hadoop

Tutorial

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Pillar of Fire
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123
Help
ZB
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CONSULTANTS SAY THREE QUINTILLION BYTES OF DATA ARE CREATED EVERY DAY.
DilbertCartoonist@gmail.com
IT COMES FROM EVERYWHERE. IT KNOWS ALL.
ACCORDING TO THE BOOK OF WIKIPEDIA, ITS NAME IS "BIG DATA."
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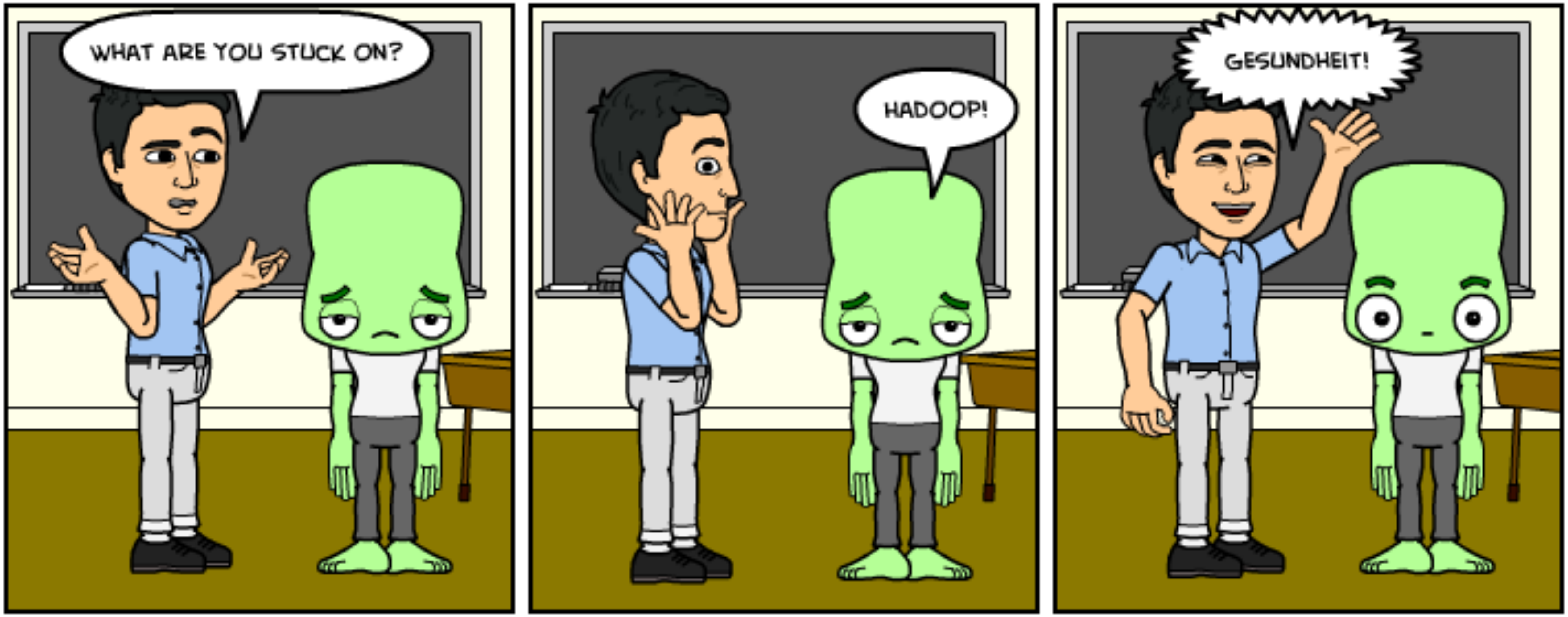
SHHHH! IT HEARS YOU.

http://goo.gl/f2CwNz

https://s3.amazonaws.com/cmj-presentations/hadoop-javaone-2014/index.html

'WHAT IS HADOOP?' BY HADOOPWIZARD



WWW.BITSTRIPS.COM

Introduction

What Is Apache Hadoop?

The Apache™ Hadoop® project develops open-source software for reliable, scalable, distributed computing.

The Apache Hadoop software library is a framework that allows for the distributed processing of large data sets across clusters of computers using simple programming models. It is designed to scale up from single servers to thousands of machines, each offering local computation and storage. Rather than rely on hardware to deliver high-availability, the library itself is designed to detect and handle failures at the application layer, so delivering a highly-available service on top of a cluster of computers, each of which may be prone to failures.

The project includes these modules:

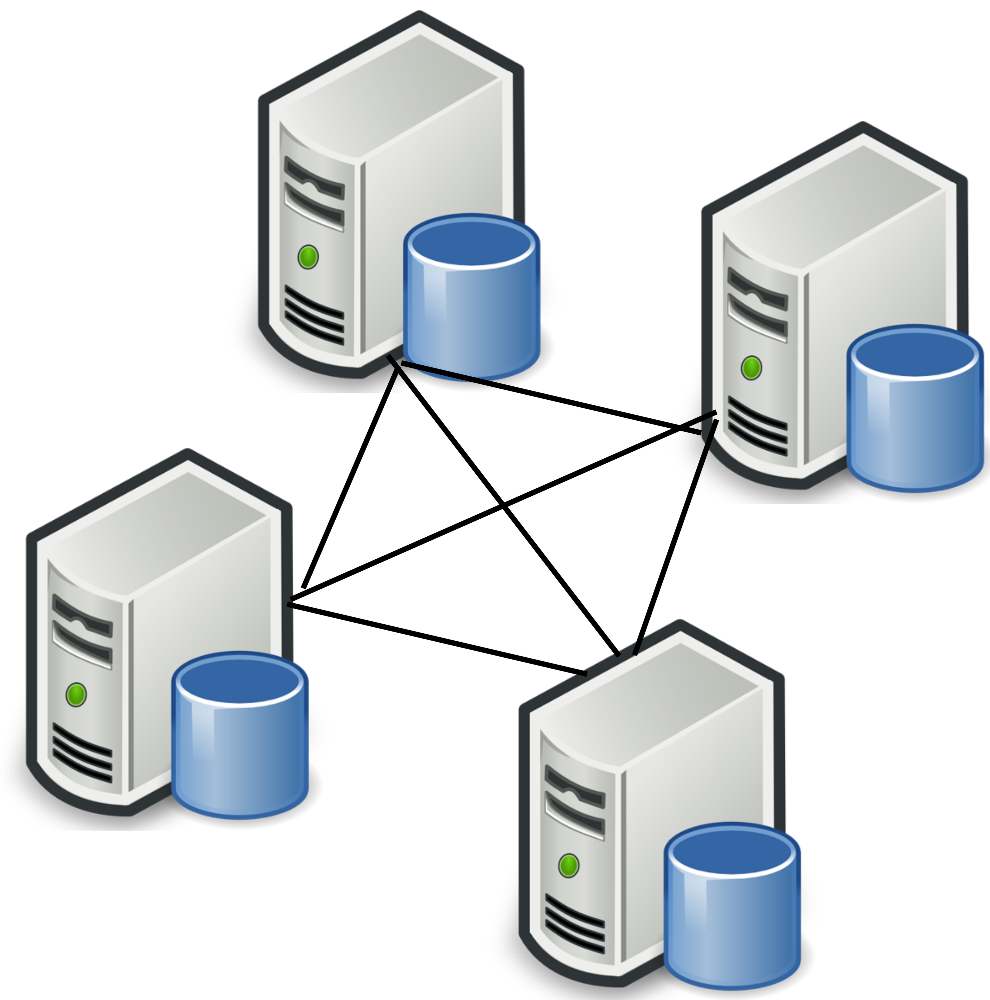
- **Hadoop Common**: The common utilities that support the other Hadoop modules.
- **Hadoop Distributed File System (HDFS™)**: A distributed file system that provides high-throughput access to application data.
- **Hadoop YARN**: A framework for job scheduling and cluster resource management.
- **Hadoop MapReduce**: A YARN-based system for parallel processing of large data sets.

http://hadoop.apache.org/

Scale up

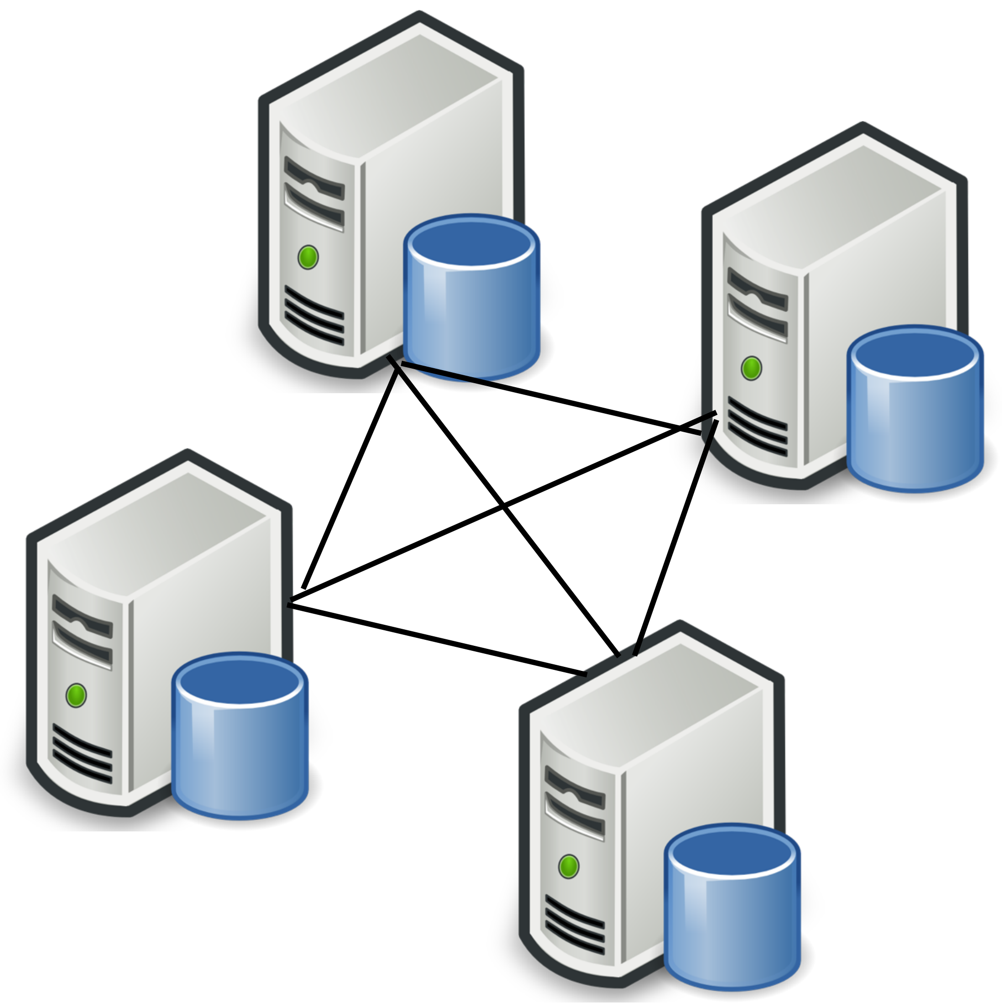
Scale up

Scale up



Scale-up

Scale-out



Hadoop Approach

- scale-out
- share nothing
- expect failure
- smart software, dumb hardware
- move processing, not data
- build applications, not infrastructure

What is Hadoop good for?

Don't use Hadoop - your data isn't that big

<100 mb - Excel
100 mb > 10 gb - Add memory and use Pandas
100 gb > 1 TB - Buy big hard drive and use Postgres
> 5 TB - life sucks consider Hadoop

http://www.chrisstucchio.com/blog/2013/hadoop_hatred.html

if your data fits in RAM
it is not Big Data

Hadoop is an evolving project

⚠ Hadoop is an evolving project ⚠

old api

org.apache.hadoop.mapred

new api

org.apache.hadoop.mapreduce

⚠ Hadoop is an evolving project ⚠

MapReduce 1	MapReduce 2
Classic MapReduce	**YARN**

http://hadoop.apache.org/

http://www.cloudera.com/

http://hortonworks.com/

http://www.mapr.com/

Amazon Elastic MapReduce

Windows® Azure™

accumulo™

FLUME

APACHE HBASE

cassandra

chukwa

KNOX

Spark

HIVE

AVRO™

mahout

Thrift

hadoop

OOZIE

APACHE GIRAPH

APACHE FALCON

WHIRR™

sqoop

HCatalog

Tez

STORM

HUE

Zebra

Owl

S4 distributed stream computing platform

Setup

Hadoop Tutorial

hduser/hduser

/opt/data

Add Hadoop User and Group

```
$ sudo addgroup hadoop
$ sudo adduser --ingroup hadoop hduser
$ sudo adduser hduser sudo

$ su hduser
$ cd ~
```

Install Hadoop

```
$ sudo mkdir -p /opt/hadoop
$ sudo tar vxzf /opt/data/hadoop-2.2.0.tar.gz -C /opt/hadoop
$ sudo chown -R hduser:hadoop /opt/hadoop/hadoop-2.2.0
$ vim .bashrc
```

```
# other stuff
# java variables
export JAVA_HOME=/usr/lib/jvm/java-7-openjdk-amd64

# hadoop variables
export HADOOP_HOME=/opt/hadoop/hadoop-2.2.0
export PATH=$PATH:$HADOOP_HOME/bin
export PATH=$PATH:$HADOOP_HOME/sbin
export HADOOP_MAPRED_HOME=$HADOOP_HOME
export HADOOP_COMMON_HOME=$HADOOP_HOME
export HADOOP_HDFS_HOME=$HADOOP_HOME
export YARN_HOME=$HADOOP_HOME
```

```
$ source .bashrc
$ hadoop version
```

Run Hadoop Job

```
$ hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-2.2.0.jar pi 4 1000
```

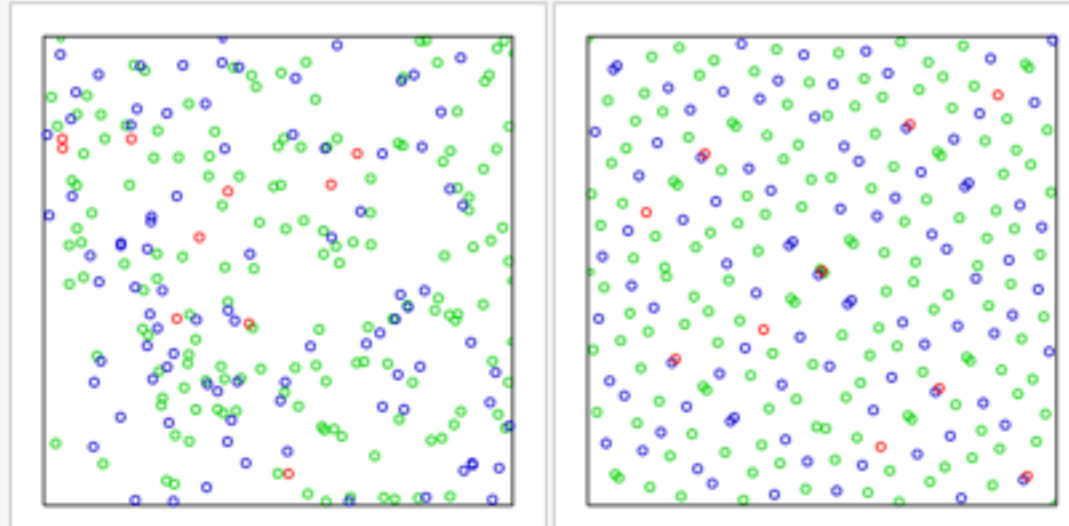
Quasi-Monte Carlo method

From Wikipedia, the free encyclopedia

In numerical analysis, **quasi-Monte Carlo method** is a method for numerical integration and solving some other problems using low-discrepancy sequences (also called quasi-random sequences or sub-random sequences). This is in contrast to the regular Monte Carlo method or Monte Carlo integration, which are based on sequences of pseudorandom numbers.

