COMP9313: Big Data Management

Lecturer: Xin Cao

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

Chapter 1 Introduction and Management

Course Info

- Lectures : 6 : 00 – 9:00 pm (Tuesday)
- Location:
  - Old Main Building 230 (K-K15-230)
  - Webstream
- Labs: Weeks 2-13
- Consultation (W *g lectures, course materials, assig*
  - Time: 3:00 – 4:00 pm (Tuesday
  - Place: 201D, K-17
- TA:
  - Xuefeng Chen, *xuefeng.chen@student.unsw.edu.au*
- Tutors: Xuefeng Chen, Wei Li, You Peng, 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 intere
  - 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 in o understand modern large-scale data ide range of topics and technologies, and will prepare able to build such systems as well as use them effi vely 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 r (e.g., like a lab/demo) to co
- Lecture length varies slightly depen gress (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.
  - Learning Sp Park. au, Andy Konwinski, Patrick Wendell. O'Reilly Media
- Reference Books and other reading
  - 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**
  - **be familiar with working on a** **erating systems**
  - have basic knowledge of linear ector 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* *this subject*

Learning outcomes

- After completing this course, you are expected to:
  - elaborate the important characteristics of Big Data
  - develop an appropriate storage structure for a Big Data repository
  - utilize the map/reduce paradigm and the to manipulate Big Data
  - utilize the Spark platform to manipulate Big Data
  - develop effi blems involving Big Data

Assessment

Coding Projects

- Projects:
  - 1 warm-up programming project on Hadoop MapReduce
  - 1 harder project on Hadoop MapReduce
  - 1 project on Spark
  - 1 project on AWS (MapReduce/Spark)

- Both results and

  - If not able to run your codes du , 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 sub
  - Use Give to [illegible] web page)
  - Classrun. Check your submissi [illegible] Read https://wiki.cse.unsw.edu.au/[illegible]

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 a** **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
- I am unlikely to accept the following
  - “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	Graph	Proj2
6	Spark	
7	Spark 2	Proj3
8	Data stream mining	
9	Finding Similar Items	Proj4
10	Recommender Systems	
11	NoSQL and High Level MapReduce Tools	
12	Revision and exam preparation	

Labs

- 5 labs on MapReduce
- 3 labs on Spark
- 1 lab on high-level MapReduce tools
- 1 lab on AWS
- 1 lab on big data machine learning

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
      - Down s it, and rename the file "x -disk2.vmdk“
      - Open VirtualBox, File->I ce
      - Browse the image folder, vf" 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 w cturer, at the discussion and
- myExperience system

Why Attend the Lectures?

Part 2: Big Data

What is Big Data?

- No standard definition! here is from Wikipedia:
  - Big data is a term for data sets that are so voluminous or complex that traditional data processing application software are inadequate to deal with them
  - Challenges include capture, storage, analysis, data curation, search, sharing, transfer, visualization, querying, updating and information
  - The term "bi e use of *predictive analytics*, *user behaviour analyt* ther advanced data analytics methods that extract v , and seldom to a particular size of data set
  - Analysis of data sets can find new correlations to "spot business trends, prevent diseases, combat crime and so on."

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

Who is generating Big Data?

Social

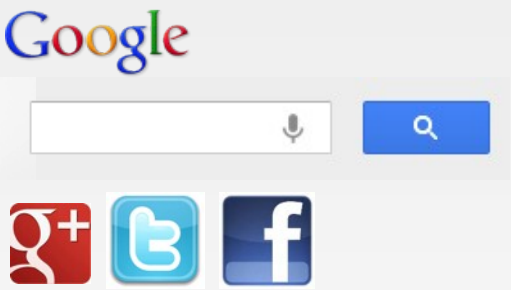
User Tracking & Engagement

Homeland Security

eCommerce

Financial Serv

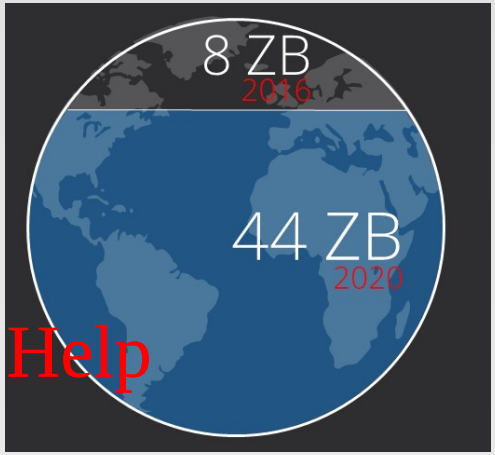
Real Time Search



Big Data Characteristics: 3V

Volume (Scale)

