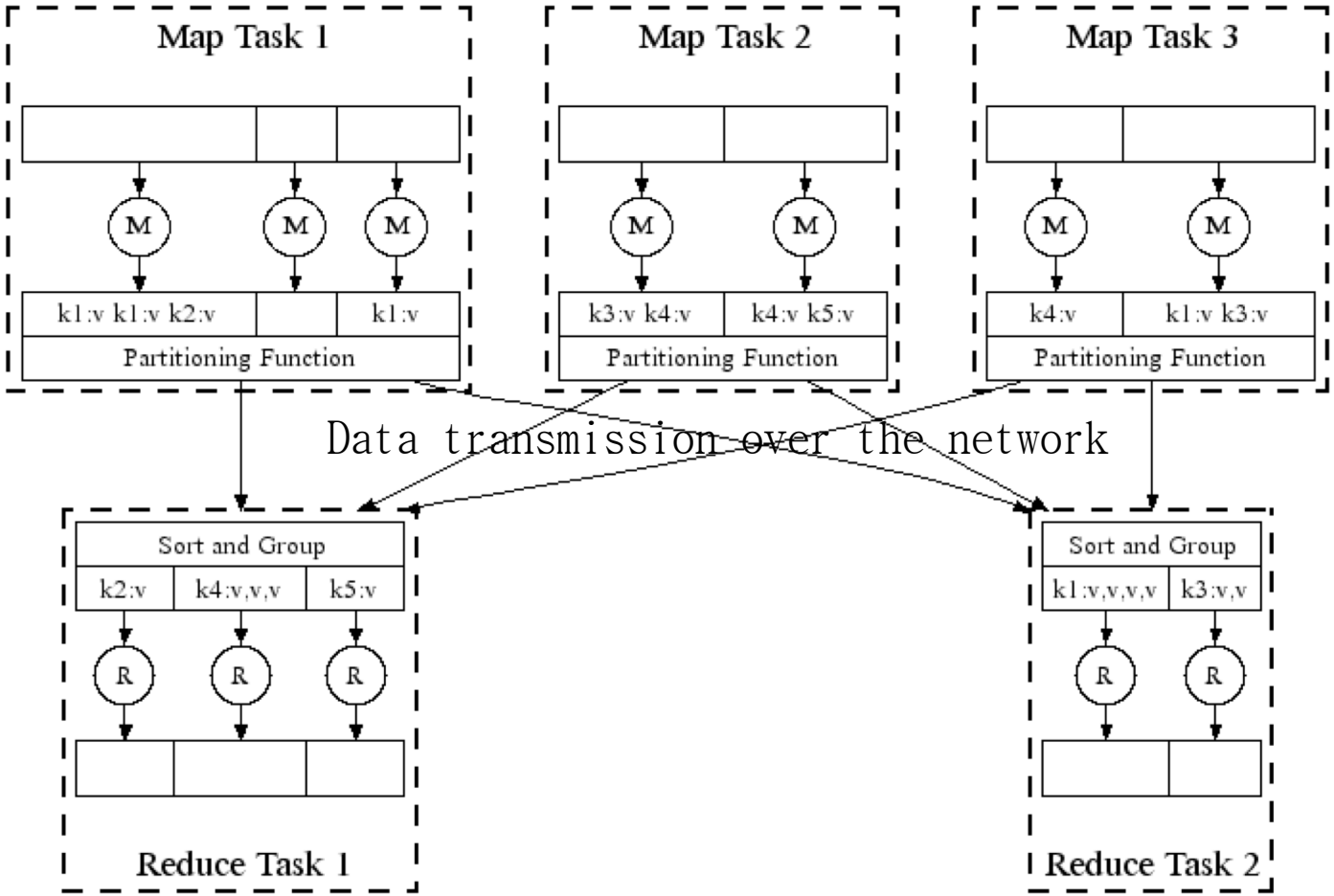
```
public static void main(String[] args) throws Exception{
        JobConf conf = new JobConf(WordCount.class);
        conf.setJobName("wordcount");
        conf.setOutputKeyClass(Text.class);
        conf.setOutputValueClass(IntWritable.class);
        conf.setMapperClass(Map.class);
        conf.setCombinerClass(Reduce.class);
        conf.setReducerClass(Reduce.class);
        conf.setInputFormat(TextInputFormat.class);
        conf.setOutputFormat(TextOutputFormat.class);

        FileInputFormat.setInputPaths(conf, new Path(args[0]));
        FileOutputFormat.setOutputPath(conf, new Path(args[1]));

        RunningJob job = JobClient.runJob(conf);

    }
```