Monte Carlo and quasi-Monte Carlo methods are stated in a similar way. The problem is to approximate the integral of a function f as the average of the function evaluated at a set of points $x_1, \ldots, x_N$:

$$\int_{[0,1]^s} f(u)\,du \approx \frac{1}{N}\sum_{i=1}^{N} f(x_i).$$



[Pseudorandom sequence] [Low-discrepancy sequence (Sobol sequence)]

256 points from a pseudorandom number source, Halton sequence, and Sobol sequence (red=1,..,10, blue=11,..,100, green=101,..,256). Points from Sobol sequence are more evenly distributed.

Since we are integrating over the s-dimensional unit cube, each x_i is a vector of s elements. The difference between quasi-Monte Carlo and Monte Carlo is the way the x_i are chosen. Quasi-Monte Carlo uses a low-discrepancy sequence such as the Halton sequence, the Sobol sequence, or the Faure sequence, whereas Monte Carlo uses a pseudorandom sequence. The advantage of using low-discrepancy sequences is a faster rate of convergence. Quasi-Monte Carlo has a rate of convergence close to $O(1/N)$, whereas the rate for the Monte Carlo method is $O(N^{-0.5})$.[1]

The Quasi-Monte Carlo method recently became popular in the area of mathematical finance or computational finance.[1] In these areas, high-dimensional numerical integrals, where the integral should be evaluated within a threshold ε, occur frequently. Hence, the Monte Carlo method and the quasi-Monte Carlo method are beneficial in these situations.

```
$ hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-2.2.0.jar
```

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.
bbp: A map/reduce program that uses Bailey-Borwein-Plouffe to compute exact digits of Pi.
dbcount: An example job that count the pageview counts from a database.
distbbp: A map/reduce program that uses a BBP-type formula to compute exact bits of Pi.
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 a quasi-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.
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.
wordmean: A map/reduce program that counts the average length of the words in the input files.
wordmedian: A map/reduce program that counts the median length of the words in the input files.
wordstandarddeviation: A map/reduce program that counts the standard deviation of the length of the words in the input files.

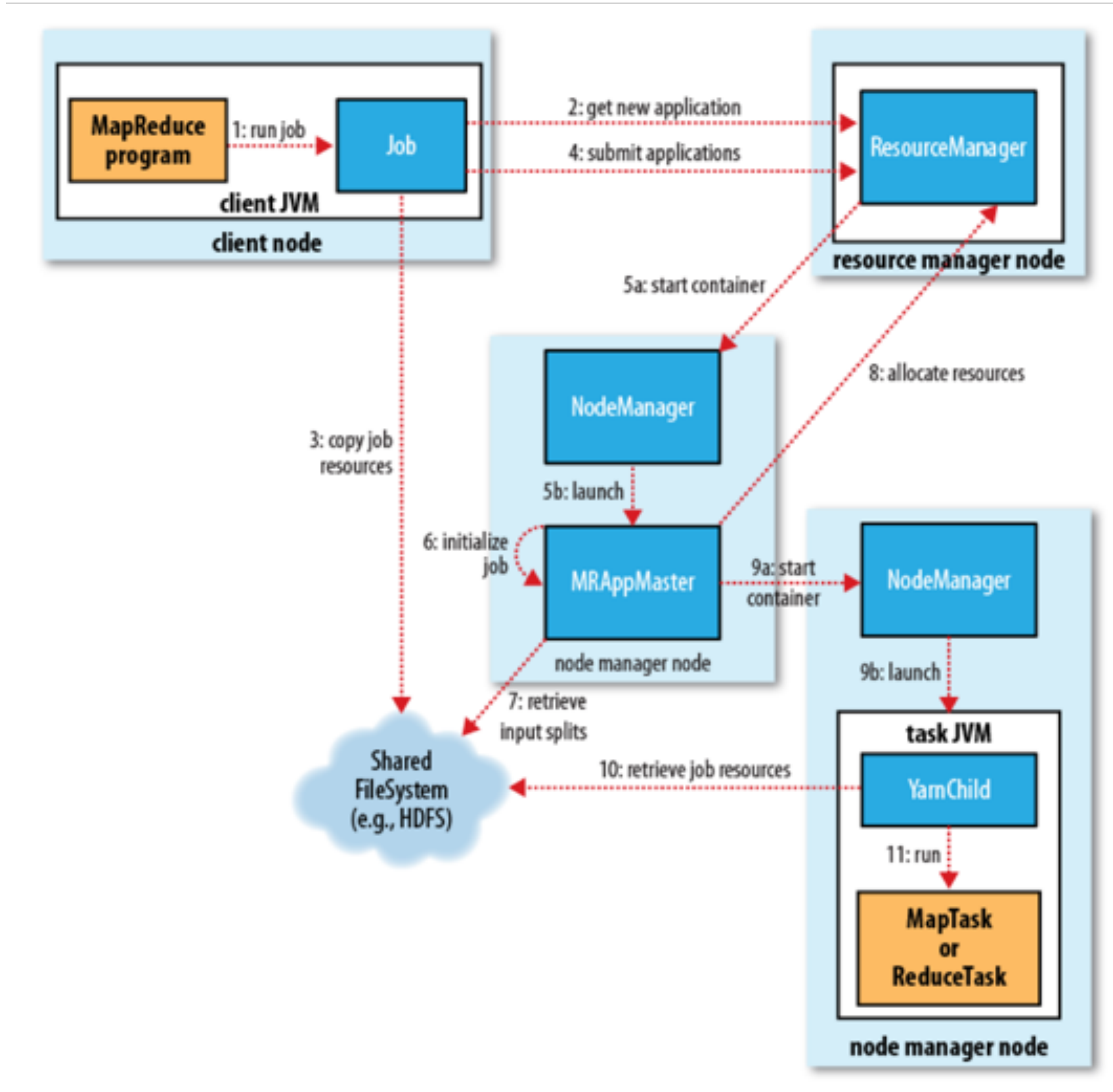
```
$ hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-2.2.0.jar pi
Usage: org.apache.hadoop.examples.QuasiMonteCarlo <nMaps> <nSamples>
```

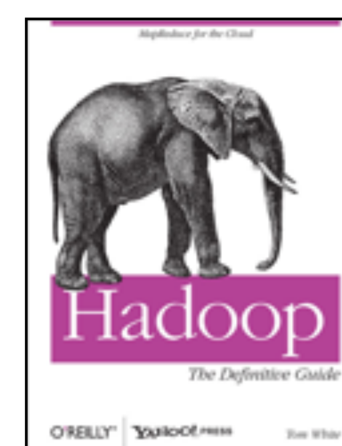
Lab 1

Run Your First Hadoop Job

- Local Standalone mode
- Pseudo-distributed mode
- Fully distributed mode

Hadoop
Pseudo-Distributed


MapReduce program
1: run job
Job
client JVM
client node
2: get new application
4: submit applications
ResourceManager
resource manager node
5a: start container
8: allocate resources
NodeManager
5b: launch
3: copy job resources
6: initialize job
MRAppMaster
node manager node
9a: start container
NodeManager
9b: launch
7: retrieve input splits
task JVM
Shared FileSystem (e.g., HDFS)
10: retrieve job resources
YarnChild
11: run
MapTask or ReduceTask
node manager node


Hadoop
The Definitive Guide
O'REILLY

Configure YARN

```
$ sudo vim etc/hadoop/yarn-site.xml
```

```
<?xml version="1.0"?>
<configuration>

  <property>
    <name>yarn.nodemanager.aux-services</name>
    <value>mapreduce_shuffle</value>
  </property>
  <property>
    <name>yarn.nodemanager.aux-services.mapreduce.shuffle.class</name>
    <value>org.apache.hadoop.mapred.ShuffleHandler</value>
  </property>

</configuration>
```

Configure Map Reduce

```
$ sudo mv etc/hadoop/mapred-site.xml.template etc/hadoop/mapred-site.xml
$ sudo vim etc/hadoop/mapred-site.xml
```

```
<configuration>
  <property>
    <name>mapreduce.framework.name</name>
    <value>yarn</value>
  </property>
</configuration>
```

Configure passwordless login

```
$ ssh-keygen -t rsa -P ''
$ cat ~/.ssh/id_rsa.pub >> ~/.ssh/authorized_keys
$ ssh localhost
$ exit
```

Configure JAVA_HOME

```
$ vim etc/hadoop/hadoop-env.sh
```

```
# other stuff

export JAVA_HOME=/usr/lib/jvm/java-7-openjdk-amd64

# more stuff
```

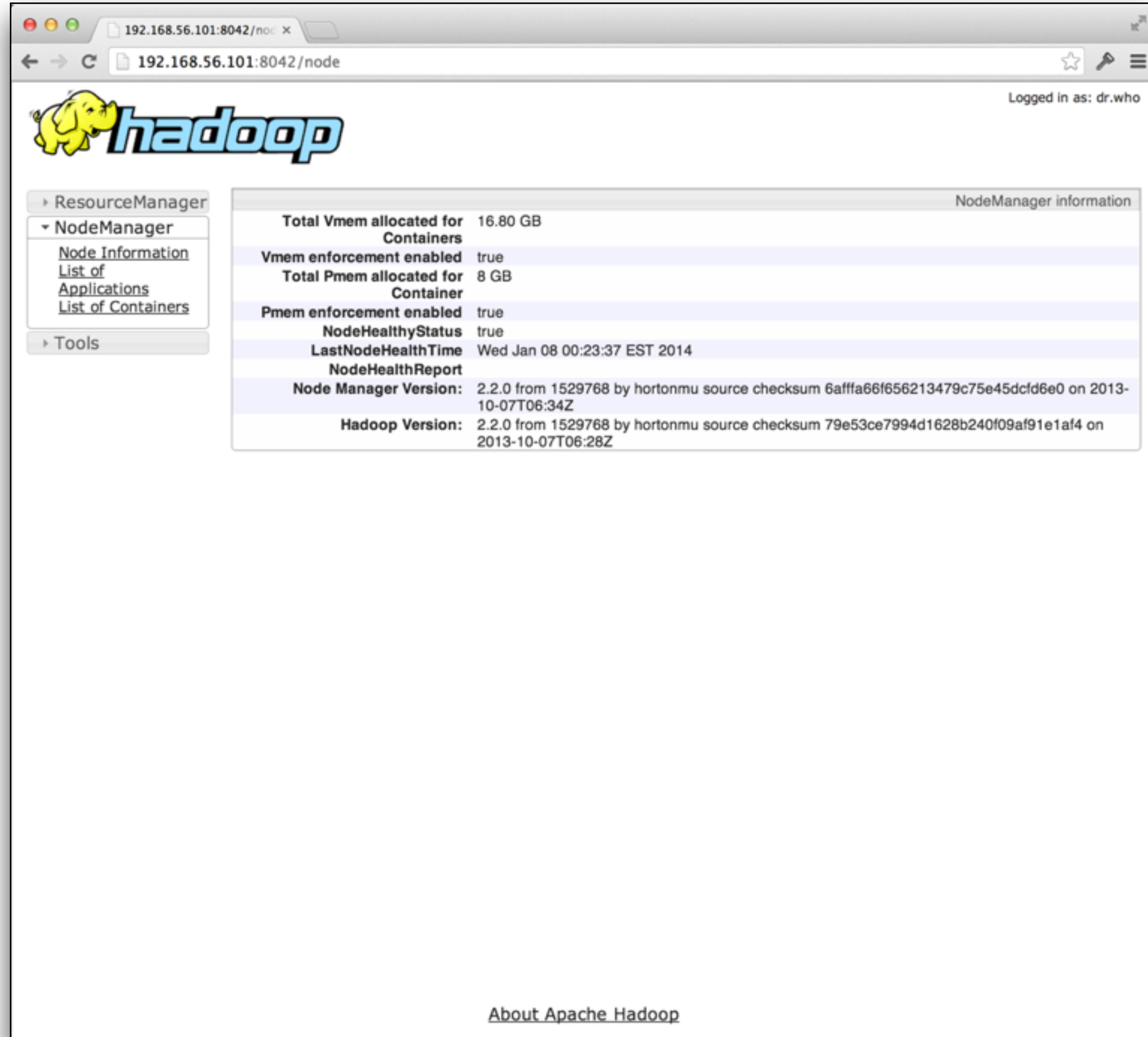
Start YARN

```
$ start-yarn.sh
```

```
$ jps
8355 Jps
8318 NodeManager
8090 ResourceManager
```

