

# **Using big data in practice: Computational infrastructures**

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# Big Data

- Defined as **Vs**
  - **Volume**: Just about *size*, Giga, Tera, Petabytes
  - **Variety**: *Formats*, text, databases, pictures, excel
  - **Velocity**: *Speed*, 10 000 tweets per second, 2 000 pictures on Instagram per second

# Data is huge (Volume)

- Facebook
  - processes 750TB/day of data
  - adds 7PB of photo storage / month
- This requires computers (a lot of them)
- Not only internet companies!
  - Banks, package delivery, governments, shops, etc.

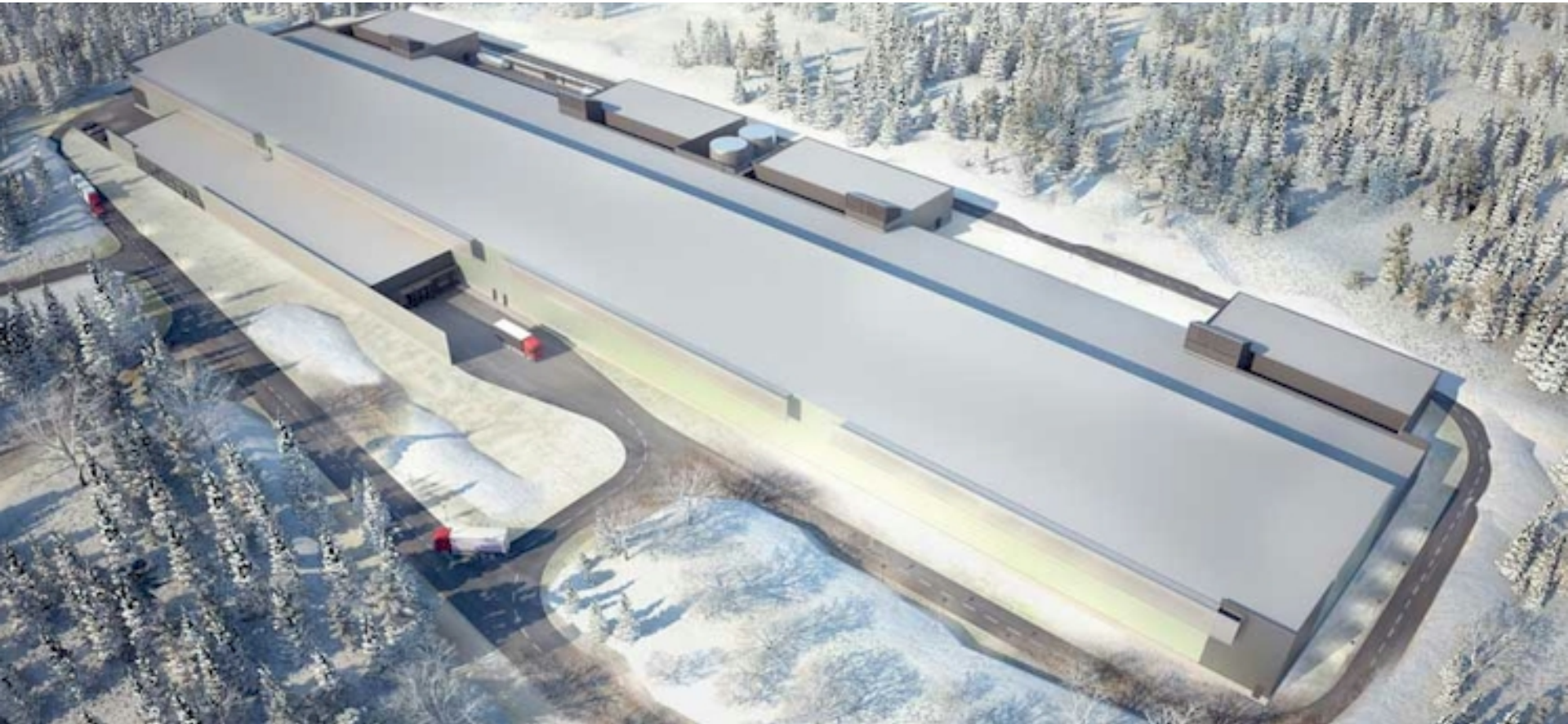
# Data is fast (Velocity)