- Data Volume
  - Growth 40% per year
  - From 8 zettabytes (2016) to 44zb (2020)
- Data volume is increasing exponentially



Number of Tweets

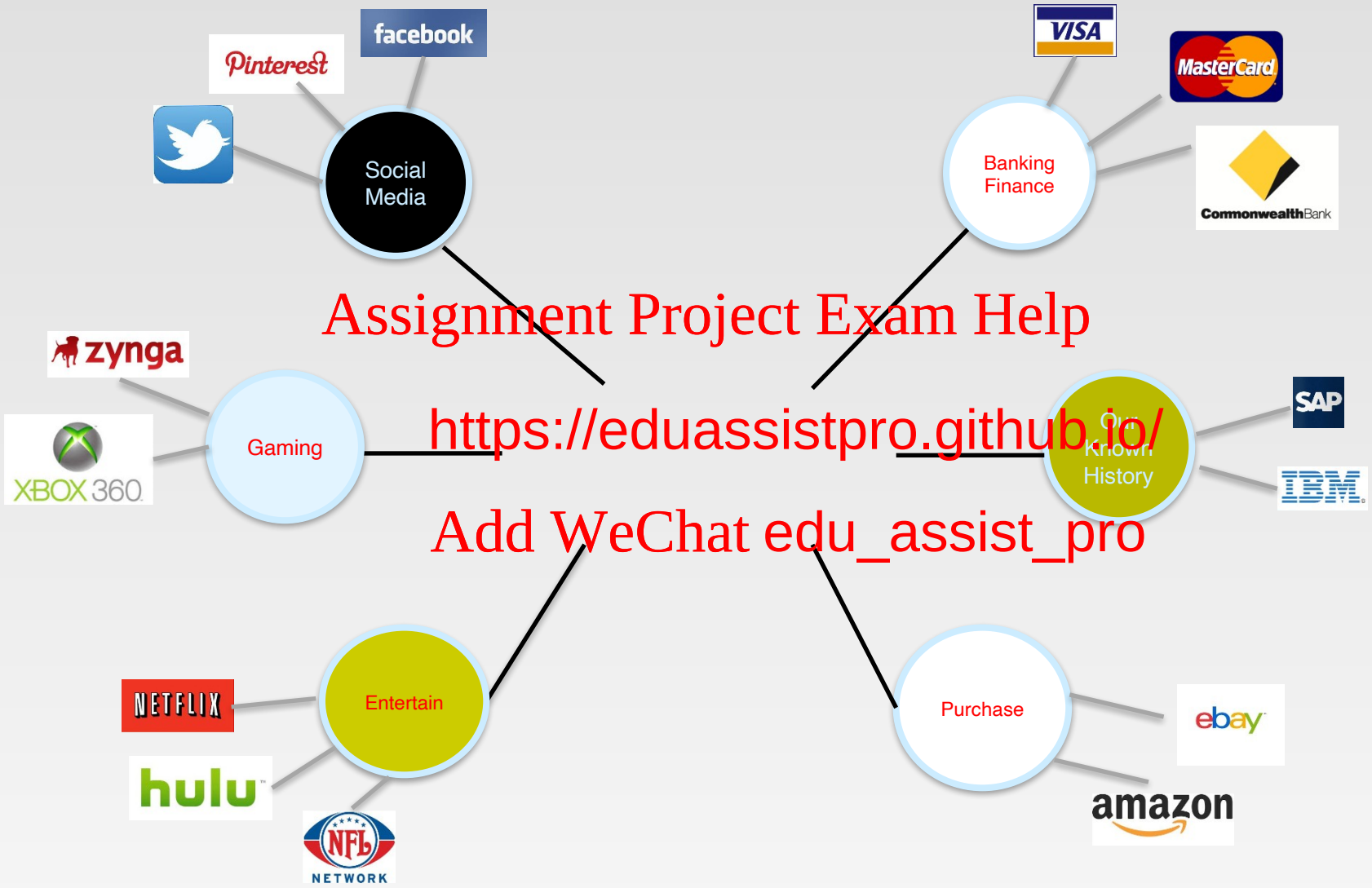
Recent Twitter Statistics

Variety (Complexity)

