Big Data Systems

CS 564- Fall 2016

ACKs: *Magda Balazinska*

BIG DATA

Definition from industry:

- high volume
- high variety
- high velocity

VOLUME

- Databases parallelize easily; techniques available from the 80's (GAMMA project)
  - data partitioning
  - parallel query processing
- SQL is embarrassingly parallel

VARIETY

- complex workloads:
  - Machine Learning tasks: e.g. click prediction, topic modeling, SVM, k-means
- various types of data:
  - text data
  - semi-structured data
  - graph data
  - multimedia (video, photos)

VELOCITY

- data is generated very fast and needs to be processed very fast
  - real time analytics
  - data streaming (each data item can be processed only once!)

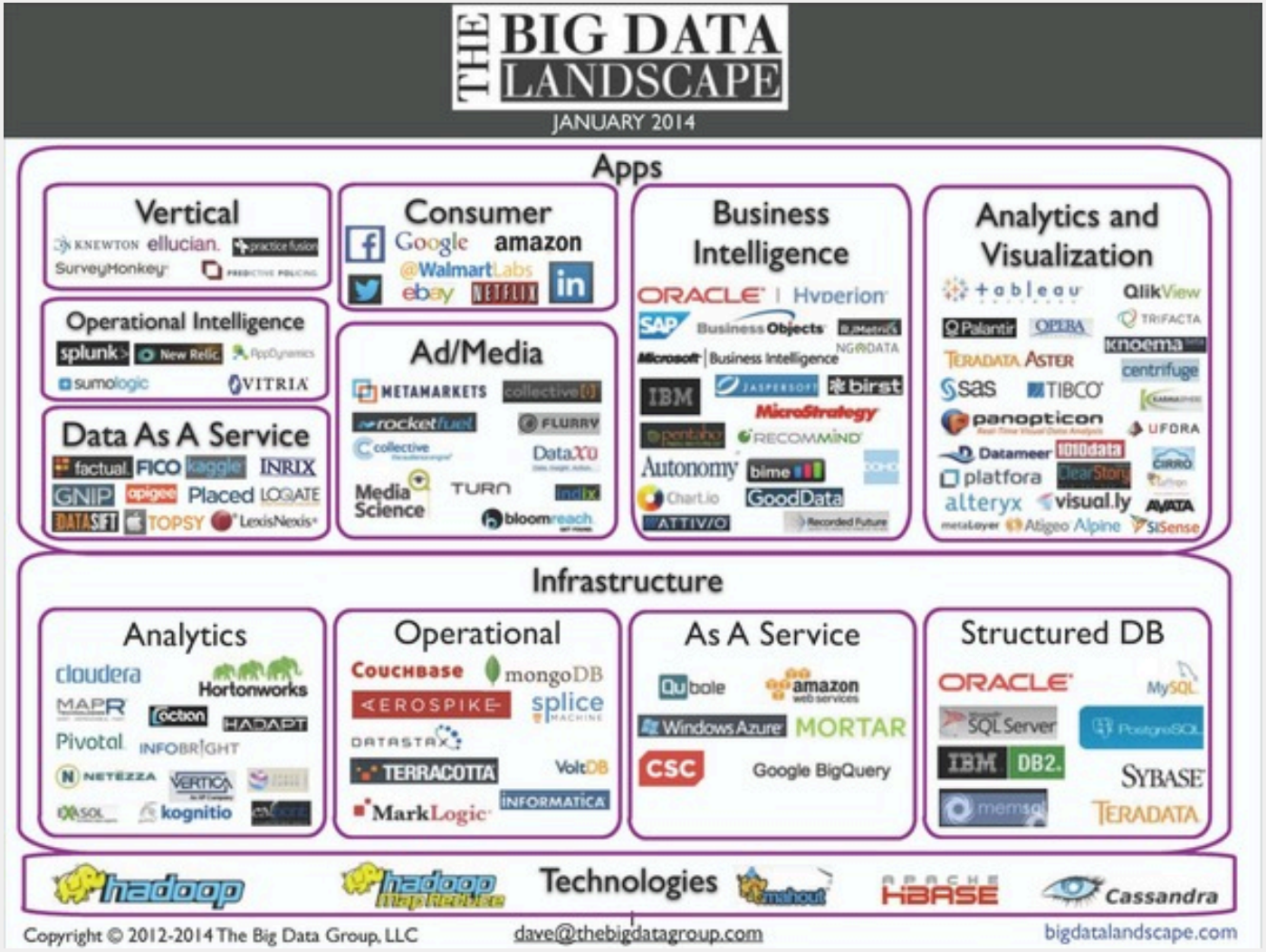
ANOTHER V: VERACITY

The data collected is often uncertain

- inconsistent data
- incomplete data
- ambiguous data

Example: sensor data

DATA LANDSCAPE



Some Examples

- Greenplum: founded in 2003 acquired by EMC in 2010. A parallel shared-nothing DBMS
- Vertica: founded in 2005 and acquired by HP in 2011. A parallel column-store shared-nothing DBMS
- AsterData: founded in 2005 acquired by Teradata in 2011. A parallel, shared-nothing, MapReduce-based data processing system
- Netezza: founded in 2000 and acquired by IBM in 2010. A parallel shared-nothing DBMS

We will See 2 Approaches

- Parallel databases, started at the 80s
  - OLTP (transaction processing)
  - OLAP (decision support queries)

- MapReduce
  - first developed by Google, published in 2004
  - only for decision support queries
