MapReduce-I
Knowledge objectives

1. Enumerate several use cases of MapReduce
2. Describe what the MapReduce environment is
3. Explain 6 benefits of using MapReduce
4. Explain four problems of MapReduce
Understanding Objectives

1. Describe the different steps of a MapReduce execution
Application Objectives

1. Identify the usefulness of MapReduce in a given use case
Typical uses

- Find which source pages link to a target page
- Count the number of accesses to each Web page
- Count the number of accesses to each domain
- Create an index structure that maps search terms to document IDs
- Retrieve introductory paragraph of all Web pages so that “x”
- Find all pairs of users accessing the same URL
- Find the average age of users accessing a given URL
- Find all friends of a given user
- Find all friends of friends of a given user
- Find all women friends of men friends of a given user
- Grouping different manifestations of the same real world object
Not so typical uses

- Mobile Commerce
- Electricity
- Agricultural Planning
- Fuel Conservation
- National Intelligence
- Drug Development and Personalization
- Financial Service Security
Opinions

Can the Hadoop Distributed File System (HDFS) replace your enterprise data warehouse (EDW)?

- No: 59%
- Maybe: 37%
- Yes: 4%

Is Hadoop a problem or an opportunity?

- Problem—because 12%
  - Hadoop and our skills for it are immature
- Opportunity—because 88%
  - It enables new application types

Can HDFS augment your enterprise data warehouse (EDW) or other data infrastructure?

- No: 3%
- Maybe: 47%
- Yes: 50%
Busting 10 Myths about Hadoop

- Hadoop consists in multiple products
- Hadoop is open source but available from vendors, too
- Hadoop is an ecosystem, not a single product
- HDFS is a file system, not a DBMS
- Hive resembles SQL but is not standard SQL
- Hadoop and MapReduce are related but don’t require each other
- MapReduce provides control for analytics, not analytics per se
- Hadoop is about data diversity, not just data volume
- Hadoop complements a DW; it’s rarely a replacement
- Hadoop enables many types of analytics, not just Web analytics

Philip Russom
Google ecosystem

- High-performance is mainly achieved by means of parallelism
  - Divide-and-conquer principle
- MapReduce
  - It is a query language that provides parallelism in a transparent manner
Hadoop ecosystem

GOVERNANCE INTEGRATION
- Data Workflow, Lifecycle & Governance
  - Pig
  - HCatalog
  - Accumulo
  - Kafka
  - Spark

DATA ACCESS
- Script
- SQL
- NoSQL
- Stream
- In-Mem

YARN: Data Operating System

SECURITY
- Authentication, Authorization, Audit & Data Protection
- Storage: HDFS
- Access: Hive
- Pipeline: Falcon
- Cluster: Knox

OPERATIONS
- Provision, Manage & Monitor
  - Ambari
  - ZooKeeper
- Scheduling
  - Oozie

DATA MANAGEMENT

HDFS
Hadoop Distributed File System

By HortonWorks

September 2013

Alberto Abelló & Oscar Romero
Sequential access

Disk buffer
Page cache
L3 cache
L2 cache
L1 cache

Pre-fetch is your friend

300 reads/sec
200MB/s

September 2013
Alberto Abelló & Oscar Romero

Ben Stopford
Progscon & JAX Finance 2015
MapReduce Basics

- Simple model to express relatively sophisticated distributed programs
  - Processes pairs [key, value]
  - Signature:

    \[
    \begin{align*}
    \text{map}(\text{key } k, \text{value } v) & \mapsto [(i_{k1}, v_{1}), \ldots, (i_{km(k,v)}, v_{m(k,v)})] \\
    \text{reduce}(\text{key } ik, \text{vset } ivs) & \mapsto [o_{v1}, \ldots, o_{v_{r(ik,ivs)}}]
    \end{align*}
    \]
WordCount Execution Example

The project Gutemberg EBook of The Outline of Science, Vol. 1 (of 4), by J. Arthur Thomson

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The Outline of Science
A Plain Story Simply Told

Edition

J. Arthur Thomson

Professor of Natural History in the University of Aberdeen

With over 500 Illustrations
Of which about 40 are in colour

September 2013

Alberto Abelló & Oscar Romero

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"The", [1, 1, 1, 1, 1, ...]