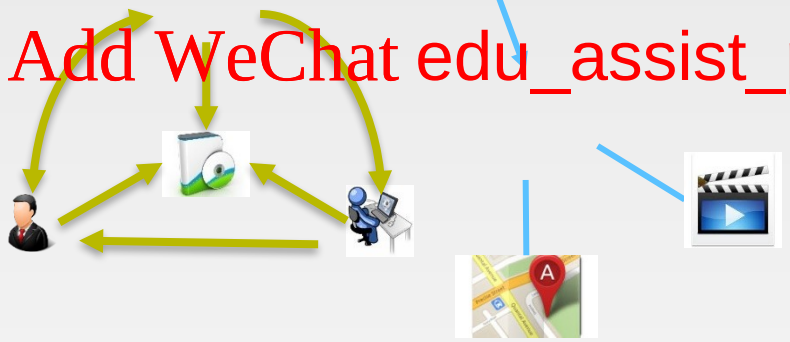
- Different Types:
  - Relational Data (Tables/Transaction/Legacy Data)
  - Text Data (Web)
  - Semi-structured Data (XML)
  - Graph Data
    - Social N
  - Streaming D
    - You can only scan the data
  - A single application can be gen ng many types of data
- Different Sources :
  - Movie reviews from 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, wh right now for store next to you
  - **Healthcare monitoring:** sens your activities and body ➔ any abnormal t 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.inter

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 q allenging in a big data context.
- Visibility/Visualization: After big dat sed, 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 big data?
  - . . .
- Can we trust the answers to our qu
  - Dirty data routinely lead to misl reports, strategic business planning decision ⇒ 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

81 million National Insurance numbers but only 60 million eligible citizens

98000 deaths each y caused by errors in medical data

500,000 dead people retain active Medicare cards

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:

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 a
- Volatility
  - Big data volatility refers to how l lid and how long should it be stored. You need to hat 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 wareh ata quality control, …
  - Big data ap
    social marketing, healthc
  - 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 pla
    - Mahout [
- Topic 2. Big data typical application
  - 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: (Not open)
    - Hadoop: HBase opensource)
- Named by Doug Cutting in 2006 (w at that time), after his son's toy elephant.

Hadoop offers

- Redundant, Fault-tolerant data storage
- Parallel computation framework
- Job coordination

Programmers

Q: Where file is located?

: How to handle ilures & data t?

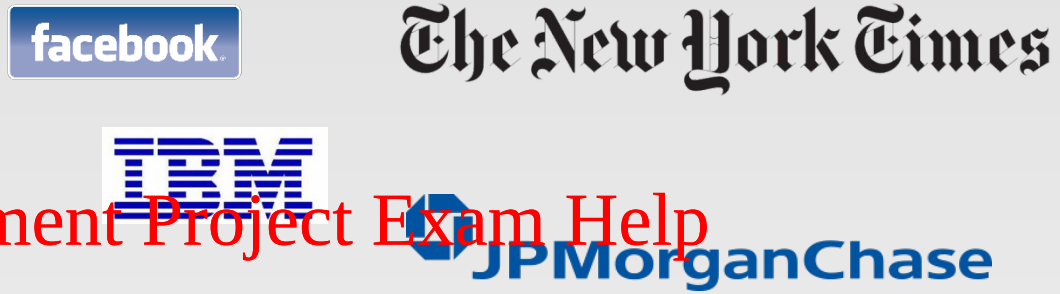
How to divide computation?

Q: How to program for scaling?

Why Use Hadoop?

