Introduction to Apache Hadoop

Chapter 1
Introduction

Introduction

Course Logistics

About Apache Hadoop

About Cloudera

Conclusion

Logistics

- Course start and end time
- Breaks
- Restrooms

About Your Instructor

- **A brief introduction to your instructor**

Introduction

Course Logistics

About Apache Hadoop

About Cloudera

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Facts about Apache Hadoop

- **Open source (using the Apache license)**
- **Around 40 core Hadoop committers from ~10 companies**
  - Cloudera, Yahoo!, Facebook, Apple, and more
- **Hundreds of contributors writing features, fixing bugs**
- **Many related projects, applications, tools, etc.**

A large ecosystem

Who uses Hadoop?

Vendor integration

Introduction

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About Cloudera

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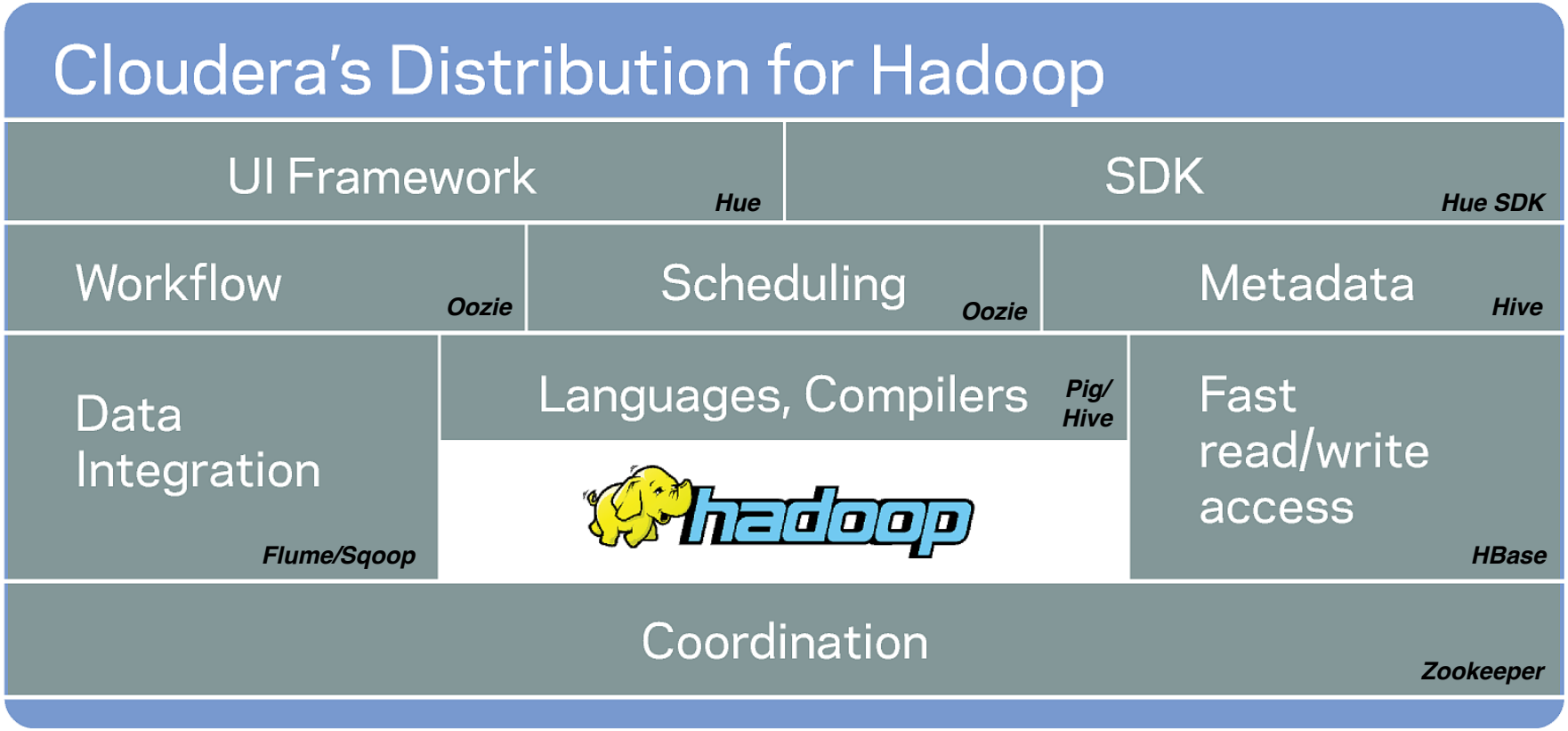
About Cloudera

- Cloudera is "The commercial Hadoop company"
- Founded by leading experts on Hadoop from Facebook, Google, Oracle and Yahoo
- Provides consulting and training services for Hadoop users
- Staff includes several committers to Hadoop projects

Cloudera Software (All Open-Source)

- **Cloudera's Distribution including Apache Hadoop (CDH)**
  - A single, easy-to-install package from the Apache Hadoop core repository
  - Includes a stable version of Hadoop, plus critical bug fixes and solid new features from the development version
- **Components**
  - Apache Hadoop
  - Apache Hive
  - Apache Pig
  - Apache HBase
  - Apache Zookeeper
  - Flume, Hue, Oozie, and Sqoop

A Coherent Platform



Cloudera Manager

- **Cloudera Manager, Free Edition**
  - The fastest, easiest way to install, configure and manage your Hadoop cluster
  - Installs CDH and management agents on each machine
  - Configuration is performed from a central location
    - No need to edit configuration files on each individual machine in the cluster
  - Supports clusters of up to 50 nodes
- **Cloudera Manager, full version**
  - Supports unlimited nodes in the cluster
  - Includes powerful, best-of-breed cluster monitoring tools
  - Provided as part of Cloudera Enterprise

Cloudera Enterprise

- **Cloudera Enterprise**
  - Complete package of software and support
  - Built on top of CDH
  - Includes the full edition of Cloudera Manager
    - Central cluster configuration
    - Powerful cluster monitoring
    - Alerting
    - Resource consumption tracking
    - LDAP integration
    - Much more
  - Phone and e-mail support for the entire Hadoop stack
    - Including priority bugfixes

Introduction

Course Logistics

About Apache Hadoop

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Conclusion

- **Apache Hadoop is a fast-growing data framework**
- **Cloudera's Distribution including Apache Hadoop offers a free, cohesive platform that encapsulates:**
  - Data integration
  - Data processing
  - Workflow scheduling
  - Monitoring

Chapter 2
The Motivation For Hadoop

The Motivation For Hadoop

In this chapter you will learn:

- **What problems exist with 'traditional' large-scale computing systems**
- **What requirements an alternative approach should have**
- **How Hadoop addresses those requirements**

The Motivation For Hadoop

Problems with Traditional Large-Scale Systems

Requirements for a New Approach

Hadoop!

Conclusion

Traditional Large-Scale Computation

- **Traditionally, computation has been processor-bound**
  - Relatively small amounts of data
  - Significant amount of complex processing performed on that data
- **For decades, the primary push was to increase the computing power of a single machine**
  - Faster processor, more RAM

Distributed Systems

- **Moore's Law: roughly stated, processing power doubles every two years**
- **Even that hasn't always proved adequate for very CPU-intensive jobs**
- **Distributed systems evolved to allow developers to use multiple machines for a single job**
  - MPI
  - PVM
  - Condor

MPI: Message Passing Interface
PVM: Parallel Virtual Machine

Distributed Systems: Problems

- **Programming for traditional distributed systems is complex**
  - Data exchange requires synchronization
  - Finite bandwidth is available
  - Temporal dependencies are complicated
  - It is difficult to deal with partial failures of the system
- **Ken Arnold, CORBA designer:**
  - "Failure is the defining difference between distributed and local programming, so you have to design distributed systems with the expectation of failure"
    - Developers spend more time designing for failure than they do actually working on the problem itself

CORBA: Common Object Request Broker Architecture

Distributed Systems: Data Storage

- **Typically, data for a distributed system is stored on a SAN**
- **At compute time, data is copied to the compute nodes**
- **Fine for relatively limited amounts of data**

SAN: Storage Area Network

The Data-Driven World

- **Modern systems have to deal with far more data than was the case in the past**
  - Organizations are generating huge amounts of data
  - That data has inherent value, and cannot be discarded
- **Examples:**
  - Yahoo – over 170PB of data
  - Facebook – over 30PB of data
  - eBay – over 5PB of data
- **Many organizations are generating data at a rate of terabytes per day**

Data Becomes the Bottleneck

- **Getting the data to the processors becomes the bottleneck**
- **Quick calculation**
  - Typical disk data transfer rate: 75MB/sec
  - Time taken to transfer 100GB of data to the processor: approx 22 minutes!
    - Assuming sustained reads
    - Actual time will be worse, since most servers have less than 100GB of RAM available
- **A new approach is needed**

The Motivation For Hadoop

Problems with Traditional Large-Scale Systems

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Hadoop!

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Partial Failure Support

- **The system must support partial failure**
  - Failure of a component should result in a graceful degradation of application performance
    - Not complete failure of the entire system

Data Recoverability

- **If a component of the system fails, its workload should be assumed by still-functioning units in the system**
  - Failure should not result in the loss of any data

Component Recovery

- **If a component of the system fails and then recovers, it should be able to rejoin the system**
  - Without requiring a full restart of the entire system

Consistency

- **Component failures during execution of a job should not affect the outcome of the job**

Scalability

- **Adding load to the system should result in a graceful decline in performance of individual jobs**
  - Not failure of the system
- **Increasing resources should support a proportional increase in load capacity**

The Motivation For Hadoop

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Hadoop!

