COMP9313: Big Data Management

Lecturer: Xin Cao

Course web site: http://www.cse.unsw.edu.au/~cs9313/

Chapter 1: Course Information and Introduction to Big Data Management

Part 1: Course Information

Course Info

Lectures: 6:00 – 9:00 pm (Wednesday)

Location:

Ritchie Theatre (K-G19-LG02)

Labs: Weeks 2-13

Consultation (Weeks 1-12): Questions *regarding lectures, course materials, assignements, exam, etc.*

Time: 3:00 – 4:00 pm (Wednesday)

Place: 201D, K-17

TA:

Xuefeng Chen, *xuefeng.chen@student.unsw.edu.au*

Tutors: Xuefeng Chen, Kai Wang, Chenji Huang, Yu Hao

Discussion and QA: WebCMS3

Lecturer in Charge

Lecturer: Xin Cao

Office: 201D K17 (outside the lift turn left)

Email: *xin.cao@unsw.edu.au*

Ext: 55932

Research interests

Database

Data Mining

Big Data Technologies

My homepage: http://www.cse.unsw.edu.au/~z3515164/

My publications list at google scholar: https://scholar.google.com.au/citations?user=kJIkUagAAAAJ&hl=en

Course Aims

This course aims to introduce you to the concepts behind Big Data, the core technologies used in managing large-scale data sets, and a range of technologies for developing solutions to large-scale data analytics problems.

This course is intended for students who want to understand modern large-scale data analytics systems. It covers a wide range of topics and technologies, and will prepare students to be able to build such systems as well as use them efficiently and effectively to address challenges in big data management.

Not possible to cover every aspect of big data management.

Lectures

Lectures focusing on the frontier technologies on big data management and the typical applications

Try to run in more interactive mode and provide more examples

A few lectures may run in more practical manner (e.g., like a lab/demo) to cover the applied aspects

Lecture length varies slightly depending on the progress (of that lecture)

Note: attendance to every lecture is assumed

Resources

Text Books

- Hadoop: The Definitive Guide. Tom White. 4th Edition - O'Reilly Media
- Mining of Massive Datasets. Jure Leskovec, Anand Rajaraman, Jeff Ullman. 2nd edition - Cambridge University Press
- Data-Intensive Text Processing with MapReduce. Jimmy Lin and Chris Dyer. University of Maryland, College Park.
- Learning Spark . Matei Zaharia, Holden Karau, Andy Konwinski, Patrick Wendell. O'Reilly Media

Reference Books and other readings

- Apache MapReduce Tutorial
- Apache Spark Quick Start
- Many other online tutorials … …

Big Data is a relatively new topic (so no fixed syllabus)

Prerequisite

Official prerequisite of this course is COMP9024 (Data Structures and Algorithms) and COMP9311 (Database Systems).

Before commencing this course, you should:

- have experiences and good knowledge of algorithm design (equivalent to COMP9024)
- have a solid background in database systems (equivalent to COMP9311)
- **have solid programming skills in Java**
- **be familiar with working on a Unix-style operating systems**
- have basic knowledge of linear algebra (e.g., vector spaces, matrix multiplication), probability theory and statistics , and graph theory

No previous experience necessary in

- MapReduce/Spark
- Parallel and distributed programming

Please do not enrol if you

Don’t have COMP9024/9311 knowledge

Cannot produce correct Java program on your own

Never worked on Unix-style operating systems

Have poor time management

Are too busy to attend lectures/labs

Otherwise, you are likely to perform badly in this subject

Learning outcomes

After completing this course, you are expected to:

- describe the important characteristics of Big Data
- develop an appropriate storage structure for a Big Data repository
- utilise the map/reduce paradigm and the Spark platform to manipulate Big Data
- use a high-level query language to manipulate Big Data
- develop efficient solutions for analytical problems involving Big Data

Assessment

Number	Name	Full Mark
1**	Coding Project 1	25
2**	Coding Project 2	25
3**	Coding Project 3	40
4*	Assignment	10
5	Final Exam	100

Later Submission Penalties:
* : zero marks
** : 10% reduction of your marks for the 1st day, 30% reduction/day for the following days

The final mark is calculated by the harmonic mean:
Final Mark= 2 * (proj1 + proj2 + proj3 + ass1) * FinalExam / (proj1 + proj2 + proj3 + ass1 + FinalExam)

You also need to achieve at least 40 marks in the final exam to pass the course.

Projects and Assignment

Projects:

- 1 project on Hadoop MapReduce
- 1 project on Spark
- 1 project on AWS (MapReduce/Spark)

Assignment: previous years exam questions

Both results and source codes will be checked.

- If not able to run your codes due to some bugs, you will not lose all marks.

CSE Computing Environment

Use Linux/command line (virtual machine image will be provided)

- Projects marked on Linux servers
- You need to be able to upload, run, and test your program under Linux

Assignment submission

- Use Give to submit (either command line or web page)
- Classrun. Check your submission, marks, etc. Read https://wiki.cse.unsw.edu.au/give/Classrun

Final exam

Final written exam (100 pts)

If you are ill on the day of the exam, do not attend the exam – I will not accept any medical special consideration claims from people who already attempted the exam

You need to achieve at least 40 marks in the final exam

No supplementary exam will be given

You May Fail Because …

Plagiarism

Code failed to compile due to some mistakes

Late submission

- 1 sec late = 1 day late
- submit wrong files

Program did not follow the spec

I am unlikely to accept the following excuses:

- “Too busy”
- “It took longer than I thought it would take”
- “It was harder than I initially thought”
- … …

Tentative Course Schedule

Week	Topic	Assignment
1	Course info and introduction to big data	
2	Hadoop MapReduce 1	
3	Hadoop MapReduce 2	Proj1
4	Hadoop MapReduce 3	
5	Spark 1	
6	Spark 2	Proj2
7	Spark 3	
8	Finding Similar Items	Proj3
9	Data stream mining	
10	Recommender Systems	
11	NoSQL and High Level MapReduce Tools	Ass1
12	Revision and exam preparation	

Labs

4 labs on MapReduce

4 labs on Spark

1 lab on high level MapReduce tools

1 lab on AWS

1 lab on big data machine learning platform [tentative]

Virtual Machine

Software: Virtualbox

Images:

- Pure Xubuntu 14.04: http://www.cse.unsw.edu.au/~z3515164/Raw_Xubuntu.zip
- Xubuntu 14.04 with pre-installed Hadoop and Eclipse plugin: http://mirror.cse.unsw.edu.au/pub/cs9313/Xubuntu.zip
  - Download the zip file and uncompress it, and rename the file "xubuntu-disk.vmdk" as "xubuntu-disk2.vmdk“
  - Open VirtualBox, File->Import Applicance
  - Browse the image folder, select the "*.ovf" file
  - The image will be imported to your computer, which may take 10 minutes
  - comp9313 is used as both username and password. The hadoop installation path is the same as in the virtual machine on lab computers.

Your Feedbacks Are Important

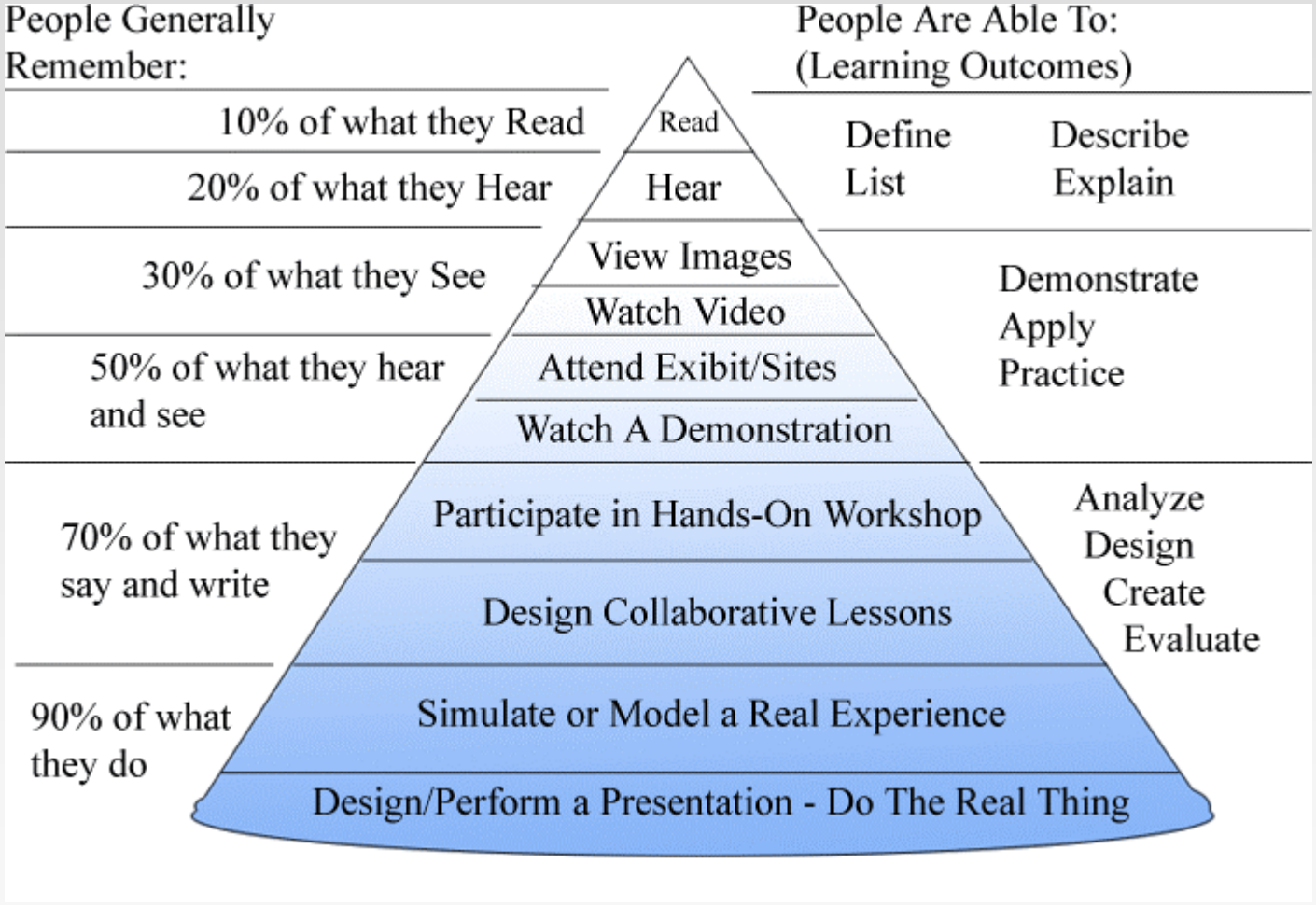
Big data is a new topic, and thus the course is tentative

The technologies keep evolving, and the course materials need to be updated correspondingly

Please advise where I can improve after each lecturer, at the discussion and QA website

myExperience system

Why Attend the Lectures?