Execution

Original Data - Hello World World Cup



Parallel Execution



Combiners

- Simply it can be said as “local reducer” for cutting down the data transmission over Map to Reduce task
- Often a map task will produce many pairs of the form (k,v1), (k,v2), … for the same key k
  - E.g., popular words in Word Count
- Can save network time by pre-aggregating at mapper
  - combine(k1, list(v1)) → v2
  - Usually same as reduce function
- Works only if reduce function is commutative and associative

Partition Function

- Inputs to map tasks are created by contiguous splits of input file
- For reduce, we need to ensure that records with the same intermediate key end up at the same worker
- System uses a default partition function e.g., hash(key) mod R
- Sometimes useful to override
  - E.g., hash(hostname(URL)) mod R ensures URLs from a host end up in the same output file

WordCount

1. Build word count application
   $ javac -classpath /opt/hadoop-1.0.0-core.jar -d wordcount_classes WordCount.java
2. Make it to archived file
   $ jar -cvf WordCount.jar -C wordcount_classes/ .
3. Setting up input files
4. Execute WordCount Job in MapReduce

```
hadoop@acloud01:~$ hadoop jar WordCount.jar org.myorg.WordCount /user/soc/input /user/soc/output
13/05/14 15:53:50 WARN mapred.JobClient: Use GenericOptionsParser for parsing the arguments. Applications should implement Tool for the same.
13/05/14 15:53:51 INFO mapred.FileInputFormat: Total input paths to process : 2
13/05/14 15:53:51 INFO mapred.JobClient: Running job: job_201305140112_0005
13/05/14 15:53:52 INFO mapred.JobClient:  map 0% reduce 0%
13/05/14 15:54:07 INFO mapred.JobClient:  map 100% reduce 0%
13/05/14 15:54:19 INFO mapred.JobClient:  map 100% reduce 100%
13/05/14 15:54:24 INFO mapred.JobClient: Job complete: job_201305140112_0005
```

5. Execution Result

```
hadoop@acloud01:~$ hadoop fs -cat /user/soc/output/part-00000
Bye     1
Goodbye 1
Hadoop  2
Hello   2
World   2
to      1
```

WordCount

- hadoop@ee6130$ hadoop fs -put test_wc.txt /user/20137011
- hadoop@ee6130$ hadoop jar WordCount.jar WordCount /user/20137011 /user/20137011/wc_result

```
12/05/14 22:06:50 WARN mapred.JobClient: Use GenericOptionsParser for parsing the arguments. Applications should implement Tool for the same.
12/05/14 22:06:50 INFO mapred.FileInputFormat: Total input paths to process : 100
12/05/14 22:06:51 INFO mapred.JobClient: Running job: job_201205142002_0008
12/05/14 22:06:52 INFO mapred.JobClient:  map 0% reduce 0%
12/05/14 22:06:59 INFO mapred.JobClient:  map 1% reduce 0%
12/05/14 22:07:01 INFO mapred.JobClient:  map 3% reduce 0%
12/05/14 22:07:02 INFO mapred.JobClient:  map 6% reduce 0%
12/05/14 22:07:04 INFO mapred.JobClient:  map 7% reduce 0%
12/05/14 22:07:05 INFO mapred.JobClient:  map 9% reduce 0%
12/05/14 22:07:07 INFO mapred.JobClient:  map 11% reduce 0%
12/05/14 22:07:08 INFO mapred.JobClient:  map 14% reduce 0%
12/05/14 22:07:10 INFO mapred.JobClient:  map 16% reduce 0%
12/05/14 22:07:11 INFO mapred.JobClient:  map 18% reduce 3%
12/05/14 22:07:13 INFO mapred.JobClient:  map 20% reduce 3%
12/05/14 22:07:14 INFO mapred.JobClient:  map 22% reduce 3%
12/05/14 22:07:16 INFO mapred.JobClient:  map 24% reduce 3%
12/05/14 22:07:17 INFO mapred.JobClient:  map 26% reduce 3%
12/05/14 22:08:23 INFO mapred.JobClient:  map 100% reduce 100%
.
```