- Twitter fire hose
  - In 2011, 1 000 Tweets per second (TPS)
  - In 2014, 20 000 TPS
  - With peaks: 143K TPS
- Services on top
  - DataSift: aggregate, filter and extract insights
- Not only internet companies!
  - Stock exchange, sensors in water network, etc.

# Scale-up vs Scale-out

- Scale-up
  - Increasing the power of your computer (i.e, disk, memory, processor)
- Scale-out
  - Use many standard computers and distribute data and computation over them

# Facebook Data Center (Sweden)







# Fundamental work

- Google File System, 2003
  - access to data using large clusters of commodity machines
- Big Table, 2003-2006
  - data storage system
  - Distributed map Key -> Value
- Map/Reduce, 2004
  - Programming paradigm over a cluster of machines



# Open-Source analogous

- HDFS (Hadoop File System)
  - Distributed File System
- Apache Hbase <http://hbase.apache.org/>
  - Distributed database
- Apache Hadoop <http://hadoop.apache.org/>
  - Distributed computation

# Hadoop Distributed File System (HDFS)

- Inspired by Google File System
- Scalable, distributed, portable file system written in Java for Hadoop framework
- Primary distributed storage used by Hadoop applications
- HDFS can be part of a Hadoop cluster or can be a stand-alone general purpose **distributed file system**
- Reliability and **fault tolerance** ensured by replicating data across multiple hosts
- Zookeeper for the distributed coordination

# MapReduce (MR)

- High-level programming model and implementation for large-scale parallel data processing
- Commodity hardware
- Fault-tolerant
- Currently, the most overhyped system in CS

# MR Data Model

- Files!  
k1 -> v1  
k2 -> v2  
k3 -> v3
- Each file a set of **(key,value) pairs**  
FirstName -> John  
LastName -> Smith  
Role -> VP  
Steps -> 12k
- A map-reduce program:
  - Input: a set of (input key, value) pairs
  - Output: a set of (output key, value) pairs

# Step 1: the MAP Phase

- User provides the MAP function:
  - Input: one (input key, value)
  - Output: a set of (intermediate key, value) pairs
- System applies map function in parallel to all input pairs