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Hadoop's History

- **Hadoop is based on work done by Google in the early 2000s**
  - Specifically, on papers describing the Google File System (GFS) published in 2003, and MapReduce published in 2004
- **This work takes a radical new approach to the problem of distributed computing**
  - Meets all the requirements we have for reliability, scalability etc
- **Core concept: distribute the data as it is initially stored in the system**
  - Individual nodes can work on data local to those nodes
    - No data transfer over the network is required for initial processing

Core Hadoop Concepts

- **Applications are written in high-level code**
  - Developers do not worry about network programming, temporal dependencies etc
- **Nodes talk to each other as little as possible**
  - Developers should not write code which communicates between nodes
  - 'Shared nothing' architecture
- **Data is spread among machines in advance**
  - Computation happens where the data is stored, wherever possible
    - Data is replicated multiple times on the system for increased availability and reliability

Hadoop: Very High-Level Overview

- **When data is loaded into the system, it is split into 'blocks'**
  - Typically 64MB or 128MB
- **Map tasks (the first part of the MapReduce system) work on relatively small portions of data**
  - Typically a single block
- **A master program allocates work to nodes such that a Map task will work on a block of data stored locally on that node**
  - Many nodes work in parallel, each on their own part of the overall dataset

Fault Tolerance

- **If a node fails, the master will detect that failure and re-assign the work to a different node on the system**
- **Restarting a task does not require communication with nodes working on other portions of the data**
- **If a failed node restarts, it is automatically added back to the system and assigned new tasks**
- **If a node appears to be running slowly, the master can redundantly execute another instance of the same task**
  - Results from the first to finish will be used

The Motivation For Hadoop

Problems with Traditional Large-Scale Systems

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Hadoop!

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The Motivation For Hadoop

In this chapter you have learned:

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- **What requirements an alternative approach should have**
- **How Hadoop addresses those requirements**

Chapter 3
Hadoop: Basic Concepts

Hadoop: Basic Concepts

In this chapter you will learn

- **What Hadoop is**
- **What features the Hadoop Distributed File System (HDFS) provides**
- **The concepts behind MapReduce**
- **How a Hadoop cluster operates**

Hadoop: Basic Concepts

What Is Hadoop?

The Hadoop Distributed File System (HDFS)

How MapReduce works

Anatomy of a Hadoop Cluster

Conclusion

Hadoop Components

- **Hadoop consists of two core components**
  - The Hadoop Distributed File System (HDFS)
  - MapReduce Software Framework
- **There are many other projects based around core Hadoop**
  - Often referred to as the 'Hadoop Ecosystem'
  - Pig, Hive, HBase, Flume, Oozie, Sqoop, etc
    - Many are discussed later in the course
- **A set of machines running HDFS and MapReduce is known as a Hadoop Cluster**
  - Individual machines are known as nodes
  - A cluster can have as few as one node, as many as several thousands
    - More nodes = better performance!

Hadoop Components: HDFS

- **HDFS, the Hadoop Distributed File System, is responsible for storing data on the cluster**
- **Data files are split into blocks and distributed across multiple nodes in the cluster**
- **Each block is replicated multiple times**
  - Default is to replicate each block three times
  - Replicas are stored on different nodes
  - This ensures both reliability and availability

Hadoop Components: MapReduce

- **MapReduce is the system used to process data in the Hadoop cluster**
- **Consists of two phases: Map, and then Reduce**
- **Each Map task operates on a discrete portion of the overall dataset**
  - Typically one HDFS data block
- **After all Maps are complete, the MapReduce system distributes the intermediate data to nodes which perform the Reduce phase**
  - Much more on this later!

Hadoop: Basic Concepts

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HDFS Basic Concepts

- **HDFS is a filesystem written in Java**
  - Based on Google's GFS
- **Sits on top of a native filesystem**
  - ext3, xfs etc
- **Provides redundant storage for massive amounts of data**
  - Using cheap, unreliable computers

HDFS Basic Concepts (cont'd)

- **HDFS performs best with a 'modest' number of large files**
  - Millions, rather than billions, of files
  - Each file typically 100Mb or more
- **Files in HDFS are 'write once'**
  - No random writes to files are allowed
- **HDFS is optimized for large, streaming reads of files**
  - Rather than random reads

How Files Are Stored

- **Files are split into blocks**
- **Data is distributed across many machines at load time**
  - Different blocks from the same file will be stored on different machines
  - This provides for efficient MapReduce processing (see later)
- **Blocks are replicated across multiple machines, known as DataNodes**
  - Default replication is three-fold
    - i.e., each block exists on three different machines
- **A master node called the NameNode keeps track of which blocks make up a file, and where those blocks are located**
  - Known as the metadata

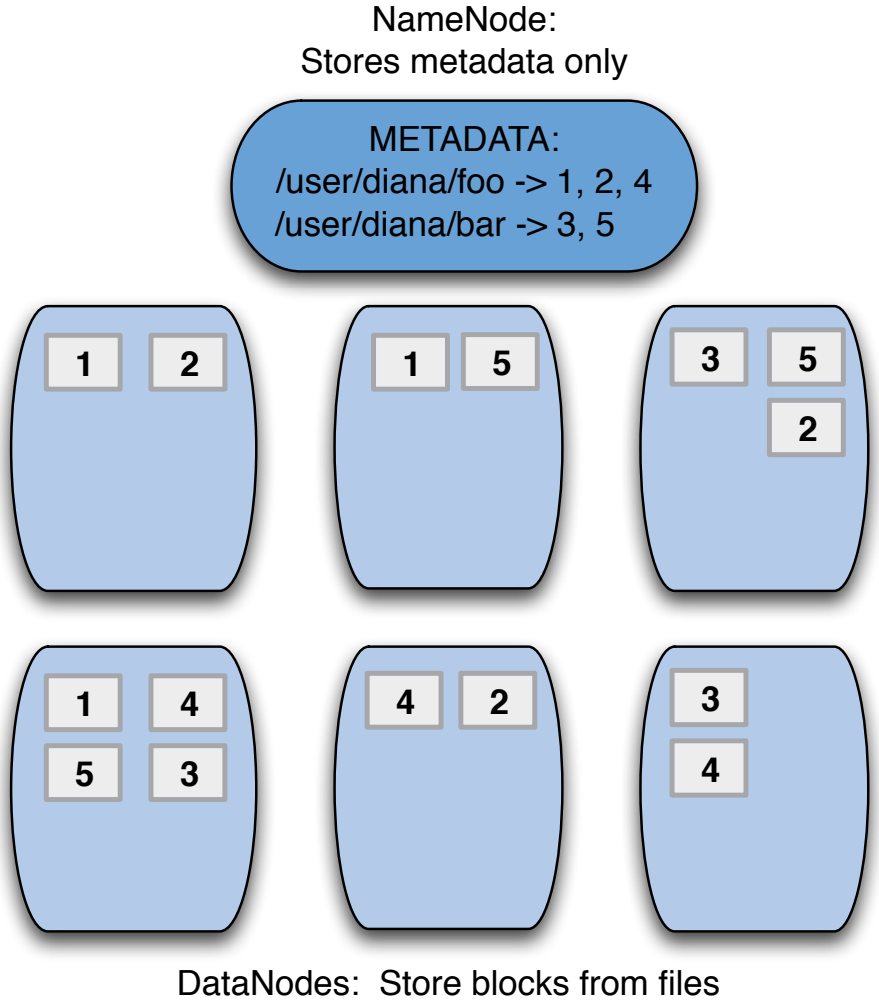
Getting Data in and out of HDFS

- **Hadoop API**
  - Use `hadoop fs` to work with data in HDFS
  - `hadoop fs -copyFromLocal` *`local_dir /hdfs_dir`*
  - `hadoop fs -copyToLocal` *`/hdfs_dir local_dir`*

- **Ecosystem Projects**
  - Flume
    - Collects data from log generating sources (e.g., Websites, syslogs, STDOUT)
  - Sqoop
    - Extracts and/or inserts data between HDFS and RDBMS

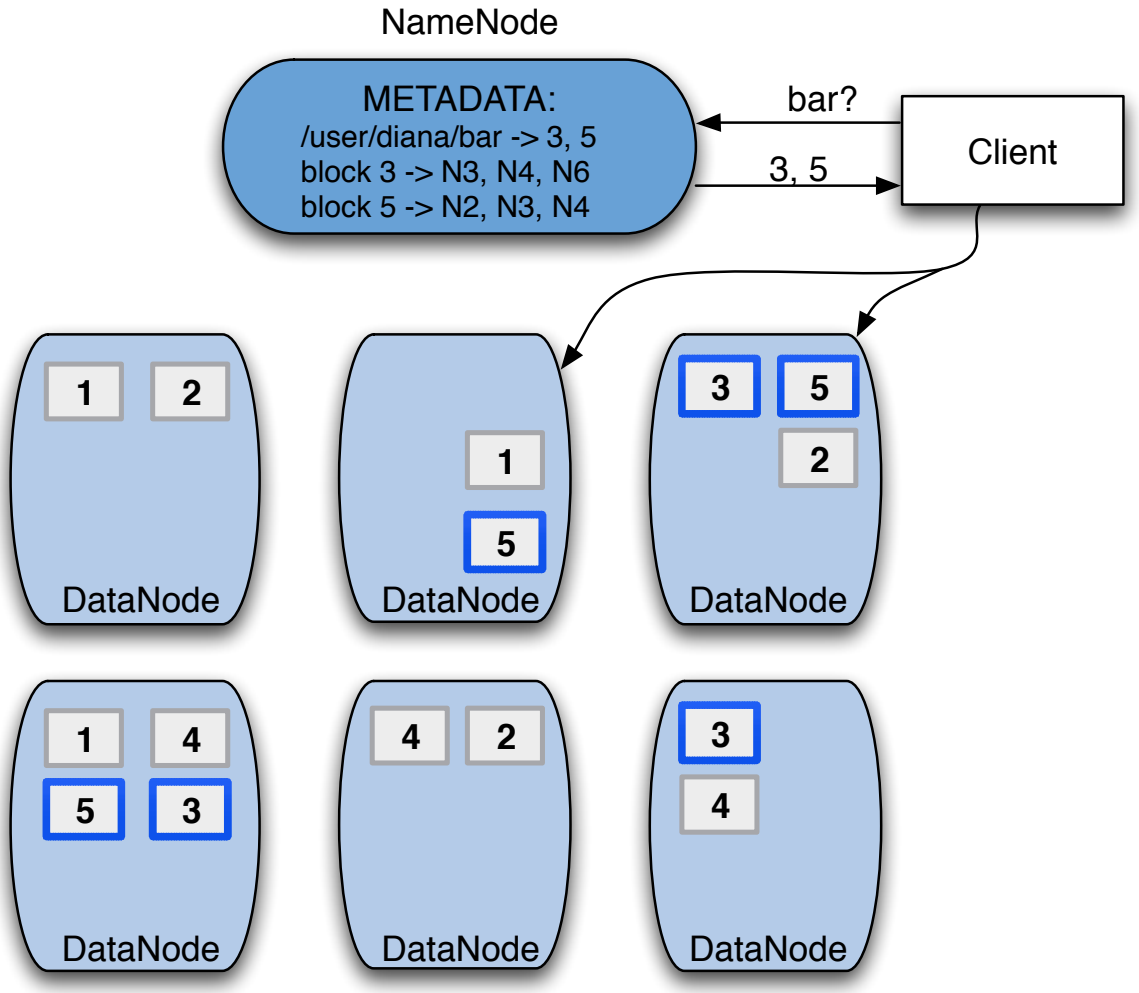
- **Business Intelligence Tools**

How Files Are Stored: Example



- **NameNode holds metadata for the data files**
- **DataNodes hold the actual blocks**
  - Each block is replicated three times on the cluster