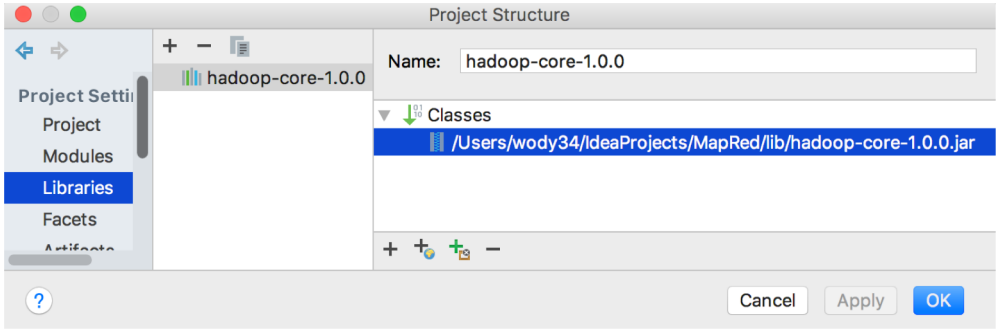
- hadoop@ee6130$ hadoop fs -get /user/20137011/wc_result/part-00000 wc_result
- hadoop@ee6130$ vi wc_result

http://143.248.146.155:50030/jobtracker.jsp

http://143.248.146.155:50070/dfshealth.jsp

Development with IntelliJ

- Download Project File in
  https://github.com/wody34/ee614/raw/master/LabMaterials/MapRed.zip
- [Setup library] Setup project library in project setting



- [Build Project] Build → Build project
- [JAR Generation]Build Artifacts for JAR generation: Build → Build Artifacts → MapRed → Build
  MapRed.jar will generated under out/artifacts/MapRed/MapRed.jar
- [Move executable] Copy MapRed.jar into the machine (143.248.146.155)

- [Execute] hadoop jar MapRed.jar WordCount /user/20137011/test_wc.txt /user/20137011/wc_result
- [Download Result]hadoop fs -get /user/20137011/wc_result wc_result
- [Validate Result] cat wc_result/ part-00000

Inverted Index

- An inverted index is a mapping of words to their location in a set of documents. Most modern search engines utilize some form of an inverted index to process user-submitted queries. In its most basic form, an inverted index is a simple hash table which maps words in the documents to some sort of document identifier. For example, if given the following 2 documents:

> Doc1: Buffalo buffalo Buffalo buffalo buffalo buffalo Buffalo buffalo.
> Doc2: Buffalo are mammals.

- we could construct the following inverted file index:

> Buffalo -> Doc1, Doc2
> buffalo -> Doc1
> buffalo. -> Doc1
> are -> Doc2
> mammals. -> Doc2

Inverted Index

- Setting up input files

```
hadoop@acloud01:~$ hadoop fs -put file0 /user/soc/input
hadoop@acloud01:~$ hadoop fs -put file1 /user/soc/input
hadoop@acloud01:~$ hadoop fs -ls /user/soc/input
Found 2 items
-rw-r--r--   2 hadoop supergroup         22 2013-05-14 15:51 /user/soc/input/file0
-rw-r--r--   2 hadoop supergroup         31 2013-05-14 15:51 /user/soc/input/file1
hadoop@acloud01:~$ hadoop fs -cat /user/soc/input/file0
Hello World Bye World
hadoop@acloud01:~$ hadoop fs -cat /user/soc/input/file1
Hello Hadoop Goodbye to Hadoop
```