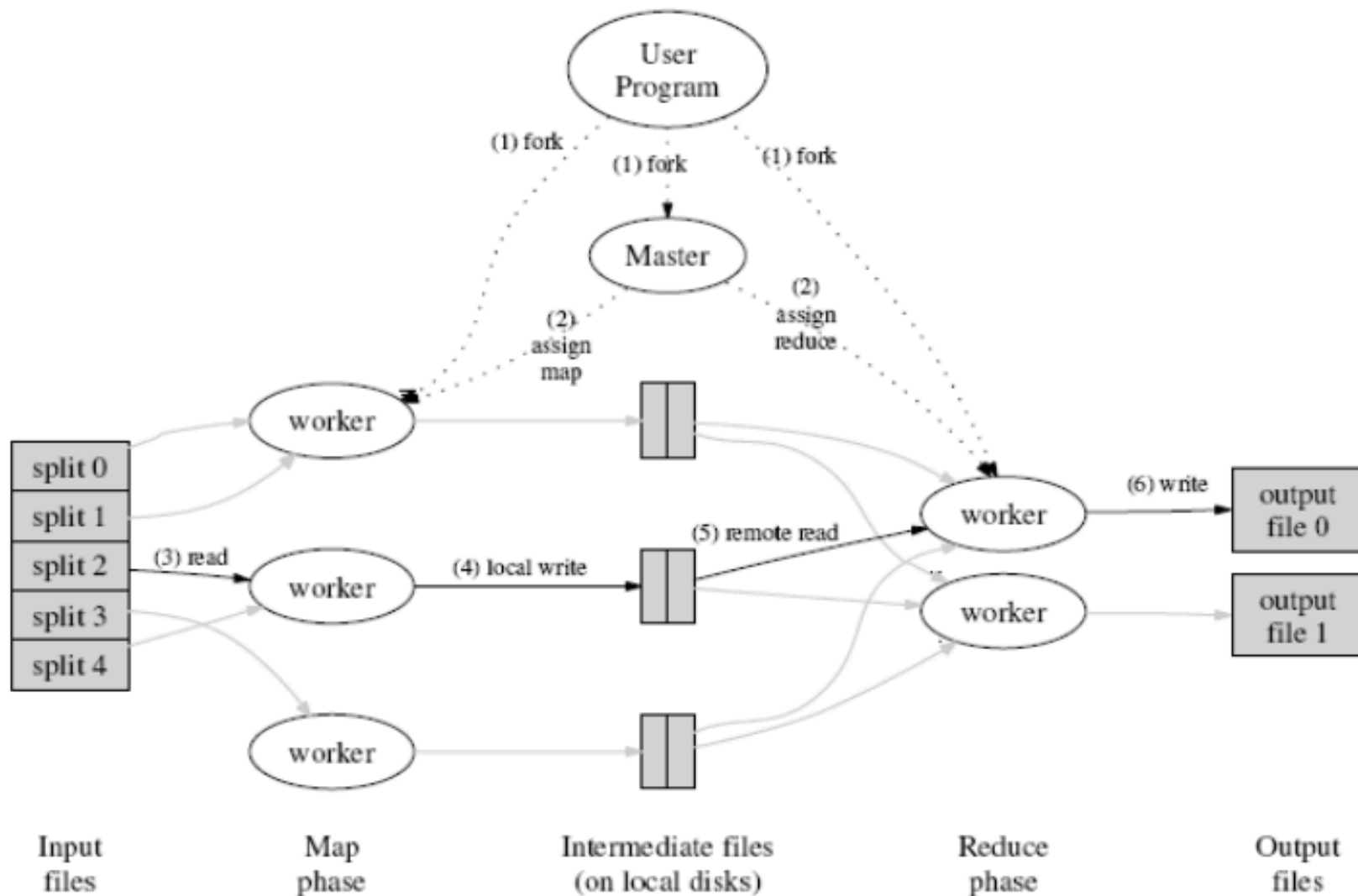
## Step 2: REDUCE phase

- User provides the REDUCE function:
  - Input: intermediate key, and set of values
  - Output: set of output values
- System groups all pairs with same key and passes values to the REDUCE function

# MR Job

- There is one **master node**
- Master **partitions input file** into M splits, by key
- Master **assigns** workers (=servers) to the M **map tasks**, keeps track of their progress
- Workers write their **output to local disk** partition into R regions
- Master **assigns** workers to the R **reduce tasks**
- Reduce **workers read** regions from the map workers' local disks

# MR Job



# Example: MR word length count

## Abridged Declaration of Independence

A Declaration By the Representatives of the United States of America, in General Congress Assembled.

When in the course of human events it becomes necessary for a people to advance from that subordination in which they have hitherto remained, and to assume among powers of the earth the equal and independent station to which the laws of nature and of nature's god entitle them, a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the change.

We hold these truths to be self-evident; that all men are created equal and independent; that from that equal creation they derive rights inherent and inalienable, among which are the preservation of life, and liberty, and the pursuit of happiness; that to secure these ends, governments are instituted among men, deriving their just power from the consent of the governed; that whenever any form of government shall become destructive of these ends, it is the right of the people to alter or to abolish it, and to institute new government, laying it's foundation on such principles and organizing it's power in such form, as to them shall seem most likely to effect their safety and happiness. Prudence indeed will dictate that governments long established should not be changed for light and transient causes: and accordingly all experience hath shewn that mankind are more disposed to suffer while evils are sufferable, than to right themselves by abolishing the forms to which they are accustomed. But when a long train of abuses and usurpations, begun at a distinguished period, and pursuing invariably the same object, evinces a design to reduce them to arbitrary power, it is their right, it is their duty, to throw off such government and to provide new guards for future security. Such has been the patient sufferings of the colonies; and such is now the necessity which constrains them to expunge their former systems of government. the history of his present majesty is a history of unremitting injuries and usurpations, among which no one fact stands single or solitary to contradict the uniform tenor of the rest, all of which have in direct object the establishment of an absolute tyranny over these states. To prove this, let facts be submitted to a candid world, for the truth of which we pledge a faith yet unsullied by falsehood.