Part 2: Introduction to Big Data

What is Big Data?

No standard definition! here is from Wikipedia:

> Big data is a term for data sets that are so big and complex that traditional data processing application software are inadequate to deal with them
>
> Challenges include capturing data, data storage, data analysis, search, sharing, transfer, visualization, querying, updating, information privacy and data source.
>
> The term "big data" often refers simply to the use of *predictive analytics*, *user behaviour analytics*, or certain other advanced data analytics methods that extract value from data, and seldom to a particular size of data set

Instead of Talking about “Big Data”…

Let’s talk about a crowded application ecosystem:

- Hadoop MapReduce
- Spark
- NoSQL (e.g., HBase, MongoDB, Neo4j)
- Pregel
- … …

Let’s talk about data science and data management:

- Finding similar items
- Graph data processing
- Streaming data processing
- Machine learning technologies
- … …

Who is generating Big Data?

Social

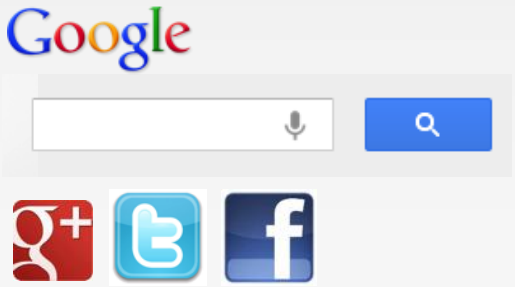
User Tracking & Engagement

Homeland Security

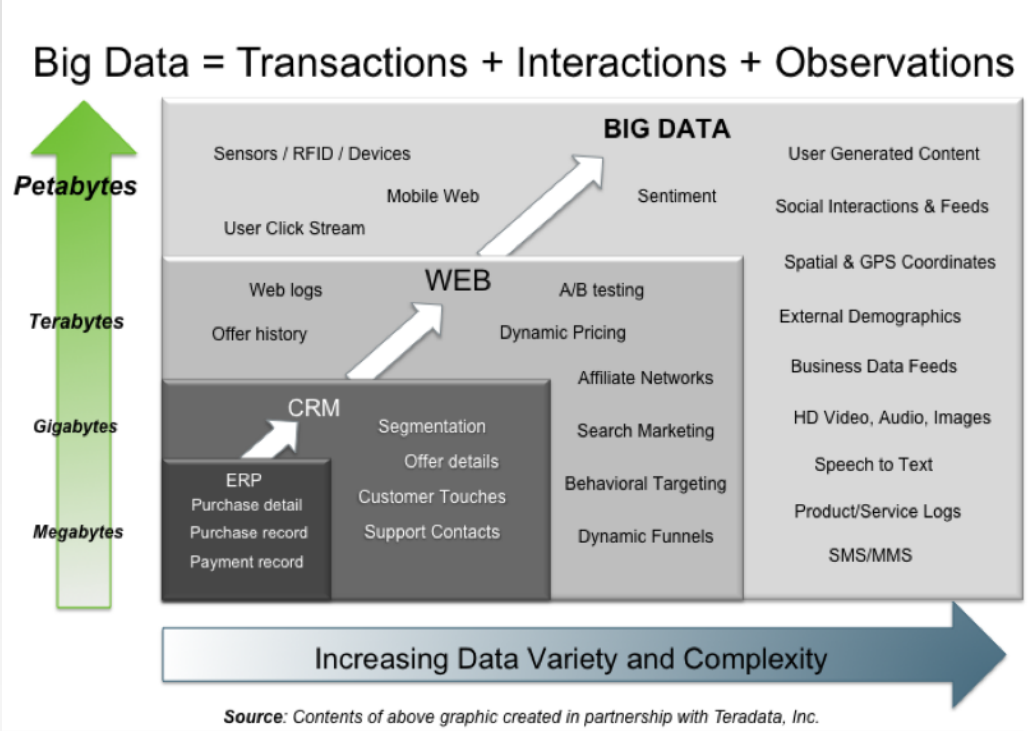
eCommerce

Financial Services

Real Time Search



Big Data Characteristics: 3V



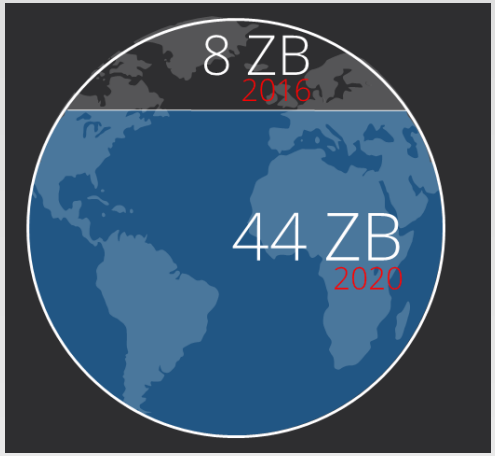
***Source**: Contents of above graphic created in partnership with Teradata, Inc.*

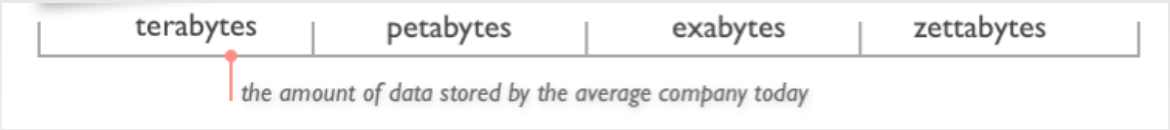
Volume (Scale)

Data Volume

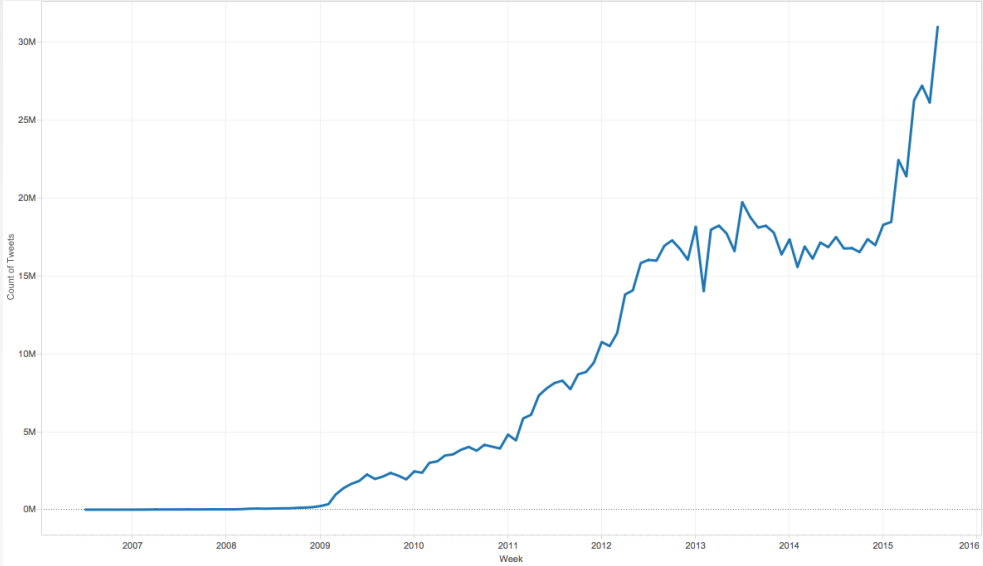
- Growth 40% per year
- From 8 zettabytes (2016) to 44zb (2020)

Data volume is increasing exponentially





Number of Tweets



Recent Twitter Statistics

Total Number of Monthly Active Twitter Users:

330 million

Last updated: 1/1/18

Total Number of Tweets sent per Day:

500 million

Last updated: 1/24/17

Percentage of Twitter users on Mobile:

80%

Last updated: 1/24/17

Number of Twitter Daily Active Users:

100 million

Last updated: 1/24/17

Variety (Complexity)

Different Types:

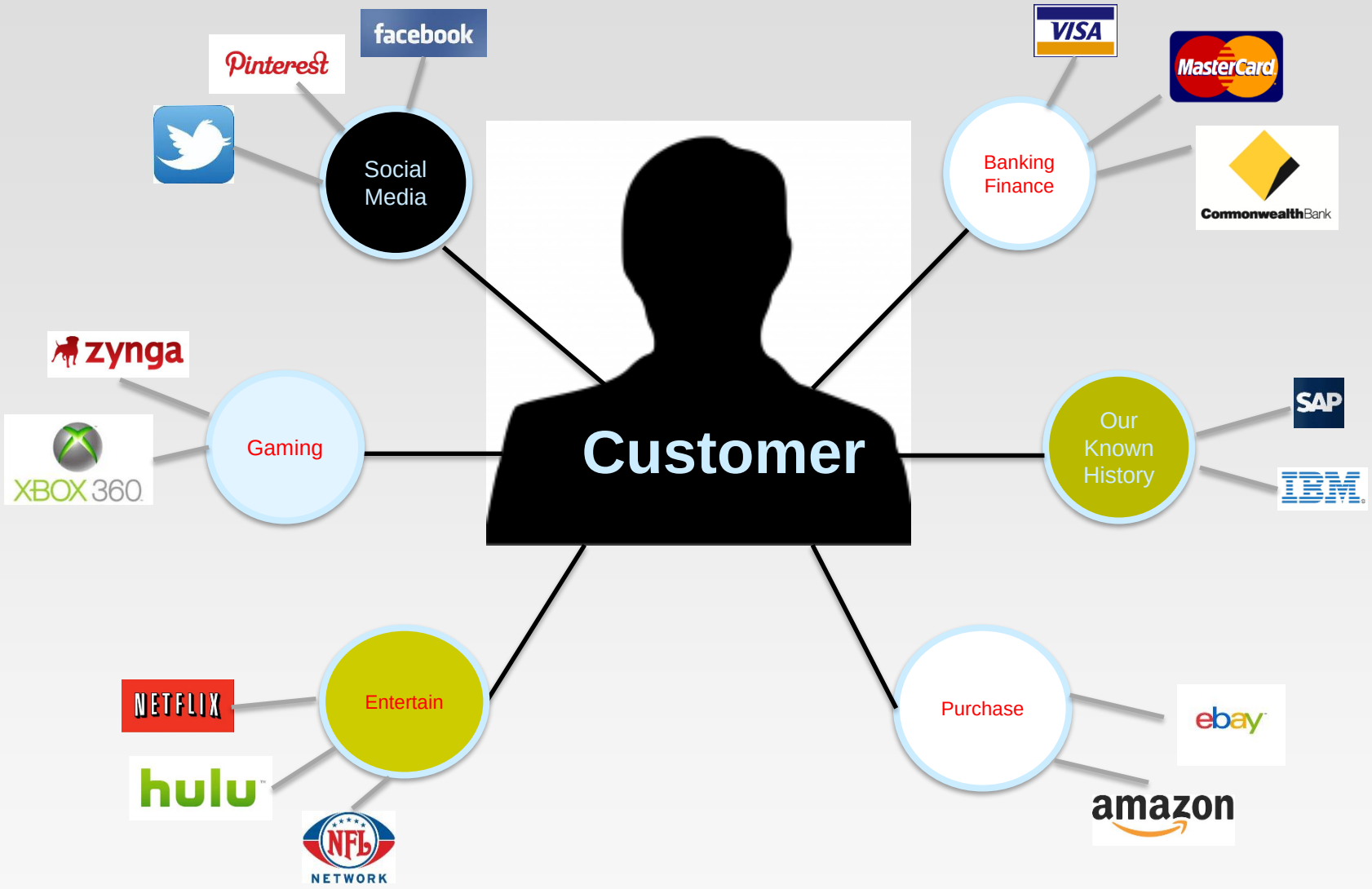
- Relational Data (Tables/Transaction/Legacy Data)
- Text Data (Web)
- Semi-structured Data (XML)
- Graph Data
  - Social Network, Semantic Web (RDF), …
- Streaming Data
  - You can only scan the data once
- A single application can be generating/collecting many types of data

Different Sources:

- Movie reviews from IMDB and Rotten Tomatoes
- Product reviews from different provider websites

To extract knowledge➔ all these types of data need to linked together

A Single View to the Customer



A Global View of Linked Big Data

Diversified social network

Velocity (Speed)

Data is being generated fast and need to be processed fast

Online Data Analytics

Late decisions ➔ missing opportunities

Examples

E-Promotions: Based on your current location, your purchase history, what you like ➔ send promotions right now for store next to you

Healthcare monitoring: sensors monitoring your activities and body ➔ any abnormal measurements require immediate reaction

Disaster management and response

Velocity in Real-world

Every second, on average, around **6,000** tweets are tweeted on Twitter (visualize them here), which corresponds to over **350,000** tweets sent per minute, **500 million** tweets per day and around **200 billion** tweets per year.

The statistics for 1 second in many applications.
http://www.internetlivestats.com/one-second/

Extended Big Data Characteristics: 6V

Volume: In a big data environment, the amounts of data collected and processed are much larger than those stored in typical relational databases.

Variety: Big data consists of a rich variety of data types.

Velocity: Big data arrives to the organization at high speeds and from multiple sources simultaneously.

Veracity: Data quality issues are particularly challenging in a big data context.

Visibility/Visualization: After big data being processed, we need a way of presenting the data in a manner that's readable and accessible.

Value: Ultimately, big data is meaningless if it does not provide value toward some meaningful goal.

Veracity (Quality & Trust)

Data = quantity + quality

When we talk about big data, we typically mean its quantity:

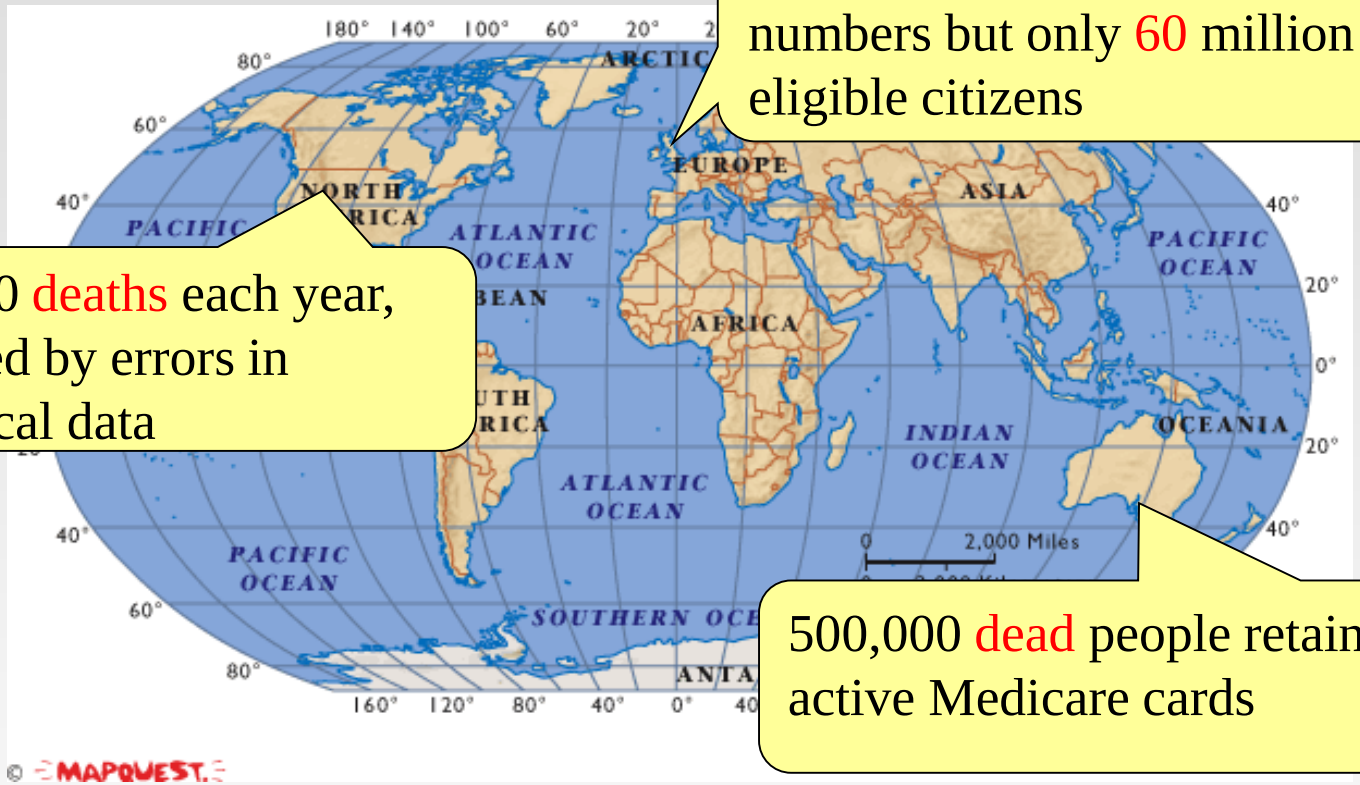
- What capacity of a system provides to cope with the sheer size of the data?
- Is a query feasible on big data within our available resources?
- How can we make our queries tractable on big data?
- . . .

Can we trust the answers to our queries?

- Dirty data routinely lead to misleading financial reports, strategic business planning decision $\Rightarrow$ loss of revenue, credibility and customers, disastrous consequences

The study of data quality is as important as data quantity

Data in real-life is often dirty



Visibility/Visualization

Visibility: the state of being able to see or be seen is implied.

Big Data – visibility = Black Hole?

Visualization: Making all that vast amount of data comprehensible in a manner that is easy to understand and read.

A visualization of Divvy bike rides across Chicago

Big data visualization tools:

BI/Visualization/ Analytics

pentaho COGNOS tableau SAS

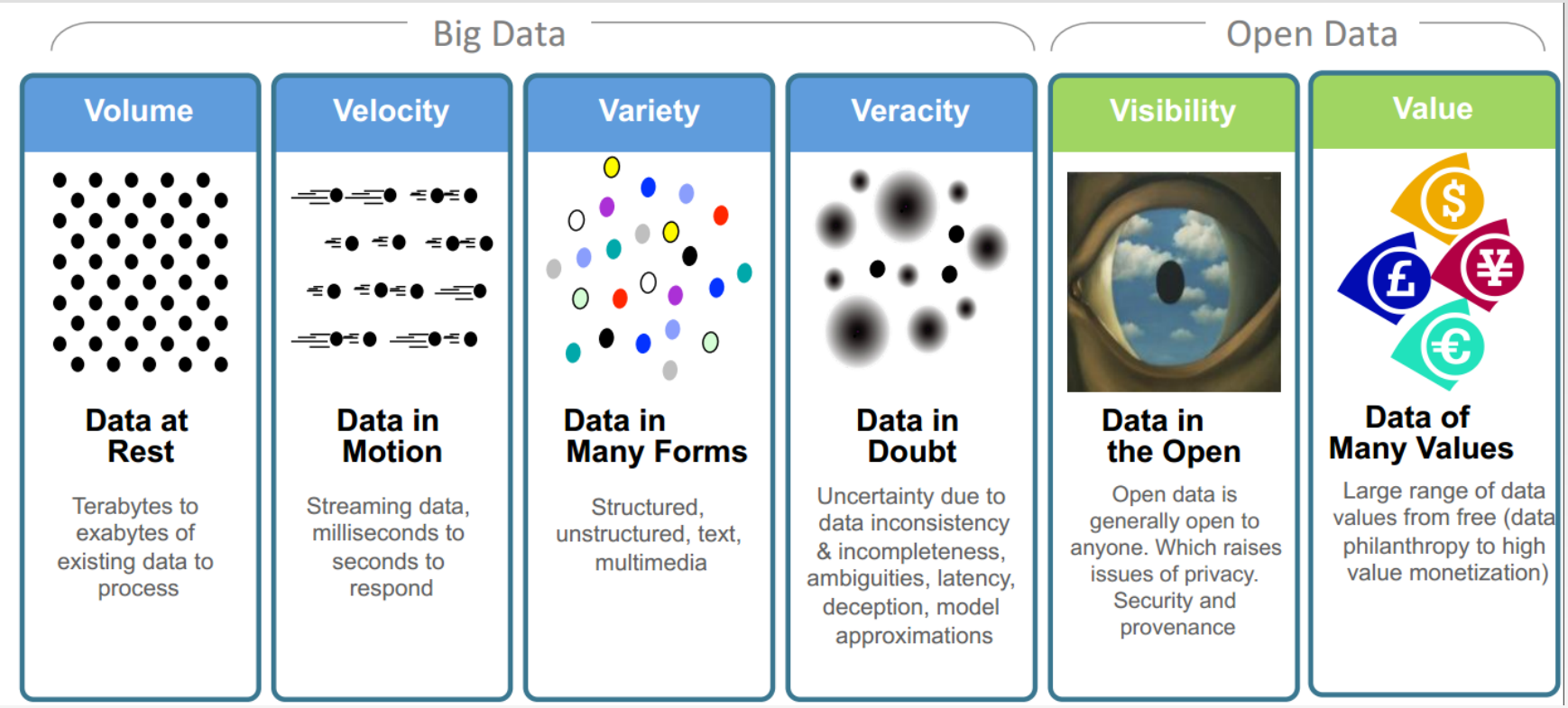
looker

DOMO ClearStory QlikView MicroStrategy Business Objects

Value

Big data is meaningless if it does not provide value toward some meaningful goal

Big Data: 6V in Summary



Transforming Energy and Utilities through Big Data & Analytics. By Anders Quitzau@IBM

Other V's

Variability

Variability refers to data whose meaning is constantly changing. This is particularly the case when gathering data relies on language processing.