- Execute InvertedIndex Job in MapReduce

```
hadoop@acloud01:~/InvertedIndexer$ hadoop jar InvertedIndexer.jar InvertedIndexer /user/soc/input /user/soc/ii_output
13/05/14 17:00:29 WARN mapred.JobClient: Use GenericOptionsParser for parsing the arguments. Applications should implement Tool for the same.
13/05/14 17:00:30 INFO mapred.FileInputFormat: Total input paths to process : 2
13/05/14 17:00:30 INFO mapred.JobClient: Running job: job_201305140112_0006
13/05/14 17:00:31 INFO mapred.JobClient:  map 0% reduce 0%
13/05/14 17:00:44 INFO mapred.JobClient:  map 66% reduce 0%
13/05/14 17:00:46 INFO mapred.JobClient:  map 100% reduce 0%
13/05/14 17:00:56 INFO mapred.JobClient:  map 100% reduce 100%
13/05/14 17:01:01 INFO mapred.JobClient: Job complete: job_201305140112_0006
```

- Execution Result

```
hadoop@acloud01:~/InvertedIndexer$ hadoop fs -cat /user/soc/ii_output/part-00000
bye     file0
goodbye file1
hadoop  file1, file1
hello   file1, file0
to      file1
world   file0, file0
```

Inverted Index

```
public class InvertedIndexer {
    public static class InvertedIndexMapper extends MapReduceBase implements Mapper<LongWritable, Text, Text, Text> {
        private final static Text word = new Text();
        private final static Text location = new Text();

        public void map(LongWritable key, Text val, OutputCollector<Text, Text> output, Reporter reporter) throws IOException {
            FileSplit fileSplit = (FileSplit)reporter.getInputSplit();
            String fileName = fileSplit.getPath().getName();
            location.set(fileName);

            String line = val.toString();
            StringTokenizer itr = new StringTokenizer(line.toLowerCase());
            while (itr.hasMoreTokens()) {
                word.set(itr.nextToken());
                output.collect(word, location);
            }
        }
    }

    public static class InvertedIndexReducer extends MapReduceBase implements Reducer<Text, Text, Text, Text> {
        public void reduce(Text key, Iterator<Text> values, OutputCollector<Text, Text> output, Reporter reporter) throws IOException {
            boolean first = true;
            StringBuilder toReturn = new StringBuilder();
            while (values.hasNext()){
                if (!first)
                    toReturn.append(", ");
                first=false;
                toReturn.append(values.next().toString());
            }
            output.collect(key, new Text(toReturn.toString()));
        }
    }
```

Original Data - file1: Hello World
file 2: World Cup

Hello	file1
World	file1
World	file2
Cup	file2

Parsing text to word and allocate location Value

Hello	file1
World	[file1, file2]
Cup	file2

Grouping by key

Hello	‘file1’
World	‘file1, file2’
Cup	‘file2'

Append string with value array

Inverted Index

```
/**
     * The actual main() method for our program; this is the
     * "driver" for the MapReduce job.
     */
    public static void main(String[] args) {
        JobClient client = new JobClient();
        JobConf conf = new JobConf(InvertedIndexer.class);

        conf.setJobName("InvertedIndexer");

        conf.setOutputKeyClass(Text.class);
        conf.setOutputValueClass(Text.class);

        FileInputFormat.addInputPath(conf, new Path(args[0]));
        FileOutputFormat.setOutputPath(conf, new Path(args[1]));

        conf.setMapperClass(InvertedIndexMapper.class);
        conf.setReducerClass(InvertedIndexReducer.class);

        client.setConf(conf);

        try {
            JobClient.runJob(conf);
        } catch (Exception e) {
            e.printStackTrace();
        }
    }
}
```

PiEstimator

- A Map-reduce program to estimate the value of Pi using quasi-Monte Carlo method
- Mapper: Generate points in a unit square and then count points inside/outside of the inscribed circle of the square
- Reducer: Accumulate points inside/outside results from the mappers
- Let numTotal = numInside + numOutside. The fraction numInside/numTotal is a rational approximation of the value (Area of the circle)/(Area of the square), where the area of the inscribed circle is Pi/4 and the area of unit square is 1
- Then, Pi is estimated value to be 4(numInside/numTotal)

PiEstimator

```
66 public class PiEstimator extends Configured implements Tool {

//tmp directory for input/output
67
68   static private final Path TMP_DIR = new Path(
69       PiEstimator.class.getSimpleName() + "_TMP_3_141592654");


//2-dimensional Halton sequence {H(i)}, where H(i) is a 2-dimensional point and i >= 1 is the index. Halton sequence is used to generate
sample points for Pi estimation.
74
75   private static class HaltonSequence {

//Bases
76
77     static final int[] P = {2, 3};

//Maximum number of digits allowed
78
79     static final int[] K = {63, 40};
80
81     private long index;
82     private double[] x;
83     private double[][] q;
84     private int[][] d;
```