HDFS: Points To Note



- **When a client application wants to read a file:**
  - It communicates with the NameNode to determine which blocks make up the file, and which DataNodes those blocks reside on
  - It then communicates directly with the DataNodes to read the data

Hadoop: Basic Concepts

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What Is MapReduce?

- **MapReduce is a method for distributing a task across multiple nodes**
- **Each node processes data stored on that node**
  - Where possible
- **Consists of two phases:**
  - Map
  - Reduce

Features of MapReduce

- **Automatic parallelization and distribution**
- **Fault-tolerance**
- **Status and monitoring tools**
- **A clean abstraction for programmers**
  - MapReduce programs are usually written in Java
- **MapReduce abstracts all the 'housekeeping' away from the developer**
  - Developer can concentrate simply on writing the Map and Reduce functions

MapReduce: The Mapper

- **Hadoop attempts to ensure that Mappers run on nodes which hold their portion of the data locally, to avoid network traffic**
  - Multiple Mappers run in parallel, each processing a portion of the input data
- **The Mapper reads data in the form of key/value pairs**
- **It outputs zero or more key/value pairs**

```
map(in_key, in_value) ->
                        (inter_key, inter_value) list
```

MapReduce: The Mapper (cont'd)

- **The Mapper may use or completely ignore the input key**
  - For example, a standard pattern is to read a line of a file at a time
    - The key is the byte offset into the file at which the line starts
    - The value is the contents of the line itself
    - Typically the key is considered irrelevant
- **If it writes anything at all out, the output must be in the form of key/value pairs**

MapReduce Example: Word Count

- Count the number of occurrences of each word in a large amount of input data

```
Map(input_key, input_value)
    foreach word w in input_value:
        emit(w, 1)
```

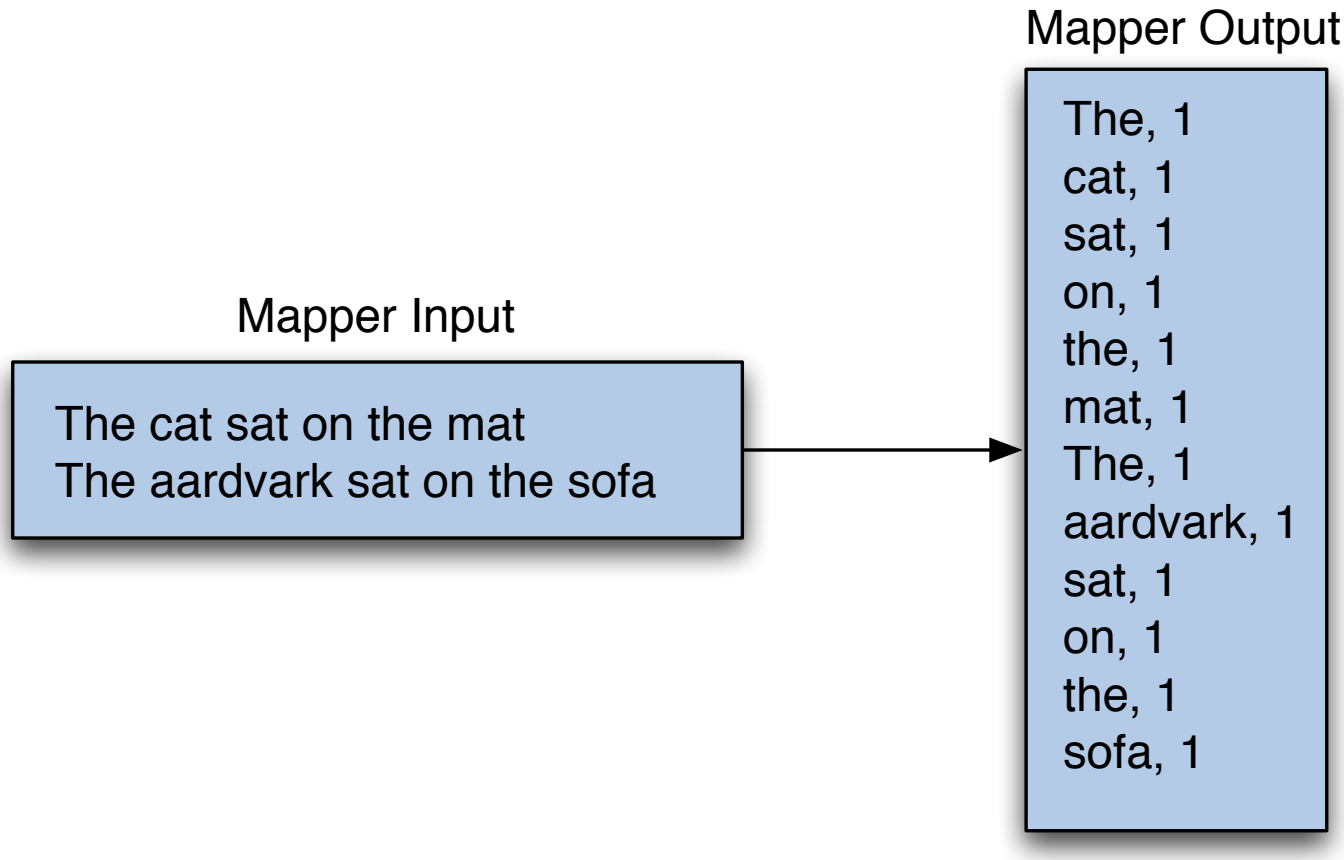
- Input to the Mapper

```
(3414, 'the cat sat on the mat')
(3437, 'the aardvark sat on the sofa')
```

- Output from the Mapper

```
('the', 1), ('cat', 1), ('sat', 1), ('on', 1),
('the', 1), ('mat', 1), ('the', 1), ('aardvark', 1),
('sat', 1), ('on', 1), ('the', 1), ('sofa', 1)
```

Map Phase



MapReduce: The Reducer

- **After the Map phase is over, all the intermediate values for a given intermediate key are combined together into a list**
- **This list is given to a Reducer**
  - There may be a single Reducer, or multiple Reducers
  - All values associated with a particular intermediate key are guaranteed to go to the same Reducer
  - The intermediate keys, and their value lists, are passed to the Reducer in sorted key order
  - This step is known as the 'shuffle and sort'
- **The Reducer outputs zero or more final key/value pairs**
  - These are written to HDFS
  - In practice, the Reducer usually emits a single key/value pair for each input key