# Example: MR word length count

## Abridged Declaration of Independence

Map Task 1  
(204 words)

A Declaration By the Representatives of the United States of America, in General Congress Assembled.  
When in the course of human events it becomes necessary for a people to advance from that subordination in which they have hitherto remained, and to assume among powers of the earth the equal and independent station to which the laws of nature and of nature's god entitle them, a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the change.  
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(key, value)

(yellow, 17)

(red, 77)

(blue, 107)

(pink, 3)

Yellow: 10+

Red: 5..9

Blue: 2..4

Pink: = 1

Map Task 2  
(190 words)

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(yellow, 20)

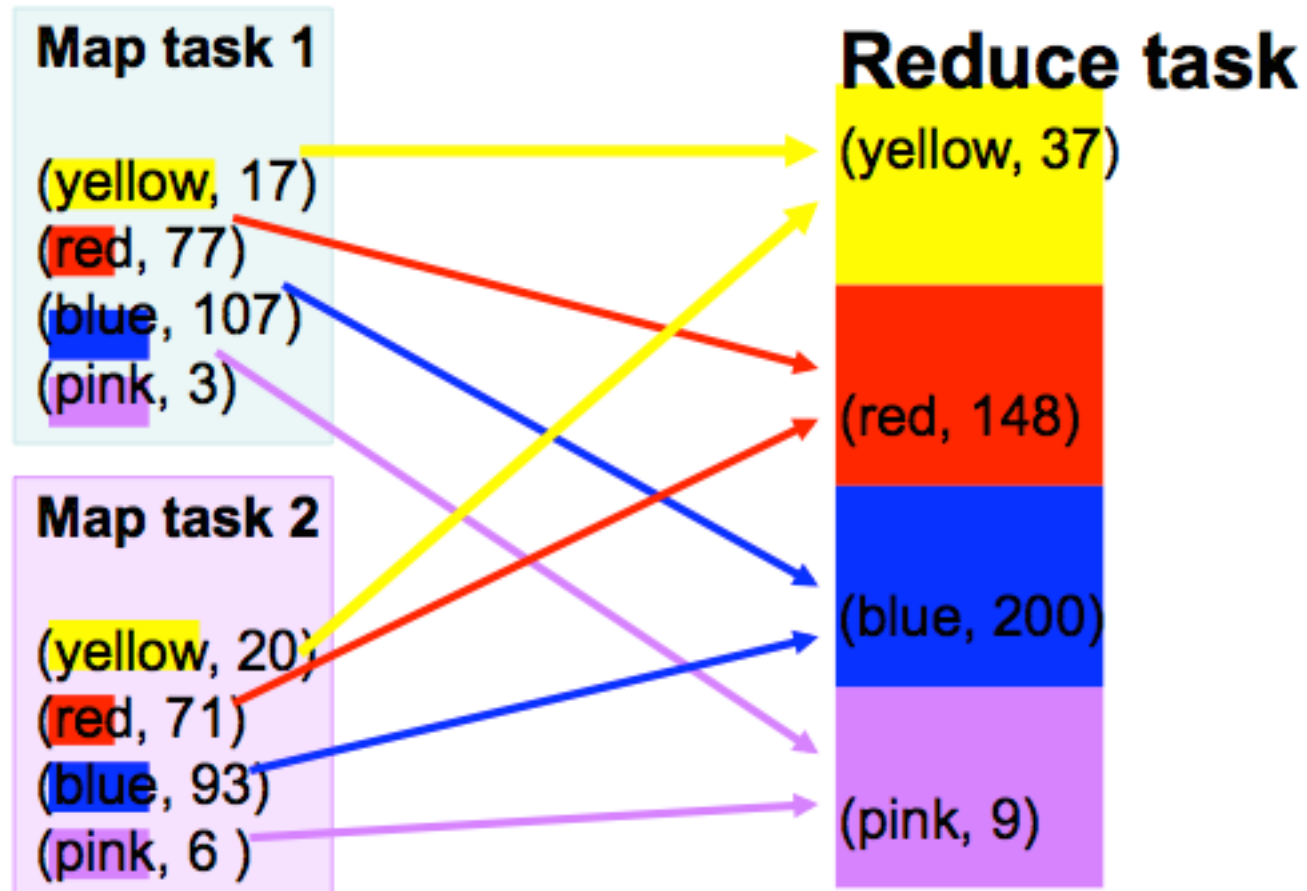
(red, 71)

