Big Data Streams Analytics
Challenges, Analysis, and Applications

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Evolution of Technology

- Hunting/Survival: Million BC to 10 K BC
- Agricultural Revolution: 10 K BC to 1800 AD
- Industrial Revolution: 1800 to 1960
- Information Revolution: 1960 to 2015
- Internet of Things: ???
- Nano, Biotec, Cogno, Cyber, Physical Systems: ???
- Internet of Things: ???

3
Cyber Physical Systems (CPS)

CPS are engineered systems that are built from, and depend upon, the seamless integration of computational algorithms and physical components. (NSF)
Adoption of Technologies

Source: Norman Poire, Merrill Lynch, 2003

Conceptual advances occur about twice a century and lead to wealth of nations
Presentation Outline

1. Challenges
2. Analysis
3. Applications
4. Massive Parallel Computing (MPC) & Big Data
5. Conclusions
1. Challenges
The rise of Industrial Big Data

This figure reflects the data generated from just one of many machines that produce a particular personal care product, underscoring the sheer volume of data created by industrial companies.
Data explosion

- More and more data collected every day.
- Necessity to analyse gigabytes of data every second.
- Necessity to analyse databases having millions of rows.

Byte $= 8$ bits, Kilobyte $= 10^3$, Megabyte $= 10^6$, Giga $= 10^9$, Tera $= 10^{12}$, Peta $= 10^{15}$, Exa $= 10^{18}$, Zetta $= 10^{21}$, Yotta $= 10^{24}$
Big Data explosion

- Data is doubled every 18 months (IDC)
- 2.5 Billions of GB are created every day (BBC)
- Facebook generates 25TB of data every day
- Airbus generates 10TB of data every 30 min
- In 2014, the world wide data is about 5ZB,
- In 2020, it is estimated to become about 35ZB.

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The Era of Tera!

Worldwide Optical Content: 103 TB
Worldwide Printed Content: 1,633 TB
U.S. Broadcast Media: 14,893 TB
Worldwide Filmed Content: 420,254 TB
Internet: 532,897 TB
Worldwide Magnetic Content: 4,999,230 TB
World Telephone Calls: 17,300,000 TB
Electronic Flow of New Info: 17,905,340 TB

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The Era of Zetta!

The Zettabyte Scale

| 1 Petabyte | 1,000 Terabytes or 250,000 DVDs |
| 200 Terabytes | A digital library of all books ever written in any language |
| 100 Petabytes | The amount of data produced in a single minute by the new particle collider at CERN |

| 1 Exabyte | 1,000 Petabytes or 250 million DVDs |
| 5 Exabytes | A transcript of all words ever spoken |
| 100 Exabytes | A video recording of all the meetings that took place last year across the world |
| 150 Exabytes | The amount of data that has traversed the Internet since its creation |
| 175 Exabytes | The amount of data that will cross the Internet in 2010 alone |

| 1 Zettabyte | 1,000 Exabytes or 250 billion DVDs |
| 66 Zettabytes | The amount of visual information conveyed from the eyes to the brain of the entire human race in a single year |

| 1 Yottabyte | 1,000 Zettabytes or 250 trillion DVDs |
| 20 Yottabytes | A holographic snapshot of the earth’s surface |

*Source: Cisco Visual Networking Index – Forecast, 2007-2012*
Limits of Traditional Systems

- Either for powerful computers there is processing limit
- Traditional data systems as RDBMS support only structured data (10%)
- Disks read/write speed is still very slow and didn’t evolve as disk space
2. Analysis
Sources of Big Data

- Sources of data
- Types of Data

Sources of data:
- Mobile Devices
- Microphones
- Readers/Scanners
- Science Facilities
- Machine Sensors
- Cameras
- Social Media
- Programs/Software

Types of Data:
- Videos
- Photos
- Text Messages
- Books
- Audios
- Logs
- Emails
- Transactions
- Images
- Click Trails
- Documents
- Public Records
What is Big Data?