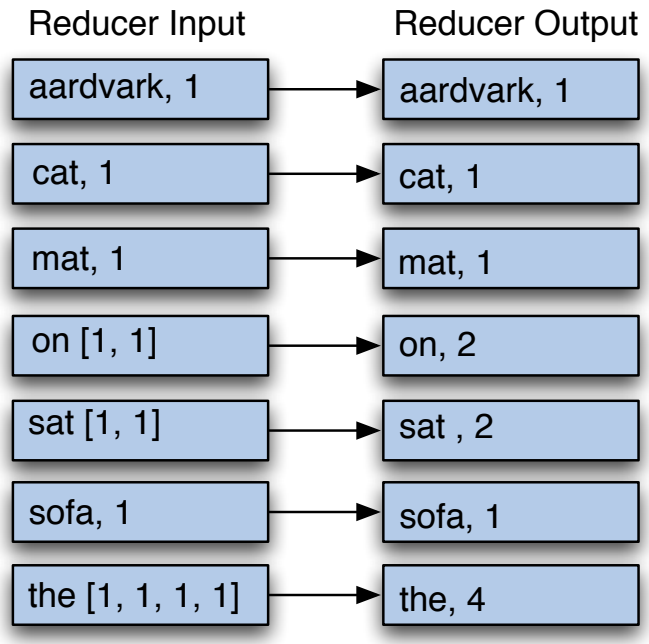
Example Reducer: Sum Reducer

- **Add up all the values associated with each intermediate key:**

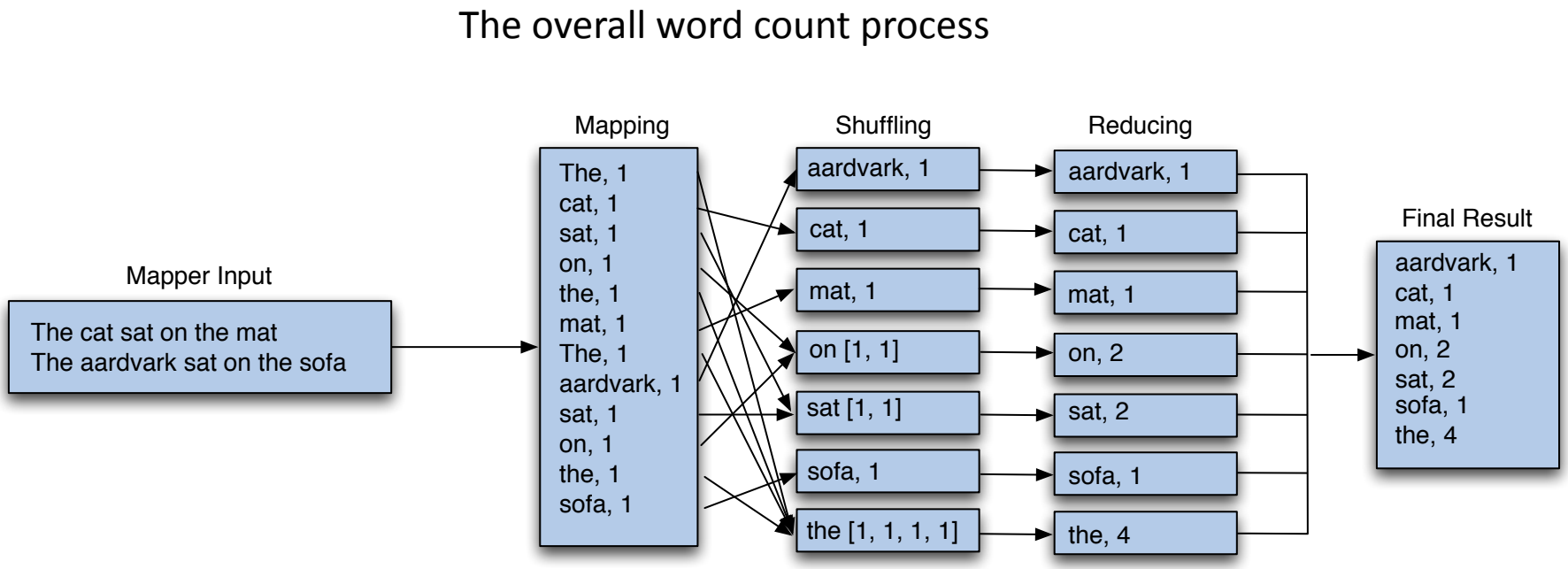
```
reduce(output_key,
           intermediate_vals)
    set count = 0
    foreach v in intermediate_vals:
        count += v
    emit(output_key, count)
```

- **Reducer output:**

```
('aardvark', 1)
('cat', 1)
('mat', 1)
('on', 2)
('sat', 2)
('sofa', 1)
('the', 4)
```



Putting It All Together



Why Do We Care About Counting Words?

- **Word count is challenging over massive amounts of data**
  - Using a single compute node would be too time-consuming
  - Using distributed nodes require moving data
  - Number of unique words can easily exceed the RAM
    - Would need a hash table on disk
  - Would need to partition the results (sort and shuffle)
- **Fundamentals of statistics often are simple aggregate functions**
- **Most aggregation functions have distributive nature**
  - e.g., max, min, sum, count
- **MapReduce breaks complex tasks down into smaller elements which can be executed in parallel**

Hadoop: Basic Concepts

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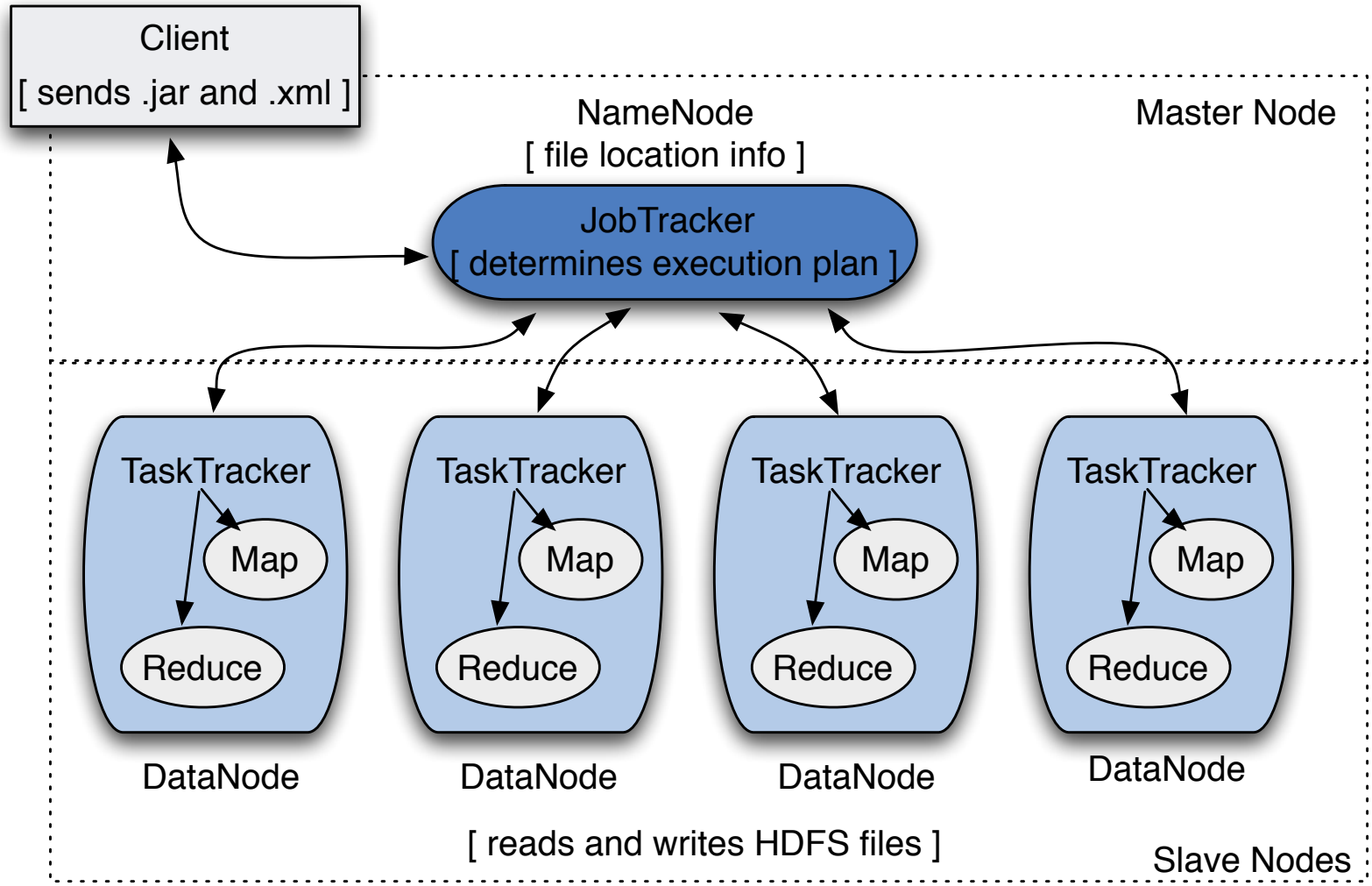
Installing A Hadoop Cluster

- **Cluster installation is usually performed by the system administrator**
  - Cloudera offers a Hadoop for System Administrators course specifically aimed at those responsible for commissioning and maintaining Hadoop clusters
- **Easiest way to download and install Hadoop is by using Cloudera's Distribution including Apache Hadoop (CDH)**
  - Vanilla Hadoop plus many patches, backports of future features
    - Current version has over 900 patches applied
  - Full documentation available at `http://cloudera.com`

The Five Hadoop Daemons

- **Hadoop is comprised of five separate daemons:**
- **NameNode**
  - Holds the metadata for HDFS
- **Secondary NameNode**
  - Performs housekeeping functions for the NameNode
  - Is not a backup or hot standby for the NameNode!
- **DataNode**
  - Stores actual HDFS data blocks
- **JobTracker**
  - Manages MapReduce jobs, distributes individual tasks to…
- **TaskTracker**
  - Responsible for instantiating and monitoring individual Map and Reduce tasks

Basic Cluster Configuration



Mitigating Risk

- **Single Points of Failure**
  - NameNode
  - Secondary NameNode
  - Jobtracker
- **Automatic restart and Failover not yet supported**
- **Mitigating Risk**
  - Carrier-grade Hardware
  - Hot Standbys
  - Monitoring

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Chapter 4
Hadoop Solutions

Hadoop Solutions

In this chapter you will learn:

- **The most common problems Hadoop can solve**
- **The types of analytics often performed with Hadoop**
- **Where the data comes from**
- **The benefits of analyzing data with Hadoop**
- **How some real-world companies use Hadoop**

Hadoop Solutions

Eight Common Hadoop-able Problems

Orbitz Hadoop Use Case

Other Examples

Conclusion

Where Does Data Come From?

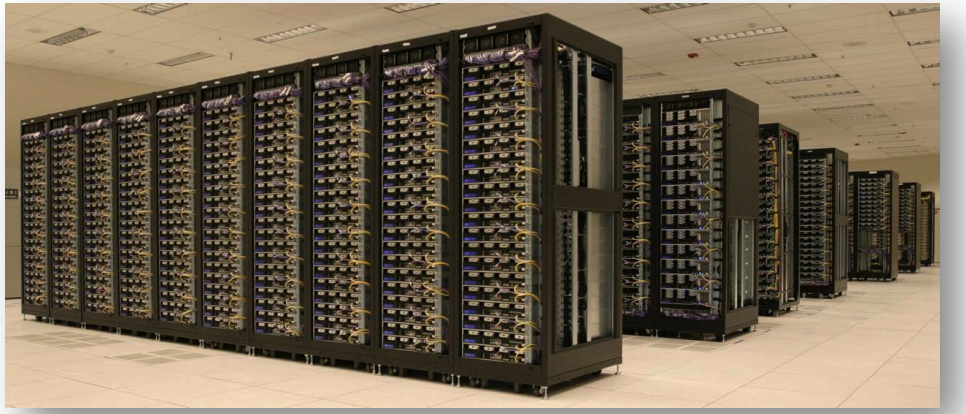
- **Science**
  - Medical imaging, sensor data, genome sequencing, weather data, satellite feeds, etc.
- **Industry**
  - Financial, pharmaceutical, manufacturing, insurance, online, energy, retail data
- **Legacy**
  - Sales data, customer behavior, product databases, accounting data, etc.
- **System Data**
  - Log files, health & status feeds, activity streams, network messages, Web Analytics, intrusion detection, spam filters

Analyzing Data: The Challenges

- **Huge volumes of data**
- **Mixed sources result in many different formats**
  - XML
  - CSV
  - EDI
  - LOG
  - Objects
  - SQL
  - Text
  - JSON
  - Binary
  - Etc.