PiEstimator

```
//Initialize to H(startindex), so the sequence begins with H(startindex+1).
88
89    HaltonSequence(long startindex) {
90      index = startindex;
91      x = new double[K.length];
92      q = new double[K.length][];
93      d = new int[K.length][];
94      for(int i = 0; i < K.length; i++) {
95        q[i] = new double[K[i]];
96        d[i] = new int[K[i]];
97      }
98
99      for(int i = 0; i < K.length; i++) {
100       long k = index;
101       x[i] = 0;
102
103       for(int j = 0; j < K[i]; j++) {
104         q[i][j] = (j == 0? 1.0: q[i][j-1])/P[i];
105         d[i][j] = (int)(k % P[i]);
106         k = (k - d[i][j])/P[i];
107         x[i] += d[i][j] * q[i][j];
108       }
109     }
110   }
```

```
//Compute next point. Assume the current point is H(index). Compute H(index+1).
//Returns:
//a 2-dimensional point with coordinates in [0,1)^2
117
118   double[] nextPoint() {
119     index++;
120     for(int i = 0; i < K.length; i++) {
121       for(int j = 0; j < K[i]; j++) {
122         d[i][j]++;
123         x[i] += q[i][j];
124         if (d[i][j] < P[i]) {
125           break;
126         }
127         d[i][j] = 0;
128         x[i] -= (j == 0? 1.0: q[i][j-1]);
129       }
130     }
131     return x;
132   }
133 }
```

PiEstimator

```
//Mapper class for Pi estimation. Generate points in a unit square and then count
points inside/outside of the inscribed circle of the square.
139
140  public static class PiMapper extends MapReduceBase
141    implements Mapper<LongWritable, LongWritable, BooleanWritable,
LongWritable> {

//Map method.
//Parameters:
//offset - samples starting from the (offset+1)th sample.
//size - the number of samples for this map
//out - output {ture->numInside, false->numOutside}
//reporter -
148
149    public void map(LongWritable offset,
150                    LongWritable size,
151                    OutputCollector<BooleanWritable, LongWritable> out,
152                    Reporter reporter) throws IOException {
153
154      final HaltonSequence haltonsequence = new HaltonSequence(offset.get());
155      long numInside = 0L;
156      long numOutside = 0L;
157
158      for(long i = 0; i < size.get(); ) {
159        //generate points in a unit square
160        final double[] point = haltonsequence.nextPoint();
161

//count points inside/outside of the inscribed circle of the square
163        final double x = point[0] - 0.5;
164        final double y = point[1] - 0.5;
165        if (x*x + y*y > 0.25) {
166          numOutside++;
167        } else {
168          numInside++;
169        }
170
171        //report status
172        i++;
173        if (i % 1000 == 0) {
174          reporter.setStatus("Generated " + i + " samples.");
175        }
176      }
177
178      //output map results
179      out.collect(new BooleanWritable(true), new
LongWritable(numInside));
180      out.collect(new BooleanWritable(false), new
LongWritable(numOutside));
181    }
182  }
```

PiEstimator

```
//Reducer class for Pi estimation. Accumulate points inside/outside results from the mappers.
187
188  public static class PiReducer extends MapReduceBase
189    implements Reducer<BooleanWritable, LongWritable,
WritableComparable<?>, Writable> {
190
191    private long numInside = 0;
192    private JobConf conf; //configuration for accessing the file system
194

//Store job configuration.
195
196    @Override
197    public void configure(JobConf job) {
198      conf = job;
199    }
```

```
//Accumulate number of points inside/outside results from the mappers.
//Parameters:
//isInside - Is the points inside?
//values - An iterator to a list of point counts
//output - dummy, not used here.
//reporter -
207
208    public void reduce(BooleanWritable isInside,
209                       Iterator<LongWritable> values,
210                       OutputCollector<WritableComparable<?>, Writable>
output,
211                       Reporter reporter) throws IOException {
212      if (isInside.get()) {
213        for(; values.hasNext(); numInside += values.next().get());
214      } else {
215        for(; values.hasNext(); numOutside += values.next().get());
216      }
217    }

Reduce task done, write output to a file.
221
222    @Override
223    public void close() throws IOException {
224      //write output to a file
225      Path outDir = new Path(TMP_DIR, "out");
226      Path outFile = new Path(outDir, "reduce-out");
227      FileSystem fileSys = FileSystem.get(conf);
228      SequenceFile.Writer writer = SequenceFile.createWriter(fileSys, conf,
229          outFile, LongWritable.class, LongWritable.class,
230          CompressionType.NONE);
231      writer.append(new LongWritable(numInside), new
LongWritable(numOutside));
232      writer.close();
233    }
234  }
```