Run Hadoop Job

```
$ hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-2.2.0.jar pi 4 1000
```



http://localhost:8042/node

Lab 2

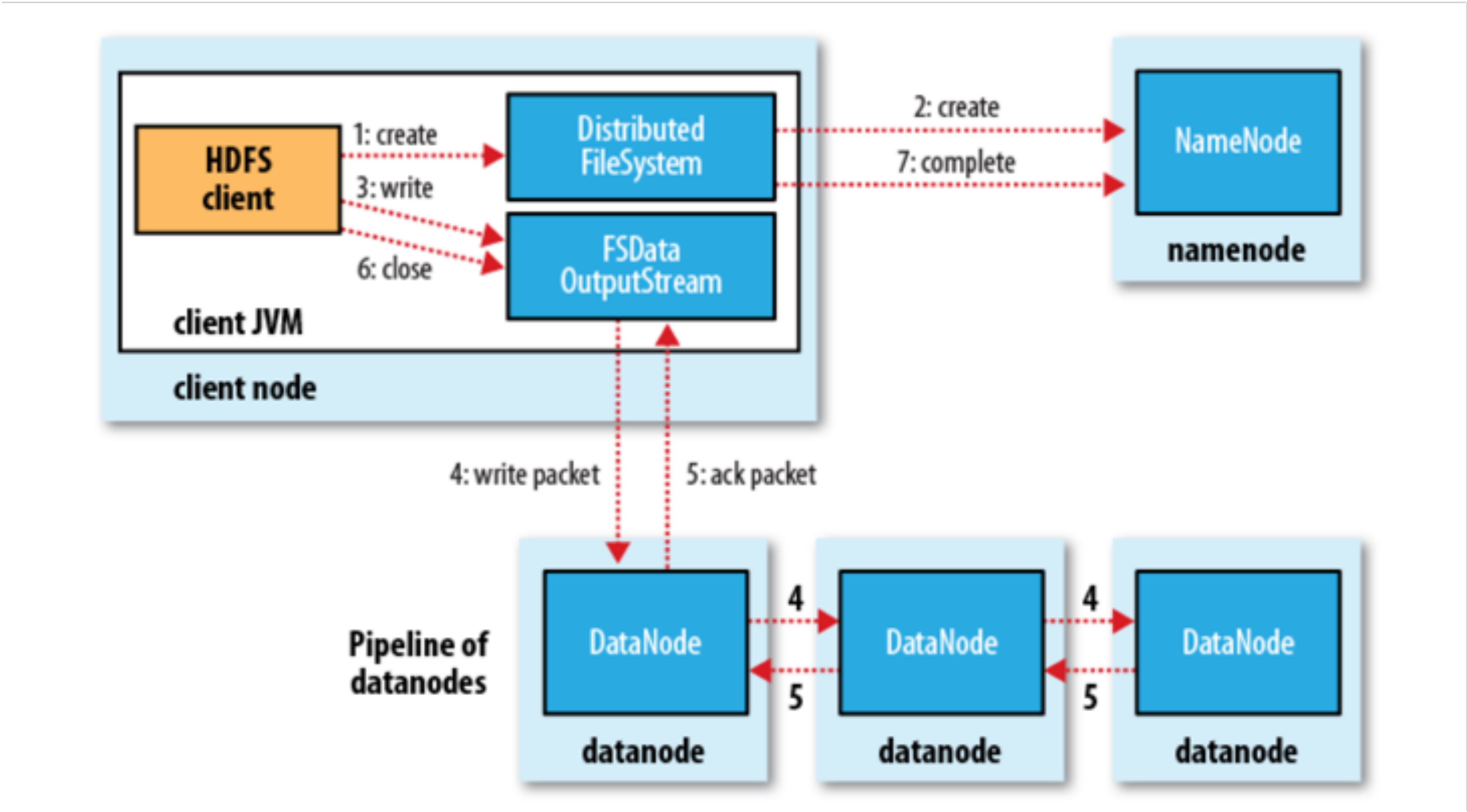
1. Start YARN
2. Run pi job
3. Monitor applications and containers

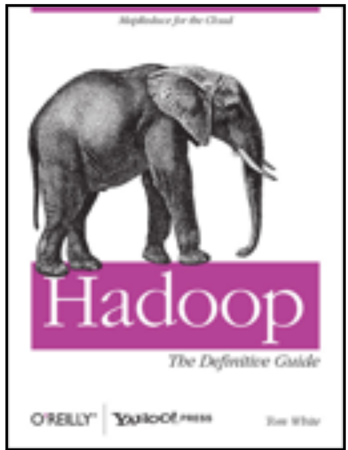
HDFS

POSIX

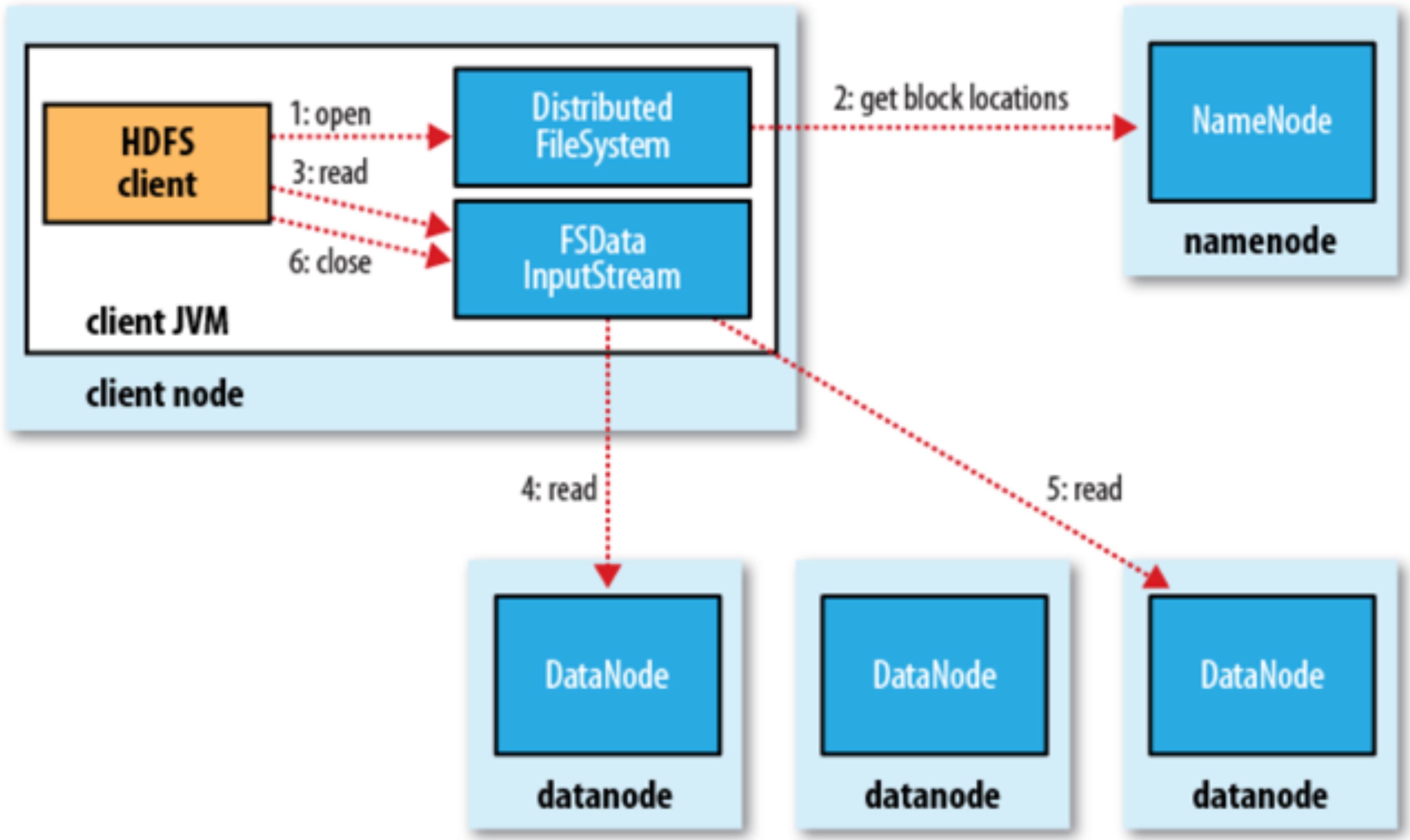
portable operating system interface

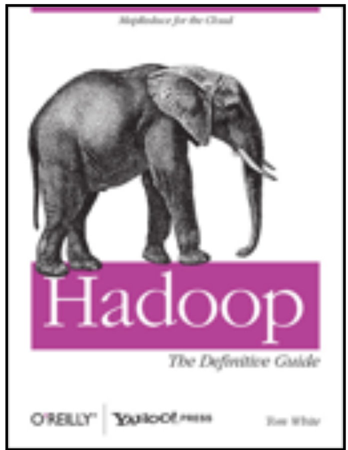
Writing Data





Reading Data





Configure HDFS

```
$ sudo mkdir -p /opt/hdfs/namenode
$ sudo mkdir -p /opt/hdfs/datanode
$ sudo chmod -R 777 /opt/hdfs
$ sudo chown -R hduser:hadoop /opt/hdfs
$ cd /opt/hadoop/hadoop-2.2.0
$ sudo vim etc/hadoop/hdfs-site.xml
```

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl" href="configuration.xsl"?>

<configuration>
  <property>
    <name>dfs.replication</name>
    <value>1</value>
  </property>
  <property>
    <name>dfs.namenode.name.dir</name>
    <value>file:/opt/hdfs/namenode</value>
  </property>
  <property>
    <name>dfs.datanode.data.dir</name>
    <value>file:/opt/hdfs/datanode</value>
  </property>
</configuration>
```

Format HDFS

```
$ hdfs namenode -format
```

Configure Core

```
$ sudo vim etc/hadoop/core-site.xml
```

```
<configuration>
  <property>
    <name>fs.default.name</name>
    <value>hdfs://localhost:9000</value>
  </property>
</configuration>
```

Start HDFS

```
$ start-dfs.sh
```

```
$ jps
6433 DataNode
6844 Jps
6206 NameNode
6714 SecondaryNameNode
```

Use HDFS commands

```
$ hdfs dfs -ls /
$ hdfs dfs -mkdir /books
$ hdfs dfs -ls /
$ hdfs dfs -ls /books
$ hdfs dfs -copyFromLocal /opt/data/moby_dick.txt /books
$ hdfs dfs -cat /books/moby_dick.txt
```

- appendToFile
- cat
- chgrp
- chmod
- chown
- copyFromLocal
- copyToLocal
- count
- cp
- du
- get
- ls
- lsr
- mkdir
- moveFromLocal
- moveToLocal
- mv
- put
- rm
- rmr
- stat
- tail
- test
- text
- touchz

http://hadoop.apache.org/docs/r2.2.0/hadoop-project-dist/hadoop-common/FileSystemShell.html

Hadoop NameNode localh

192.168.56.101:50070/dfshealth.jsp

NameNode 'localhost:9000' (active)

Started:	Tue Jan 07 13:09:59 EST 2014
Version:	2.2.0, 1529768
Compiled:	2013-10-07T06:28Z by hortonmu from branch-2.2.0
Cluster ID:	CID-4a58fa87-92c5-4f73-9a49-3e6fd7d87a69
Block Pool ID:	BP-1094298621-127.0.1.1-1389117580724

Browse the filesystem
NameNode Logs

Cluster Summary

Security is *OFF*
34 files and directories, 16 blocks = 50 total.
Heap Memory used 33.51 MB is 72% of Commited Heap Memory 46.04 MB. Max Heap Memory is 966.69 MB.
Non Heap Memory used 28.40 MB is 95% of Commited Non Heap Memory 29.63 MB. Max Non Heap Memory is 214 MB.

Configured Capacity	:	5.78 GB			
DFS Used	:	2.80 MB			
Non DFS Used	:	3.36 GB			
DFS Remaining	:	2.42 GB			
DFS Used%	:	0.05%			
DFS Remaining%	:	41.79%			
Block Pool Used	:	2.80 MB			
Block Pool Used%	:	0.05%			
DataNodes usages	:	Min %	Median %	Max %	stdev %
		0.05%	0.05%	0.05%	0.00%
Live Nodes	:	1 (Decommissioned: 0)			
Dead Nodes	:	0 (Decommissioned: 0)			
Decommissioning Nodes	:	0			
Number of Under-Replicated Blocks	:	0			

NameNode Journal Status:

Current transaction ID: 384

Journal Manager	State
FileJournalManager(root=/opt/hdfs/namenode)	EditLogFileOutputStream(/opt/hdfs/namenode/current/edits_inprogress_0000000000000000384)

http://localhost:50070/dfshealth.jsp

Lab 3

1. Start HDFS
2. Experiment HDFS commands

    (ls, mkdir, copyFromLocal, cat)

Combine
Hadoop & HDFS

Run Hadoop Job

