

Big Data /Data Science Data Intensive (Science) Technologies

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High Performance computing Curriculum, Jan 2015 <http://www.hpc.uva.nl/>

UvA-SURFsara

Content

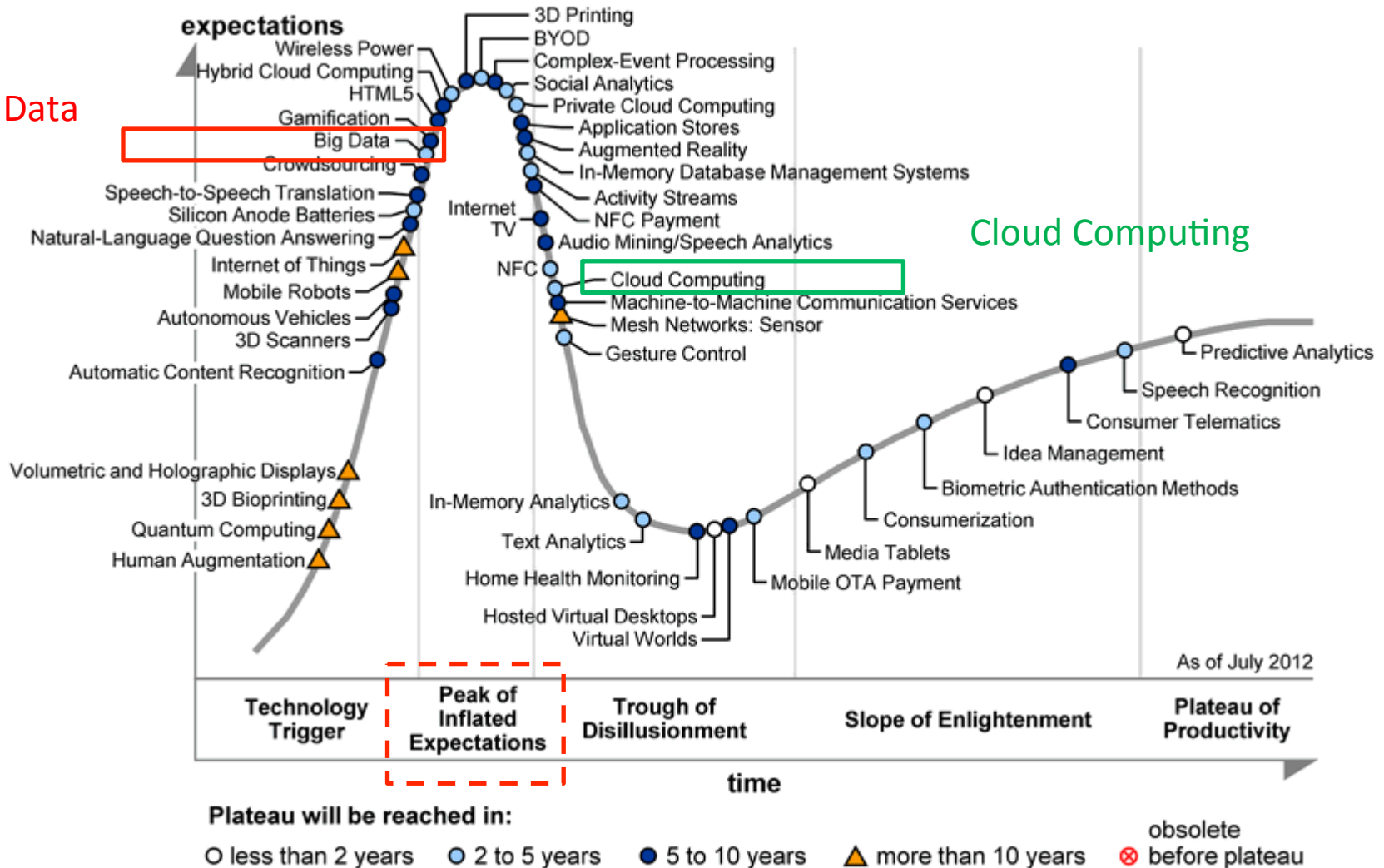
- Introduction and definitions
- Data Analytics
- Solutions for Big Data Analytics: NoSQL, MapReduce, Storm
- The Network (Internet)
- When to consider BigData solution
- Scientific e-infrastructure – some challenges to overcome

Big data was big news in 2012

- and probably in 2013 too.
- The Harvard Business Review talks about it as ***“The Management Revolution”***.
- The Wall Street Journal says ***“Meet the New Big Data”***,
and ***“Big Data is on the Rise, Bringing Big Questions”***.