Viscosity

This term is sometimes used to describe the latency or lag time in the data relative to the event being described. We found that this is just as easily understood as an element of Velocity.

Volatility

Big data volatility refers to how long is data valid and how long should it be stored. You need to determine at what point is data no longer relevant to the current analysis.

More V's in the future …

How many v's are there in big data? http://www.clc-ent.com/TBDE/Docs/vs.pdf

Tag Clouds of Big Data

Why Study Big Data Technologies?

The hottest topic in both research and industry

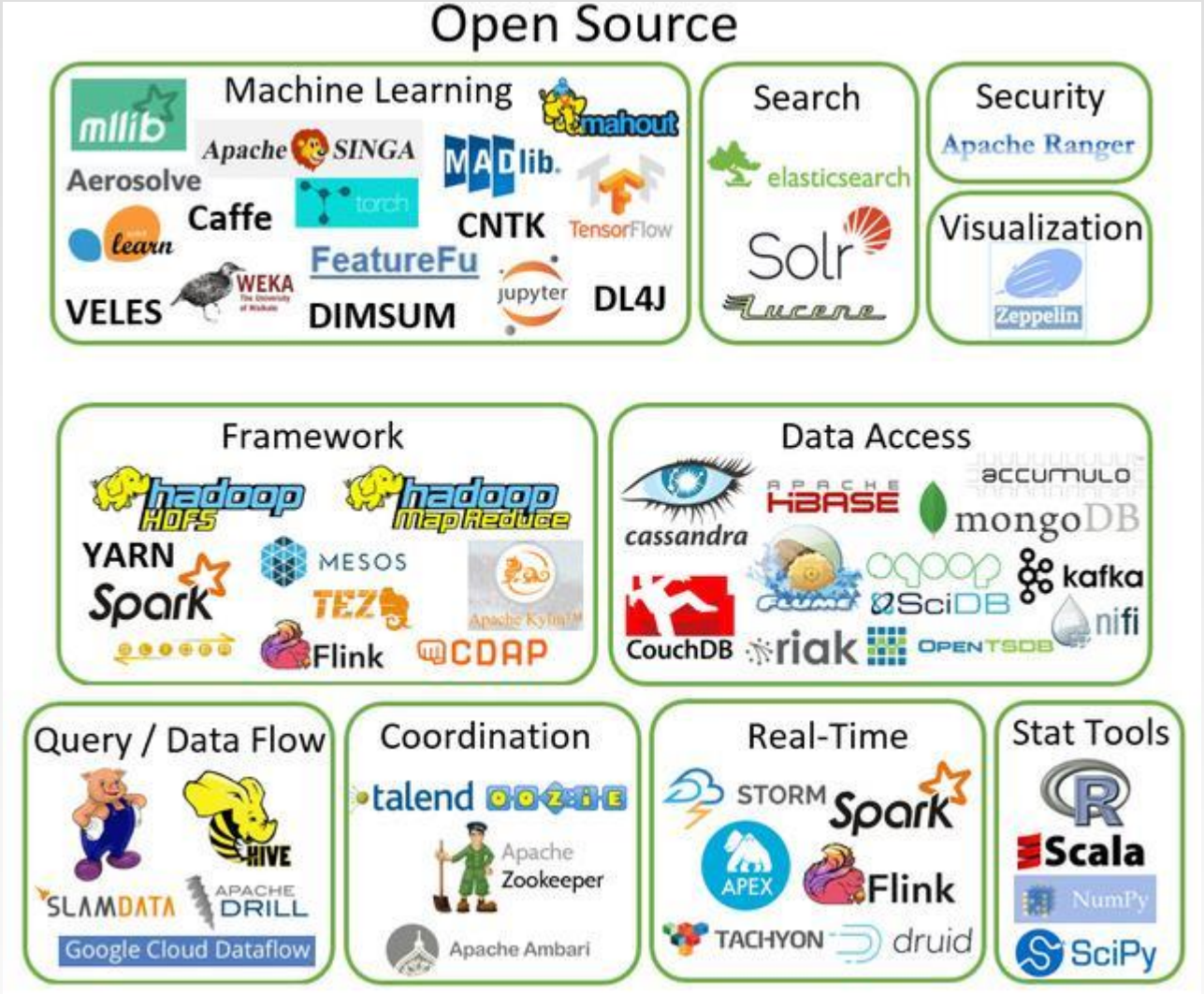
Highly demanded in real world

A promising future career

- Research and development of big data systems:
  - distributed systems (eg, Hadoop), visualization tools, data warehouse, OLAP, data integration, data quality control, …
- Big data applications:
  - social marketing, healthcare, …
- Data analysis: to get values out of big data
  - discovering and applying patterns, predicative analysis, business intelligence, privacy and security, …

Get enough credits

Big Data Open Source Tools



What will the course cover

Topic 1. Big data management tools

Apache Hadoop

- MapReduce
- YARN/HDFS/HBase/Hive/Pig (briefly introduced)
- Spark
- AWS platform
- Mahout/MLlib [tentative]

Topic 2. Big data typical applications

Finding similar items

Graph data processing

Data stream mining

Recommender Systems

Distributed processing is non-trivial

How to assign tasks to different workers in an efficient way?

What happens if tasks fail?

How do workers exchange results?

How to synchronize distributed tasks allocated to different workers?

Big data storage is challenging

Data Volumes are massive

Reliability of Storing PBs of data is challenging

All kinds of failures: Disk/Hardware/Network Failures

Probability of failures simply increase with the number of machines …

What is Hadoop

Open-source data storage and processing platform

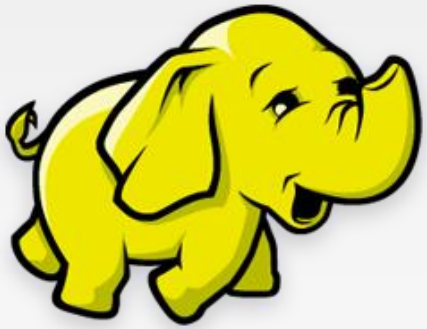
Before the advent of Hadoop, storage and processing of big data was a big challenge

Massively scalable, automatically parallelizable

Based on work from Google

- Google: GFS + MapReduce + BigTable (Not open)
- Hadoop: HDFS + Hadoop MapReduce + HBase（opensource)

Named by Doug Cutting in 2006 (worked at Yahoo! at that time), after his son's toy elephant.



Hadoop offers

Redundant, Fault-tolerant data storage

Parallel computation framework

Job coordination

Programmers

No longer need to worry about

Q: Where file is located?

Q: How to handle failures & data lost?

Q: How to divide computation?

Q: How to program for scaling?

Why Use Hadoop?

Cheaper

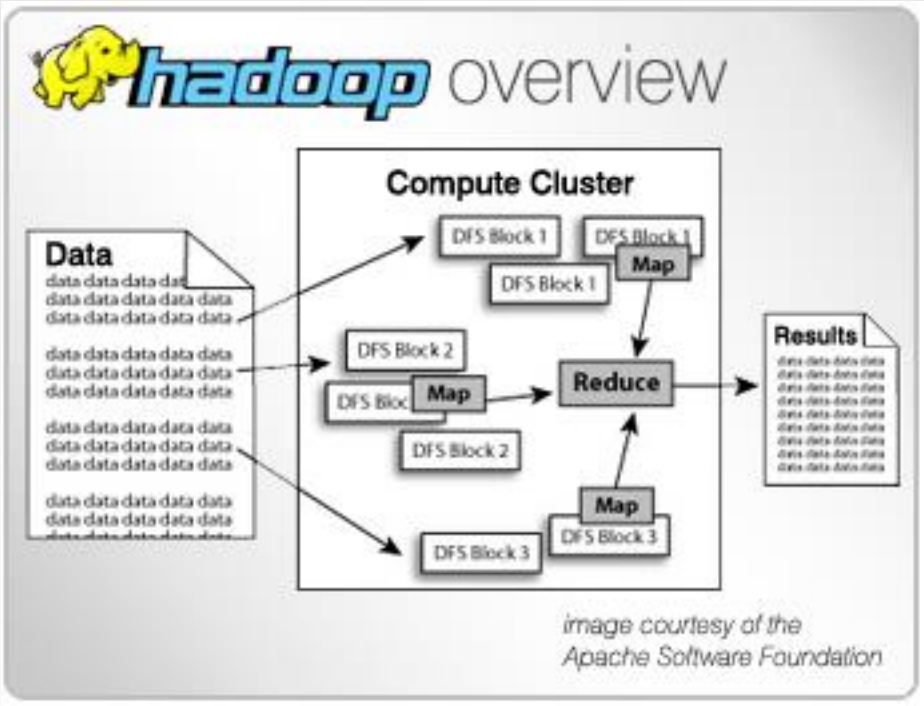
- Scales to Petabytes or more easily

Faster

- Parallel data processing

Better

- Suited for particular types of big data problems



Companies Using Hadoop

Hadoop is a set of Apache Frameworks and more…

Data storage (HDFS)