```
$ hadoop jar share/hadoop/mapreduce/hadoop-mapreduce-examples-2.2.0.jar wordcount /books out
$ hdfs dfs -ls out
$ hdfs dfs -cat out/_SUCCESS
$ hdfs dfs -cat out/part-r-00000
```

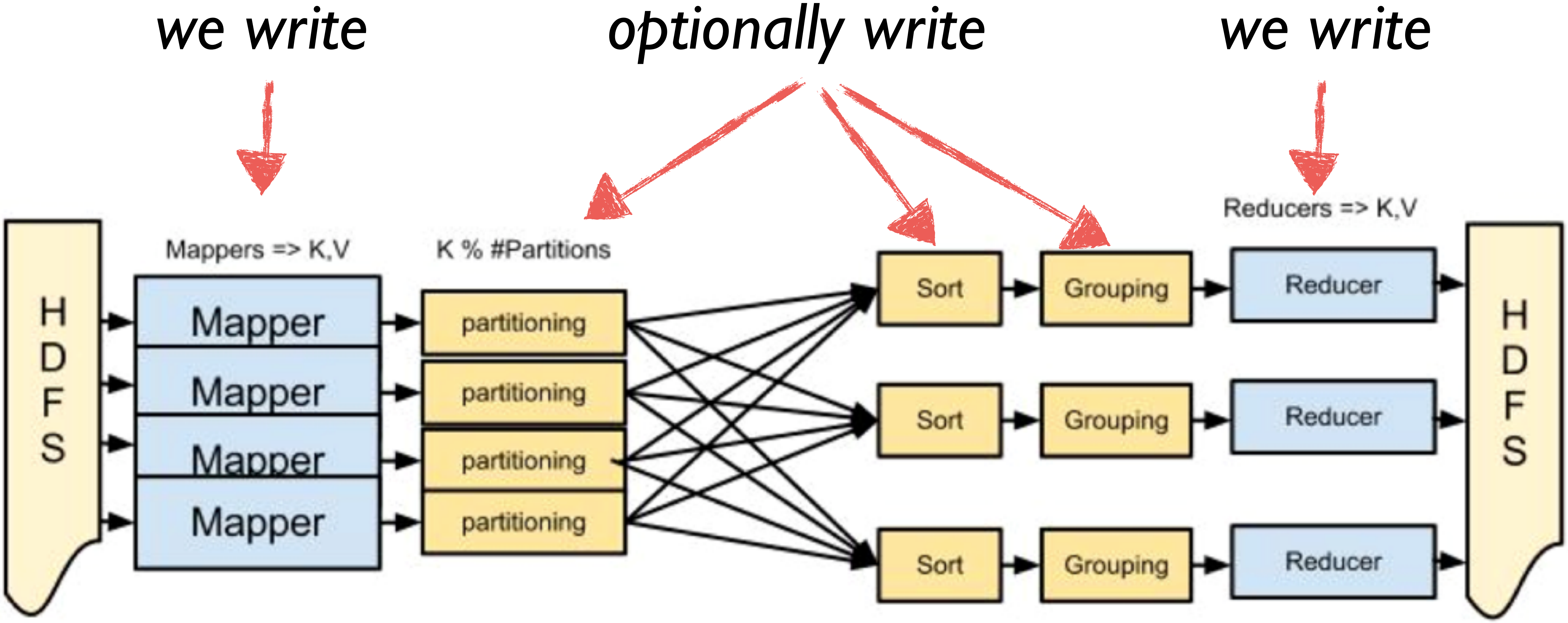
```
young-armed	1
young;	2
younger	2
youngest	1
youngish	1
your	251
your@login	1
yours	5
yours?	1
yourselbs	1
yourself	14
yourself,	5
yourself,"	1
yourself.'	1
yourself;	4
yourself?	1
yourselves	1
yourselves!	3
yourselves,	1
yourselves,"	1
yourselves;	1
youth	5
youth,	2
youth.	1
youth;	1
youthful	1
```

Lab 4

1. Run wordcount job
2. Review output
3. Run wordcount job again with same parameters

Writing Map Reduce Jobs

{K1,V1}



The MapReduce Pipeline

A mapper receives (Key, Value) & outputs (Key, Value)
A reducer receives (Key, Iterable[Value]) and outputs (Key, Value)
Partitioning / Sorting / Grouping provides the Iterable[Value] & Scaling

{K1,V1} ⟶ {K2, List<V2>} ⟶ {K3,V3}

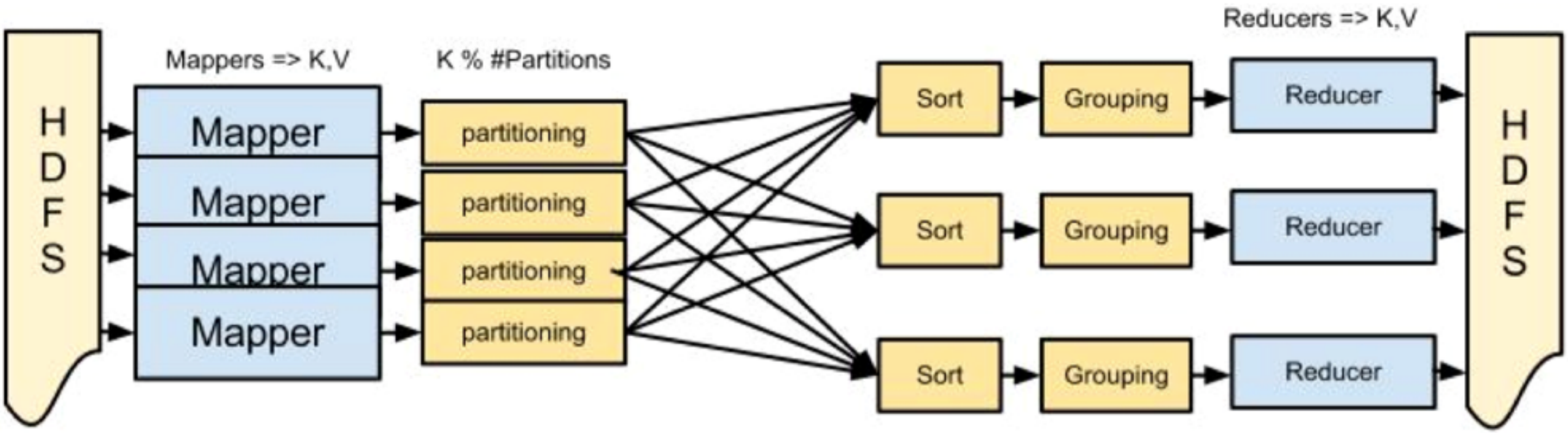
MOBY DICK; OR THE WHALE

By Herman Melville

CHAPTER 1. Loomings.

Call me Ishmael. Some years ago--never mind how long precisely--having little or no money in my purse, and nothing particular to interest me on shore, I thought I would sail about a little and see the watery part of the world. It is a way I have of driving off the spleen and regulating the circulation. Whenever I find myself growing grim about the mouth; whenever it is a damp, drizzly November in my soul; whenever I find myself involuntarily pausing before coffin warehouses, and bringing up the rear of every funeral I meet; and especially whenever my hypos get such an upper hand of me, that it requires a strong moral principle to prevent me from deliberately stepping into the street, and methodically knocking people's hats off--then, I account it high time to get to sea as soon as I can. This is my substitute for pistol and ball. With a philosophical flourish Cato throws himself upon his sword; I quietly take to the ship. There is nothing surprising in this. If they but knew it, almost all men in their degree, some time or other, cherish very nearly the same feelings towards the ocean with me.

There now is your insular city of the Manhattoes, belted round by wharves as Indian isles by coral reefs--commerce surrounds it with her surf. Right and left, the streets take you waterward. Its extreme downtown is the battery, where that noble mole is washed by waves, and cooled by breezes, which a few hours previous were out of sight of land. Look at the crowds of water-gazers there.



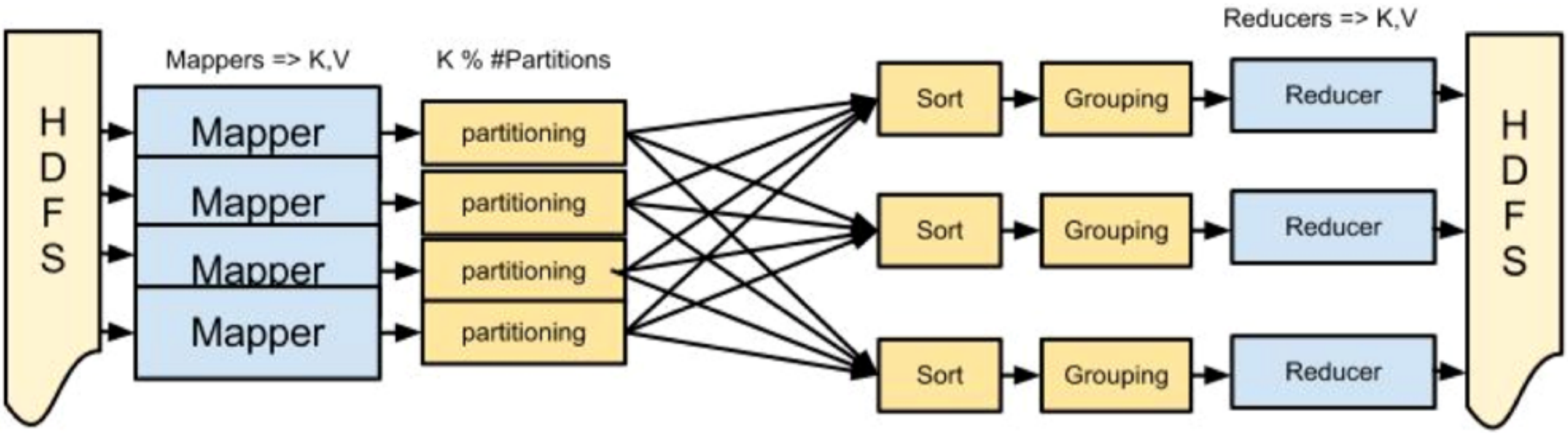
K *V*

```
1  Call me Ishmael. Some years ago--never mind how long precisely--having
2  little or no money in my purse, and nothing particular to interest me on
3  shore, I thought I would sail about a little and see the watery part of
4  the world. It is a way I have of driving off the spleen and regulating
5  the circulation.
```

{K1,V1} ⟶ {K2, List<V2>} ⟶ {K3,V3}

Mapper

```
package com.manifestcorp.hadoop.wc;

import java.io.IOException;

import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.io.Text;
import org.apache.hadoop.mapreduce.Mapper;
                                                 K1     V1    K2      V2
public class WordCountMapper extends Mapper<Object, Text, Text, IntWritable> {

    private static final String SPACE = " ";

    private static final IntWritable ONE = new IntWritable(1);
    private Text word = new Text();
                                 K1        V1
    public void map(Object key, Text value, Context context)
                                throws IOException, InterruptedException {
        String[] words = value.toString().split(SPACE);

        for (String str: words) {
            word.set(str);  K2   V2
            context.write(word, ONE);
        }

    }
}
```



K	V
1	Call me Ishmael. Some years ago--never mind how long precisely--having
2	little or no money in my purse, and nothing particular to interest me on
3	shore, I thought I would sail about a little and see the watery part of
4	the world. It is a way I have of driving off the spleen and regulating
5	the circulation.

map

K	V
Call	1
me	1
Ishmael.	1
Some	1
years	1
ago--never	1
mind	1
how	1
of	1
long	1
little	1
of	1
or	1
of	1

sort

K	V
ago--never	1
Call	1
how	1
Ishmael.	1
me	1
little	1
long	1
mind	1
of	1
of	1
of	1
or	1
Some	1
years	1

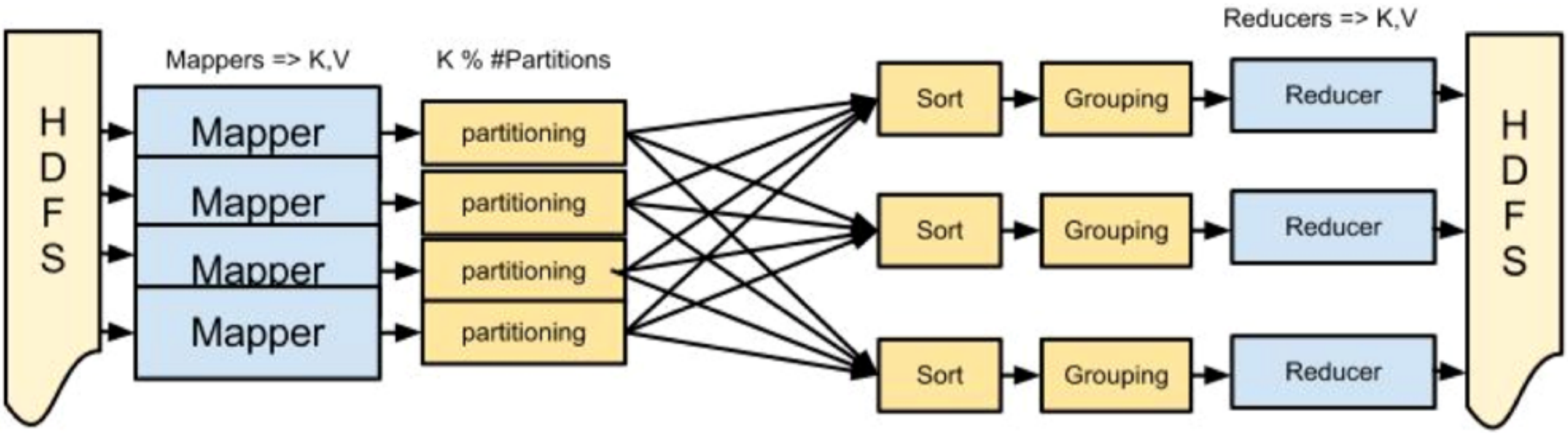
group

K	V
ago--never	1
Call	1
how	1
Ishmael.	1
me	1
little	1
long	1
mind	1
of	1,1,1
or	1
Some	1
years	1

{K1,V1} → {K2, List<V2>} → {K3,V3}

Reducer

```
package com.manifestcorp.hadoop.wc;

import java.io.IOException;

import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.io.Text;
import org.apache.hadoop.mapreduce.Reducer;
                                                   K2     V2          K3    V3
public class WordCountReducer extends Reducer<Text, IntWritable, Text, IntWritable> {
                              K2                          V2
    public void reduce(Text key, Iterable<IntWritable> values, Context context)
                                            throws IOException, InterruptedException {
        int total = 0;

        for (IntWritable value : values) {
            total++;
        }
                      K3                 V3
        context.write(key, new IntWritable(total));
    }
}
```



K	*V*
1	Call me Ishmael. Some years ago--never mind how long precisely--having
2	little or no money in my purse, and nothing particular to interest me on
3	shore, I thought I would sail about a little and see the watery part of
4	the world. It is a way I have of driving off the spleen and regulating
5	the circulation.

map →

K	*V*
Call	1
me	1
Ishmael.	1
Some	1
years	1
ago--never	1
mind	1
how	1
of	1
long	1
little	1
of	1
or	1
of	1

sort →

K	*V*
ago--never	1
Call	1
how	1
Ishmael.	1
me	1
little	1
long	1
mind	1
of	1
of	1
of	1
or	1
Some	1
years	1

group →

K	*V*
ago--never	1
Call	1
how	1
Ishmael.	1
me	1
little	1
long	1
mind	1
of	1,1,1
or	1
Some	1
years	1

reduce →

K	*V*
ago--never	1
Call	1
how	1
Ishmael.	1
me	1
little	1
long	1
mind	1
of	3
or	1
Some	1
years	1

{K1,V1} → {K2, List<V2>} → {K3,V3}

Driver