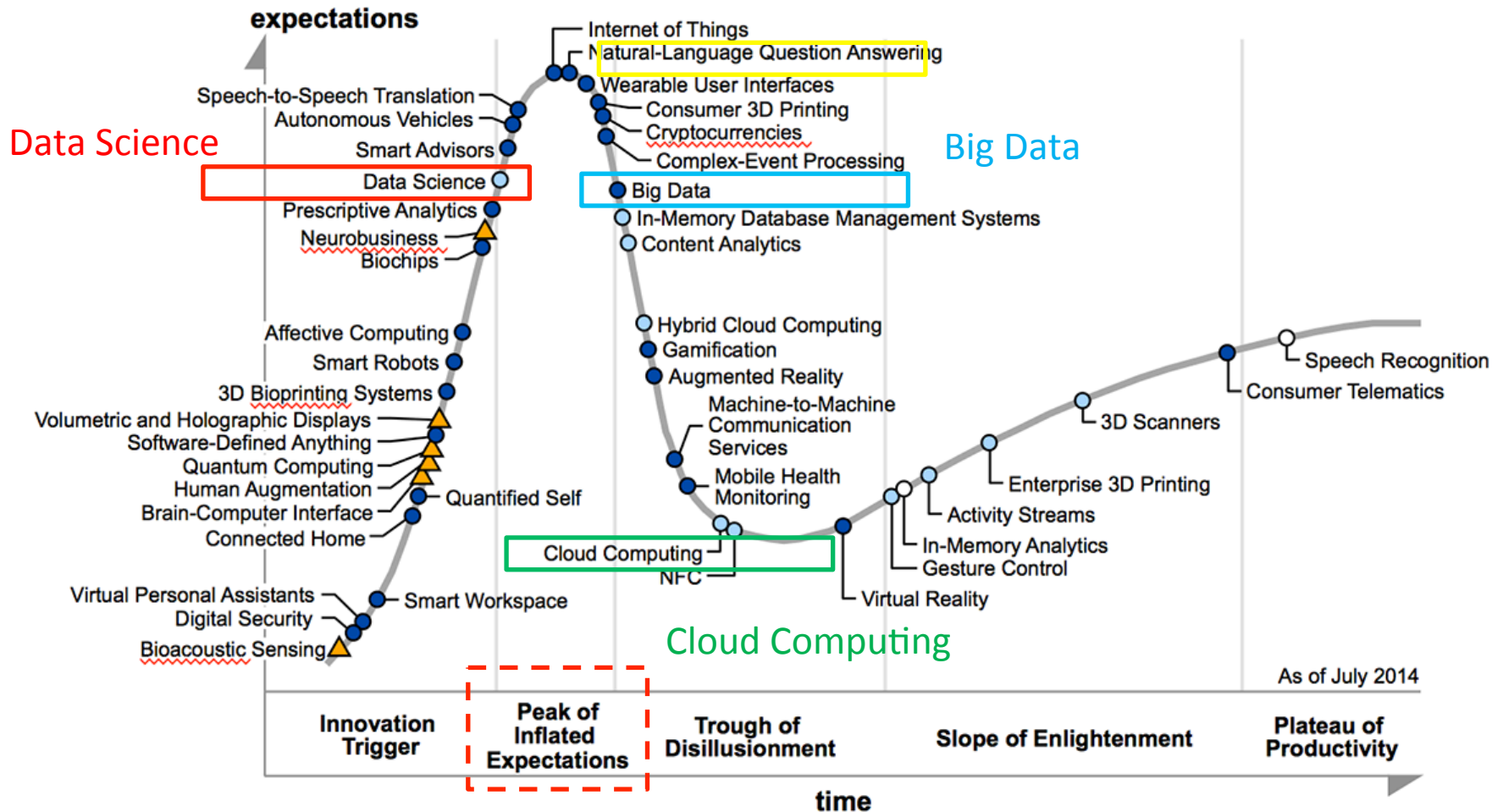
BigData is the new hype

Big Data



Source <http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp>

Gartner Technology Hypecycle (2014)



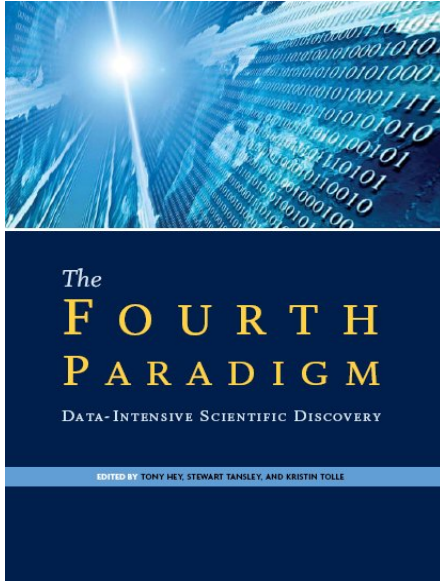
Plateau will be reached in:

○ less than 2 years ● 2 to 5 years ● 5 to 10 years ▲ more than 10 years ⊗ obsolete before plateau

Source <http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp>

Visionaries and Drivers:

Seminal works and High level reports



The Fourth Paradigm: Data-Intensive Scientific Discovery.

By Jim Gray, Microsoft, 2009. Edited by Tony Hey, et al.

<http://research.microsoft.com/en-us/collaboration/fourthparadigm/>



Riding the wave: How Europe can gain from the rising tide of scientific data.

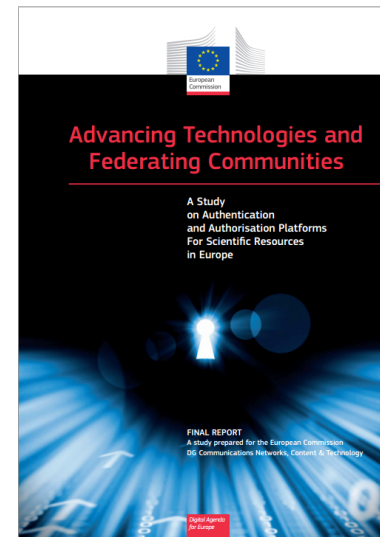
Final report of the High Level Expert Group on Scientific Data. October 2010.

<http://cordis.europa.eu/fp7/ict/e-infrastructure/docs/hlg-sdi-report.pdf>



NIST Big Data Working Group (NBD-WG)

<https://www.rd-alliance.org/>

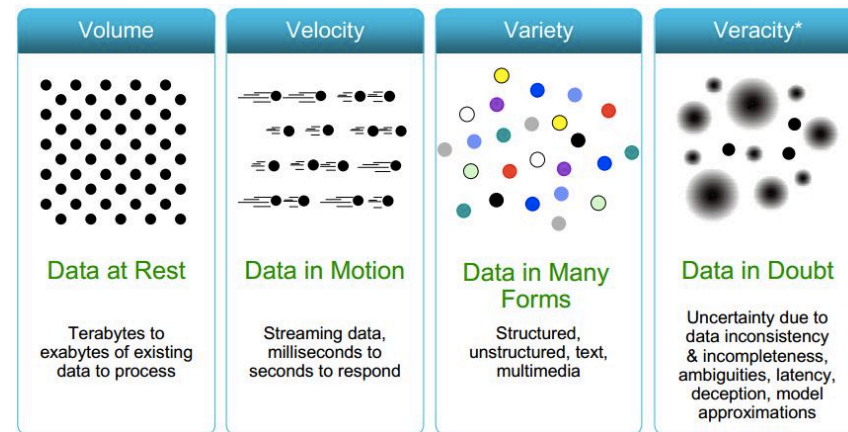


AAA Study: Study on AAA Platforms For Scientific data/information Resources in Europe,

TERENA, UvA, LIBER, UinvDeb.

Where Big Data Comes From?