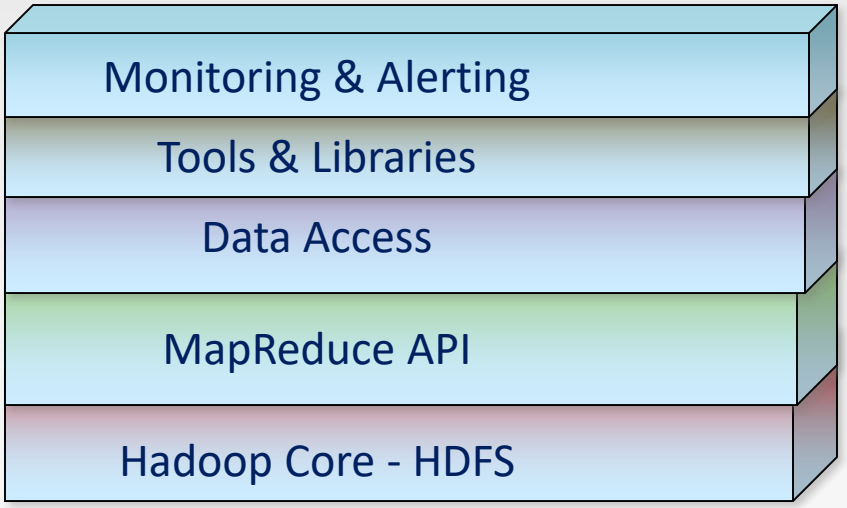
- Runs on commodity hardware (usually Linux)
- Horizontally scalable

Processing (MapReduce)

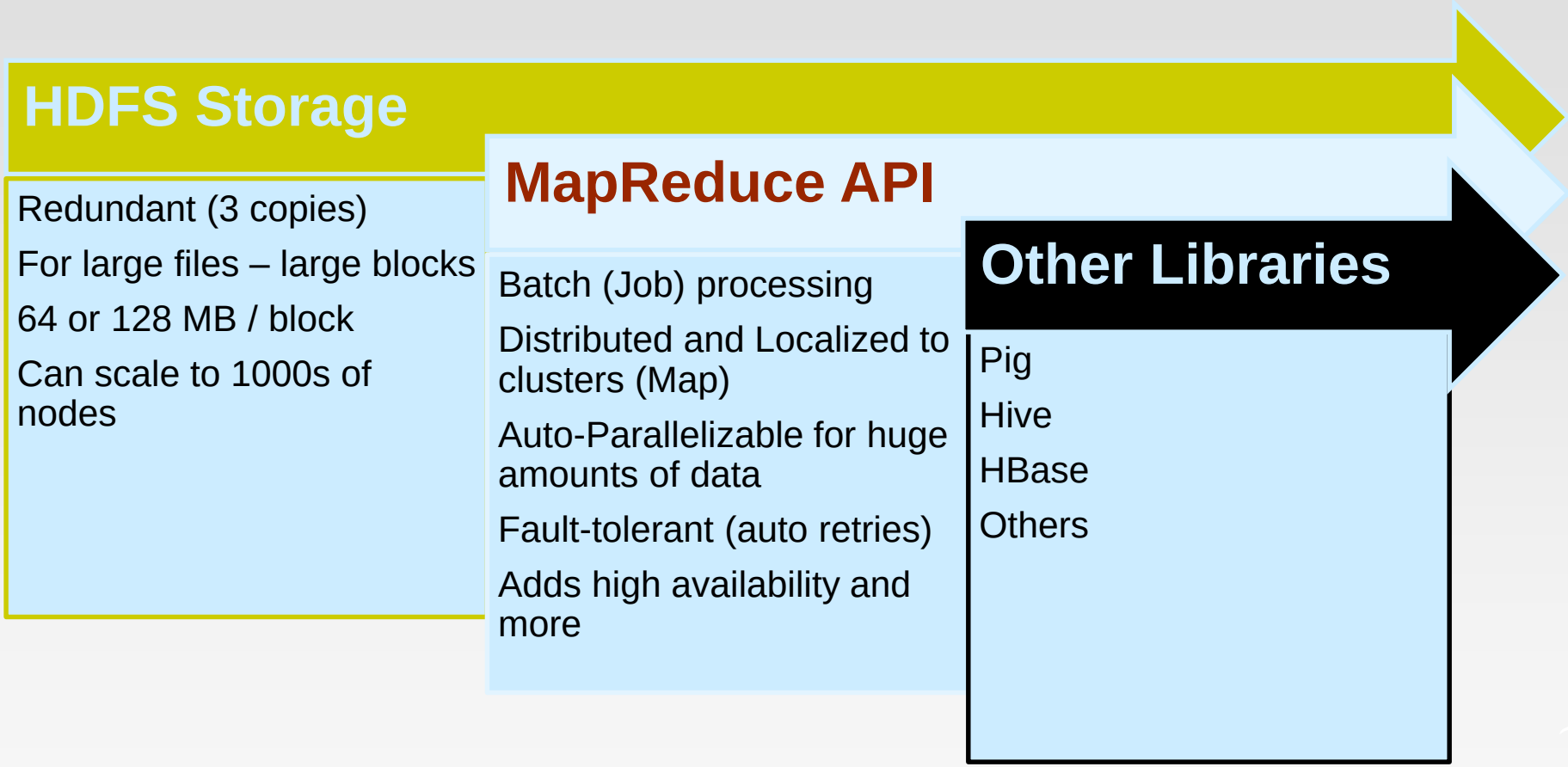
- Parallelized (scalable) processing
- Fault Tolerant

Other Tools / Frameworks

- Data Access
  - HBase, Hive, Pig, Mahout
- Tools
  - Hue, Sqoop
- Monitoring
  - Greenplum, Cloudera



What are the core parts of a Hadoop distribution?