```java
package com.manifestcorp.hadoop.wc;

import org.apache.hadoop.fs.Path;
import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.io.Text;
import org.apache.hadoop.mapreduce.Job;
import org.apache.hadoop.mapreduce.lib.input.FileInputFormat;
import org.apache.hadoop.mapreduce.lib.output.FileOutputFormat;

public class MyWordCount {

    public static void main(String[] args) throws Exception {

        Job job = new Job();
        job.setJobName("my word count");
        job.setJarByClass(MyWordCount.class);

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

        job.setMapperClass(WordCountMapper.class);
        job.setReducerClass(WordCountReducer.class);

        job.setOutputKeyClass(Text.class);
        job.setOutputValueClass(IntWritable.class);

        System.exit(job.waitForCompletion(true) ? 0 : 1);
    }
}
```

pom.xml

```
<project xmlns="http://maven.apache.org/POM/4.0.0"
         xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
         xsi:schemaLocation="http://maven.apache.org/POM/4.0.0 http://maven.apache.org/xsd/maven-4.0.0.xsd">
  <modelVersion>4.0.0</modelVersion>
  <groupId>com.manifestcorp.hadoop</groupId>
  <artifactId>hadoop-mywordcount</artifactId>
  <version>0.0.1-SNAPSHOT</version>
  <packaging>jar</packaging>

  <properties>
    <hadoop.version>2.2.0</hadoop.version>
  </properties>

  <build>
    <plugins>
      <plugin>
        <artifactId>maven-compiler-plugin</artifactId>
        <version>2.3.2</version>
        <configuration>
          <source>1.6</source>
          <target>1.6</target>
        </configuration>
      </plugin>
    </plugins>
  </build>

  <dependencies>
    <dependency>
      <groupId>org.apache.hadoop</groupId>
      <artifactId>hadoop-client</artifactId>
      <version>${hadoop.version}</version>
      <scope>provided</scope>
    </dependency>
  </dependencies>
</project>
```

Run Hadoop Job