- Big Data is not **Specific application type**, but rather a **trend** –or even a collection of Trends- napping multiple application types
- Data growing in multiple ways
 - More data (volume of data)
 - More Type of data (variety of data)
 - Faster Ingest of data (velocity of data)
 - More Accessibility of data (internet, instruments , ...)
 - Data Growth and availability exceeds organization ability to make intelligent decision based on it



Data is Big If It is Measured in MW

- A good sweet spot for a data center is **15 MW**
- Facebook's leased data centers are typically between **2.5 MW** and **6.0 MW**.
- Facebook's Pineville data center is **30 MW**
- Google's computing infrastructure uses **260 MW**

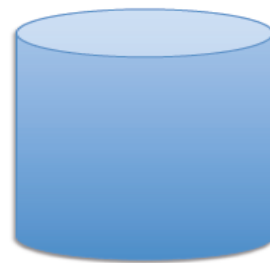
Jim Gray Vision

- “ We have to do better at **producing tools** to support the **whole research cycle**—from **data capture and data curation to data analysis and data visualization**. **Today, the tools for capturing data both at the mega-scale and at the milli-scale are just dreadful**. After you have captured the data, you need to curate it before you can start doing any kind of data analysis, and **we lack good tools for both data curation and data analysis.**”
- “Then comes the **publication** of the results of your research, and the published literature is just the tip of the data iceberg. By this I mean that people collect a lot of data and then reduce this down to some number of column inches in Science or Nature—or 10 pages if it is a computer science person writing. **So what I mean by data iceberg is that there is a lot of data that is collected but not curated or published in any systematic way.** “

Based on the transcript of a talk given by Jim Gray to the NRC-CSTB1 in Mountain View, CA, on January 11, 2007

Advice From Jim Gray

1. Analysing Big data requires **scale-out** solutions **not scale-up** solutions (GrayWulf)
2. **Move** the analysis to the data.
3. Work with scientists to find the most common “**20 queries**” and make them fast.
4. Go from “**working to working.**”



Scale up

vs



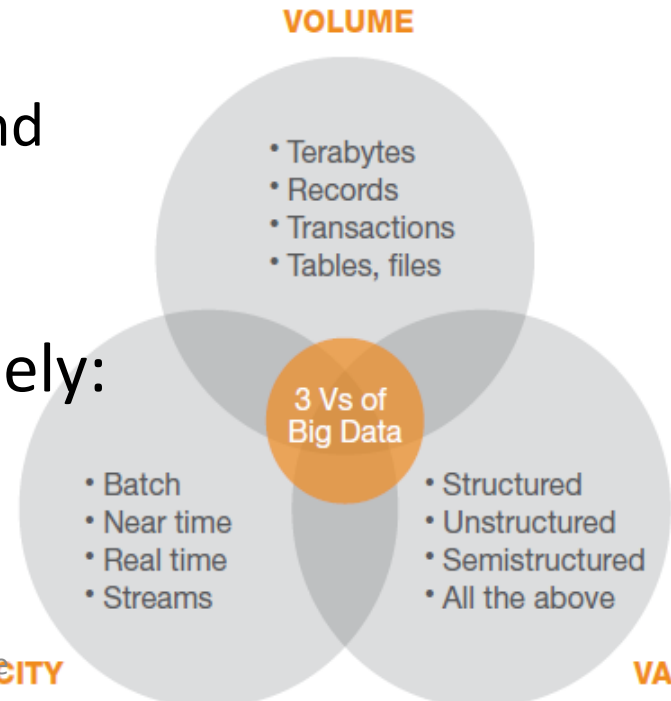
Scale out

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How We Define Big Data

- **Big** in Big Data refers to:
 - **Big size** is the primary definition.
 - **Big complexity** rather than big volume. it can be small and not all large datasets are big data
 - size matters... but so does **accessibility, interoperability** and **reusability**.
- define Big Data using 3 Vs; namely:
 - volume, variety, velocity

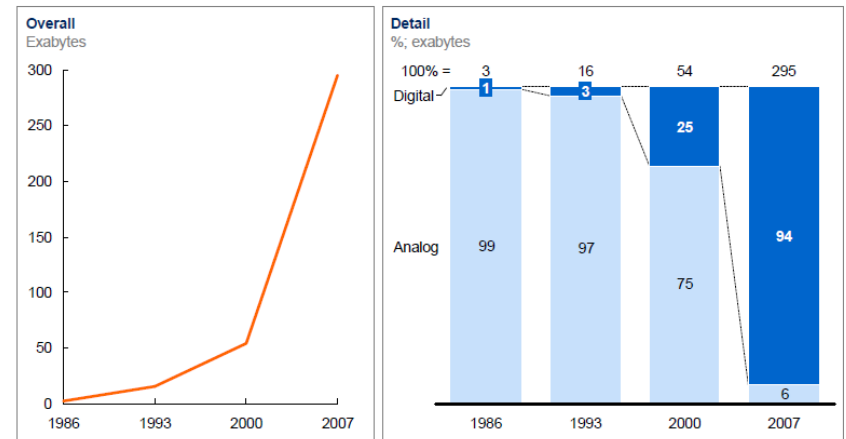


volume, variety, and velocity

- Aggregation that used to be measured in petabytes (**PB**) is now referenced by a term: **zettabytes (ZB)**.
 - A **zettabyte** is a **trillion gigabytes (GB)**
 - or a **billion terabytes**
- in 2010, we crossed the **1ZB** marker, and at the end of 2011 that number was estimated to be **1.8ZB**

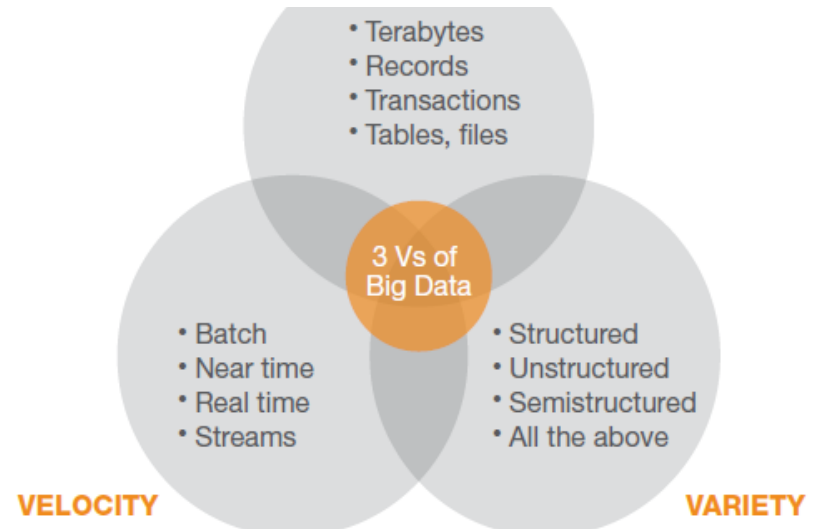
Data storage has grown significantly, shifting markedly from analog to digital after 2000

Global installed, optimally compressed, storage



NOTE: Numbers may not sum due to rounding.