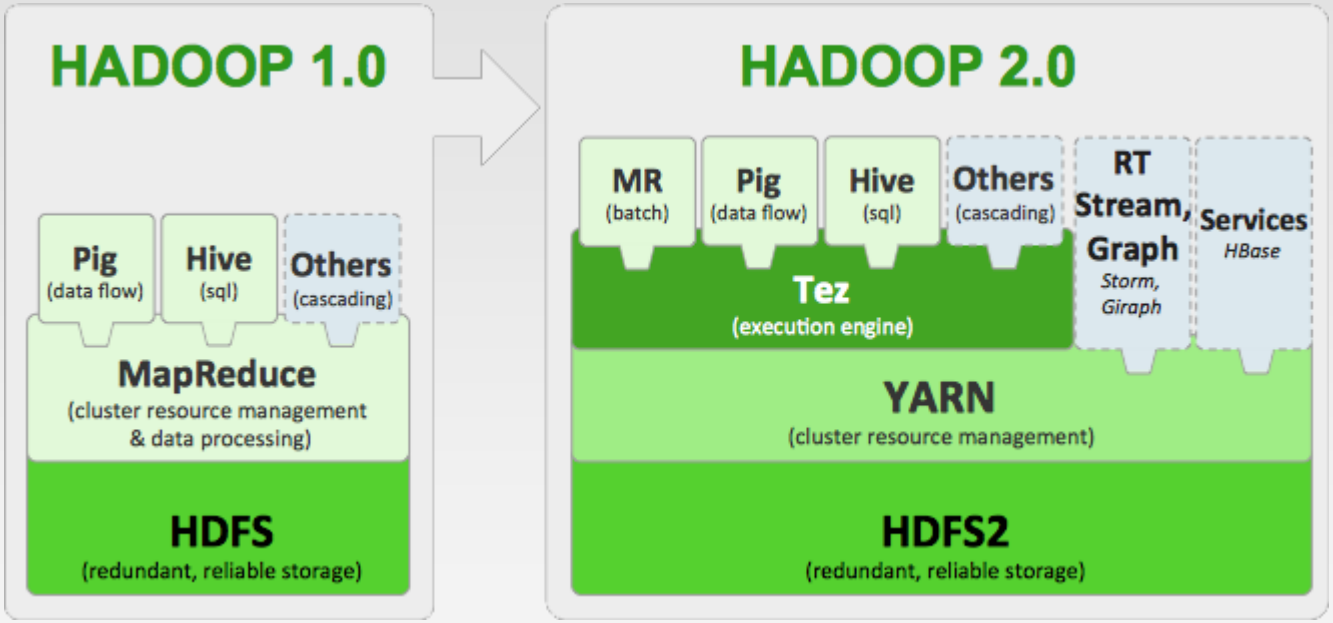
Hadoop 2.0

Single Use System

Batch apps

Multi-Purpose Platform

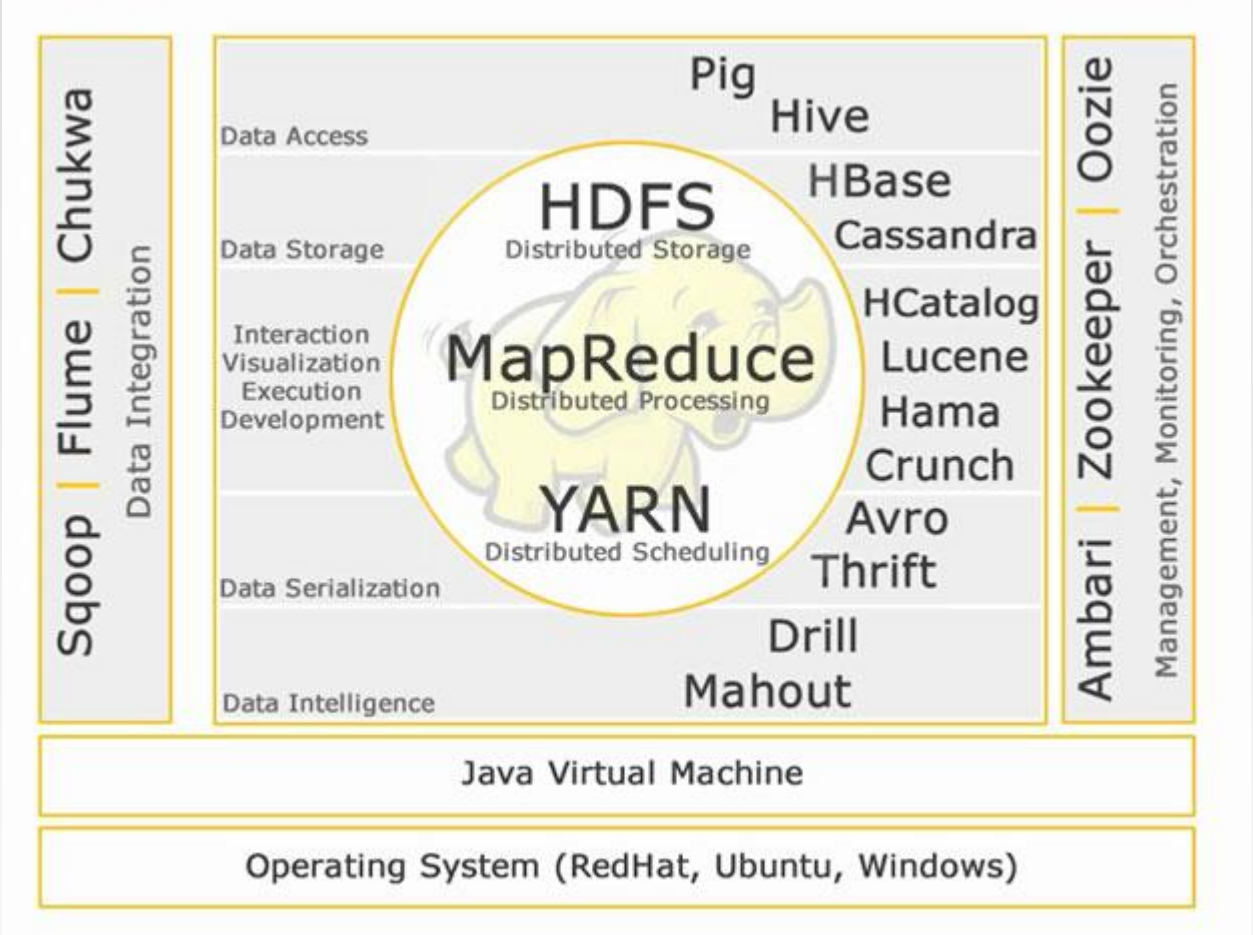
Batch, Interactive, Online, Streaming



Hadoop YARN *(Yet Another Resource Negotiator)*: a resource-management platform responsible for managing computing resources in clusters and using them for scheduling of users' applications

Hadoop Ecosystem

A combination of technologies which have proficient advantage in solving business problems.



http://www.edupristine.com/blog/hadoop-ecosystem-and-components

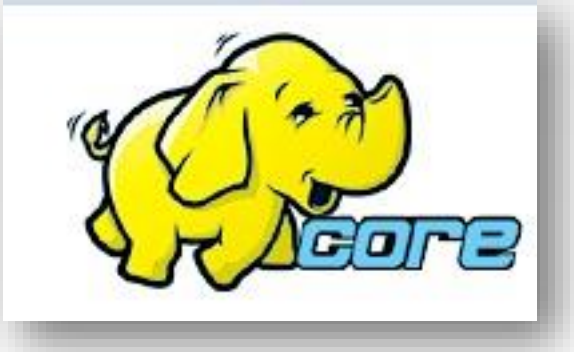
Common Hadoop Distributions

Open Source

- Apache

Commercial

- Cloudera
- Hortonworks
- MapR
- AWS MapReduce
- Microsoft Azure HDInsight (Beta)



Setting up Hadoop Development

Hadoop Binaries

Local install
- Linux
- Windows

Cloudera's Demo VM
- Need Virtualization software, i.e. VMware, etc…

Cloud
- AWS
- Microsoft (Beta)
- Others

Data Storage

Local
- File System
- HDFS Pseudo-distributed (single-node)

Cloud
- AWS
- Azure
- Others

MapReduce

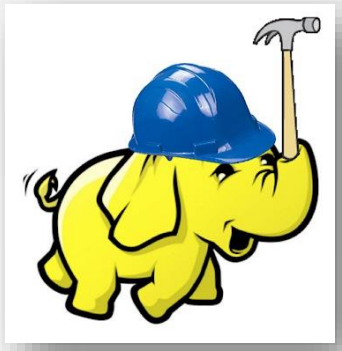
Local

Cloud

Other Libraries & Tools

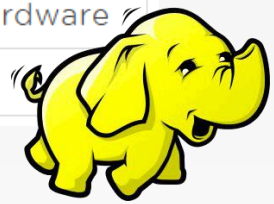
Vendor Tools

Libraries

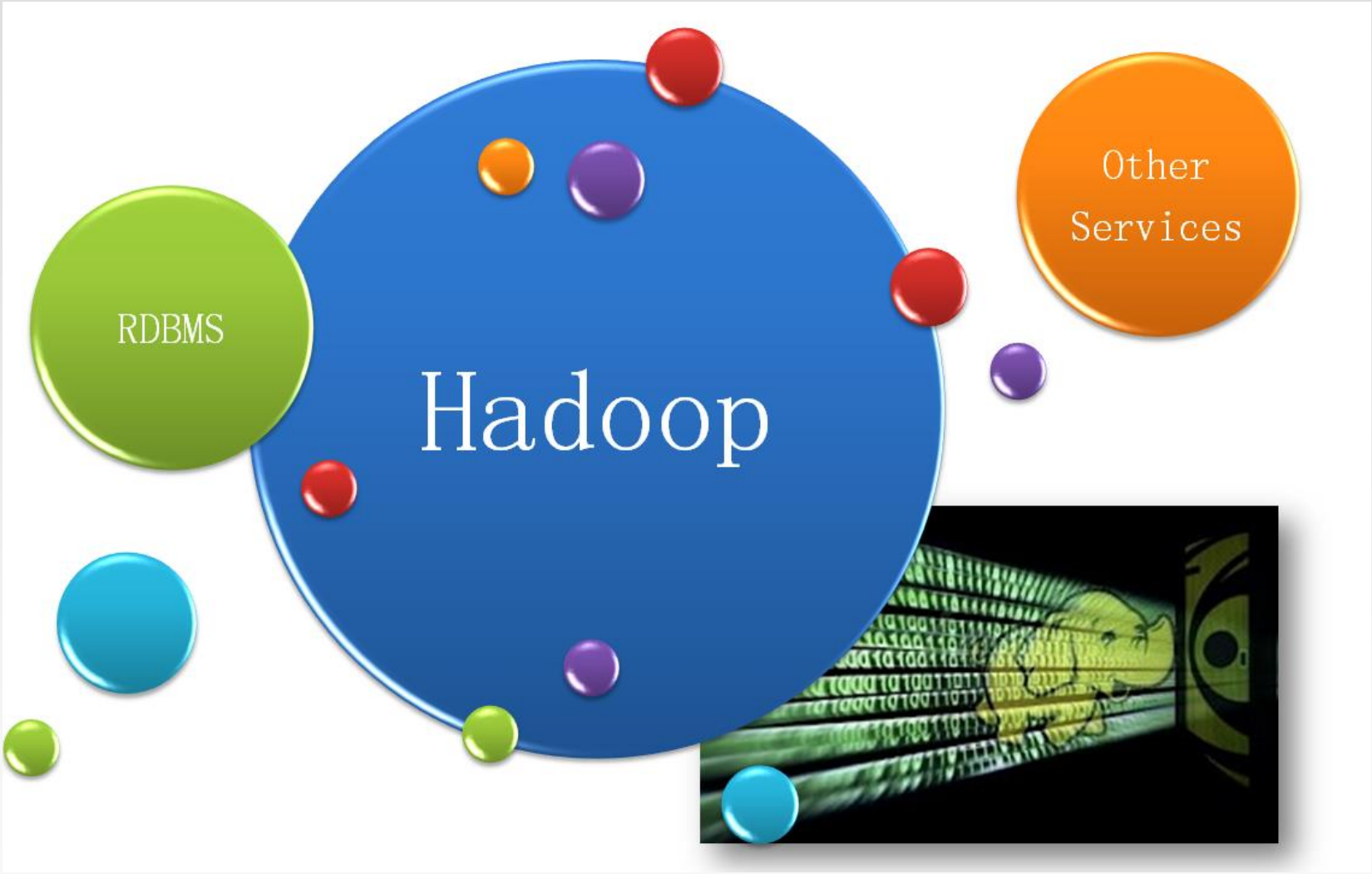


Comparing: RDBMS vs. Hadoop

Feature	RDBMS	Hadoop
Data Variety	Mainly for Structured data.	Used for Structured, Semi-Structured and Unstructured data
Data Storage	Average size data (GBS)	Use for large data set (Tbs and Pbs)
Querying	SQL Language	HQL (Hive Query Language)
Schema	Required on write (static schema)	Required on read (dynamic schema)
Speed	Reads are fast	Both reads and writes are fast
Cost	License	Free
Use Case	OLTP (Online transaction processing)	Analytics (Audio, video, logs etc), Data Discovery
Data Objects	Works on Relational Tables	Works on Key/Value Pair
Throughput	Low	High
Scalability	Vertical	Horizontal
Hardware Profile	High-End Servers	Commodity/Utility Hardware
Integrity	High (ACID)	Low



The Changing Data Management Landscape



AWS (Amazon Web Services)

Amazon

From Wikipedia 2006


Article Talk Head

Amazon.com

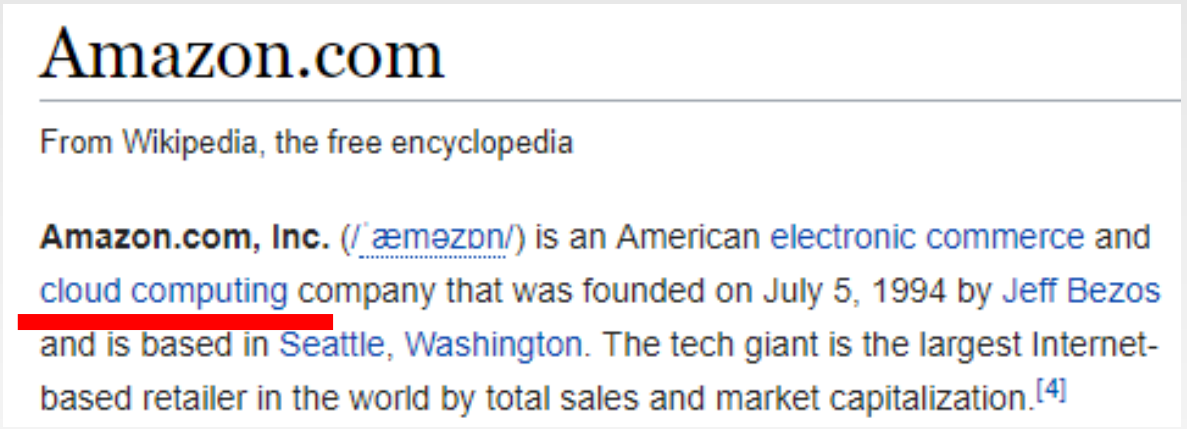
From Wikipedia, the free encyclopedia

This is an old revision of this page 05:10, 20 March 2006 (→Customer permanent link to this revision, wh revision.