```
$ hadoop jar target/hadoop-mywordcount-0.0.1-SNAPSHOT.jar com.manifestcorp.hadoop.wc.MyWordCount /books out
```

Lab 5

1. Write Mapper class
2. Write Reducer class
3. Write Driver class
4. Build (mvn clean package)
5. Run mywordcount job
6. Review output

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AWS Architecture Center

The AWS Architecture Center is designed to provide you with the necessary guidance and best practices to build highly scalable and reliable applications in the AWS Cloud. These resources will help you understand the AWS platform, its services and features, and will provide architectural guidance for design and implementation of systems that run on the AWS infrastructure.

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AWS Reference Architectures

The flexibility of AWS allows you to design your application architectures the way you like. AWS Reference Architecture Datasheets provide you with the architectural guidance you need in order to build an application that takes full advantage of the AWS cloud. Each datasheet includes a visual representation of the architecture and basic description of how each service is used.

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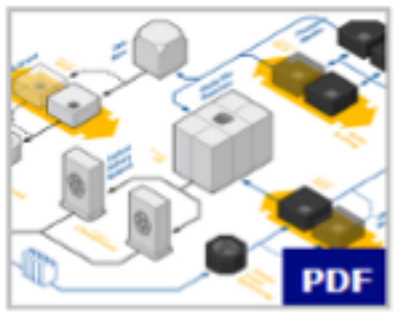

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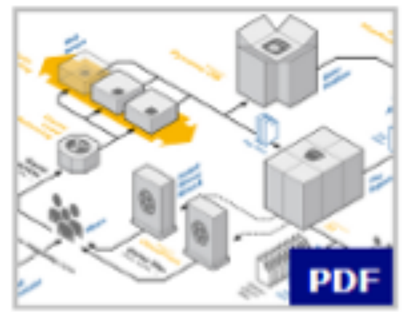

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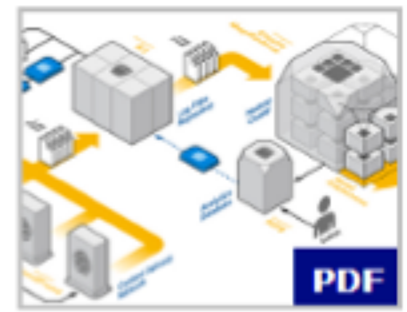

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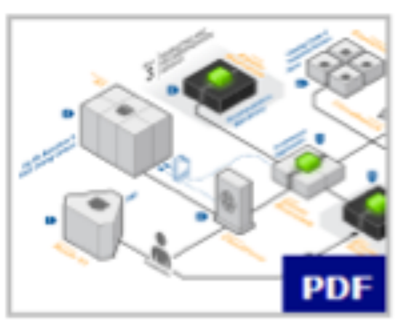

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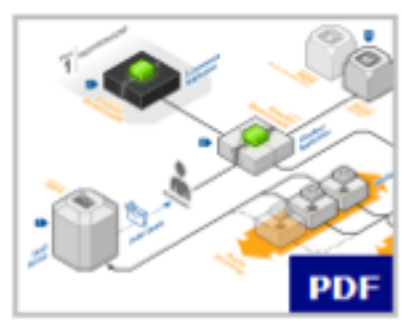
Build elastic Web Front-ends for an e-Commerce website (PDF)



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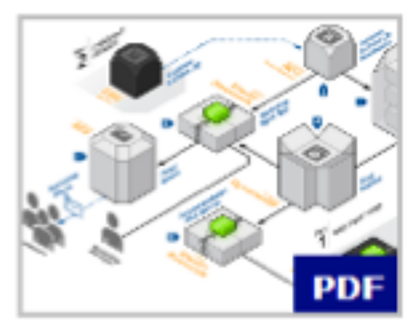
Build highly scalable checkout pipeline for an e-Commerce website (PDF)



E-Commerce Website Part 3: Marketing and Recommendations
Build highly scalable recommendation engine for an e-Commerce website (PDF)

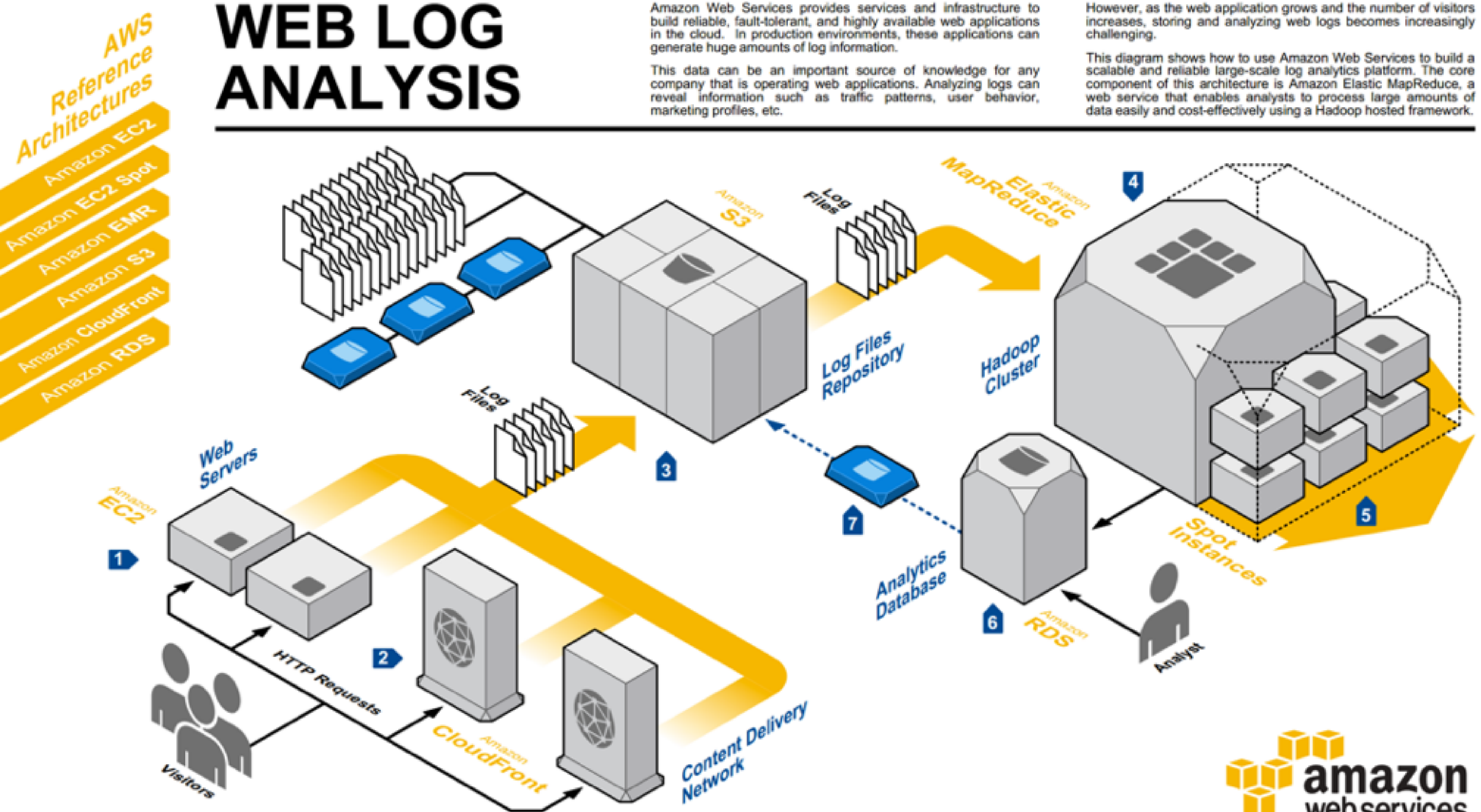
WEB LOG ANALYSIS

Amazon Web Services provides services and infrastructure to build reliable, fault-tolerant, and highly available web applications in the cloud. In production environments, these applications can generate huge amounts of log information.

This data can be an important source of knowledge for any company that is operating web applications. Analyzing logs can reveal information such as traffic patterns, user behavior, marketing profiles, etc.

However, as the web application grows and the number of visitors increases, storing and analyzing web logs becomes increasingly challenging.

This diagram shows how to use Amazon Web Services to build a scalable and reliable large-scale log analytics platform. The core component of this architecture is Amazon Elastic MapReduce, a web service that enables analysts to process large amounts of data easily and cost-effectively using a Hadoop hosted framework.



System Overview

1 The web front-end servers are running on **Amazon Elastic Compute Cloud** (Amazon EC2) instances.

2 **Amazon CloudFront** is a content delivery network that uses low latency and high data transfer speeds to distribute static files to customers. This service also generates valuable log information.

3 Log files are periodically uploaded to **Amazon Simple Storage Service** (Amazon S3), a highly available and reliable data store. Data is sent in parallel from multiple web servers or edge locations.

4 An **Amazon Elastic MapReduce** cluster processes the data set. **Amazon Elastic MapReduce** utilizes a hosted Hadoop framework, which processes the data in a parallel job flow.

5 When **Amazon EC2** has unused capacity, it offers EC2 instances at a reduced cost, called the *Spot Price*. This price fluctuates based on availability and demand. If your workload is flexible in terms of time of completion or required capacity, you can dynamically extend the capacity of your cluster using **Spot Instances** and significantly reduce the cost of running your job flows.

6 Data processing results are pushed back to a relational database using tools like *Apache Hive*. The database can be an **Amazon Relational Database Service** (Amazon RDS) instance. **Amazon RDS** makes it easy to set up, operate, and scale a relational database in the cloud.

7 Like many services, **Amazon RDS** instances are priced on a pay-as-you-go model. After analysis, the database can be backed-up into **Amazon S3** as a database snapshot, and then terminated. The database can then be recreated from the snapshot whenever needed.

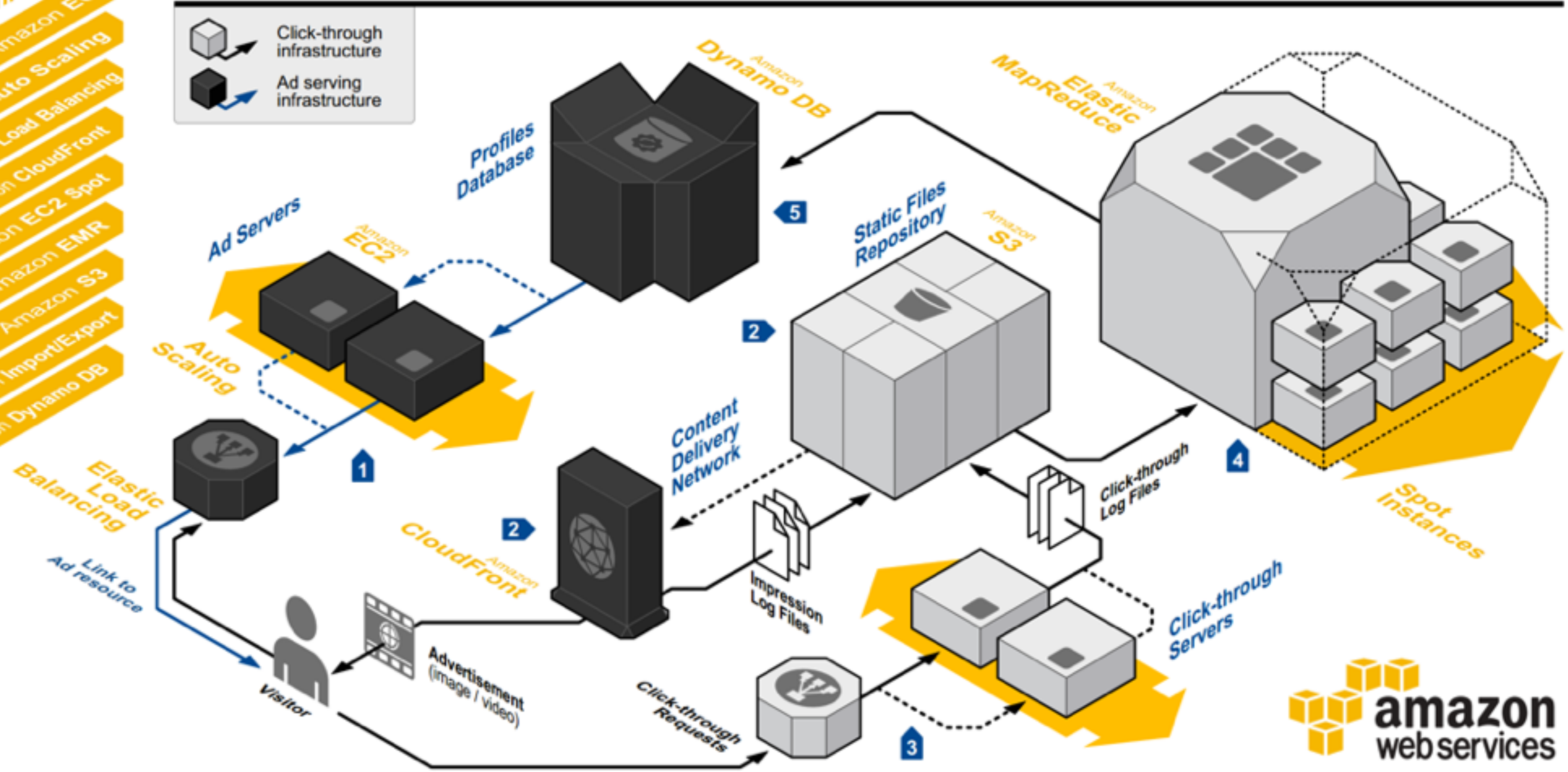
AWS Reference Architectures

Amazon EC2
Auto Scaling
Elastic Load Balancing
Amazon CloudFront
Amazon EC2 Spot
Amazon EMR
Amazon S3
Amazon Import/Export
Amazon Dynamo DB

ADVERTISEMENT SERVING

Internet advertising services need to serve targeted advertising and must do so under limited time. These are just two of multiple technical challenges they face.

Amazon Web Services provides services and infrastructure to build reliable, fault-tolerant, and highly available ad serving platforms in the cloud. In this document, we describe the two main parts of such a system: ad serving infrastructure and click-through collection featuring a data analysis cluster.



System Overview

1 When visitors load a web page, ad servers return a pointer to the ad resource to be displayed. These servers are running on **Amazon Elastic Compute Cloud** (Amazon EC2) instances. They query a data set stored in an **Amazon DynamoDB** table to find relevant ads depending on the user's profile.

2 Ad files are downloaded from **Amazon CloudFront**, a content delivery service with low latency, high data-transfer speeds, and no commitments. Log information from displayed ads is stored on **Amazon Simple Storage Service** (Amazon S3), a highly available data store.

3 The click-through servers are a group of **Amazon EC2** instances dedicated to collecting click-through data. This information is contained in the log files of the click-through web servers, which are periodically uploaded to **Amazon S3**.