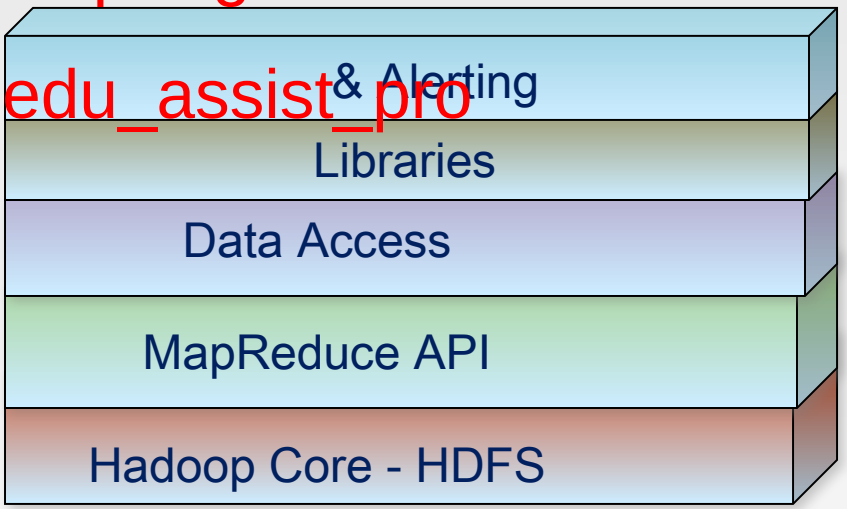
- Cheaper
  - Scales to Petabytes or more easily
- Faster
  - Parallel data processing
- Better
  - Suited for p ms