(diff) ← Previous revision | Latest revisi

Amazon.com
(NASDAQ: AMZN) is an American electronic commerce company based in Seattle, Washington. It was one of the

From Wikipedia 2017


Amazon.com

From Wikipedia, the free encyclopedia

Amazon.com, Inc. (/ˈæməzɒn/) is an American electronic commerce and cloud computing company that was founded on July 5, 1994 by Jeff Bezos and is based in Seattle, Washington. The tech giant is the largest Internet-based retailer in the world by total sales and market capitalization.[4]

AWS (Amazon Web Services)

AWS is a subsidiary of Amazon.com, which offers a suite of cloud computing services that make up an on-demand computing platform.

Amazon Web Services (AWS) provides a number of different services, including:

Amazon Elastic Compute Cloud (EC2)
Virtual machines for running custom software

Amazon Simple Storage Service (S3)
Simple key-value store, accessible as a web service

Amazon Elastic MapReduce (EMR)
Scalable MapReduce computation

Amazon DynamoDB
Distributed NoSQL database, one of several in AWS

Amazon SimpleDB
Simple NoSQL database

...

Cloud Computing Services in AWS

IaaS

EC2, S3, …

Highlight: EC2 and S3 are two of the earliest products in AWS

PaaS

Aurora, Redshift, …

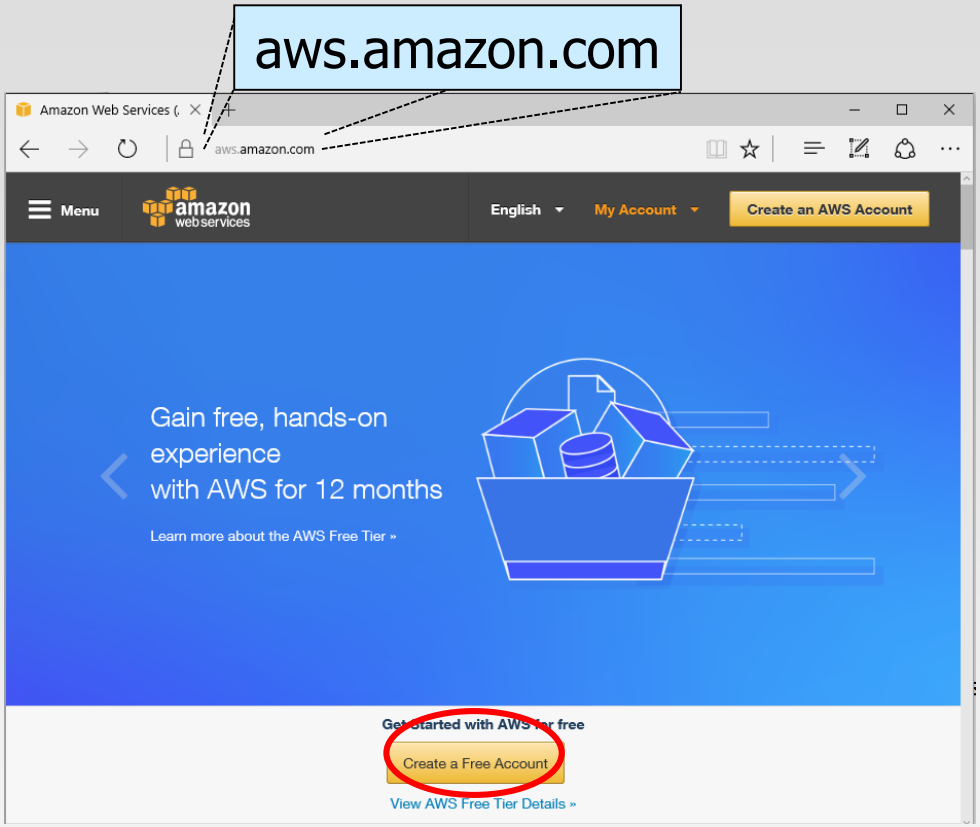
Highlight: Aurora and Redshift are two of the fastest growing products in AWS

SaaS

WorkDocs, WorkMail

Highlight: May not be the main focus of AWS

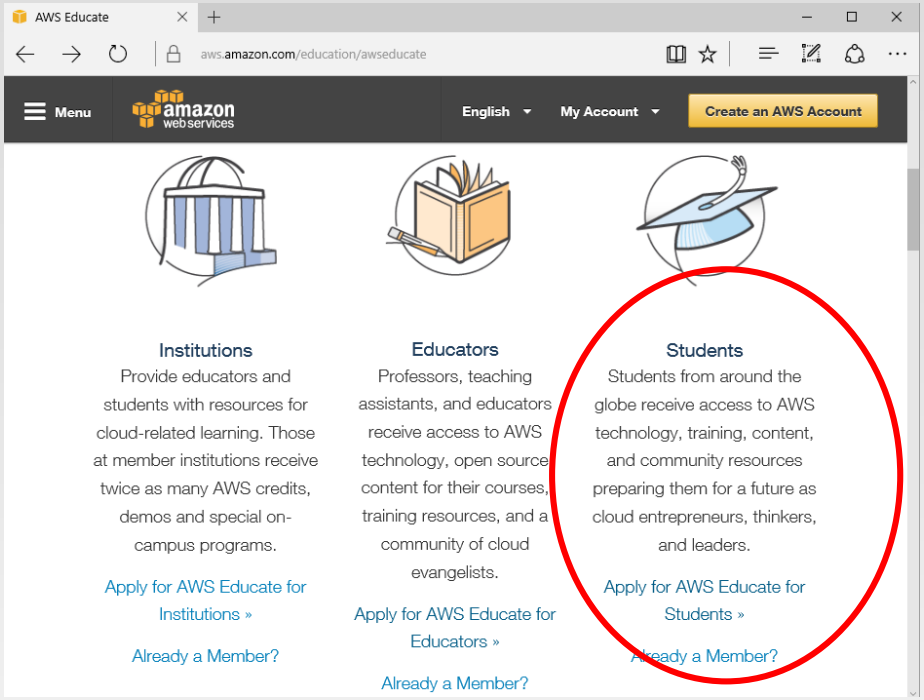
Setting up an AWS account



Sign up for an account on aws.amazon.com

- You need to choose an username and a password
- These are for the management interface only
- Your programs will use other credentials (RSA keypairs, access keys, ...) to interact with AWS

Signing up for AWS Educate



Complete the web form on https://aws.amazon.com/education/awseducate/

- Assumes you already have an AWS account
- Use your UNSW email address!
- Amazon says it should only take 2-5 minutes (but don't rely on this!!)

This should give you $100/year in AWS credits. **Be careful!!!**

Part 2: Introduction to MapReduce

What is MapReduce

Origin from Google, [OSDI'04]

MapReduce: Simplified Data Processing on Large Clusters

Jeffrey Dean and Sanjay Ghemawat

Programming model for parallel data processing

Hadoop can run MapReduce programs written in various languages: e.g. Java, Ruby, Python, C++

For large-scale data processing

Exploits large set of commodity computers

Executes process in distributed manner

Offers high availability

Motivation for MapReduce

Typical big data problem challenges:

- How do we break up a large problem into smaller tasks that can be executed in parallel?
- How do we assign tasks to workers distributed across a potentially large number of machines?
- How do we ensure that the workers get the data they need?
- How do we coordinate synchronization among the different workers?
- How do we share partial results from one worker that is needed by another?
- How do we accomplish all of the above in the face of software errors and hardware faults?

Motivation for MapReduce

There was need for an abstraction that hides many system-level details from the programmer.

MapReduce addresses this challenge by providing a simple abstraction for the developer, transparently handling most of the details behind the scenes in a ***scalable***, ***robust***, and ***efficient*** manner.

MapReduce separates the ***what*** from the ***how***

Typical Big Data Problem

Iterate over a large number of records

Extract something of interest from each — Map

Shuffle and sort intermediate results

Aggregate intermediate results

Generate final output — Reduce

Key idea: provide a functional abstraction for these two operations

The Idea of MapReduce

Inspired by the map and reduce functions in functional programming

We can view map as a transformation over a dataset

- This transformation is specified by the function *f*
- Each functional application happens in isolation
- The application of *f* to each element of a dataset can be parallelized in a straightforward manner

We can view reduce as an aggregation operation

- The aggregation is defined by the function *g*
- Data locality: elements in the list must be “brought together”
- If we can group elements of the list, also the reduce phase can proceed in parallel

The framework coordinates the map and reduce phases:

- Grouping intermediate results happens in parallel

Everything Else?