  - ecosystem around it: Hadoop, PigLatin, Hive, …

PARALLEL DBMS

- The goal is to improve performance by executing multiple operations in parallel (scale-out)
- Terminology to measure performance:
  - Speed-up: using more processors, how much faster does the task run (if problem size is fixed)?
  - Scale-up: using more processors, does performance remain the same as we increase the problem size?

Scale-up vs Scale-out

Scale-up

- using more powerful machines, more processors/RAM per machine

Scale-out

- using a larger number of servers

ARCHITECTURES

- Shared memory
  - nodes share RAM + disk
  - easy to program, expensive to scale
- Shared disk
  - nodes access the same disk, hard to scale
- Shared nothing
  - nodes have their own RAM+disk
  - connected through a fast network

Parallel Query Evaluation

- Inter-query parallelism:
  - each query runs on one processor
- Inter-operator parallelism:
  - each query runs on multiple processors
  - an operator runs on one processor
- Intra-operator parallelism:
  - An operator runs on multiple processors

Parallel Data Storage

Horizontal data partitioning

- block partitioned
- hash partitioned
- range partitioned

Uniform vs skewed partitioning

Parallel Query Evaluation

- Parallel Selection
- Parallel Join
  - hash join
  - broadcast join

MapReduce

- Google [Dean 2004]
- Open source implementation: Hadoop
- MapReduce:
  - high-level programming model and implementation for large-scale parallel data processing
  - designed to simplify task of writing parallel programs