Companies Using Hadoop

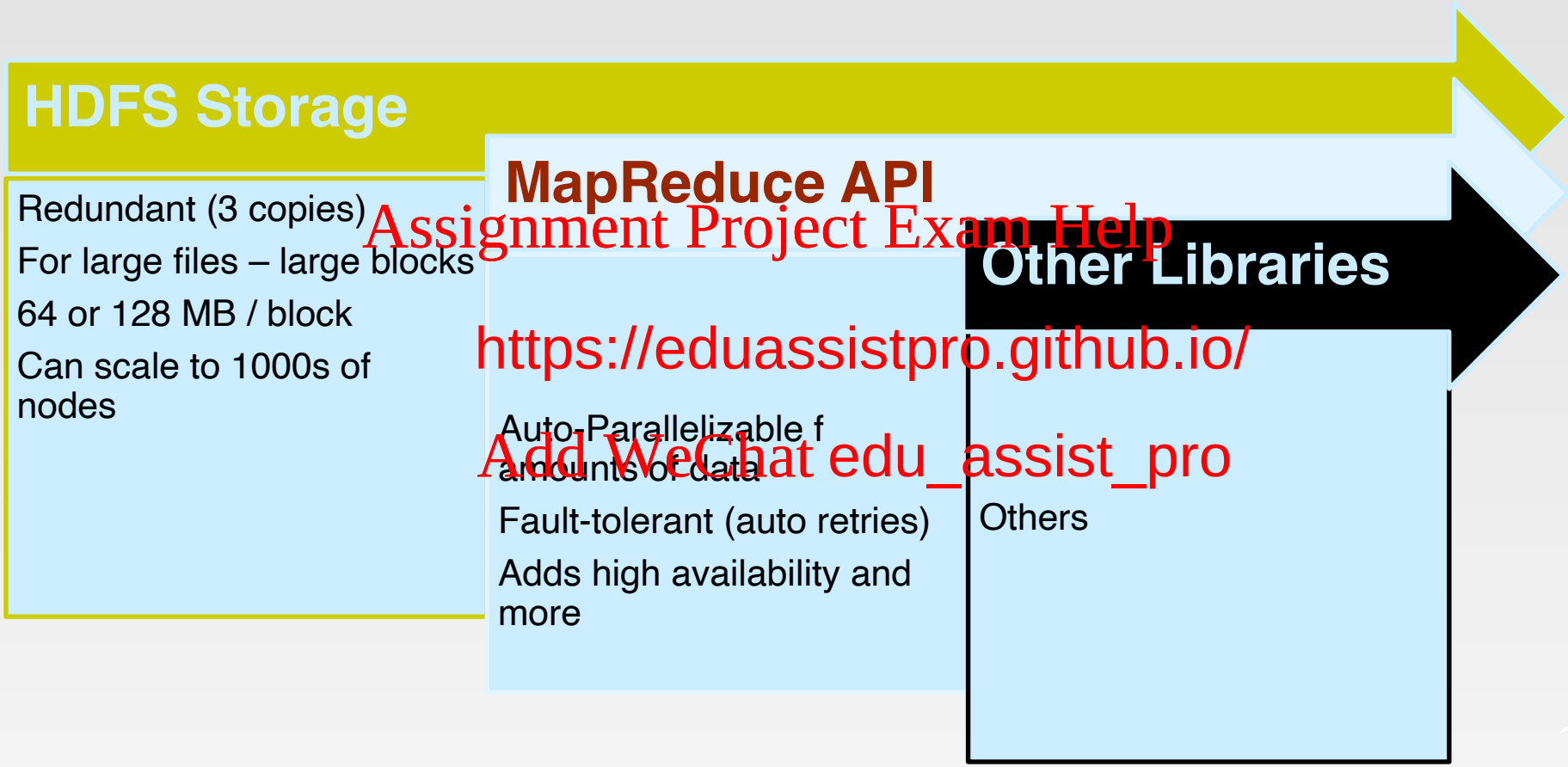


Hadoop is a set of Apache Frameworks and more…

- Data storage (HDFS)
  - Runs on commodity hardware (usually Linux)
  - Horizontally scalable
- Processing (MapReduce)
  - Parallelized (scalable) processing
  - Fault Tolera
- Other Tools / Fr
  - 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

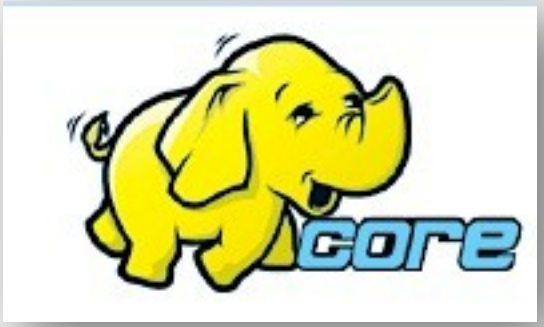
Hadoop Ecosystem

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
  - Hortonwork
  - MapR
  - AWS MapReduce
  - Microsoft Azure HDInsight (Bet



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

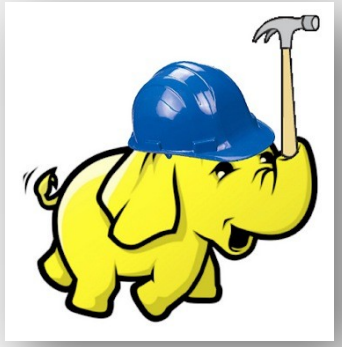
- Local
  - File System
  - HDFS Pseudo-
- Cloud
  - AWS
  - Azure
  - Others

MapReduce

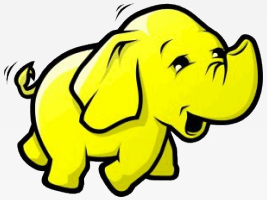
- Local

Other Libraries & Tools

- Vendor Tools
- Libraries



Comparing: RDBMS vs. Hadoop



The Changing Data Management Landscape

Philosophy to Scale for Big Data Processing

Divide Work

Combine Results

MapReduce

- Typical big data problem
  - Iterate over a large number of records
  - Extract something of interest from each
  - Shuffle and sort intermediate results
  - Aggregate intermediate results
  - Generate fin

- Programmers specify two functions:

  map $(k_1, v_1) \rightarrow [<k_2, v_2>]$

  reduce $(k_2, [v_2]) \rightarrow [<k_3, v_3>]$

  - All values with the same key are sent to the same reducer
- The execution framework handles everything else…

Understanding MapReduce

- Map>>
  - (K1, V1) →
    - Info in
    - Input Split
  - list (K2, V2)
    - Key / Value out (intermediate values)
    - One list per local node
    - Can implement local Reducer (or Combiner)
- Shuffle/Sort>>
- Reduce
  - (K2, list(V2)) →
    - Shuffle / Sort phase precedes Reduce phase
    - Combines Map output into a list
  - list (K3, V3)
    - Usually aggregates intermediate values

(input) <k1, v1> → **map** → <k2, v2> → **combine** → <k2, list(V2)> → **reduce** → <k3, v3> *(output)*

WordCount - Mapper

- Reads in input pair <k1,v1>
- Outputs a pair <k2, v2>
  - Let's count number of each word in user queries (or Tweets/Blogs)
  - The input to the mapper will be <queryID, QueryText>:

<Q1, "The teacher went to the store. The store was closed; the store opens in the .” >