What is Common Across Hadoop-able Problems?

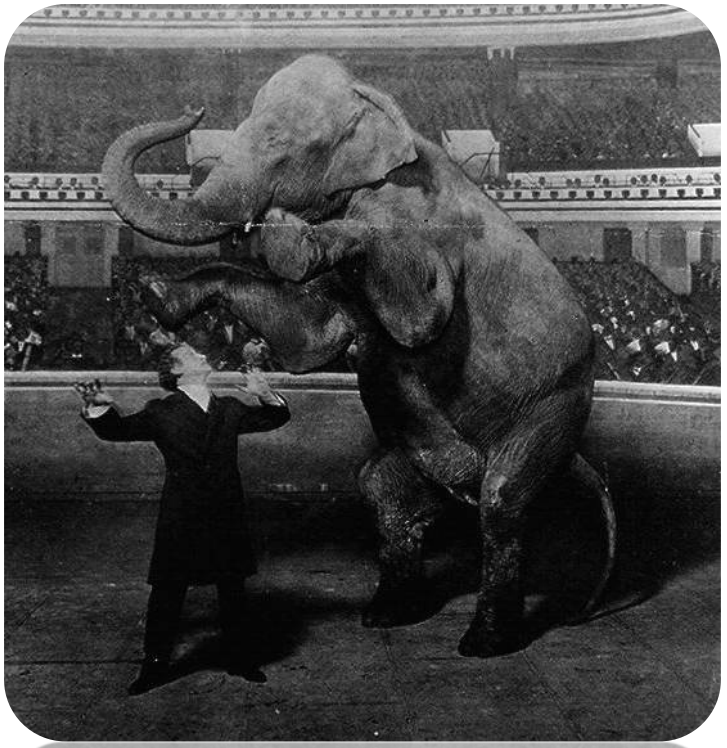
- **Nature of the data**
  - Complex data
  - Multiple data sources
  - Lots of it



- **Nature of the analysis**
  - Batch processing
  - Parallel execution
  - Spread data over a cluster of servers and take the computation to the data

Benefits of Analyzing With Hadoop

- Previously impossible/impractical to do this analysis
- Analysis conducted at lower cost
- Analysis conducted in less time
- Greater flexibility
- Linear scalability



What Analysis is Possible With Hadoop?

- Text mining
- Index building
- Graph creation and analysis
- Pattern recognition
- Collaborative filtering
- Prediction models
- Sentiment analysis
- Risk assessment

Eight Common Hadoop-able Problems

1. Modeling true risk
2. Customer churn analysis
3. Recommendation engine
4. PoS transaction analysis
5. Analyzing network data to predict failure
6. Threat analysis
7. Search quality
8. Data “sandbox”

1. Modeling True Risk

Challenge:

- **How much risk exposure does an organization really have with each customer?**
  - Multiple sources of data and across multiple lines of business

Solution with Hadoop:

- **Source and aggregate disparate data sources to build data picture**
  - e.g. credit card records, call recordings, chat sessions, emails, banking activity
- **Structure and analyze**
  - Sentiment analysis, graph creation, pattern recognition

Typical Industry:

- Financial Services (banks, insurance companies)

2. Customer Churn Analysis

Challenge:

- **Why is an organization really losing customers?**
  - Data on these factors comes from different sources

Solution with Hadoop:

- **Rapidly build behavioral model from disparate data sources**
- **Structure and analyze with Hadoop**
  - Traversing
  - Graph creation
  - Pattern recognition

Typical Industry:

- Telecommunications, Financial Services

3. Recommendation Engine/Ad Targeting

Challenge:

- **Using user data to predict which products to recommend**

Solution with Hadoop:

- **Batch processing framework**
  - Allow execution in in parallel over large datasets
- **Collaborative filtering**
  - Collecting 'taste' information from many users
  - Utilizing information to predict what similar users like

Typical Industry

- Ecommerce, Manufacturing, Retail
- Advertising

4. Point of Sale Transaction Analysis

Challenge:

- **Analyzing Point of Sale (PoS) data to target promotions and manage operations**
  - Sources are complex and data volumes grow across chains of stores and other sources

Solution with Hadoop:

- **Batch processing framework**
  - Allow execution in in parallel over large datasets
- **Pattern recognition**
  - Optimizing over multiple data sources
  - Utilizing information to predict demand

Typical Industry:

- Retail

5. Analyzing Network Data to Predict Failure

Challenge:

- **Analyzing real-time data series from a network of sensors**
  - Calculating average frequency over time is extremely tedious because of the need to analyze terabytes

Solution with Hadoop:

- **Take the computation to the data**
  - Expand from simple scans to more complex data mining
- **Better understand how the network reacts to fluctuations**
  - Discrete anomalies may, in fact, be interconnected
- **Identify leading indicators of component failure**

Typical Industry:

- Utilities, Telecommunications, Data Centers

6. Threat Analysis/Trade Surveillance

Challenge:

- **Detecting threats in the form of fraudulent activity or attacks**
  - Large data volumes involved
  - Like looking for a needle in a haystack

Solution with Hadoop:

- **Parallel processing over huge datasets**
- **Pattern recognition to identify anomalies,**
  - i.e., threats

Typical Industry:

- Security, Financial Services,
  General: spam fighting, click fraud

7. Search Quality

Challenge:

- **Providing real time meaningful search results**

Solution with Hadoop:

- **Analyzing search attempts in conjunction with structured data**
- **Pattern recognition**
  - Browsing pattern of users performing searches in different categories

Typical Industry:

- Web, Ecommerce

8. Data "Sandbox"

Challenge:

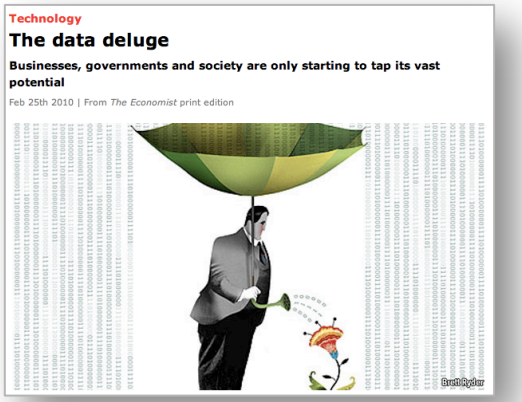
- **Data Deluge**
  - Don't know what to do with the data or what analysis to run

Solution with Hadoop:

- **"Dump" all this data into an HDFS cluster**
- **Use Hadoop to start trying out different analysis on the data**
- **See patterns to derive value from data**

Typical Industry:

- Common across all industries



Hadoop Solutions

Eight Common Hadoop-able Problems

Orbitz Hadoop Use Case

Other Examples

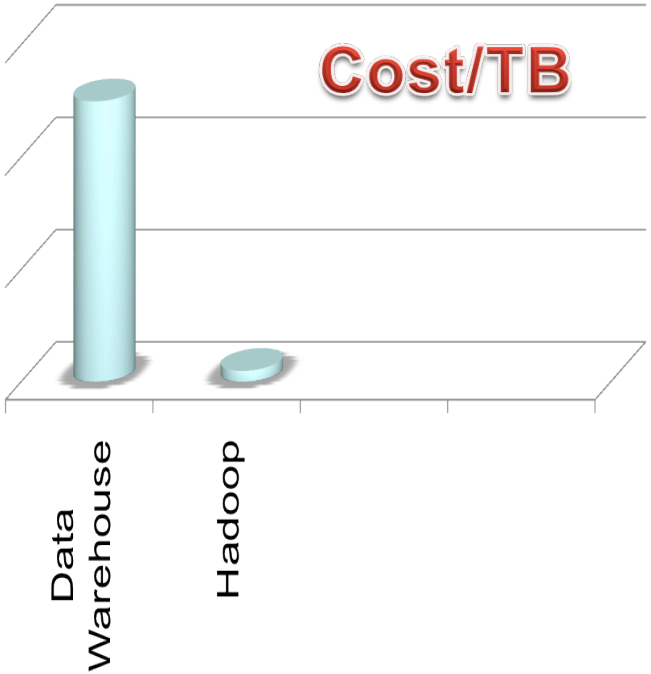
Conclusion

Who Is Orbitz?