Big Data is so large that it becomes difficult to process it using the traditional systems, resulting into:

- Large and growing files
- At high speed
- In various formats

The 3V:
- Volume
- Velocity
- Variety
What is Big Data?

- Big Data are high **Volume**, high **Velocity** and/or high **Variety** of data that require new forms of processing to enable decision making and make analytics.
- Big Data is not only about high data, but also about alternative processing techniques that can better handle the 3V.
- Big Data is human generated (social media) or machine generated (logs).
- Big Data high volume require high hardware resources (storing, processing).
- Most Big Data is unstructured data that cannot be used with SQL and classical tools.
- Big Data system is a complex system and require high skilled users to implement it.
The 3V of Big Data
Big Data = 5V (Now!)

- **Volume**
  - Terabytes
  - Records/Arch
  - Transactions
  - Tables, Files

- **Velocity**
  - Batch
  - Real/near-time
  - Processes
  - Streams

- **Variety**
  - Structured
  - Unstructured
  - Multi-factor
  - Probabilistic

- **Value**
  - Statistical
  - Events
  - Correlations
  - Hypothetical

- **Veracity**
  - Trustworthiness
  - Authenticity
  - Origin, Reputation
  - Availability
  - Accountability
Big Data Evolution

- Big Data will grow 650% the next 5 years (Gartner)
- More and more jobs are based on Big Data tools
- Big Data tools are becoming more popular
- Many Big Data papers and books are recently published (2011-2014)
- By 2015, 50% of enterprise data will be processed with Big Data tools
Apache Hadoop is an open-source software framework for storage and large-scale processing of Big Data-sets on clusters of commodity hardware.
Big Data Basic Architecture

Cloud Economy

User Applications
- Scientific Computing, Enterprise ISV, Social Networking, Gaming
- Animoto, Sales Force, Google Document

User-level and infrastructure level Platform
- Cloud Programming Environment and Tools: Web 2.0, Mashups, Concurrent and Distributed Programming, Workflow
- Cloud Hosting Platforms: QoS Negotiation Admission Control, Pricing, SLA Management, Monitoring
- Google AppEngine, MapReduce, Aneka, Microsoft Azure

Infrastructure
- Cloud Physical Resources: Storage, virtualized clusters, servers, network.
- Amazon EC2, GoGrid, RightScale, Jovent
Big Data General Architecture

- **Application layer**
- **Processing layer** (MapReduce, Hive, …)
- **Logical layer** (Hbase, BigTable, …)
- **Physical layer** (Distributed file system: GFS, HDFS, …)

- **Big Data Business Functions as a Service**
- **Data as a Service**
- **Platform as a Service**
- **Infrastructure as a Service**
Big Data & Hadoop Architecture
Big Data & Hadoop Advantages

- Abstraction for distributed tasks that simplify programming
- Handle hardware failure due to redundancy (fault tolerance)
- Allows to store and process very big files
- Increase read/write and network bandwidth performance
- High scalability on thousands of machines
- Linear scalability in cost and performance
- Handle both structured and unstructured data sets
Doug Cutting & Mike Cafarella started working on Nutch

2002

Google publishes GFS & MapReduce papers

2003

Yahoo! donates Hadoop project to Apache which maintains it as open source project

2004

Doug Cutting adds DFS & MapReduce support to Nutch

2005

Yahoo! hires Cutting, Hadoop spins out of Nutch

2006

2007

2008

2009

Cloudera Founded

Doug Cutting joins Cloudera and maintains Cloudera Hadoop distribution
A typical Hadoop system is composed by a master server (with one or two backup mirrors) and a many low cost machines/slaves (thousands) running linux.