  - The output

<The, 1> <teacher, 1> <the, 1> <store,1> <the, 1> <store,1> <was, 1> <closed, 1> <the 1> <store, 1> <opens, 1> <in, 1> <the, 1> <opens, 1> <at, 1> <9am, 1>

WordCount - Reducer

- Accepts the Mapper output (k2, v2), and aggregates values on the key to generate (k3, v3)
  - For our example, the reducer input would be:

    <The, 1> <teacher, 1> <went, 1> <to, 1> <the, 1> <**store**, 1>
    <the, 1> <store, 1> <was, 1> <closed, 1> <the, 1> <**store**, 1>
    <opens, 1> <in, 1> <the, 1> <morning, 1> <the 1> <**store**, 1>
    <opens, 1

  - The output

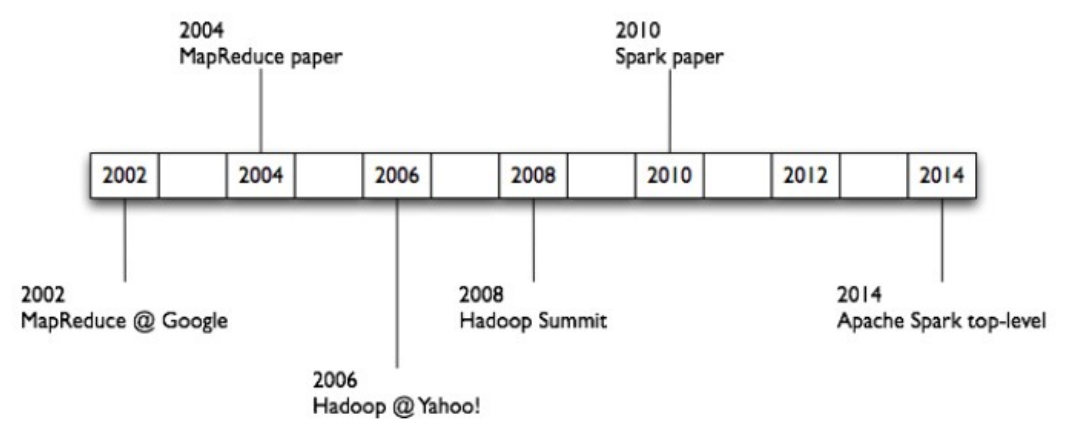
    <The, 6> <teacher, 1> <went, 1> <**ore, 4**> <was, 1>
    <closed, 1> <opens, 2> <in, 1 <at, 1> <9am, 1>

MapReduce Example - WordCount

- Hadoop MapReduce is an implementation of MapReduce
  - MapReduce is a computing paradigm (Google)
  - Hadoop MapReduce is an open-source software

Spark

- One popular answer to “What’s beyond MapReduce?”
- Open-source engine for large-scale data processing
  - Supports generalized dataflows
  - Written in Scala, with bindings in Java and Python
- Brief history:
  - Developed
  - Open-sourc
  - Became top-level Apache proje 2014
  - Commercial support provided b