4 Ad impression and click-through data are retrieved and processed by an **Amazon Elastic MapReduce** cluster using a hosted Hadoop framework to process the data in a parallel job flow. The cluster's capacity can be dynamically extended using **Spot Instances** to reduce the processing time and the cost of running the job flow.

5 Data processing results are pushed back into **Amazon DynamoDB**, a fully managed NoSQL database service that provides fast and predictable performance with seamless scalability. **Amazon DynamoDB** tables can store and retrieve any amount of data, and serve any level of request traffic, both of which are specific requirements for storing and quickly retrieving visitors' profile information.

The high availability and fast performance of **Amazon DynamoDB** enable ad server front-ends to serve requests with predictable response time, even with high traffic volumes or large profile's data sets.

AWS Reference Architectures

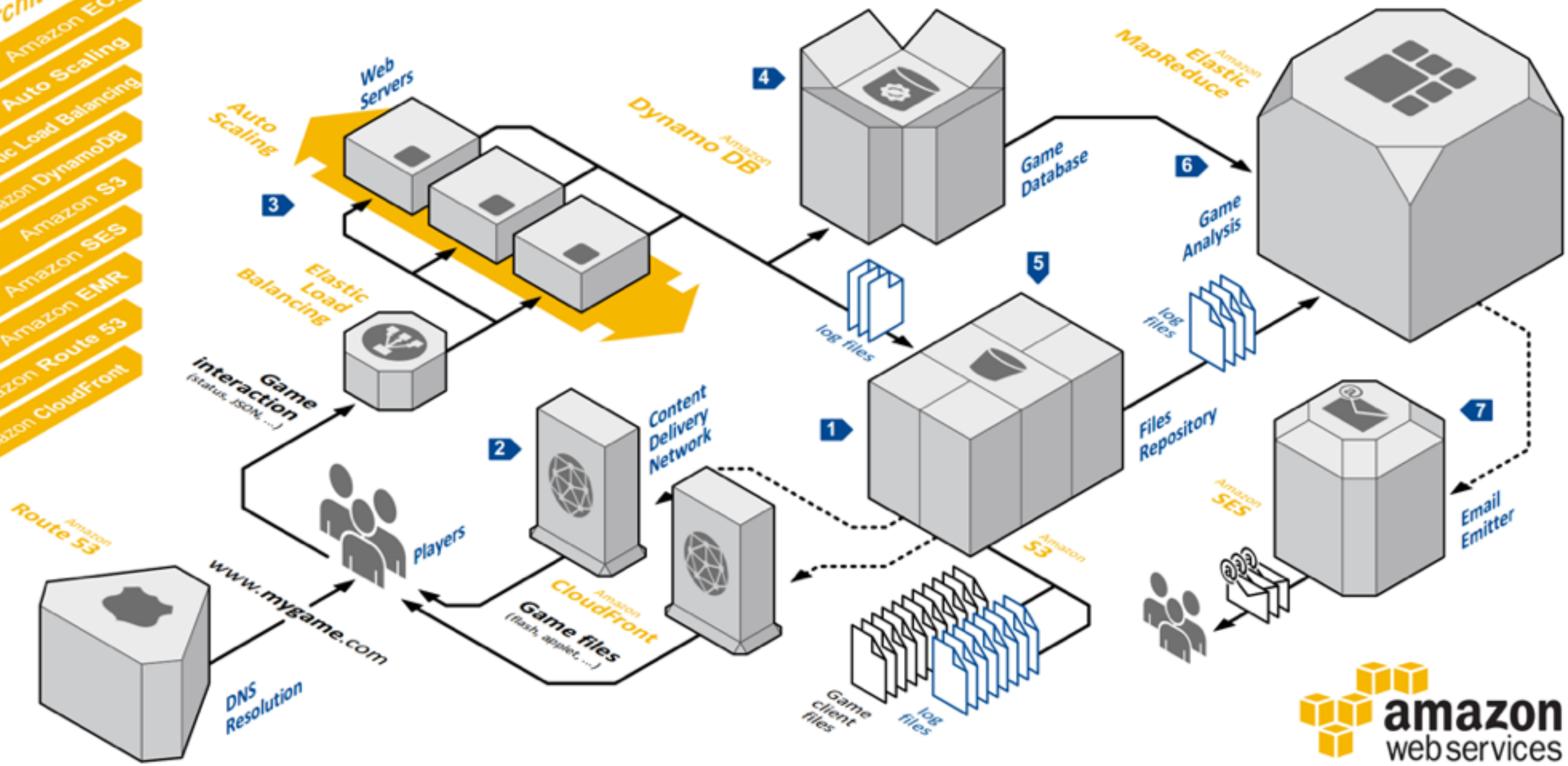
Amazon EC2
Auto Scaling
Elastic Load Balancing
Amazon DynamoDB
Amazon S3
Amazon SES
Amazon EMR
Amazon Route 53
Amazon CloudFront

ONLINE GAMES

Online games back-end infrastructures can be challenging to maintain and operate. Peak usage periods, multiple players, and high volumes of write operations are some of the most common problems that operations teams face.

But the most difficult challenge is ensuring flexibility in the scale of that system. A popular game might suddenly receive millions of users in a matter of hours, yet it must continue to provide a satisfactory player experience. Amazon Web Services provides different tools and services that can be used for building online games that scale under high usage traffic patterns.

This document presents a cost-effective online game architecture featuring automatic capacity adjustment, a highly available and high-speed database, and a data processing cluster for player behavior analysis.



System Overview

1 Browser games can be represented as client-server applications. The client generally consists of static files, such as images, sounds, flash applications, or Java applets. Those files are hosted on **Amazon Simple Storage Service** (Amazon S3), a highly available and reliable data store.

2 As the user base grows and becomes more geographically distributed, a high-performance cache like **Amazon CloudFront** can provide substantial improvements in latency, fault tolerance, and cost. By using **Amazon S3** as the origin server for the **Amazon CloudFront** distribution, the game infrastructure benefits from fast network data transfer rates and a simple publishing/caching workflow.

3 Requests from the game application are distributed by **Elastic Load Balancing** to a group of web servers running on **Amazon Elastic Compute Cloud** (Amazon EC2) instances. **Auto Scaling** automatically adjusts the size of this group, depending on rules like network load, CPU usage, and so on.

4 Player data is persisted on **Amazon DynamoDB**, a fully managed NoSQL database service. As the player population grows, **Amazon DynamoDB** provides predictable performance with seamless scalability.

5 Log files generated by each web server are pushed back into **Amazon S3** for long-term storage.

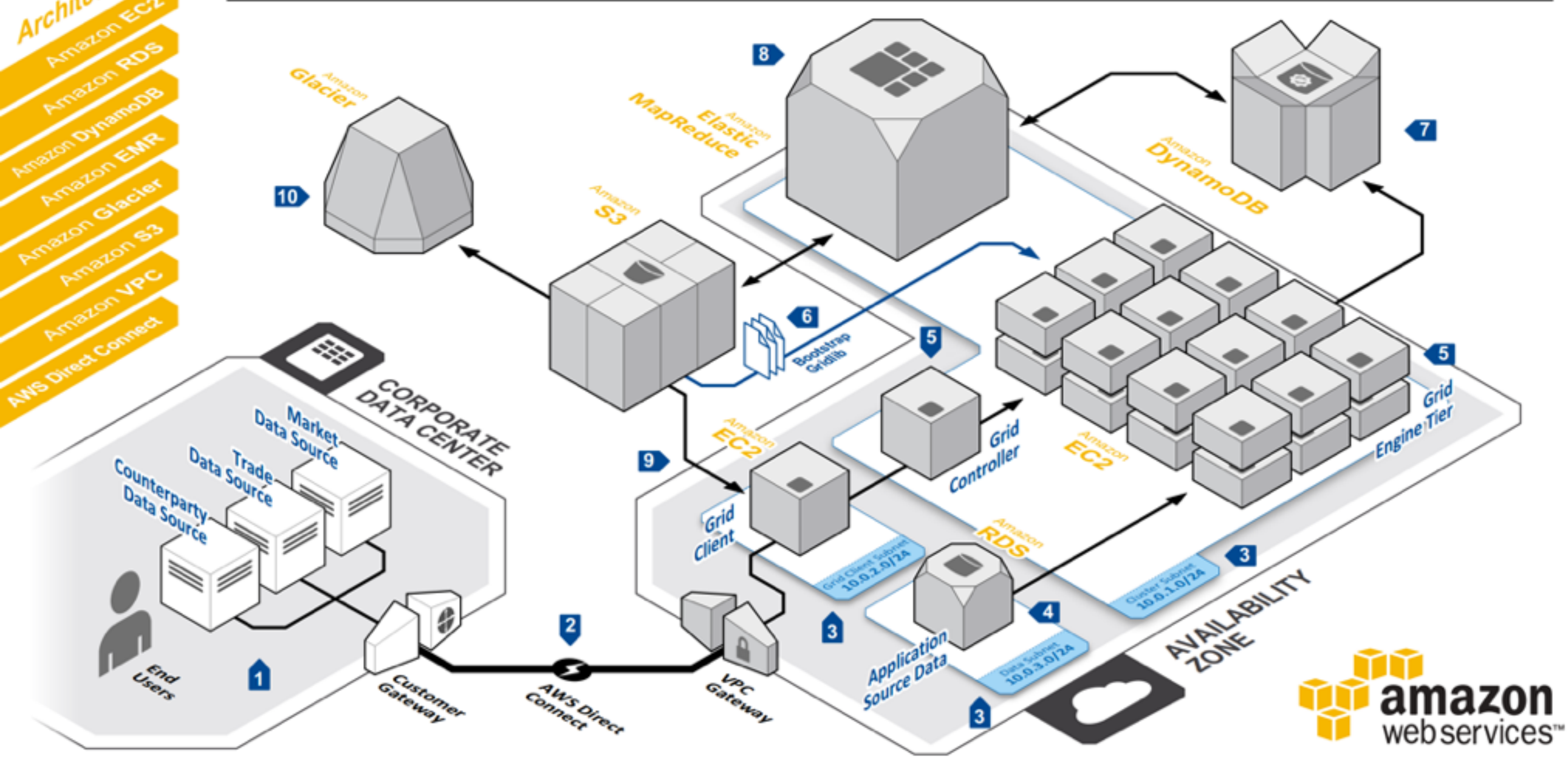
6 Managing and analyzing high data volumes produced by online games platforms can be challenging. **Amazon Elastic MapReduce** (Amazon EMR) is a service that processes vast amounts of data easily. Input data can be retrieved from web server logs stored on **Amazon S3** or from player data stored in **Amazon DynamoDB** tables to run analytics on player behavior, usage patterns, etc. Those results can be stored again on **Amazon S3**, or inserted in a relational database for further analysis with classic business intelligence tools.

7 Based on the needs of the game, **Amazon Simple Email Service** (Amazon SES) can be used to send email to players in a cost-effective and scalable way.

AWS Reference Architectures

FINANCIAL SERVICES GRID COMPUTING

Financial services grid computing on the cloud provides dynamic scalability and elasticity for operation when compute jobs are required, and utilizing services for aggregation that simplify the development of grid software.
On demand provisioning of hardware, and template driven deployment, combined with low latency access to existing on-premise data sources make AWS a powerful platform for high performance grid computing systems.



System Overview

1 Date sources for market, trade, and counterparties are installed on startup from on premise data sources, or from **Amazon Simple Storage Service** (Amazon S3).

2 **AWS DirectConnect** can be used to establish a low latency and reliable connection between the corporate data center site and AWS, in 1 to 10Gbit increments. For situations with lower bandwidth requirements, a VPN connection to the **VPC Gateway** can be established.

3 Private subnetworks are specifically created for customer source data, compute grid clients, and the grid controller and engines.

4 Application and corporate data can be securely stored in the cloud using the **Amazon Relational Database Service** (Amazon RDS).

5 Grid controllers and grid engines are running **Amazon Elastic Compute Cloud** (Amazon EC2) instances started on demand from **Amazon Machine Images** (AMIs) that contain the operating system and grid software.

6 Static data such as holiday calendars and QA libraries and additional gridlib bootstrapping data can be downloaded on startup by grid engines from **Amazon S3**.

7 Grid engine results can be stored in **Amazon DynamoDB**, a fully managed database providing configurable read and write throughput, allowing scalability on demand.

8 Results in **Amazon DynamoDB** are aggregated using a map/reduce job in **Amazon Elastic MapReduce** (Amazon EMR) and final output is stored in **Amazon S3**.

9 The compute grid client collects aggregate results from **Amazon S3**.