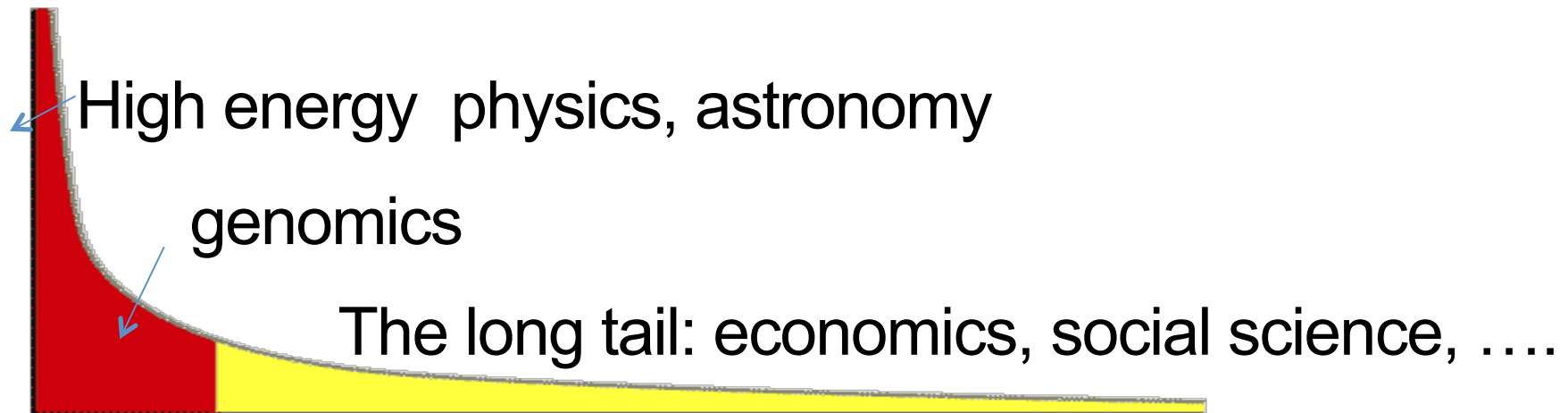
SOURCE: Hilbert and López, "The world's technological capacity to store, communicate, and compute information," *Science*, 2011



volume, variety, and velocity

How much data?

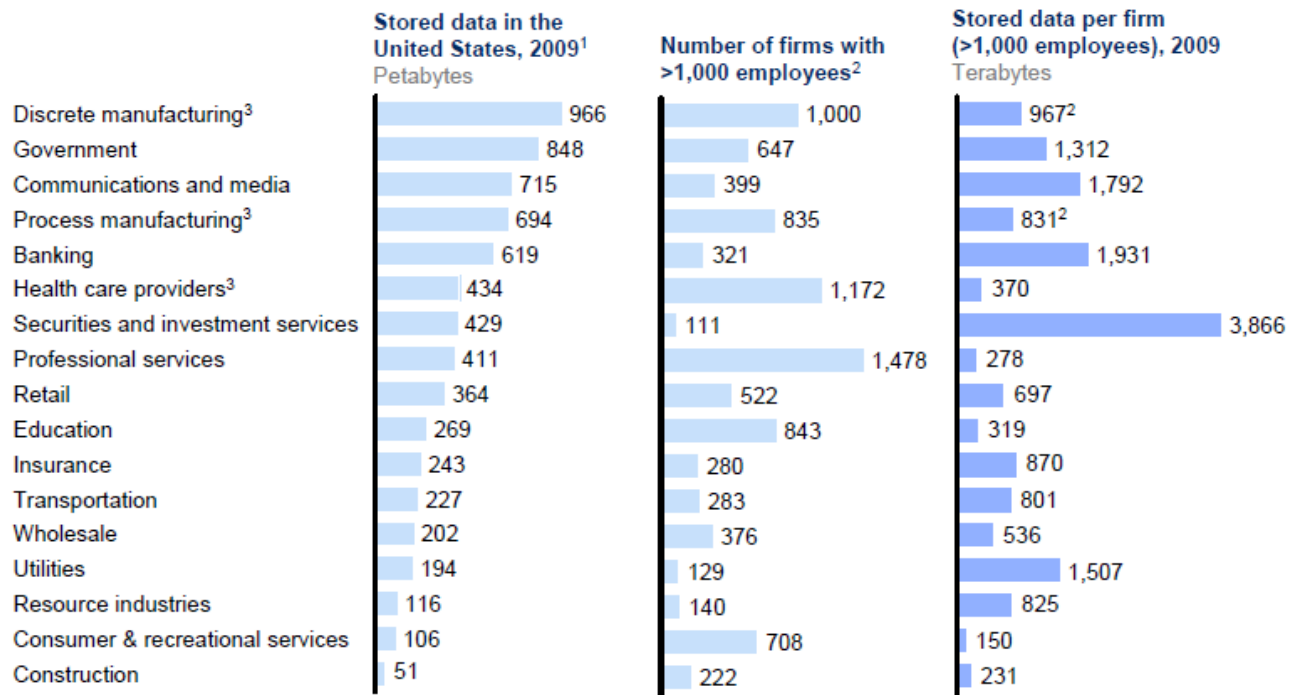
- Google processes **20 PB a day (2008)**
- Wayback Machine has 3 PB + **100 TB/month** (3/2009)
- Facebook has 2.5 PB of user data + **15 TB/day** (4/2009)
- eBay has 6.5 PB of user data + **50 TB/day** (5/2009)
- CERN's Large Hydron Collider (LHC) generates **15 PB a year**



volume, variety, and velocity

How much data?

Companies in all sectors have at least 100 terabytes of stored data in the United States; many have more than 1 petabyte



1 Storage data by sector derived from IDC.

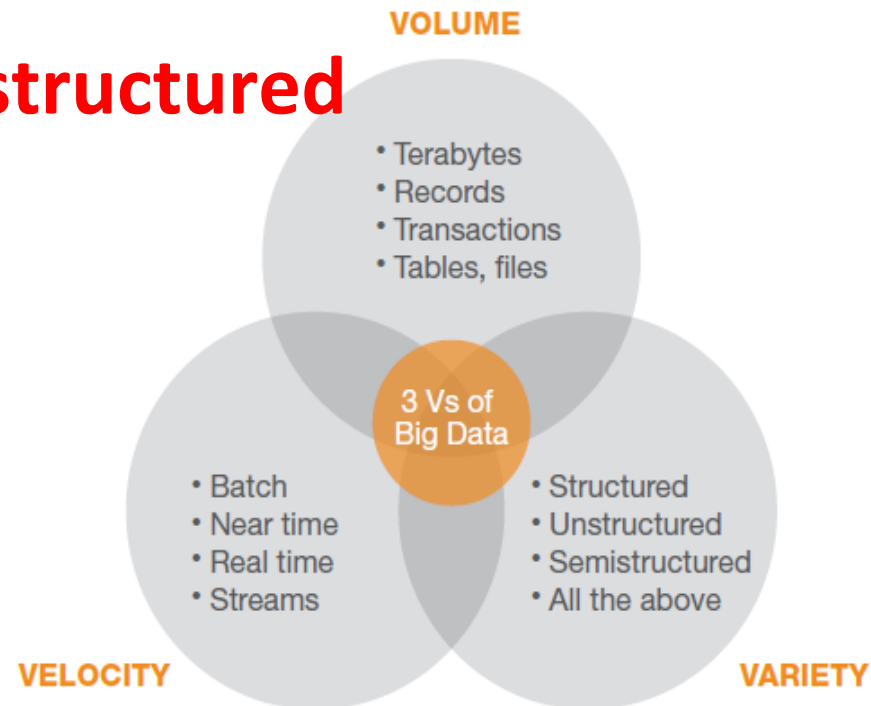
2 Firm data split into sectors, when needed, using employment

3 The particularly large number of firms in manufacturing and health care provider sectors make the available storage per company much smaller.