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57631
public void map(LongWritable key, Text value) {
    String line = value.toString();
    Key
    Value
    String tokenizer = new StringTokenizer(line);
    while (tokenizer.hasMoreTokens()) {
        Key
        Value
        Blackbox
        write(new Text(tokenizer.nextToken()),
            new IntWritable(1));
    }
}

public void reduce(Text key, Iterable<IntWritable> values) {
    int sum = 0;
    Key
    Values
    Blackbox
    for (IntWritable val : values) {
        Key
        Value
        sum += val.get();
    }
    write(key, new IntWritable(sum));
}
Benefits

- Programming (functional) model simple yet expressive
  - Without joins
- Able to process structured or unstructured
- Elastically scalable
  - Transparently distributes data
    - Exploits data locality
  - Hides parallelization
  - Balances workload
  - Provides fine grained fault tolerance
Problems

- Writes intermediate results to disk
  - Reduce tasks pull intermediate data
- Defines the execution plan on the fly
  - Schedules one block at a time
- Does not provide transactions
- Does not benefit from compression
Market tools

“... But to really unlock the power of Hadoop, you must be able to efficiently extract data stored across multiple (often tens or hundreds) of nodes with a user-friendly ETL (extract, transform and load) tool that will then allow you to move your Hadoop data into a relational data mart or warehouse where you can use BI tools for analysis. “

Ian Fyfe
Pentaho
Reference Architecture

ETL (Extraction, Transformation and Load)

WWW

MapReduce

ROLAP  MOLAP  VOLAP

DM  DM  DM

BigTable

September 2013
Alberto Abelló & Oscar Romero
Big elephant or little elephant?

**Trademark**
- Expensive
- Many functionalities
- Mature

**Open source**
- Free
- Simple functionalities
- Young
Friends or foes

MapReduce
Java
Oracle

Oracle Grid Engine

Hadoop Distributed File System (HDFS)
Activity

- **Objective:** Understand the usefulness of MapReduce

- **Tasks:**
  1. (6’) Read two use cases
  2. (12’) Explain the use cases to the others
  3. (5’) Find the main characteristics needed to use Hadoop
  4. Hand in a prioritized list of characteristics

- **Roles for the team-mates during task 2:**
  a) Explains his/her material
  b) Asks for clarification of blur concepts
  c) Mediates and **controls time**
Algorithm: Data Load

1. The input data is partitioned into blocks
   - It can be done by using HDFS or any other storage (e.g., HadoopDB, MongoDB, Cassandra, CouchDB, etc.)
2. Replicate them in different nodes
Algorithm: Map Phase (I)

3. Each map subplan reads a subset of blocks (i.e., split)
4. Divides it into records
5. Executes the map for each record and leaves them in memory divided into spills
Algorithm: Map Phase (II)

6. Each spill is then partitioned per reducers
   - Using a hash function $f$ over the new key
7. Each partition is sorted independently
   - If a combine is defined, it is executed locally after sorting
8. Store the spills into disk (massive writing)
Algorithm: Map phase (III)

9. Spill partitions are merged
   - Each merge is sorted independently
10. Store the result into disk
Algorithm: Shuffle and Reduce

11. Reducers fetch data from mappers (massive data transfer)
12. Mappers output is merged and sorted
13. Reduce function is executed per key
14. Store the result into disk
Local-Global Aggregation: Combine

- Combine is executed locally
  - Assumes uniform random distribution of input
  - Reduces the number of tuples sent to reducers
- Only possible when the reducer function is:
  - Commutative
  - Associative
- Only makes sense if $|I|/|O| >> \#CPU$
Summary

- MapReduce usefulness
- MapReduce benefits
- MapReduce problems
- MapReduce algorithm
Bibliography

- J. Dean et al. *MapReduce: Simplified Data Processing on Large Clusters*. OSDI’04
- P. Sadagale and M. Fowler. *NoSQL distilled*. Addison-Wesley, 2013
- M. Stonebraker et al. *MapReduce and parallel DBMSs: friends or foes?* Communication of ACM 53(1), 2010
Resources

- http://hadoop.apache.org
- http://www.cloudera.com
- http://flink.incubator.apache.org
  - Former http://stratosphere.eu
- https://spark.apache.org