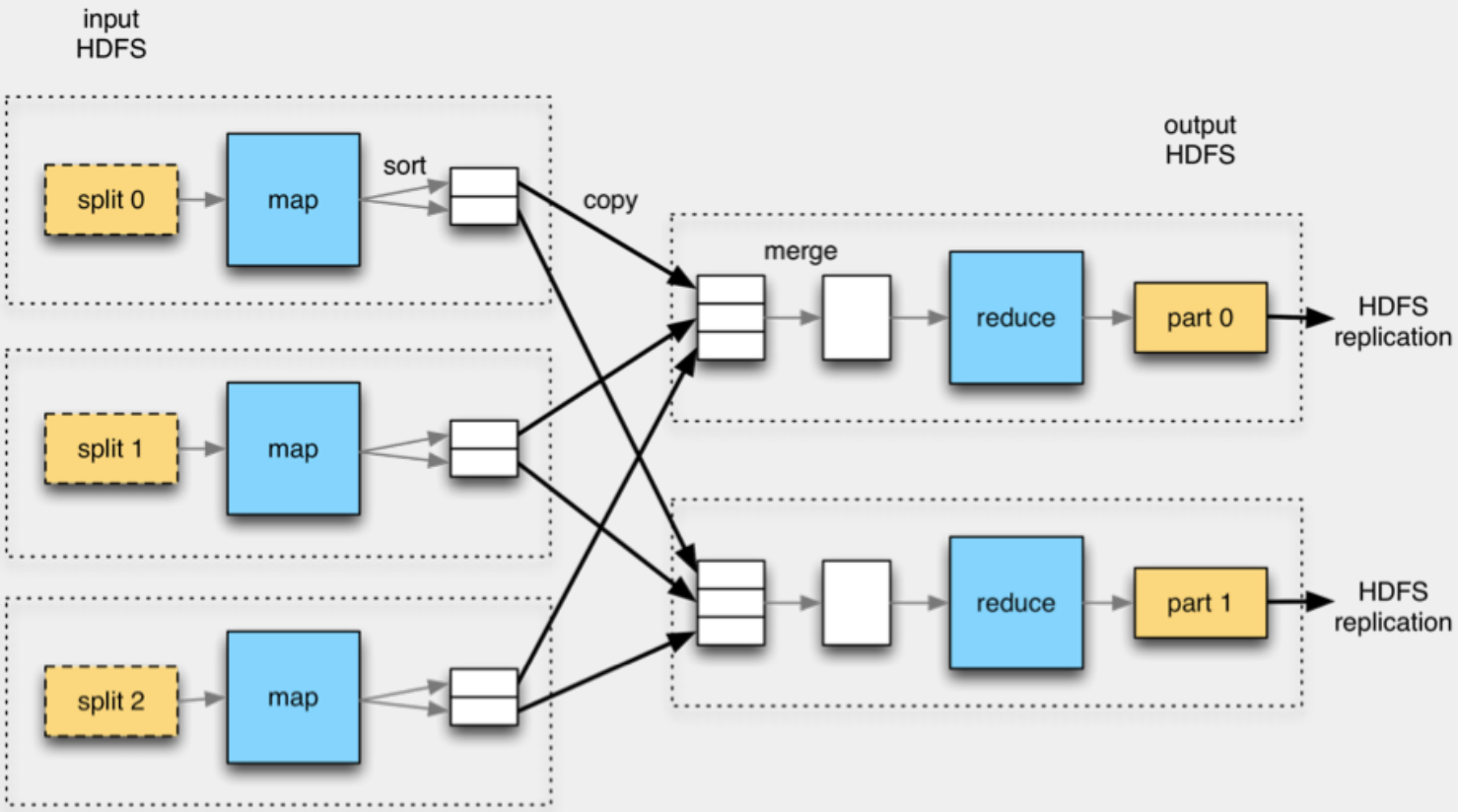
MapReduce

- Hides messy details in MapReduce runtime library
  - automatic parallelization
  - load balancing
  - network and disk transfer optimizations
  - handling of failures
  - robustness

MapReduce Pipeline

- read the partitioned data (HDFS, GFS)
- Map: extract something you care about from each record
- Shuffle and Sort (done by the system)
- Reduce: aggregate, summarize, filter, transform
- write the results

MapReduce Dataflow



source: *Hadoop – The Definitive Guide*, by Tom White

Data Model

- A file = a bag of (key, value) pairs

- A MapReduce program:
  - Input: a bag of (input key, value) pairs
  - Output: a bag of (output key, value) pairs

The Map Function

User provides the MAP function:

- **Input**: (input key, value)
- **Output**: bag of (intermediate key, value)

The system applies the map function in parallel to all (input key, value) pairs in the input file

The Reduce Function

User provides the REDUCE function:

- **Input**: (intermediate key, bag of values)
- **Output**: bag of (output key, values)

The system groups all pairs with the same intermediate key, and passes the bag of values to the REDUCE function

Example: Word Count

- Count the number of occurrences of each word in a large collection of documents

- Each Document
  - key = document id (did)
  - value = set of words (word)

MapReduce Jobs

- A MapReduce job consists of one single "query"
  - e.g. count the words in all docs
- More complex queries may consist of multiple jobs

MapReduce Ecosystem

Lots of extensions to address limitations:

- Capabilities to write DAGs of MapReduce jobs
- Declarative languages
- Most companies use both types of engines (MR and DBMS), with increased integration
- Potential replacement to MapReduce: Spark

MapReduce Ecosystem

PIG Latin (Yahoo!)

- New language, like Relational Algebra
- open source

Hive (Facebook)

- SQL-like language
- open source

SQL / Tenzing (Google)

- SQL on MR
- Proprietary – morphed into BigQuery

PARALLEL DBMS VS MAPREDUCE

Parallel DBMS:

- Relational data model and schema
- Declarative query language: SQL
- Can easily combine operators into complex queries
- Query optimization, indexing, and physical tuning
- Streams data from one operator to the next without blocking

PARALLEL DBMS VS MAPREDUCE

MapReduce:

- data model is a file with key-value pairs
- no need to "load data" before processing
- easy to write user-defined operators
- can easily add nodes to the cluster
- intra-query fault-tolerance thanks to results on disk
- Arguably more scalable, but also needs more nodes