PiEstimator

```
//Run a map/reduce job for estimating Pi.
//Returns:
//the estimated value of Pi
240
241  public static BigDecimal estimate(int numMaps, long numPoints, JobConf
jobConf
242      ) throws IOException {
243    //setup job conf
244    jobConf.setJobName(PiEstimator.class.getSimpleName());
245
246    jobConf.setInputFormat(SequenceFileInputFormat.class);
247
248    jobConf.setOutputKeyClass(BooleanWritable.class);
249    jobConf.setOutputValueClass(LongWritable.class);
250    jobConf.setOutputFormat(SequenceFileOutputFormat.class);
251
252    jobConf.setMapperClass(PiMapper.class);
253    jobConf.setNumMapTasks(numMaps);
254
255    jobConf.setReducerClass(PiReducer.class);
256    jobConf.setNumReduceTasks(1);
257
258    // turn off speculative execution, because DFS doesn't handle
259    // multiple writers to the same file.
260    jobConf.setSpeculativeExecution(false);
261
262    //setup input/output directories
263    final Path inDir = new Path(TMP_DIR, "in");
264    final Path outDir = new Path(TMP_DIR, "out");
265    FileInputFormat.setInputPaths(jobConf, inDir);
266    FileOutputFormat.setOutputPath(jobConf, outDir);
267
268    final FileSystem fs = FileSystem.get(jobConf);
269    if (fs.exists(TMP_DIR)) {
270      throw new IOException("Tmp directory " + fs.makeQualified(TMP_DIR)
271          + " already exists.  Please remove it first.");
272  }
273      if (!fs.mkdirs(inDir)) {
274        throw new IOException("Cannot create input directory " + inDir);
275      }
276      try {
277        //generate an input file for each map task
279      for(int i=0; i < numMaps; ++i) {
280        final Path file = new Path(inDir, "part"+i);
281        final LongWritable offset = new LongWritable(i * numPoints);
282        final LongWritable size = new LongWritable(numPoints);
283        final SequenceFile.Writer writer = SequenceFile.createWriter(
284            fs, jobConf, file,
285            LongWritable.class, LongWritable.class, CompressionType.NONE);
286        try {
287          writer.append(offset, size);
288        } finally {
289          writer.close();
290        }
291        System.out.println("Wrote input for Map #"+i);
292      }
293
294      //start a map/reduce job
295      System.out.println("Starting Job");
296      final long startTime = System.currentTimeMillis();
297      JobClient.runJob(jobConf);
298      final double duration = (System.currentTimeMillis() - startTime)/1000.0;
299      System.out.println("Job Finished in " + duration + " seconds");
300
301      //read outputs
302      Path inFile = new Path(outDir, "reduce-out");
303      LongWritable numInside = new LongWritable();
304      LongWritable numOutside = new LongWritable();
305      SequenceFile.Reader reader = new SequenceFile.Reader(fs, inFile, jobConf);
306      try {
307        reader.next(numInside, numOutside);
308      } finally {
309        reader.close();
310      }
311
312      //compute estimated value
313      return BigDecimal.valueOf(4).setScale(20)
314          .multiply(BigDecimal.valueOf(numInside.get()))
315          .divide(BigDecimal.valueOf(numMaps))
316          .divide(BigDecimal.valueOf(numPoints));
317    } finally {
318      fs.delete(TMP_DIR, true);
319    }
320  }
```