SOURCE: IDC; US Bureau of Labor Statistics; McKinsey Global Institute analysis

volume, **variety**, and velocity

- The variety characteristic of Big Data is really about trying to **capture all** of the data that pertains to our **decision-making** process.
- Making sense out of **unstructured** data, such as **opinion**, or analysing images.

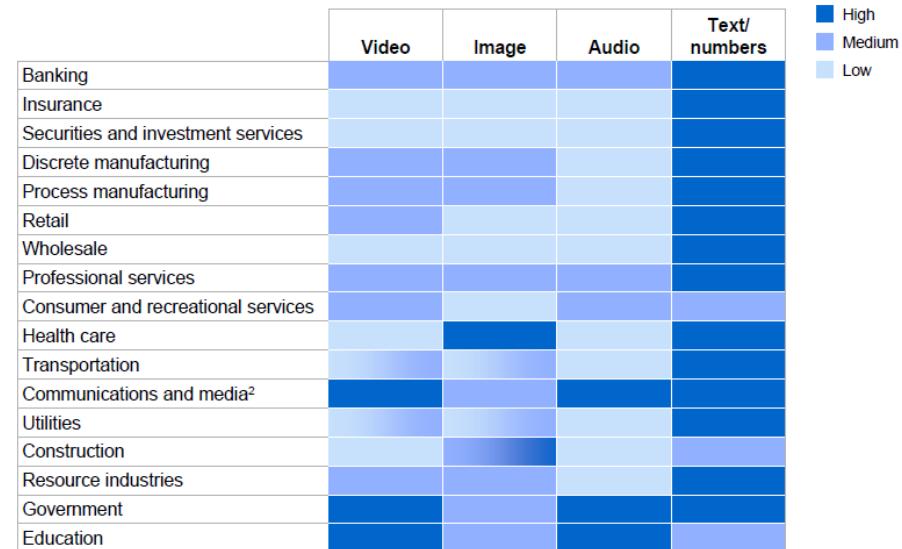


volume, **variety**, and velocity

Type of Data

- 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

The type of data generated and stored varies by sector¹



¹ We compiled this heat map using units of data (in files or minutes of video) rather than bytes.

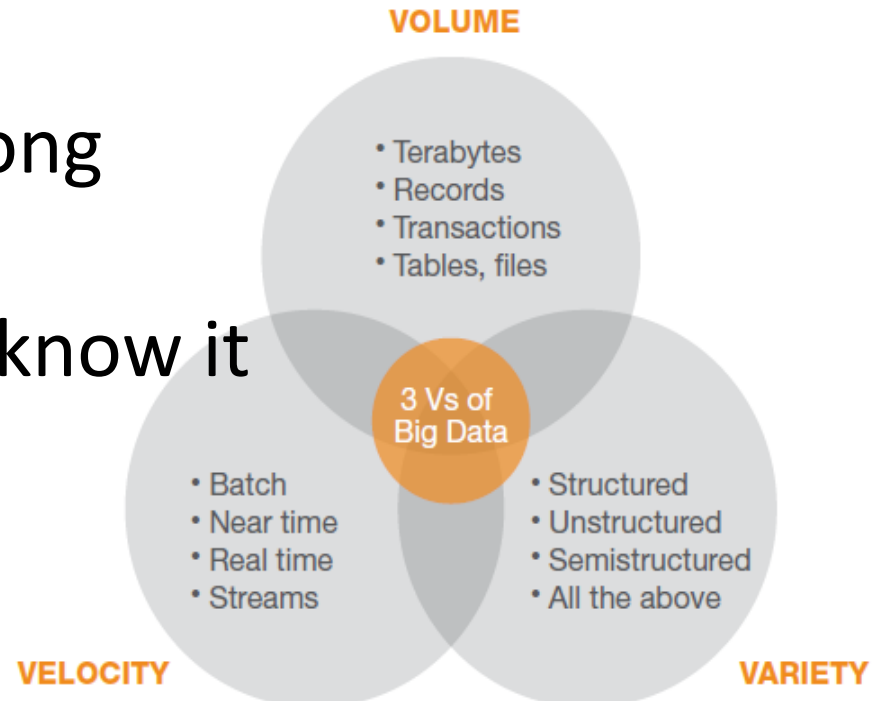
² Video and audio are high in some subsectors.

SOURCE: McKinsey Global Institute analysis

volume, variety, and **velocity**

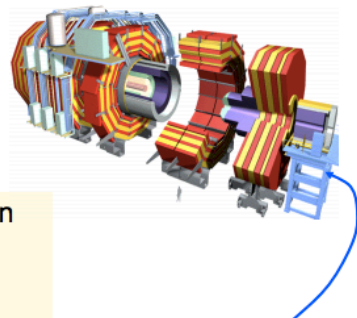
- velocity is the **rate** at which data is generated and is **processed** or **well understood**

- In other terms “How long does it take you to do something about it or know it has even arrived?”

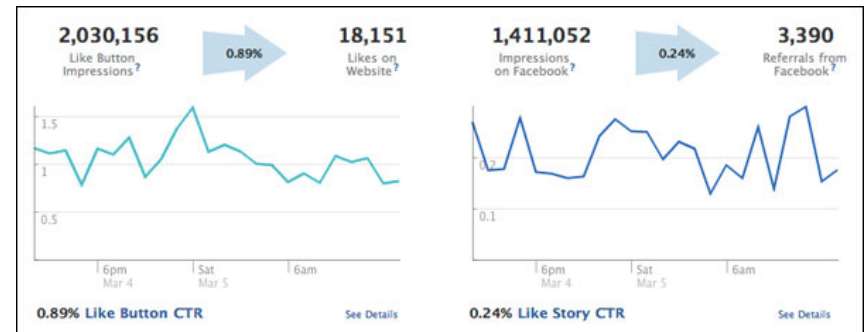
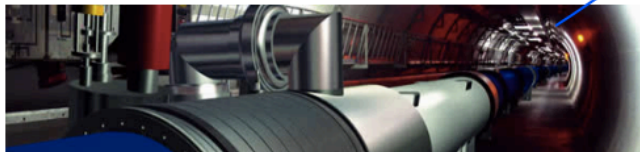


volume, variety, and **velocity**

 ... generate lots of data ...