- **Orbitz Worldwide**
- **Orbitz started in 1999, Orbitz site launched in 2001**
  - Leading online travel consumer brands including Orbitz, Cheaptickets, The Away Network, ebookers and HotelClub.
- **Business to business services**
  - Orbitz Worldwide Distribution provides hotel booking capabilities to a number of leading carriers such as Amtrak, Delta, LAN, KLM, Air France
  - Orbitz for Business provides corporate travel services to a number of Fortune 100 clients

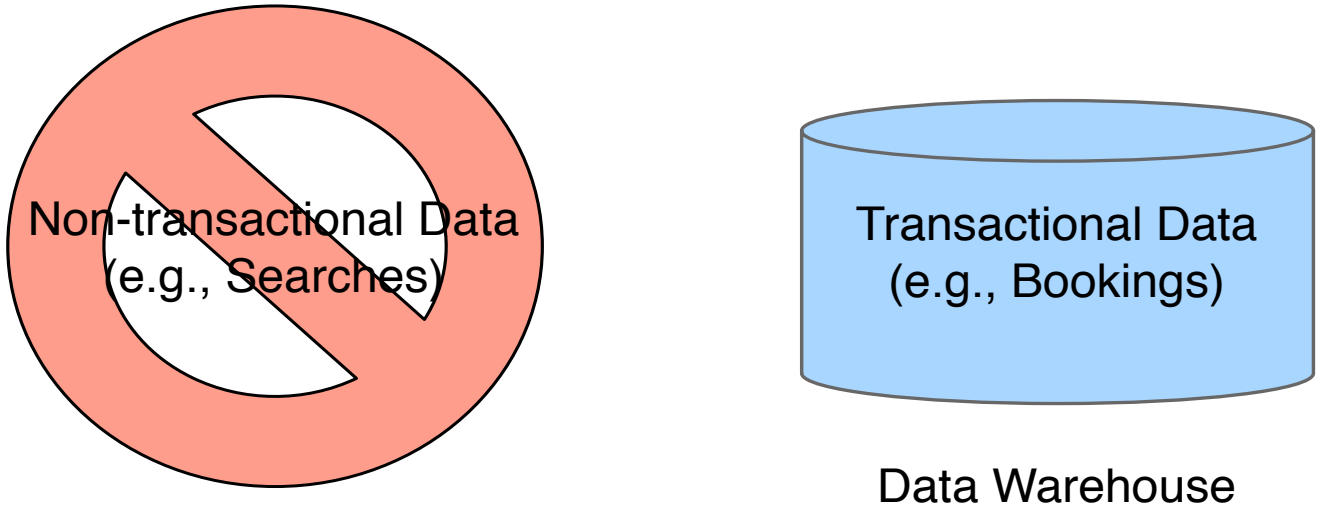
Why Is Orbitz Using Hadoop?

- **Challenge:**
  - Orbitz performs millions of searches and transactions daily, which leads to hundreds of gigabytes of log data every day
  - Not all of that data has value (i.e., it is logged for historic reasons)
  - Much is quite valuable
  - Want to capture even more data
- **Solution with Hadoop:**
  - Hadoop provides Orbitz with efficient, economical, scalable, and reliable storage and processing of these large amounts of data
  - Hadoop places no constraints on how data is processed



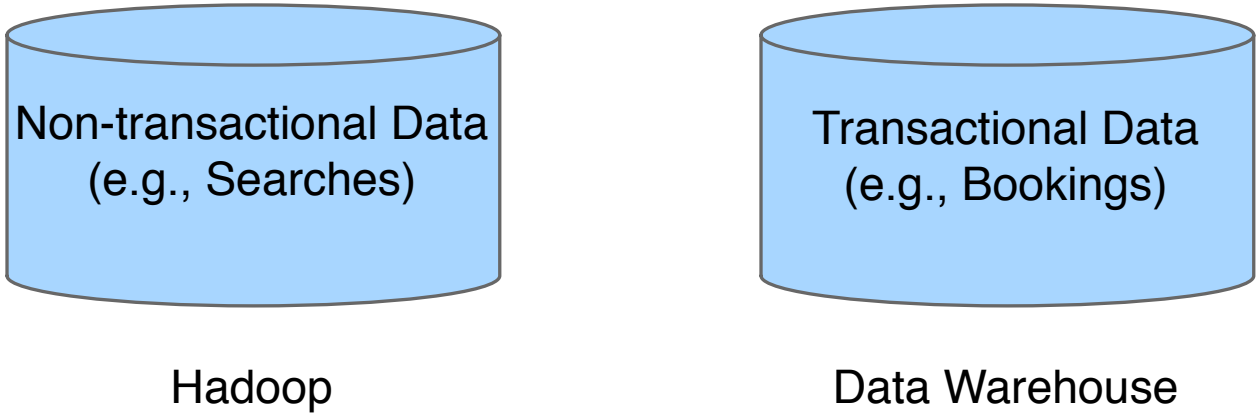
Before Hadoop

- **Orbitz's data warehouse contains a full archive of all transactions**
  - Every booking, refund, cancellation etc.
- **Non-transactional data was thrown away because it was uneconomical to store**



After Hadoop

- **Hadoop was deployed late 2009/early 2010 to begin collecting this non-transactional data. Orbitz has been using CDH for that entire period with great success.**
- **Much of this non-transactional data is contained in web analytics logs.**

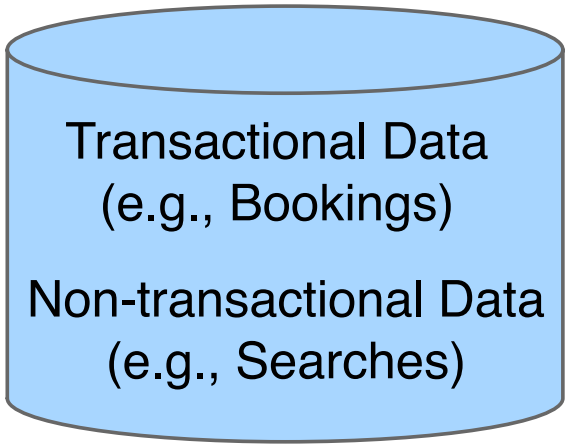


What Now?

- **Access to this non-transactional data enables a number of applications…**
  - Optimizing hotel search
    - E.g., optimize hotel ranking and show consumers hotels more closely matching their preferences
  - User specific product Recommendations
  - Web page performance tracking
  - Analyses to optimize search result cache performance
  - User segments analysis, which can drive personalization
    - E.g., Safari users click on hotels with higher mean and median prices as opposed to other users.

Next Steps

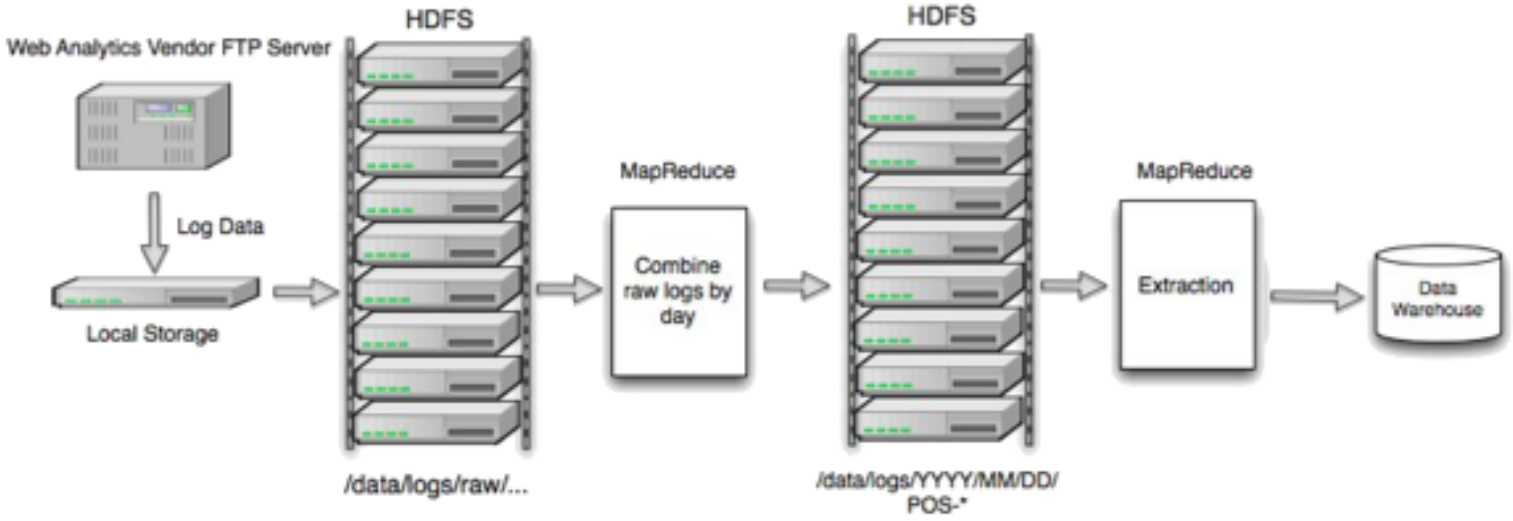
- **Most of these efforts are driven by development teams**
- **Next challenge is to make data more available to the rest of the organization**
- **The goal is a unified view of the data, allowing Orbitz to use the power of its existing tools for reporting and analysis.**
  - E.g., JasperSoft, Pentaho, Informatica, MicroStrategy, etc.



Data Warehouse

How Orbitz Is Aggregating Data For Import

- **Typical processing flow for large volumes of non-transactional data being collected at Orbitz**
  - Converts large volumes of un-structured data into structured data
  - Structured data can then be queried, extracted, or exported into the data warehouse



Hadoop Solutions

Ten Common Hadoop-able Problems

Orbitz Hadoop Use Case

Other Examples

Conclusion

Case Study: A Major National Bank

- **Background**
  - 100M customers
  - Relational data: 2.5B records/month
    - Card transactions, home loans, auto loans, etc.
    - Data volume growing by TB+/year
  - Needs to incorporate non-relational data as well
    - Web clicks, check images, voice data
- **Uses Hadoop to**
    - Identify credit risk, fraud
    - Proactively manage capital

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Case study: Netflix

- **Before Hadoop**
  - Nightly processing of logs
  - Imported into a database
  - Analysis/BI
- **As data volume grew, it took more than 24 hours to process and load a day's worth of logs**
- **Today, an hourly Hadoop job processes logs for quicker availability to the data for analysis/BI**
- **Currently ingesting approx. 1TB/day**

04-28

Case Study: Hadoop as cheap storage

- **Yahoo**
  - Before Hadoop: 1 million for 10 TB storage
  - With Hadoop: $1 million for 1 PB of storage
- **Other Large Company**
  - Before Hadoop: $5 million to store data in Oracle
  - With Hadoop: $240k to store the data in HDFS
- **Facebook**
  - Hadoop as unified storage

Hadoop Solutions

10 Common Hadoop-able Problems

Orbitz Hadoop Use Case

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Conclusion

- **Hadoop has become a valuable business intelligence tool, and will become an increasingly important part of a BI infrastructure**
- **Hadoop won't replace your EDW**
  - But any organization with a large EDW should at least be exploring Hadoop as a complement to its BI infrastructure
- **Use Hadoop to offload the time and resource intensive processing of large data sets so you can free up your data warehouse to serve user needs**