PiEstimator

```
//Parse arguments and then runs a map/reduce job. Print output in standard out.
//Returns:
//a non-zero if there is an error. Otherwise, return 0.
327
328  public int run(String[] args) throws Exception {
329    if (args.length != 2) {
330      System.err.println("Usage: "+getClass().getName()+" <nMaps> <nSamples>");
331      ToolRunner.printGenericCommandUsage(System.err);
332      return -1;
333    }
334
335    final int nMaps = Integer.parseInt(args[0]);
336    final long nSamples = Long.parseLong(args[1]);
337
338    System.out.println("Number of Maps  = " + nMaps);
339    System.out.println("Samples per Map = " + nSamples);
340
341    final JobConf jobConf = new JobConf(getConf(), getClass());
342    System.out.println("Estimated value of Pi is "
343        + estimate(nMaps, nSamples, jobConf));
344    return 0;
345  }


//main method for running it as a stand alone command.
349
350  public static void main(String[] argv) throws Exception {
351    System.exit(ToolRunner.run(null, new PiEstimator(), argv));
352  }
353}
```

PiEstimator

```
hadoop@acloud01:/opt/hadoop-1.0.0$ hadoop jar hadoop-examples-1.0.0.jar pi 6 1000
Warning: $HADOOP_HOME is deprecated.

Number of Maps  = 6
Samples per Map = 1000
Wrote input for Map #0
Wrote input for Map #1
Wrote input for Map #2
Wrote input for Map #3
Wrote input for Map #4
Wrote input for Map #5
Starting Job
13/05/14 15:06:18 INFO mapred.FileInputFormat: Total input paths to process : 6
13/05/14 15:06:18 INFO mapred.JobClient: Running job: job_201305140112_0002
13/05/14 15:06:19 INFO mapred.JobClient:  map 0% reduce 0%
13/05/14 15:06:32 INFO mapred.JobClient:  map 66% reduce 0%
13/05/14 15:06:38 INFO mapred.JobClient:  map 100% reduce 0%
13/05/14 15:06:41 INFO mapred.JobClient:  map 100% reduce 22%
13/05/14 15:06:50 INFO mapred.JobClient:  map 100% reduce 100%
13/05/14 15:06:55 INFO mapred.JobClient: Job complete: job_201305140112_0002
13/05/14 15:06:55 INFO mapred.JobClient: Counters: 30
13/05/14 15:06:55 INFO mapred.JobClient:   Job Counters
13/05/14 15:06:55 INFO mapred.JobClient:     Launched reduce tasks=1
13/05/14 15:06:55 INFO mapred.JobClient:     SLOTS_MILLIS_MAPS=32176
13/05/14 15:06:55 INFO mapred.JobClient:     Total time spent by all reduces waiting after reserving slots (ms)=0
13/05/14 15:06:55 INFO mapred.JobClient:     Total time spent by all maps waiting after reserving slots (ms)=0
13/05/14 15:06:55 INFO mapred.JobClient:     Launched map tasks=6
13/05/14 15:06:55 INFO mapred.JobClient:     Data-local map tasks=6
13/05/14 15:06:55 INFO mapred.JobClient:     SLOTS_MILLIS_REDUCES=16216
13/05/14 15:06:55 INFO mapred.JobClient:   File Input Format Counters
13/05/14 15:06:55 INFO mapred.JobClient:     Bytes Read=708
13/05/14 15:06:55 INFO mapred.JobClient:   File Output Format Counters
13/05/14 15:06:55 INFO mapred.JobClient:     Bytes Written=97
13/05/14 15:06:55 INFO mapred.JobClient:   FileSystemCounters
13/05/14 15:06:55 INFO mapred.JobClient:     FILE_BYTES_READ=138
13/05/14 15:06:55 INFO mapred.JobClient:     HDFS_BYTES_READ=1440
13/05/14 15:06:55 INFO mapred.JobClient:     FILE_BYTES_WRITTEN=151083
13/05/14 15:06:55 INFO mapred.JobClient:     HDFS_BYTES_WRITTEN=215
13/05/14 15:06:55 INFO mapred.JobClient:   Map-Reduce Framework
13/05/14 15:06:55 INFO mapred.JobClient:     Map output materialized bytes=168
13/05/14 15:06:55 INFO mapred.JobClient:     Map input records=6
13/05/14 15:06:55 INFO mapred.JobClient:     Reduce shuffle bytes=140
13/05/14 15:06:55 INFO mapred.JobClient:     Spilled Records=24
13/05/14 15:06:55 INFO mapred.JobClient:     Map output bytes=108
13/05/14 15:06:55 INFO mapred.JobClient:     Total committed heap usage (bytes)=1341587456
13/05/14 15:06:55 INFO mapred.JobClient:     CPU time spent (ms)=1860
13/05/14 15:06:55 INFO mapred.JobClient:     Map input bytes=144
13/05/14 15:06:55 INFO mapred.JobClient:     SPLIT_RAW_BYTES=732
13/05/14 15:06:55 INFO mapred.JobClient:     Combine input records=0
13/05/14 15:06:55 INFO mapred.JobClient:     Reduce input records=12
13/05/14 15:06:55 INFO mapred.JobClient:     Reduce input groups=12
13/05/14 15:06:55 INFO mapred.JobClient:     Combine output records=0
13/05/14 15:06:55 INFO mapred.JobClient:     Physical memory (bytes) snapshot=1315565568
13/05/14 15:06:55 INFO mapred.JobClient:     Reduce output records=0
13/05/14 15:06:55 INFO mapred.JobClient:     Virtual memory (bytes) snapshot=16225529856
13/05/14 15:06:55 INFO mapred.JobClient:     Map output records=12
Job Finished in 37.665 seconds
Estimated value of Pi is 3.13800000000000000000
```