Handles scheduling

- Assigns workers to map and reduce tasks

Handles “data distribution”

- Moves processes to data

Handles synchronization

- Gathers, sorts, and shuffles intermediate data

Handles errors and faults

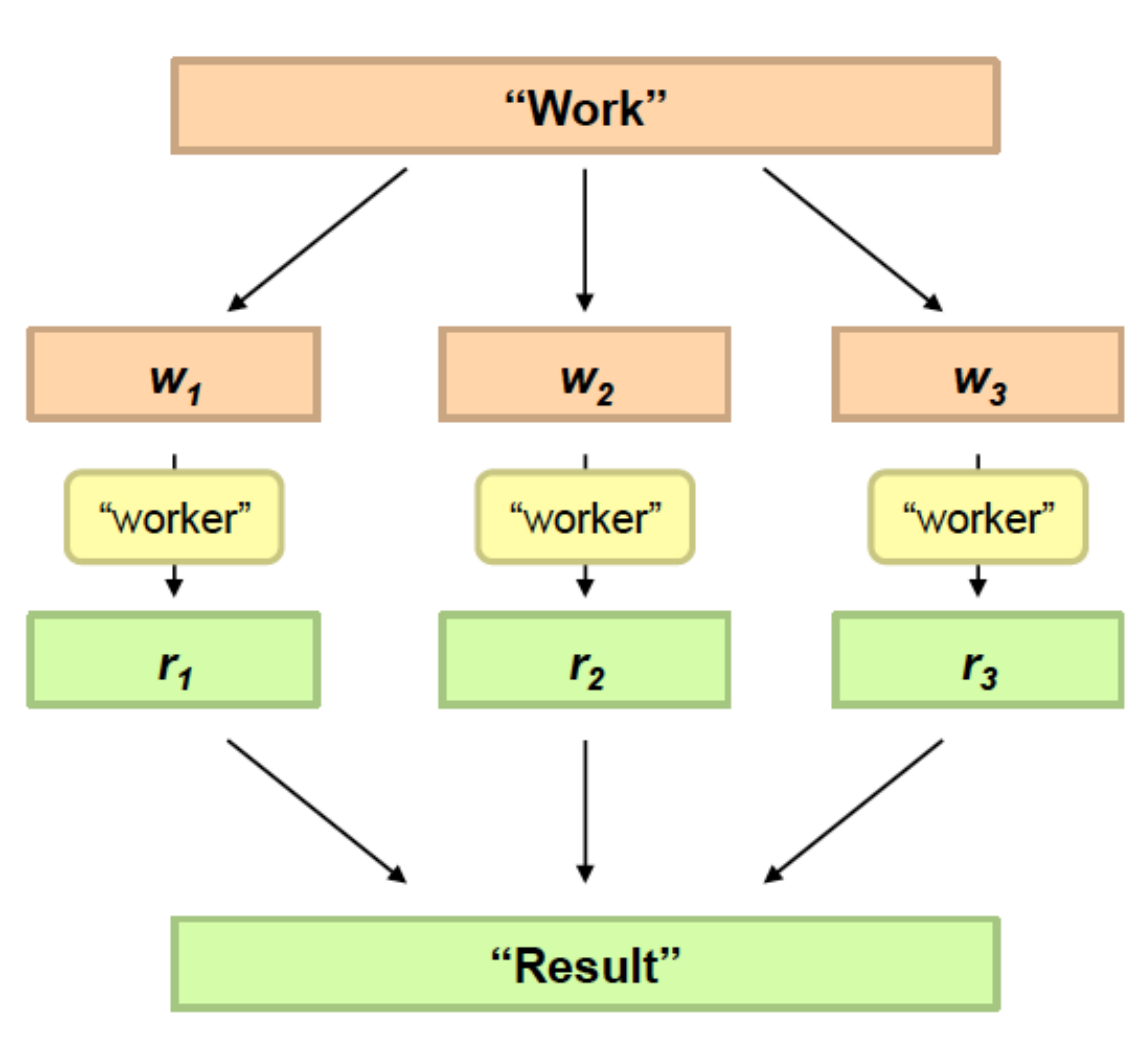
- Detects worker failures and restarts

Everything happens on top of a distributed file system (HDFS)

You don’t know:

- Where mappers and reducers run
- When a mapper or reducer begins or finishes
- Which input a particular mapper is processing
- Which intermediate key a particular reducer is processing

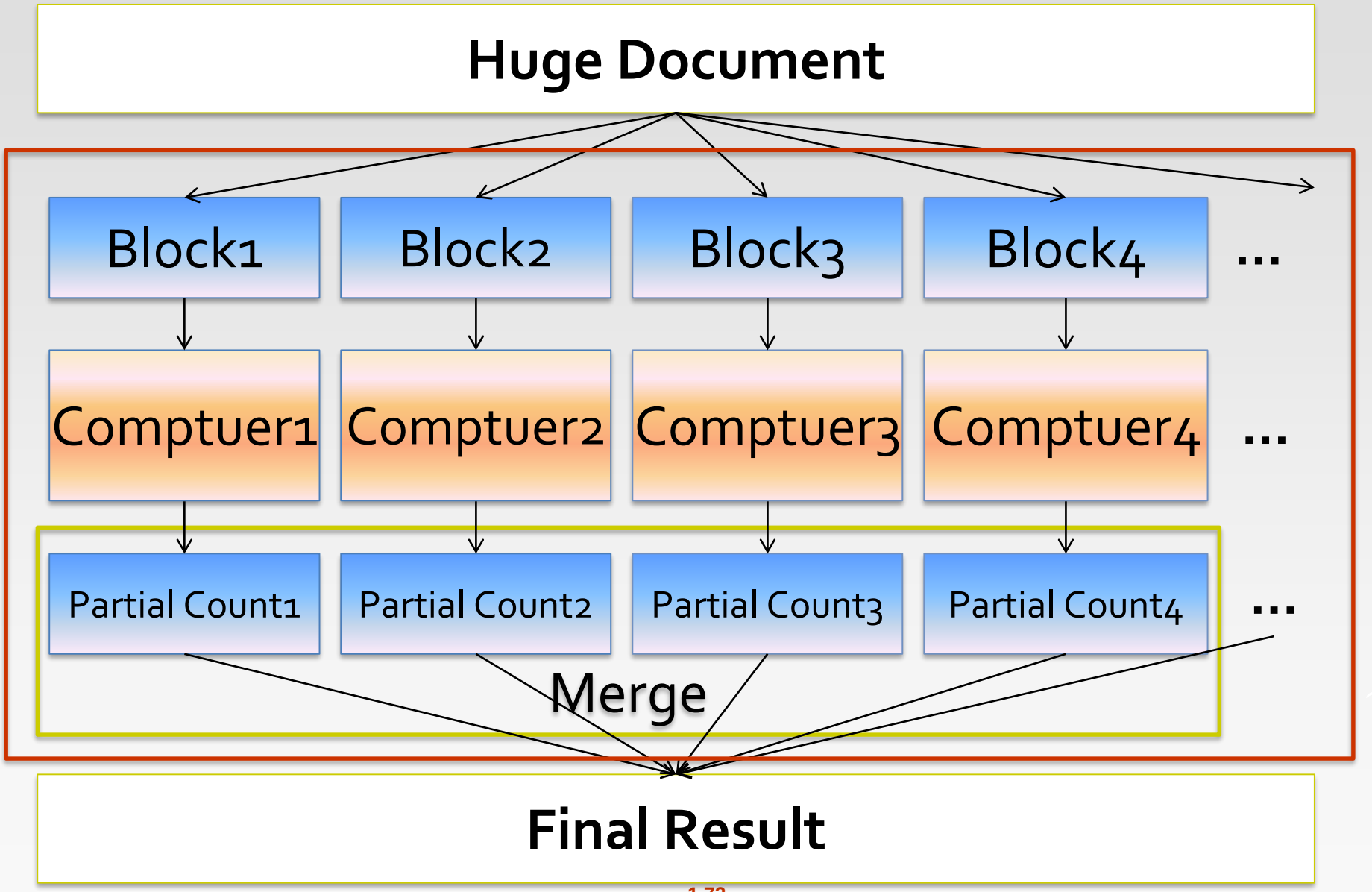
Philosophy to Scale for Big Data Processing



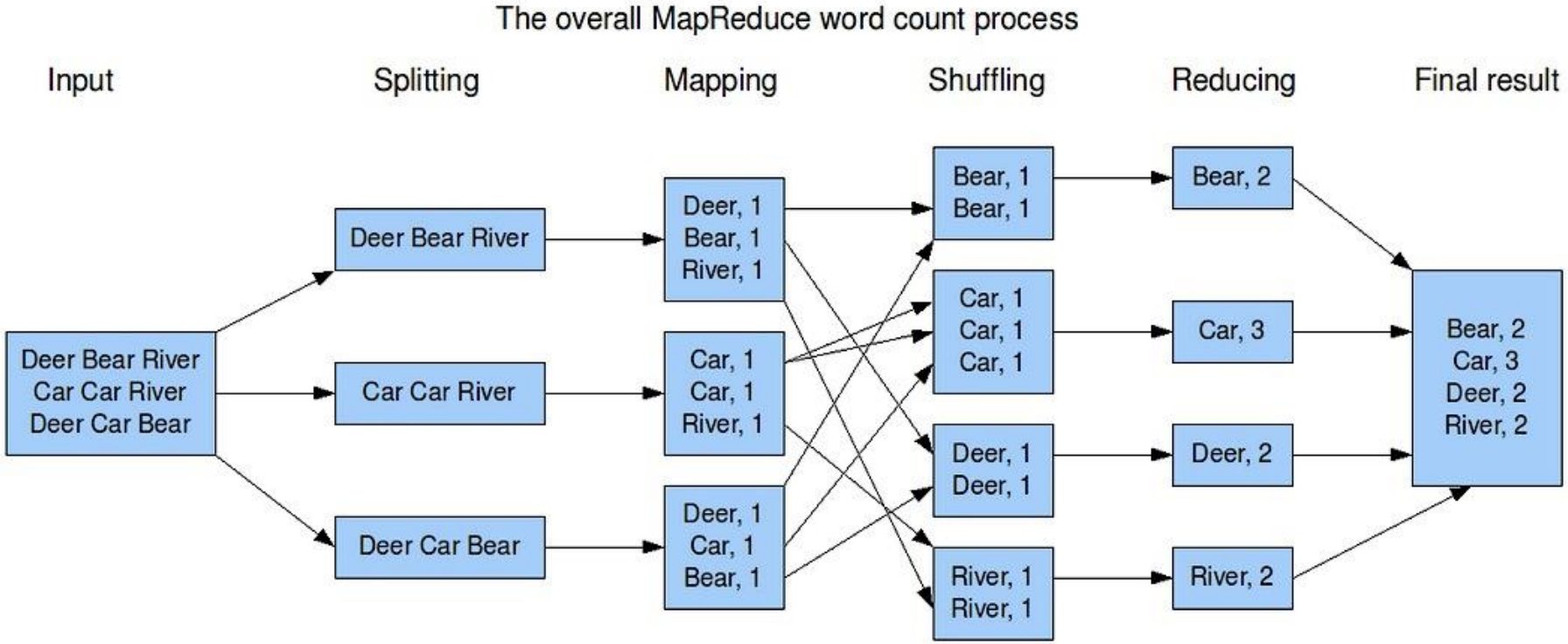
Divide Work

Combine Results

Distributed Word Count



MapReduce Example - WordCount



Hadoop MapReduce is an implementation of MapReduce

MapReduce is a computing paradigm (Google)

Hadoop MapReduce is an open-source software

End of Chapter 1