The accelerator generates 40 million particle collisions (events) every second at the centre of each of the four experiments' detectors



Today, it is possible using real-time analytics to optimize Like buttons across both website and on Facebook.

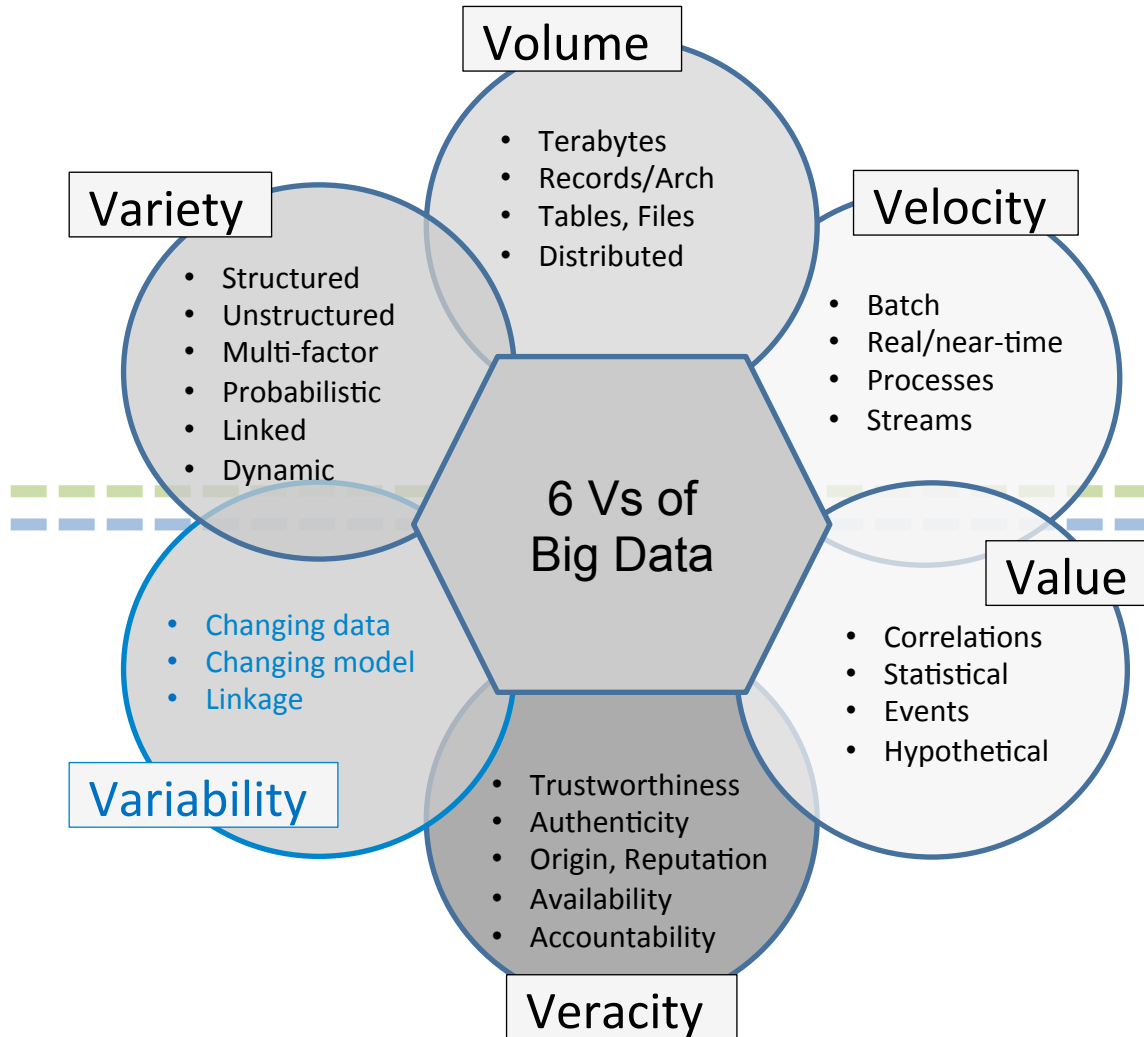
FaceBook use anonymised data to show you the number of times people saw Like buttons, clicked Like buttons, saw Like stories on Facebook, and clicked Like stories to visit a given website.

volume, variety, velocity, and **veracity**

- Veracity refers to the **quality** or trustworthiness of the data.
- A common complication is that the data is saturated with both **useful signals** and **lots of noise** (data that can't be trusted)



Improved: 5+1 V's of Big Data



Generic Big Data Properties

- Volume
- Variety
- Velocity

Acquired Properties (after entering system)

- Value
- Veracity
- Variability

Commonly accepted
3V's of Big Data



Big Data Definition: From 5+1V to 5 Parts

(1) Big Data Properties: 5V

- Volume, Variety, Velocity, Value, Veracity
- Additionally: Data Dynamicity (Variability)

(2) New Data Models

- Data Lifecycle and Variability
- Data linking, provenance and referral integrity

(3) New Analytics

- Real-time/streaming analytics, interactive and machine learning analytics







(4) New Infrastructure and Tools

- High performance Computing, Storage, Network
- Heterogeneous multi-provider services integration
- New Data Centric (multi-stakeholder) service models
- New Data Centric security models for trusted infrastructure and data processing and storage

(5) Source and Target

- High velocity/speed data capture from variety of sensors and data sources
- Data delivery to different visualisation and actionable systems and consumers
- Full digitised input and output, (ubiquitous) sensor networks, full digital control

Big Data platform must include the six key imperatives

	Big Data Platform Imperatives		Technology Capability
1	Discover, explore, and navigate Big Data sources		Federated Discovery, Search, and Navigation
2	Extreme performance—run analytics closer to data		Massively Parallel Processing Analytic appliances
3	Manage and analyze unstructured data		Hadoop File System/MapReduce Text Analytics
4	Analyze data in motion		Stream Computing
5	Rich library of analytical functions and tools		In-Database Analytics Libraries Big Data Visualization
6	Integrate and govern all data sources		Integration, Data Quality, Security, Lifecycle Management, MDM, etc

The Big Data platform manifesto: imperatives and underlying technologies

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Data Analytics

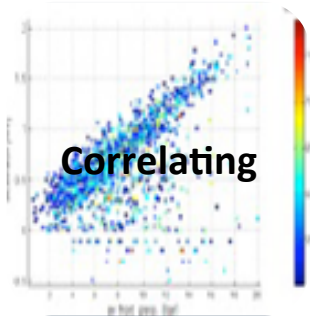
Analytics Characteristics are not new

- Value: produced when the analytics output is put into action
- Veracity: measure of accuracy and timeliness
- Quality:
 - well-formed data
 - Missing values
 - cleanliness
- Latency: time between measurement and availability
- Data types have differing pre-analytics needs

Analytics @ Twitter



- How many request/day?
- What's the average latency?
- How many signups, sms, tweets?