Conclusion (cont'd)

- **Data is big and getting bigger**
- **Data is often unstructured or complex**
- **Hadoop is used to retrieve value out of data**
- **Examples are Orbitz, eBay, Netflix, eHarmony, etc.**
- **Benefits of Hadoop:**
  - Handles less structured data
  - Return On Byte
  - Lower TCO

Chapter 5
The Hadoop Ecosystem

The Hadoop Ecosystem

In this chapter you will learn

- **What other projects exist around core Hadoop**
- **The differences between Hive and Pig**
- **When to use HBase**
- **How Flume is typically deployed**
- **What other ecosystem projects exist**

The Hadoop Ecosystem

Introduction

Hive and Pig

HBase

Flume

Other Ecosystem Projects

Conclusion

Introduction

- **The term 'Hadoop' is taken to be the combination of HDFS and MapReduce**
- **There are numerous other projects surrounding Hadoop**
  - Typically referred to as the 'Hadoop Ecosystem'
  - Most are incorporated into Cloudera's Distribution Including Apache Hadoop (CDH)
- **All use either HDFS, MapReduce, or both**

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Hive and Pig

- **Although MapReduce is very powerful, it can also be complex to master**
- **Many organizations have business or data analysts who are skilled at writing SQL queries, but not at writing Java code**
- **Many organizations have programmers who are skilled at writing code in scripting languages**
- **Hive and Pig are two projects which evolved separately to help such people analyze huge amounts of data via MapReduce**
  - Hive was initially developed at Facebook, Pig at Yahoo!
- **Cloudera offers a two-day course, *Cloudera Training For Apache Hive and Pig***

Hive and Pig

- **What is Hive?**
  - An SQL-like interface to Hadoop

```
SELECT * FROM purchases WHERE price > 100 GROUP BY
storeid
```

- **What is Pig?**
  - A dataflow language for transforming large data sets

```
purch = LOAD "/user/dave/purchases" AS (itemID,
                    price, storeID, purchaserID);
bigticket = FILTER purchases BY price > 10000;
...
```

Hive vs. Pig

	Hive	Pig
Language	HiveQL (SQL-like)	Pig Latin, a dataflow language
Schema	Table definitions that are stored in a metastore	A schema is optionally defined at runtime. Metastore coming soon
Programmatic access	JDBC, ODBC	PigServer (Java API)

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HBase: 'The Hadoop Database'

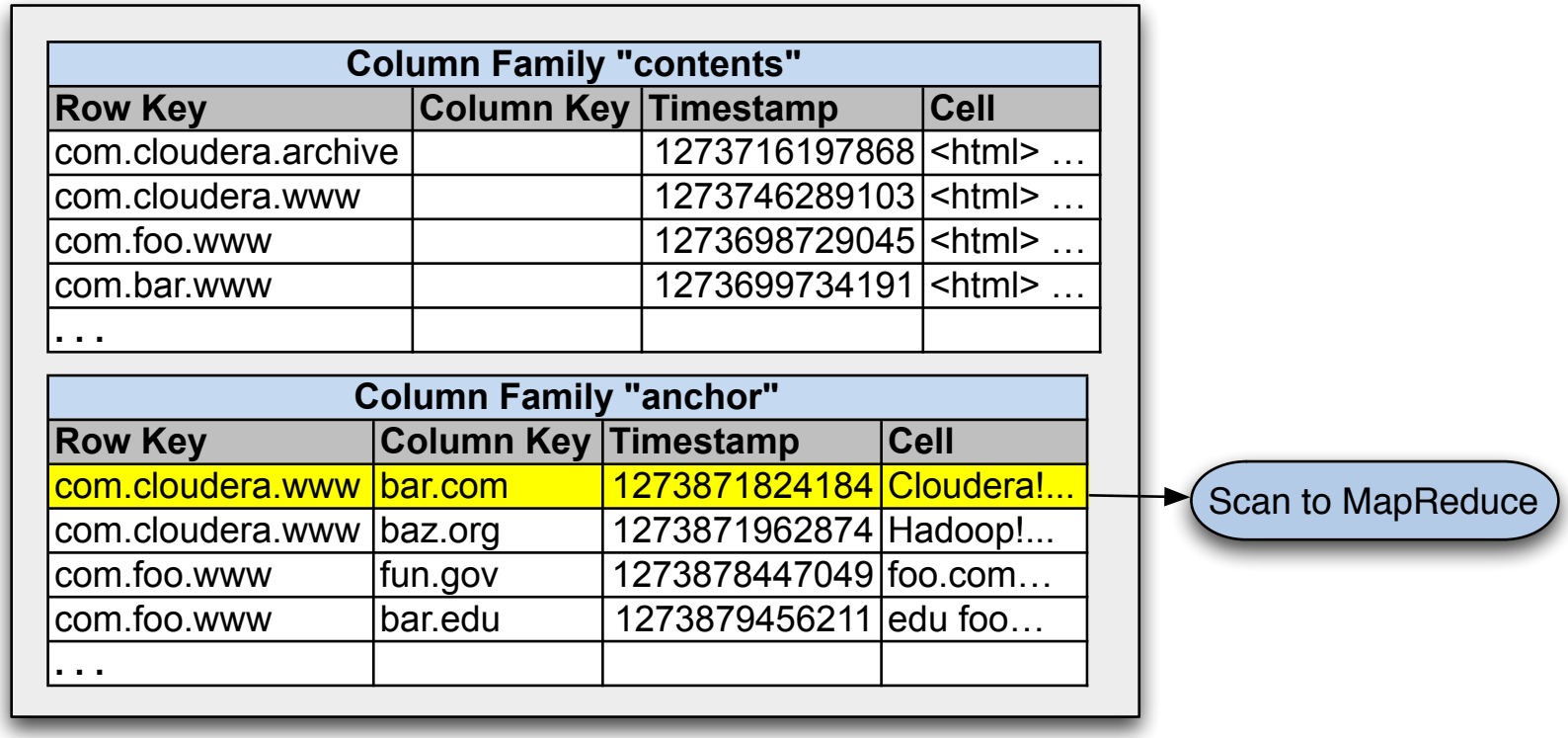
- **HBase is a column family-store database layered on top of HDFS**
  - Based on Google's Big Table
  - Provides interactive access to data
- **Can store massive amounts of data**
  - Multiple Terabytes, up to Petabytes of data
- **High Write Throughput**
  - Scales up to millions of writes per second
- **Copes well with sparse data**
  - Tables can have many thousands of columns
    - Even if a given row only has data in a few of the columns
- **Has a constrained access model**
  - Limited to lookup of a row by a single key
  - No transactions
    - Single row operations only

HBase vs A Traditional RDBMS

	RDBMS	HBase
Data layout	Row or column-oriented	Column Family-oriented
Transactions	Yes	Single row only
Query language	SQL	get/put/scan
Security	Authentication/Authorization	TBD
Indexes	Yes	Row-key only
Max data size	TBs	PB+
Read/write throughput limits	1000s queries/second	Millions of queries/second

HBase Data as Input to MapReduce Jobs

- **Rows from an HBase table can be used as input to a MapReduce job**
  - Each row is treated as a single record
  - MapReduce jobs can sort/search/index/query data in bulk



Column Family "contents"			
Row Key	**Column Key**	**Timestamp**	**Cell**
com.cloudera.archive		1273716197868	<html> …
com.cloudera.www		1273746289103	<html> …
com.foo.www		1273698729045	<html> …
com.bar.www		1273699734191	<html> …
. . .			

Column Family "anchor"			
Row Key	**Column Key**	**Timestamp**	**Cell**
com.cloudera.www	bar.com	1273871824184	Cloudera!...
com.cloudera.www	baz.org	1273871962874	Hadoop!...
com.foo.www	fun.gov	1273878447049	foo.com…
com.foo.www	bar.edu	1273879456211	edu foo…
. . .			

HBase Use Case

- **WorldLingo**
  - Hardware: 44 servers (each server has two dual-core CPUs, 2TB storage, 48GB RAM)
  - Two separate Hadoop/HBase clusters with 22 nodes each.
  - Hadoop is primarily used to run HBase and Map/Reduce jobs scanning over the HBase tables to perform specific tasks.
  - HBase is used as a scalable and fast storage back end for millions of documents.
  - Store 12 million documents with a target of 450 million in the near future.

When To Use HBase

- **Use HBase if…**
  - You need random write, random read, or both (but not neither)
  - You need to do many thousands of operations per second on multiple TB of data
  - Your access patterns are well-known and simple
- **Don't use HBase if…**
  - You only append to your dataset, and tend to read the whole thing
  - You primarily do ad-hoc analytics (ill-defined access patterns)
  - Your data easily fits on one beefy node

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What Is Flume?