Master has “Name Node” and “Job tracker” components that manage respectively “Data node” and “Task tracker” in other machines.
Hadoop 1.0

- **Hadoop 1.0**
  - **MapReduce**
    - (cluster resource management & data processing)
  - **HDFS**
    - (redundant, reliable storage)
  - **Pig**
    - (data flow)
  - **Hive**
    - (sql)
  - **Others**
    - (cascading)

**Other projects used by Hadoop Programming model**

Distributed redundant storage
Hadoop File System (HDFS)

- It is based on Google paper about “Google File System” (GFS)
- It is a distributed and redundant file system
- It stores files in blocks (typically blocks of 64MB) in multiple machines (typically 3 copies of each block on different machines)
Main Hadoop Components

- **Hbase**: a non relational database (NoSQL database)
- **Hive**: A Data warehouse: is a query and analysis language (SQL alternative for non relational databases)
- **Pig latin**: Programming language to write MapReduce programs
- **Oozie**: Manage and schedule Hadoop jobs
- **Mahoot**: Machine learning algorithm
- **Flume**: Collect log data
- **Sqoop**: For transferring data between Hadoop and relational databases
MapReduce is a programming model to process Big Datasets.

- It is composed of 2 functions: “Map” divides problems to smaller ones and “Reduce” combines results.
- The Map and Reduce functions are to be written by the user.
- MapReduce take care of all the details of distributed computation.
- The main server (master node) is not overloaded by computation, it is responsible only of communication with user application and managing the other nodes.
- The tasks are sent to data (not the data sent to worker machine!) which improves the system performance and mainly the bandwidth.
MapReduce Execution Steps

1. The data is split in M pieces of 64 MB and transferred in many copies to a cluster of machines.
2. The master machine assigns M map tasks to slave machines.
3. A slave who is assigned a map task uses the input data and the user-defined Map function to create key/value intermediate pairs buffered in its memory.
4. The R location of intermediate pairs are passed to the master, who is responsible for forwarding these locations to the reduce slave machines.
5. When a reduce slave is notified by the master about these locations, it uses remote procedure calls to read the buffered data from the local disks of the map slaves.
6. The reduce slaves iterate all intermediate pairs data of a partition and the user-defined Map function to get the final output for that partition.
MapReduce Example 1: Counting the number of sweets

1. Sweets are distributed by **master** (father) to **workers** (children)
2. **Master** gives **Map tasks** (counting)
3. **Map workers** do the **Map tasks**
4. **Map workers** notify **master**, who assign tasks to **reduce workers**
5. **Reduce workers** get intermediate pairs of data from **map workers**
6. **Reduce workers** use data pairs and **reduce function** to get the final results
MapReduce Example 2:
Counting the number of occurrences of each word in a large collection of documents.

Map Function

```java
map(String key, String value):
    // key: document name
    // value: document contents
    for each word w in value:
        EmitIntermediate(w, "1");
```

Reduce Function

```java
reduce(String key, Iterator values):
    // key: a word
    // values: a list of counts
    int result = 0;
    for each v in values:
        result += parseInt(v);
        Emit(AsString(result));
```

(a, "1805")
(is, "1297")
(shape, "547")
...

(a, "1,765,489")
...

MapReduce Architecture

Client Program -> Submit Job -> Job Tracker

- Map Task
  - InputFormat
  - RAM
  - partition() (combine())

- Reduce Task
  - Task Tracker
  - Region1
  - Region2

DFS

- Input file
- split1
- split2
- split3
- split4
- split5

M1

DFS

- Task Tracker
- Region1
- Region2

R1

- Task Tracker
- Output file 1

DFS

- Task Tracker
- Region1
- Region2

R2

- Task Tracker
- Output file 2

DFS

Map Phase

Reduce Phase

- Assign TaskTrackers
- Co-ordinate map and reduce phases
- Provide job progress info
3. Applications
Big Data Applications

- Used by most of big companies
- **Google** use a private Big Data system running more than one million servers
- The **Yahoo! Search** is a Hadoop application that runs on a more than 10,000 core Linux cluster
- **FaceBook** social network has the largest Hadoop cluster in the world with a storage of 100PB (2012) and grows by half a PB per day.
- **Tweeter** social network is also based on Hadoop
Big Data Applications

- Los Angeles police is using a data base (LADP) of the 30 million crimes of the last 80 years to predict the possible hotspots for future crimes.