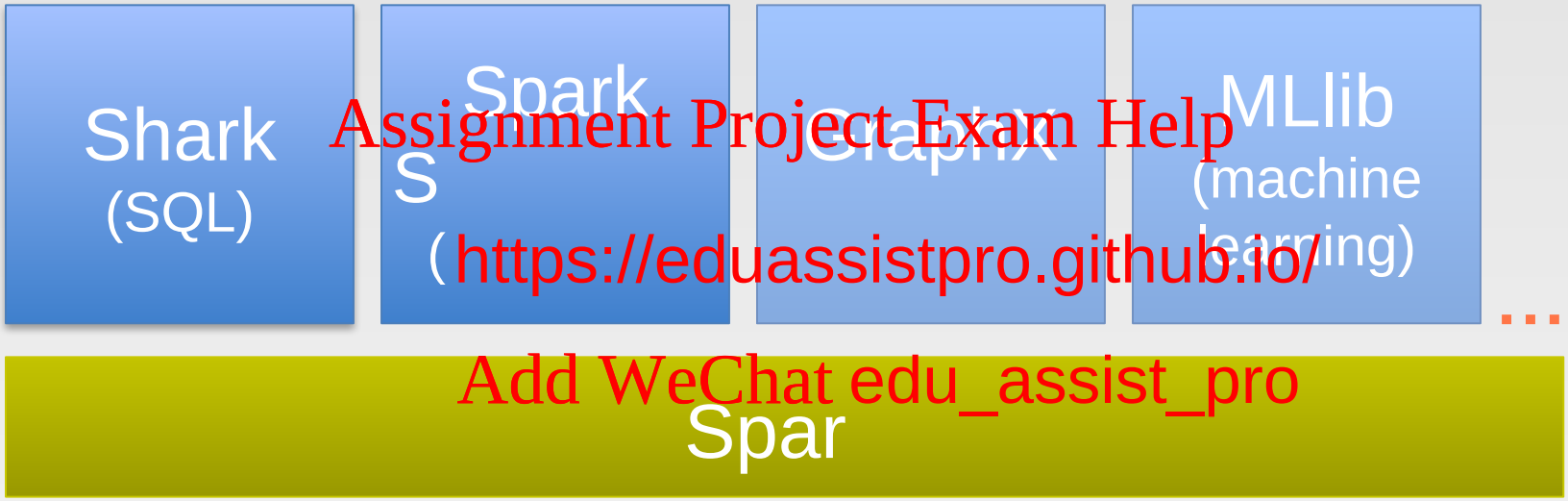


Spark

- Fast and expressive cluster computing system interoperable with Apache Hadoop
- Improves efficiency through:
  - **In-memory** computing primitives
  - General computation graphs
- Improves usabili
  - Rich APIs in
  - Interactive shell
- **Spark is not**
  - a modified version of Hadoop
  - dependent on Hadoop because it has its own cluster management
  - Spark uses Hadoop for storage purpose only

Spark Platform

- Spark is the basis of a wide set of projects in the Berkeley Data Analytics Stack (BDAS)



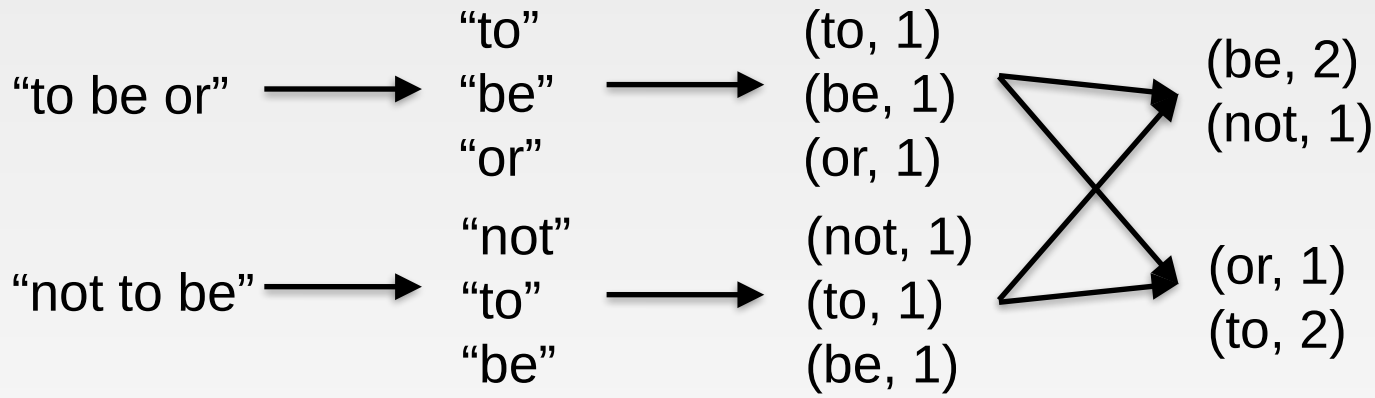
- Spark SQL (SQL on Spark)
- Spark Streaming (stream processing)
- GraphX (graph processing)
- MLlib (machine learning library)

Spark

WordCount in Spark (Scala)

Transformation

Action



AWS (Amazon Web Services)

- Amazon

From Wikipedia 2006

From Wikipedia 2017

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 Si
    Simple key- b service
  - Amazon Elastic MapReduce (E
    Scalable MapReduce computat
  - 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:* A e fastest growing products in
- 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!!!**

Big Data Applications

- Finding similar items
- Graph data processing
- Data stream mining
- Recommender