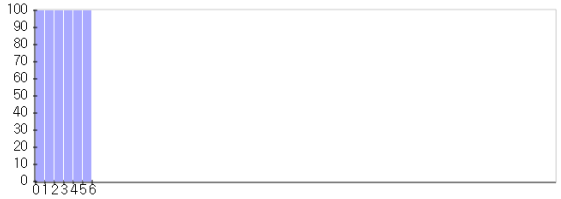
Can compare the error and performance with variation of input arguments
- Number of Map
- Samples per Map

Hadoop job_201305140112_0002 on acloud01

User: hadoop
Job Name: PiEstimator
Job File: hdfs://acloud01:9000/opt/hdfs/mapred/staging/hadoop/.staging/job_201305140112_0002/job.xml
Submit Host: acloud01
Submit Host Address: 143.248.152.16
Job-ACLs: All users are allowed
Job Setup: Successful
Status: Succeeded
Started at: Tue May 14 15:06:18 KST 2013
Finished at: Tue May 14 15:06:54 KST 2013
Finished in: 36sec
Job Cleanup: Successful

Kind	% Complete	Num Tasks	Pending	Running	Complete	Killed	Failed/Killed Task Attempts
map	100.00%	6	0	0	6	0	0 / 0
reduce	100.00%	1	0	0	1	0	0 / 0

Map Completion Graph - close



Reduce Completion Graph - close

Graph reversal

- Given a directed graph as an adjacency list:

  src1: dest11, dest12, …

  src2: dest21, dest22, …

  Ex) 11 → 2, 10
  7 → 8, 11
  8 → 9
  …

- Construct the graph in which all the links are reversed

  dest1: src11, src21, src31, …

  dest2: src12, src22, src32, …

  Ex) 2 ← 11
  10 ← 3, 11
  9 ← 8, 11

Search Application Pseudo Code

- Input: (line number, line) records
- Output: line number whose line value is same as pattern
- Map

  if(line matches pattern)

    output(line)
- Reduce

  Identity function

Sort Application Pseudo Code

- Input: (key[word], value[]) record
- Output: sorted record order by key[word]
- Map
  - Identity function
- Reduce
  - Identity function
- Partitioning function
  - Define partitioning function H() which satisfy if key1 < key2 then H(key1) < H(key2)

Integration Pseudo Code

- Input: (start, end) which define the range of Integration
- Output: Integration result
- Map

```
def map(start, end)
        sum = 0
        for(x=start; x<end; x+=step) :
                sum += f(x) * step
        output(“”, sum)
```

- Reduce

```
def reduce(key, values) :
        output(key, sum(values))
```

Lab 13-2 Requirements

- Implement and test hadoop applications which is introduced in Lab 6
  - Wordcount
  - Inverted Index