10 Aggregate results can be archived using **Amazon Glacier**, a low-cost, secure, and durable storage service.

AWS Reference Architectures

Amazon EMR

Amazon S3

AWS Elastic Beanstalk

Amazon RDS

Amazon DynamoDB

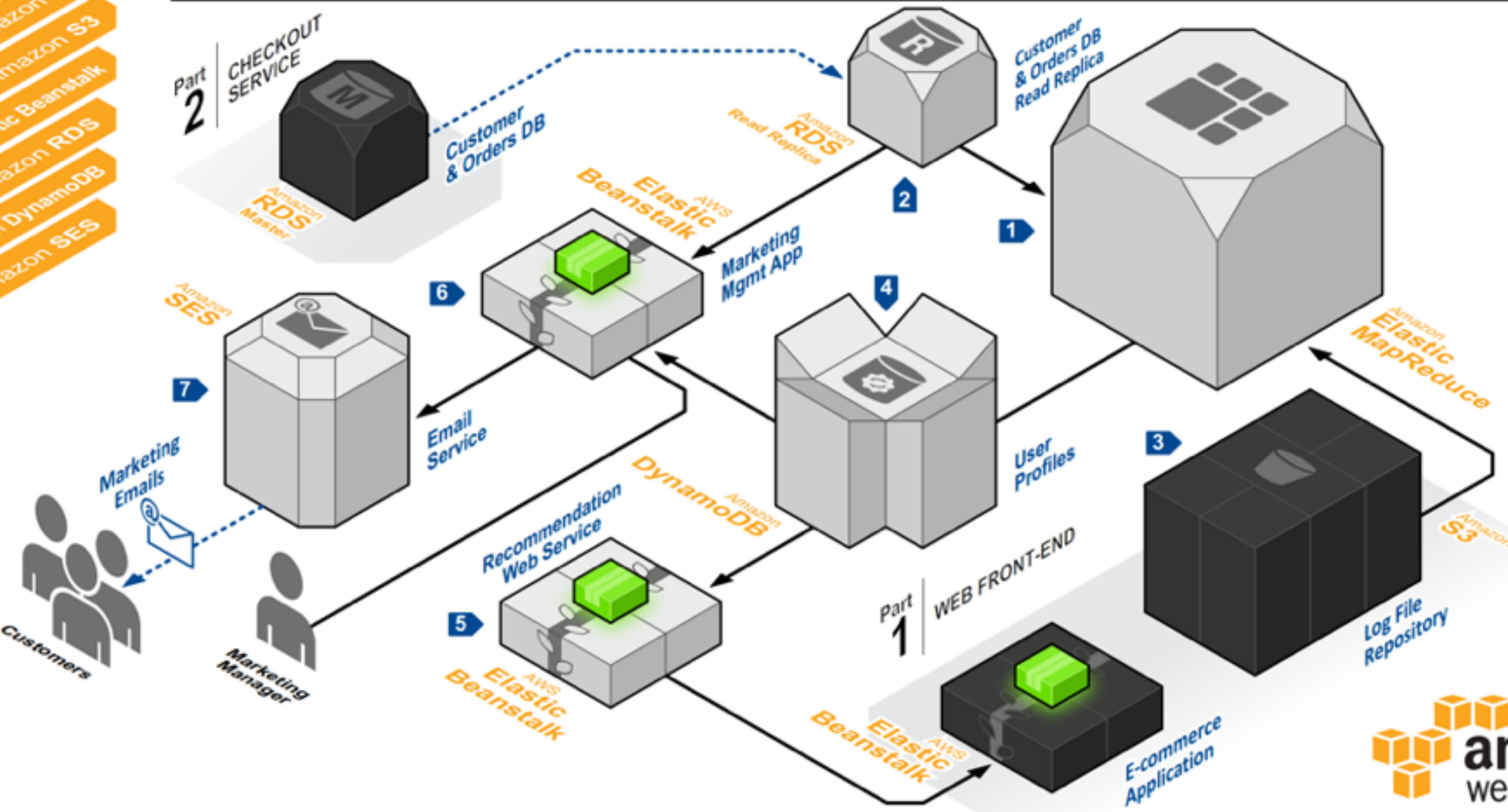
Amazon SES

E-COMMERCE WEBSITE

PART 3: MARKETING & RECOMMENDATIONS

With Amazon Web Services, you can build a recommendation and marketing service to manage targeted marketing campaigns and offer personalized product recommendations to customers who are browsing your e-commerce site.
In order to build such a service, you have to process very large amounts of data from multiple data sources. The resulting user profile information has to be available to deliver real-time product recommendations on your e-commerce website.

The insights that you gain about your customers can also be used to manage personalized marketing campaigns targeted at specific customer segments.
With the tools that AWS provides, you can build highly scalable recommendation services that can be consumed by different channels, such as dynamic product recommendations on the e - commerce website or targeted email campaigns for your customers.



amazon web services™

System Overview

1 **Amazon Elastic MapReduce** (Amazon EMR) is a hosted Hadoop framework that runs on Amazon Elastic Compute Cloud (Amazon EC2) instances. It aggregates and processes user data from server log files and from the customer´s purchase history.

2 An **Amazon Relational Database Services** (Amazon RDS) Read Replica of customer and order databases is used by Amazon EMR to compute user profiles and by **Amazon Simple Email Service** (Amazon SES) to send targeted marketing emails to customers.

3 Log files produced by the e-commerce web front end have been stored on **Amazon Simple Storage Service** (Amazon S3) and are consumed by the Amazon EMR cluster to compute user profiles.

4 User profile information generated by the Amazon EMR cluster is stored in **Amazon DynamoDB**, a scalable, high-performance managed NoSQL database that can serve recommendations with low latency.

5 A recommendation web service used by the web front end is deployed by **AWS Elastic Beanstalk**. This service uses the profile information stored on Amazon DynamoDB to provide personalized recommendations to be shown on the e-commerce web front end.

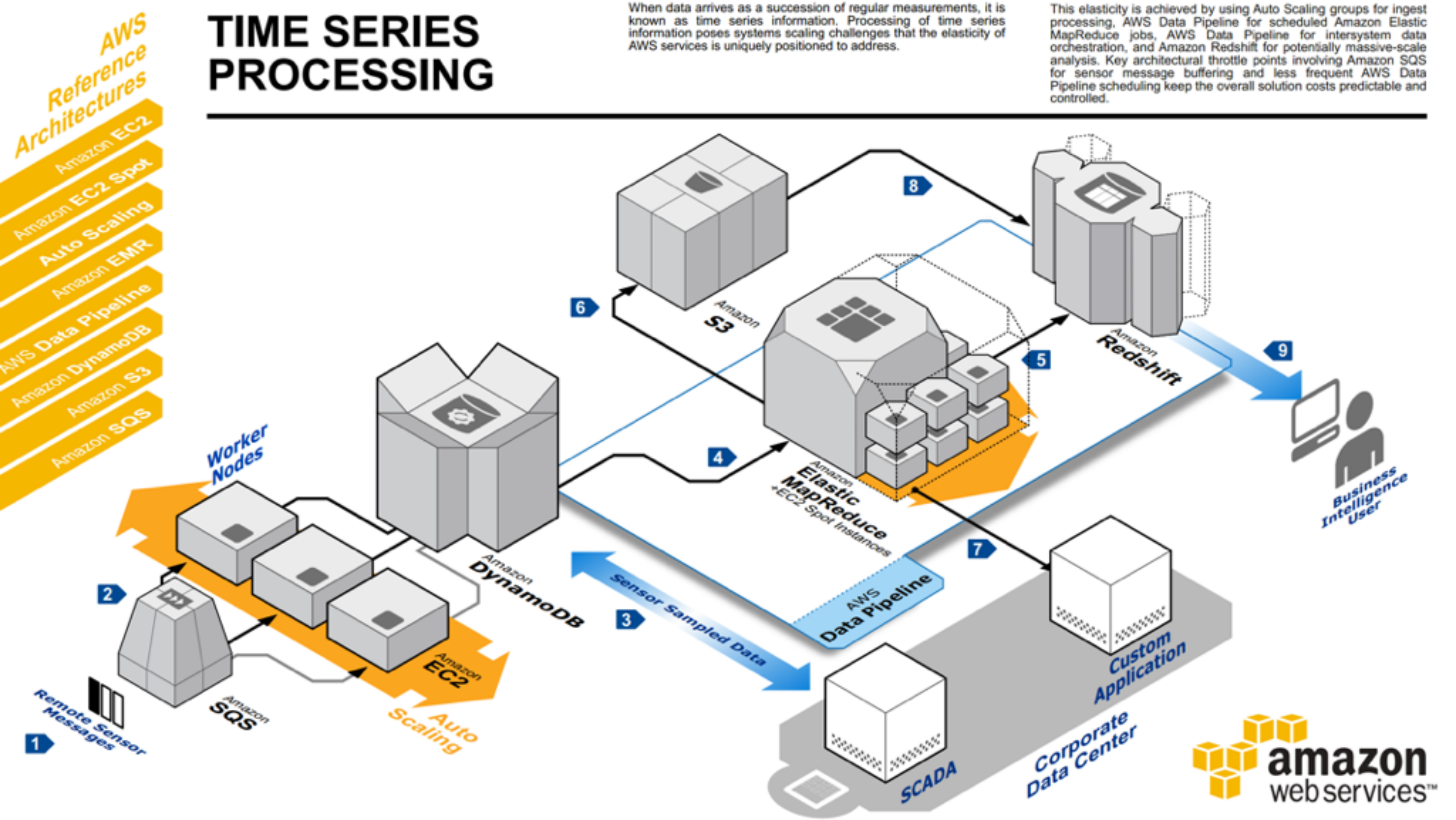
6 A marketing administration application deployed by **AWS Elastic Beanstalk** is being used by marketing managers to send targeted email campaigns to customers with specific user profiles. The application reads customer email addresses from an **Amazon RDS Read Replica** of the customer database.

7 **Amazon SES** is used to send marketing emails to customers. **Amazon SES** is based on the scalable technology used by Amazon web sites around the world to send billions of messages a year.

TIME SERIES PROCESSING

When data arrives as a succession of regular measurements, it is known as time series information. Processing of time series information poses systems scaling challenges that the elasticity of AWS services is uniquely positioned to address.

This elasticity is achieved by using Auto Scaling groups for ingest processing, AWS Data Pipeline for scheduled Amazon Elastic MapReduce jobs, AWS Data Pipeline for intersystem data orchestration, and Amazon Redshift for potentially massive-scale analysis. Key architectural throttle points involving Amazon SQS for sensor message buffering and less frequent AWS Data Pipeline scheduling keep the overall solution costs predictable and controlled.



System Overview

1 Remote devices such as power meters, mobile clients, ad-network clients, industrial meters, satellites, and environmental meters measure the world around them and send sampled sensor data as messages via HTTP(S) for processing.

2 Send messages to an **Amazon Simple Queue Service** queue for processing into Amazon DynamoDB using autoscaled **Amazon EC2** workers. Or, if the sensor source can do so, post sensor samples directly to **Amazon DynamoDB**. Try starting with a DynamoDB table that is a week-oriented, time-based table structure.

3 If a Supervisory Control and Data Acquisition (SCADA) system exists, create a flow of samples to or from **Amazon DynamoDB** to support additional cloud processing or other existing systems, respectively.

4 Using **AWS Data Pipeline**, create a pipeline with a regular **Amazon Elastic MapReduce** job that both calculates expensive sample processing and delivers samples and results.

5 The pipeline places results into **Amazon Redshift** for additional analysis.

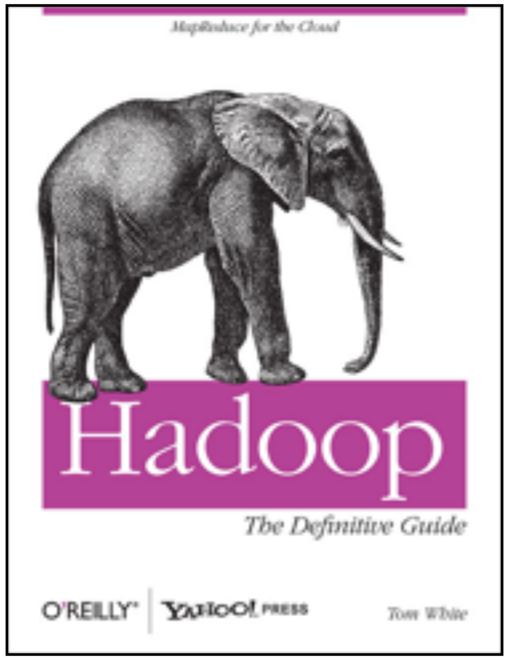
6 The pipeline exports historical week-oriented sample tables, from **Amazon DynamoDB** to **Amazon Simple Storage Service** (Amazon S3)

7 The pipeline also optionally exports results in a format custom applications can accept.

8 **Amazon Redshift** optionally imports historic samples to reside with calculated results.

9 Using in-house or Amazon partner business intelligence solutions, **Amazon Redshift** supports additional analysis on a potentially massive scale.

Resources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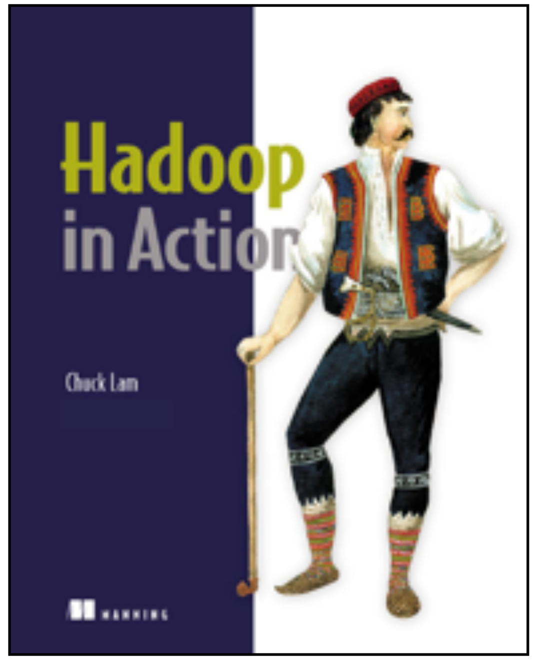
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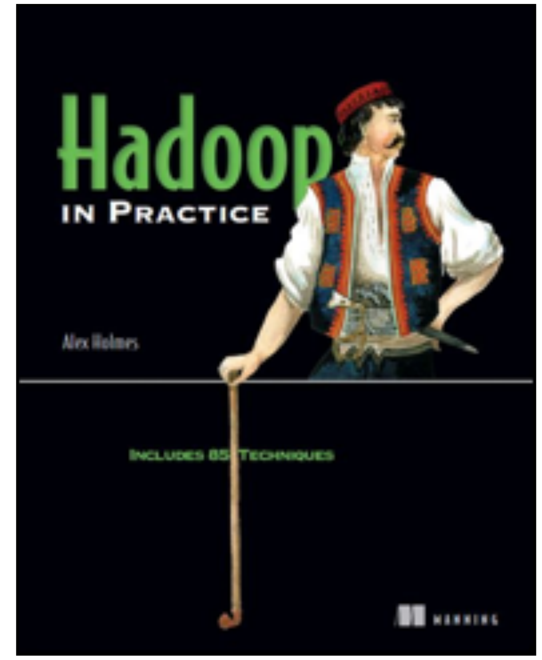
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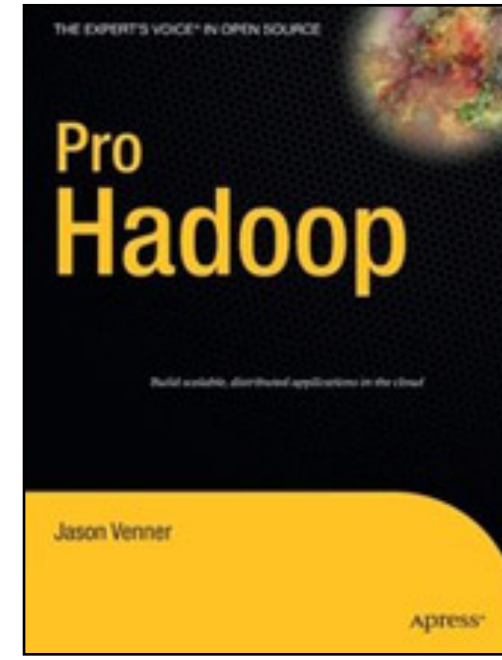
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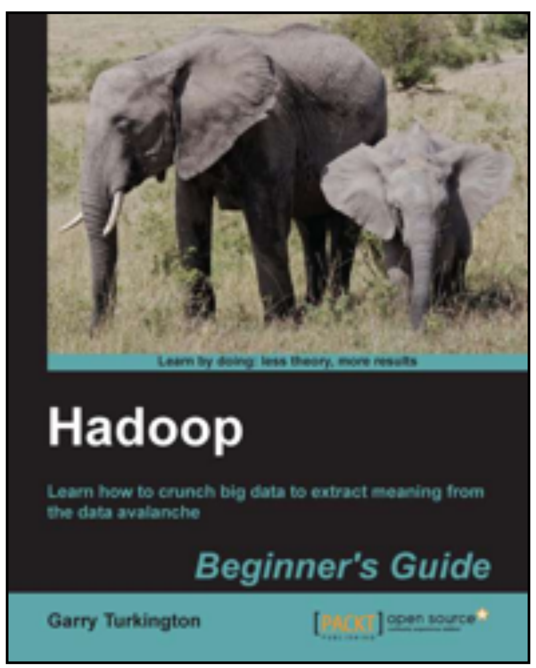
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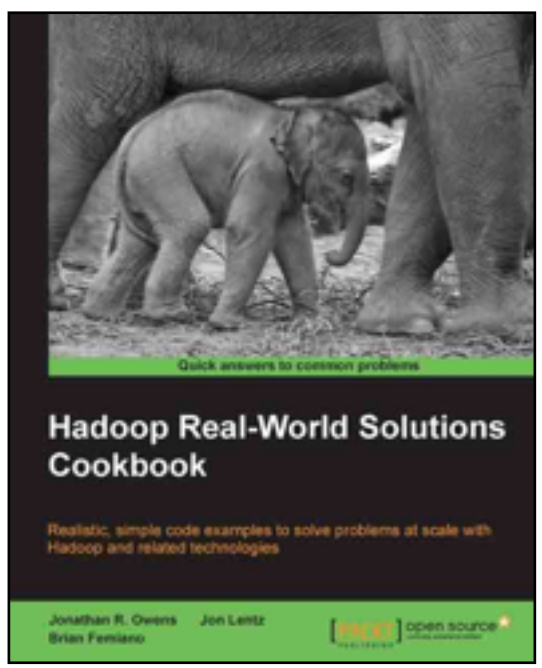
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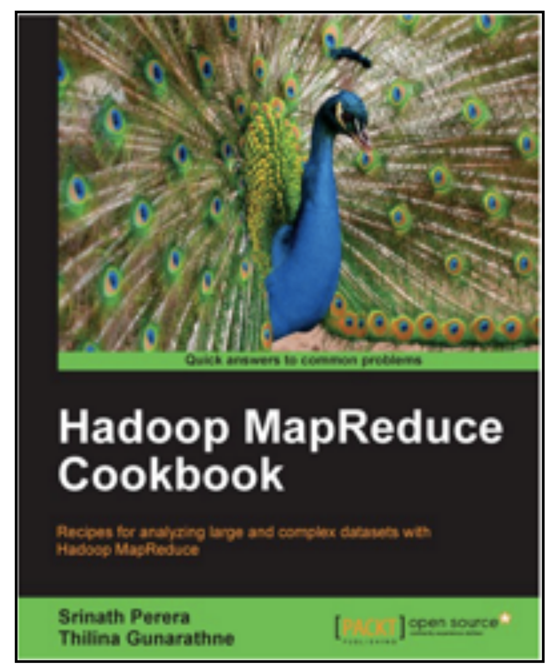
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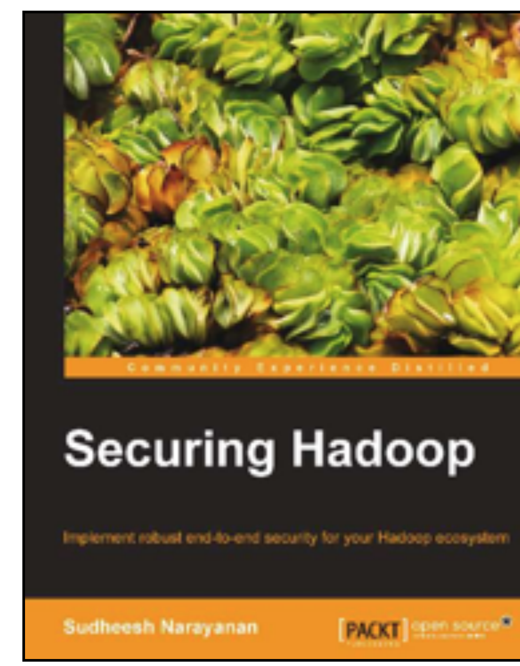
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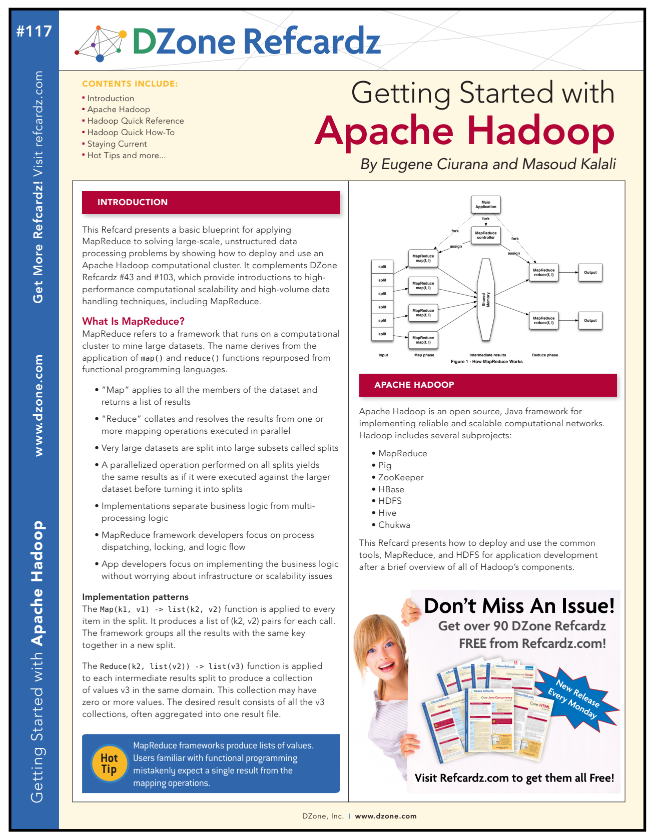
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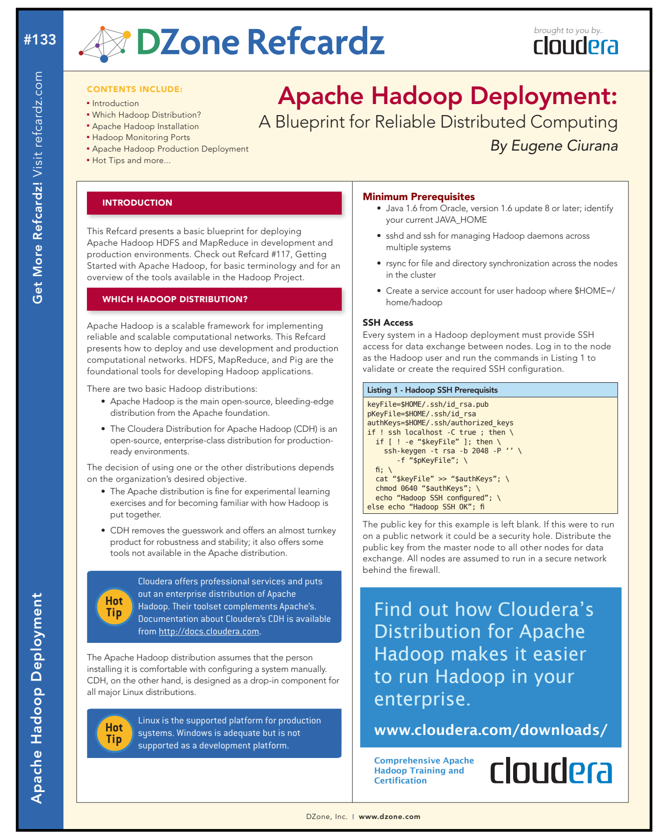
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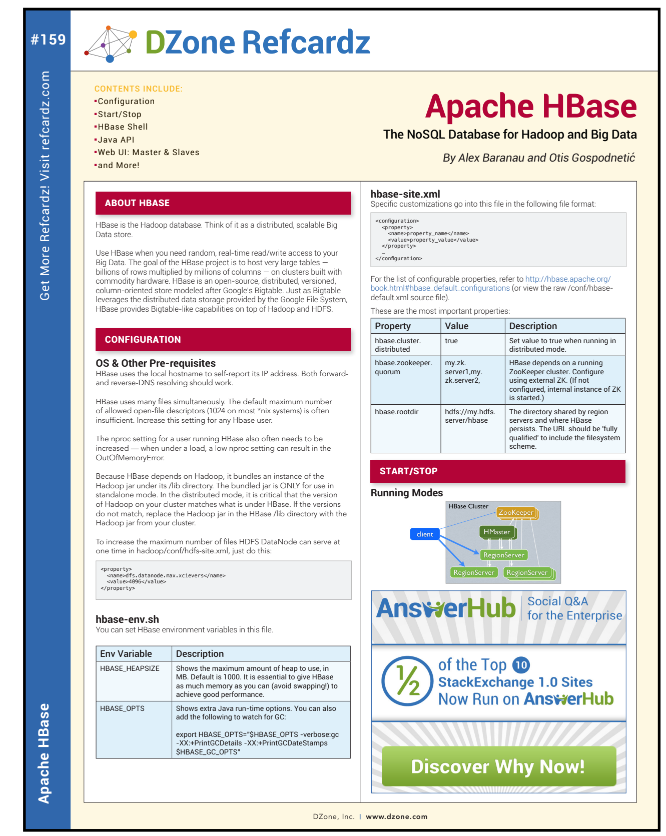
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