- Desktop vs Mobile user ?
- What devices fail at the same time?
- What features get user hooked?

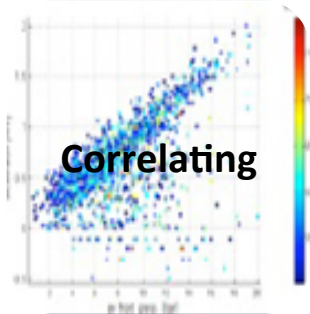


- What features get re-tweeted
- Duplicate detection
- Sentiment analysis

Note the Time dimension



- Real time (msec/sec)

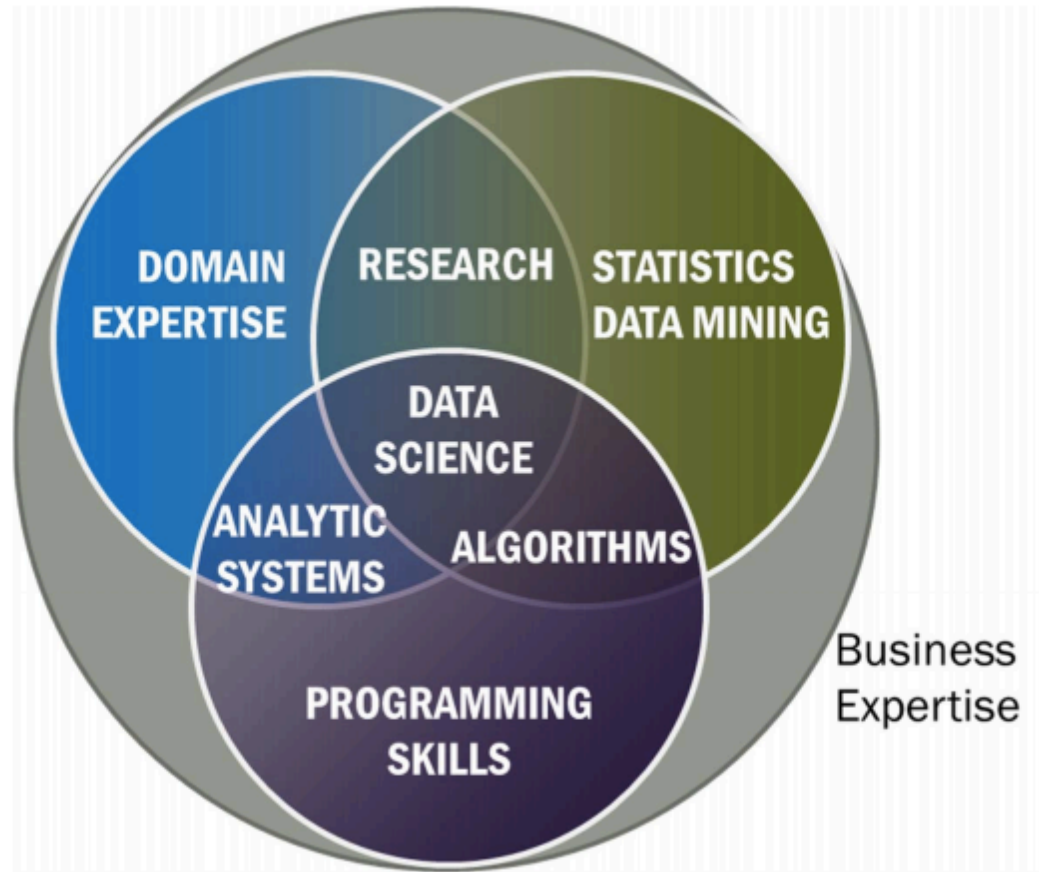


- Near real time (Min/Hours)



- Batch (Days..)

Skills required for Data Analytics



The Real Time Boom..

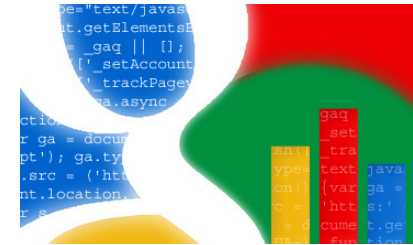
Facebook Real Time
Social Analytics



SaaS Real Time
User Tracking



Google Real Time
Web Analytics



Twitter paid tweet analytics



New Real Time
Analytics Startups..



Google Real Time Search

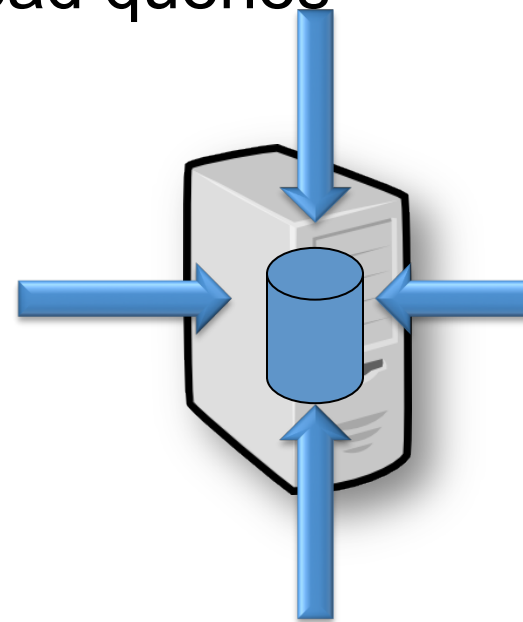


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Traditional analytics applications

- Scale-up Database
 - Use traditional SQL database
 - Use stored procedure for event driven reports
 - Use flash memory disks to reduce disk I/O
 - Use read only replica to **scale-out** read queries
- Limitations
 - Doesn't scale on write
 - Extremely expensive (HW + SW)