(blue, 93)

(pink, 6 )



# Example: MR word length count



# MapReduce (MR) tools

- MR implementation



- MR Query Language

*Pig Latin*

- MR Query Engine



# Pig Latin

- High-level language
- SQL-like
- Very large datasets, translated in Map and Reduce Tasks

```
A = LOAD 'file1' AS (sid,pid,mass,px:double);
B = LOAD 'file2' AS (sid,pid,mass,px:double);
C = FILTER A BY px < 1.0;
D = JOIN C BY sid,
        B BY sid;
    STORE D INTO 'output.txt';
```

# Commercial products

- Hadoop as catch-all big-data solution
  - Small clusters (10s of machines)
  - Massive in-house clusters
  - Public Cloud
- Hortonworks
  - Consultancy company for Apache Hadoop
- Cloudera
- HP Vertica Analytics Platform



# Stream processing Big Data tools

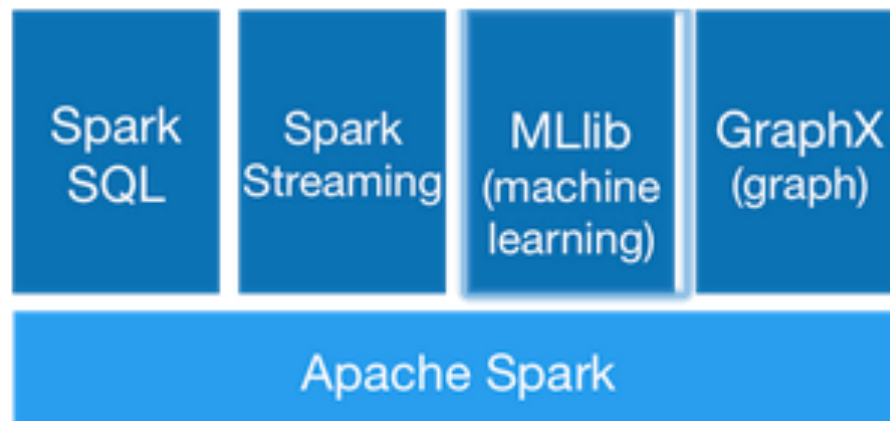
- Batch vs Stream processing
  - Data is large but always available on disk
  - Data is arriving fast and cannot be stored / needs to be processed immediately
- Streams of data
  - Twitter
  - Internet of Things
  - Smart Cities
  - Nuclear power plant



# Apache Spark



- <https://spark.apache.org/> databricks.com
- General system for large-scale data processing
- Faster (in-memory), interactive
- Version 1.6 released in March 2016



# Conclusion

- If it fits in memory, it's not big data
- If it's big data, you cannot use Excel/SPSS/R
- The way to go is scale-out and distributed computation
- Map/Reduce for batch processing
- Hadoop or Spark as out-of-the-box systems
  - Also with high-level query interfaces like Pig/R/Python