- Used by economics for market study, e.g. a company in London is collecting a huge data (40TB) from companies around the world for market prediction.

- NASA is using Big Data to make decisions and complex computations.

- Used by scientists, to make mathematical models to resolve future problems.

- Used in weather forecasting, health care, oil industry, etc.
Hadoop Commercial Distributions

- Cloudera
- Hortonworks Drive
- MapR Technologies
- Amazon Web Services Elastic MapReduce
- IBM InfoSphere BigInsights
- Pivotal Software
- Teradata Hadoop
- Microsoft Windows Azure HDInsight
- Intel Hardware-Enhanced Performance Hadoop

➤ The most popular
4. MPC & Big Data
Massive Parallel Computing & Big Data

- The use of **multicore processors** combined with **centralization** is an emerging trend.
- One can think of this as a small cluster (the multicore processor in a smartphone, tablet, laptop, etc.) that both depends upon and contributes to the **Cloud**.

http://en.wikipedia.org/wiki/Supercomputer
MPC & Big Data: Science and Engineering Applications

- **Bioinformatics** - Biotechnology, Genetics, DNA and protein analysis, etc.
- **Physics** - Applied, nuclear, particle, condensed matter, high pressure, fusion, etc.
- **Mechanical Engineering** - From prosthetics to spacecraft
- **Electrical Engineering** - Circuit Design, Microelectronics, etc.
- **Computer Science, Mathematics**, etc.
- **Defence, Weapons**, etc.
MPC & Big Data: Industrial and Commercial Applications

- Databases, data mining
- Web search engines, web based business services
- Medical imaging and diagnosis
- Pharmaceutical design
- Financial and economic modelling
- Advanced graphics, virtual reality, multi-media technologies, etc.
Oil companies use seismic processing, to create models with high fidelity.

Sensors collect seismic data that is assembled into high-resolution maps (100TB+).

MPC are required for storage and analysis for the collected Big Data.
Scientists use Molecular Dynamics to simulate the trajectories of several atoms.

Molecular Dynamics simulations require several CPU years to create simulations of very short time (Micro-seconds, Nano-seconds).
Massive computational power is required to solve the equations that describe the atmosphere.

The equations are too complex to run in real-time, even with the use of supercomputers.

Weather forecast model accuracy is limited to about five or six days into the future.

A Zettaflop \(10^{21}\) supercomputer is required to accomplish full weather modelling for 2 weeks (Top500 Chinese Tianhe-2 is just a 33.86-petaflops \(10^{15}\) supercomputer!).
MPC & Big Data: Smart Cities

- Smart Cities of tomorrow sensors will generate over 4.1 terabytes per day per square kilometre by 2016.
- CAPIM is a platform designed to automate the process of collecting and aggregating context information on a large scale.
- Using BlobSeer cloud storage system.
- Using 116 dedicated parallel nodes of Grid’5000 cloud computing system.
Green Cloud Computing

User Applications

Reducing Power Cost and Maximizing Revenue

Cloud Datacenter

Power Cost and Carbon Emission
5. Conclusions
Potential Research Questions

- Can a hybrid Cloud-MPC system provide best-of-both-worlds?

- Can storage service power be reduced without reducing availability?

- Which applications can cope with limited bandwidth between sites?

- How should compute, storage, and power be managed to optimize for performance, fault-tolerance, and energy?
Big Data Conferences

2nd International Conference on Big Data and Analytics in Healthcare
Singapore • 22nd - 24th July 2014

BigComp 2015
February 9-11, 2015, Jeju Island, Korea

Big Data Innovation Summit
January 22 & 23, 2015
Las Vegas, USA

IEEE BigData 2014

INNS Conference on Big Data
We emphasize new approaches to solving hard big data problems
9-11 August 2015 - San Francisco, USA
Thanks for your attention!!
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