- **Flume is a distributed, reliable, available service for efficiently moving large amounts of data as it is produced**
  - Ideally suited to gathering logs from multiple systems and inserting them into HDFS as they are generated
- **Developed in-house by Cloudera, and released as open-source software**
  - Now an Apache Incubator project
- **Design goals:**
  - Reliability
  - Scalability
  - Manageability
  - Extensibility

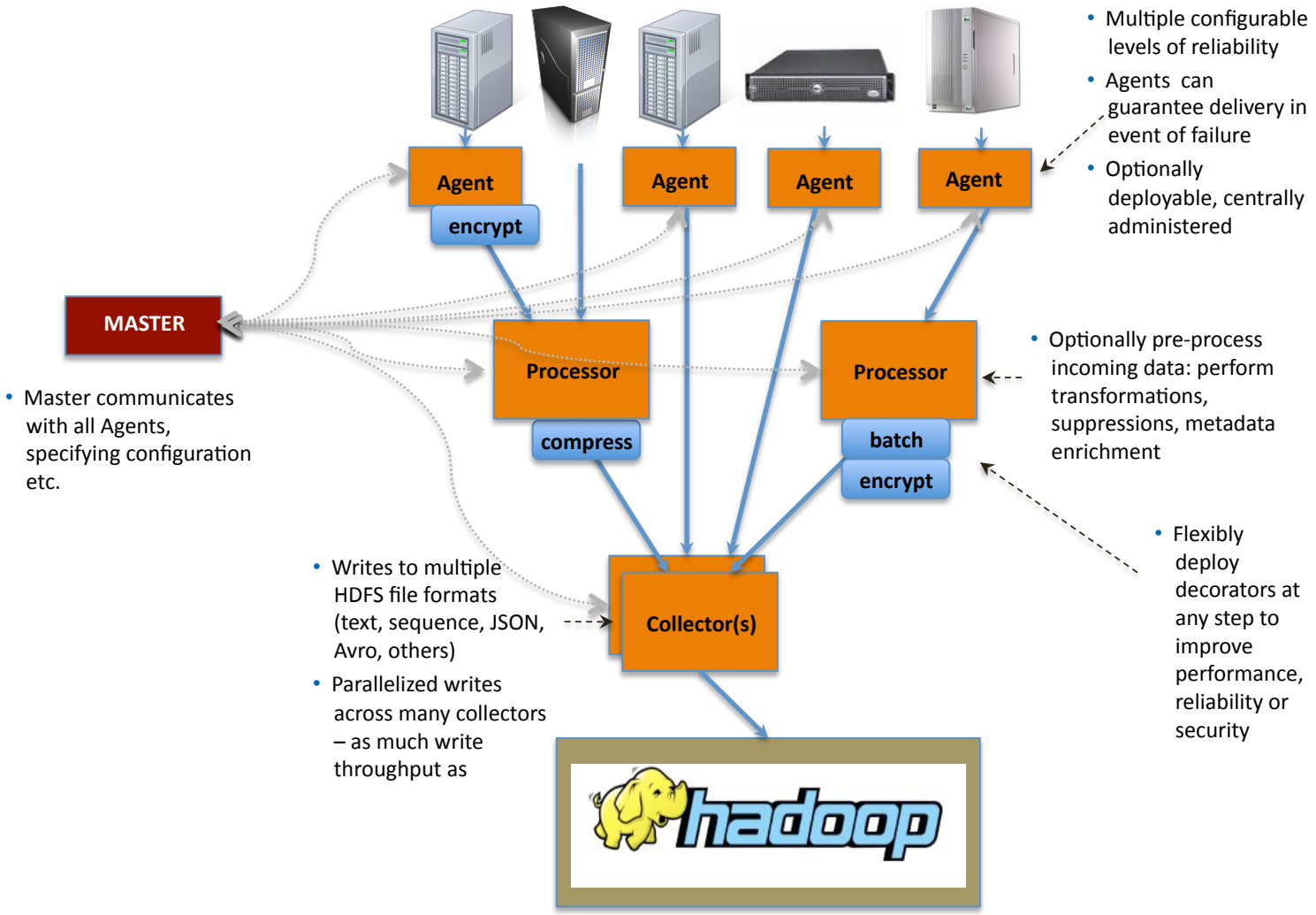
Flume's Design Goals

- **Flume is designed to continue delivering events in the face of system component failure**
- **Flume scales horizontally to support scalability**
  - As load increases, more machines can be added to the configuration
- **Flume provides a central Master controller for manageability**
  - Administrators can monitor and reconfigure data flows on the fly
- **Flume can be extended by adding connectors to existing storage layers or data platforms**
  - General sources already provided include data from files, syslog, and standard output (stdout) from a process
  - General endpoints already provided include files on the local filesystem or in HDFS
  - Other connectors can be added using Flume's API

Flume: General System Architecture

- **The Master holds configuration information for each Node, plus a version number for that node**
  - Version number is associated with the Node's configuration
- **Nodes communicate with the Master every five seconds**
  - Node passes its version number to the Master
  - If the Master has a later version number for the Node, it tells the Node to reconfigure itself
    - The Node then requests the new configuration information from the Master, and dynamically applies that new configuration

Flume: High-Level Overview



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Sqoop: Retrieving Data From RDBMSs

- **Sqoop: SQL to Hadoop**
- **Extracts data from RDBMSs and inserts it into HDFS**
  - Also works the other way around
- **Command-line tool which works with any RDBMS**
  - Optimizations available for some specific RDBMSs
- **Generates Writeable classes for use in MapReduce jobs**
- **Developed at Cloudera, released as Open Source**
  - Now an Apache Incubator project

Sqoop: Custom Connectors

- **Cloudera has partnered with other vendors and developers to develop connectors between their applications and HDFS**
  - MySQL
  - Postgres
  - Netezza
  - Teradata
  - Oracle (partnered with Quest Software)
- **These connectors are made freely available as they are released**
  - Not open-source, but free to use
- **Support is available as part of Cloudera Enterprise**

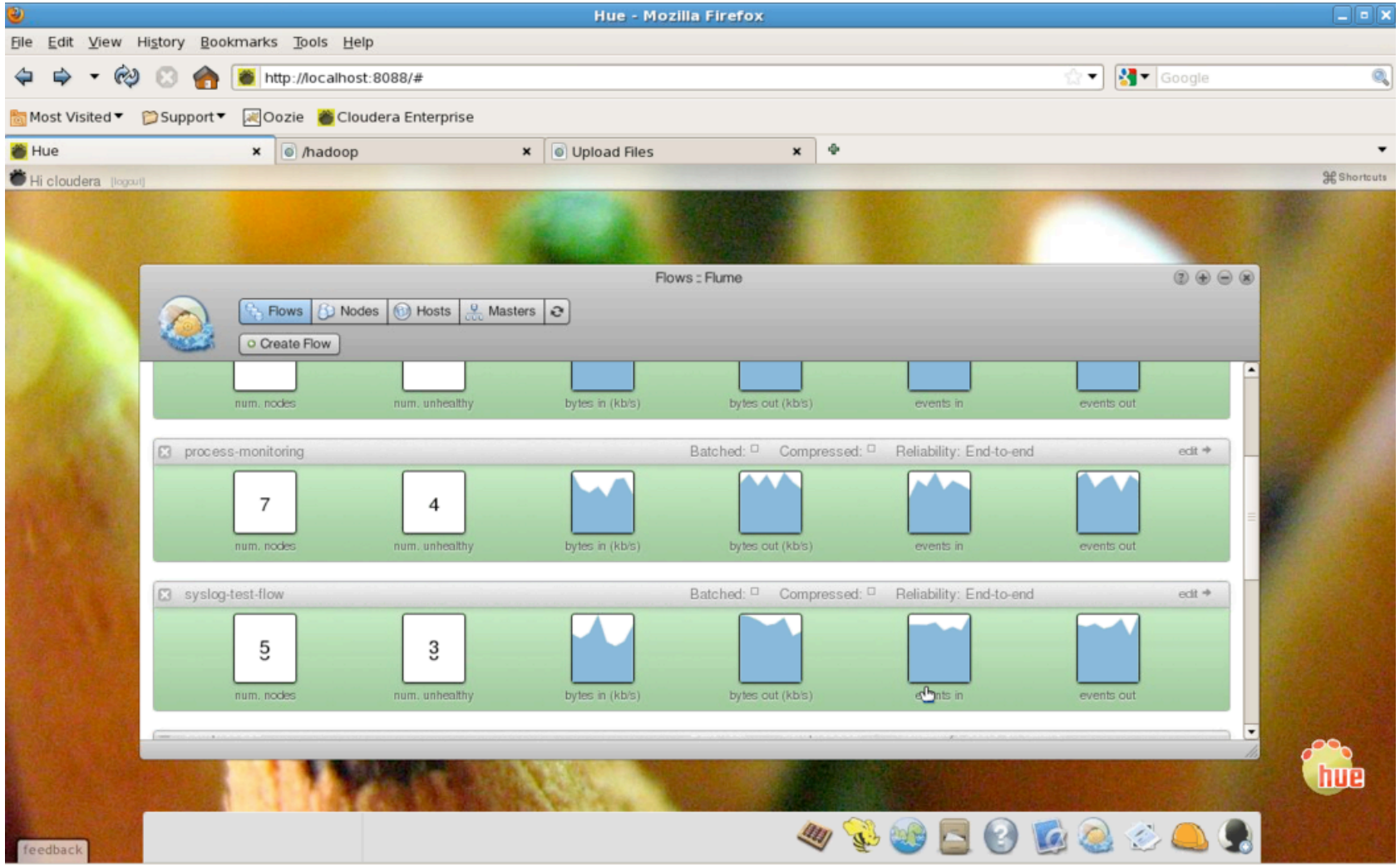
Oozie

- **Oozie provides a way for developers to define an entire workflow**
  - Comprised of multiple MapReduce jobs
- **Allows some jobs to run in parallel, others to wait for the output of a previous job**
- **Workflow definitions are written in XML**

Hue

- **Graphical front-end to developer and administrator functionality**
  - Uses a Web browser as its front-end
- **Developed by Cloudera, released as Open Source**
- **Extensible**
  - Publically-available API
- **Cloudera Enterprise includes extra functionality**
  - Advanced user management
  - Integration with LDAP, Active Directory
  - Accounting
  - Cluster Monitoring

Hue (cont'd)



The Hadoop Ecosystem

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Hive and Pig

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Conclusion

In this chapter you have learned

- What other projects exist around core Hadoop
- The differences between Hive and Pig
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- How Flume is typically deployed
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Chapter 6
Conclusion

Conclusion

In this course, you have learned:

- **Why Hadoop is needed**
- **The basic concepts of HDFS and MapReduce**
- **What sort of problems can be solved with Hadoop**
- **What other projects are included in the Hadoop ecosystem**

Conclusion (cont'd)

- **Thank you for coming!**
- **Cloudera offers a wide range of courses including**
  - Developer training
  - System administrator training
  - Hive and Pig training
  - HBase training
- **Please see `http://university.cloudera.com` for more details**
- **If you have any further questions, please feel free to contact us via `http://cloudera.com`**