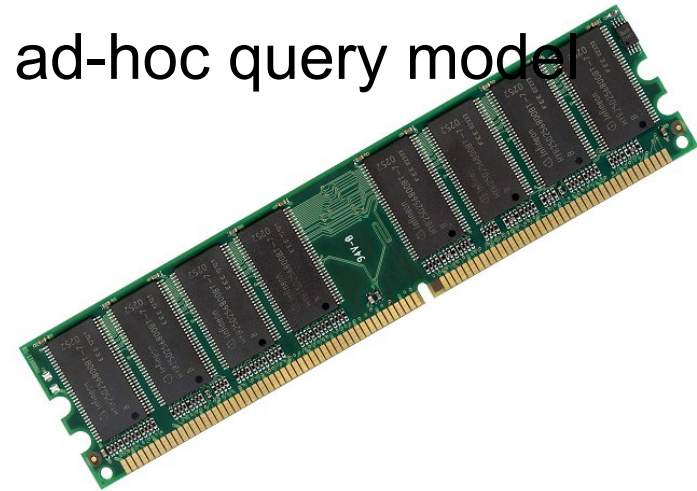
CEP – Complex Event Processing

- Process the data as it comes
- Maintain a window of the data in-memory
- Pros:
 - Extremely low-latency
 - Relatively low-cost
- Cons
 - Hard to scale (Mostly limited to scale-up)
 - Not agile - Queries must be pre-generated
 - Fairly complex



In Memory Data Grid

- Distributed in-memory database
- Scale out
- Pros
 - Scale on write/read
 - Fits to event driven (CEP style) , ad-hoc query model
- Cons
 - Cost of memory vs disk
 - Memory capacity is limited



Database Transactions

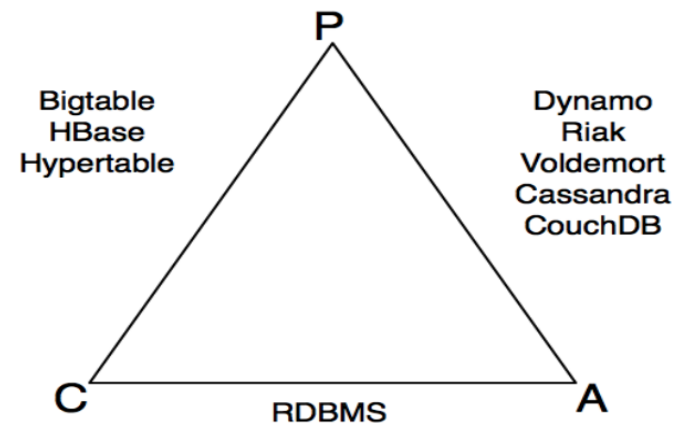
Transactions are a way to **make ACID operations** a general commodity

[Transaction Processing Concepts and Techniques, J. Gray and A. Reuter, 1993]

- **Atomicity**
 - a transaction is an indivisible unit of work
 - an **all-or-nothing** proposition
 - all updates to a database, displays on the clients' screens, message queues e.g., salary increase for all 1 million employees or none
- **Isolation**
 - a transaction's behavior **not affected by other transactions** running concurrently e.g., reserve a seat
 - serialization techniques
- **Consistency**
 - a transaction is an indivisible unit of work
 - $S \rightarrow [T \mid \text{abort}] \rightarrow S$
 - integrity constraints
- **Durability**
 - Persistence
 - a transaction's effects **are permanent** after it commits

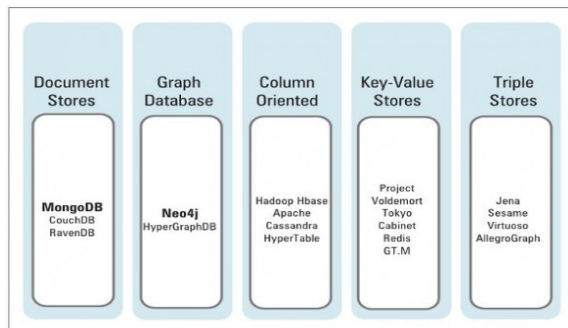
NoSQL

- Use distributed database
 - Hbase, Cassandra, MongoDB
- Pros
 - Scale on write/read
 - Elastic
- Cons
 - Read latency
 - Consistency tradeoffs are hard
 - Maturity – fairly young technology



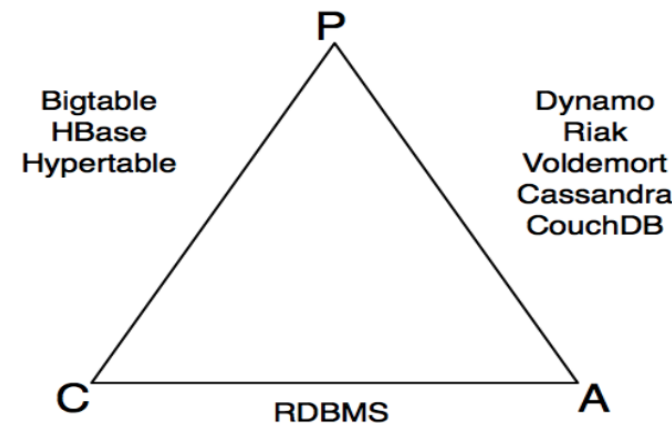
NoSQL

Year	System/ Paper	Scale to 1000s	Primary Index	Secondary Indexes	Transactions	Joins/ Analytics	Integrity Constraints	Views	Language/ Algebra	Data model	my label
1971	RDBMS	0	✓	✓	✓	✓	✓	✓	✓	tables	sql-like
2003	memcached	✓	✓	0	0	0	0	0	0	key-val	nosql
2004	MapReduce	✓	0	0	0	✓	0	0	0	key-val	batch
2005	CouchDB	✓	✓	✓	record	MR	0	✓	0	document	nosql
2006	BigTable (Hbase)	✓	✓	✓	record	compat. w/MR	/	0	0	ext. record	nosql
2007	MongoDB	✓	✓	✓	EC, record	0	0	0	0	document	nosql
2007	Dynamo	✓	✓	0	0	0	0	0	0	ext. record	nosql
2008	Pig	✓	0	0	0	✓	/	0	✓	tables	sql-like
2008	HIVE	✓	0	0	0	✓	✓	0	✓	tables	sql-like
2008	Cassandra	✓	✓	✓	EC, record	0	✓	✓	0	key-val	nosql
2009	Voldemort	✓	✓	0	EC, record	0	0	0	0	key-val	nosql
2009	Riak	✓	✓	✓	EC, record	MR	0			key-val	nosql
2010	Dremel	✓	0	0	0	/	✓	0	✓	tables	sql-like
2011	Megastore	✓	✓	✓	entity groups	0	/	0	/	tables	nosql
2011	Tenzing	✓	0	0	0	0	✓	✓	✓	tables	sql-like
2011	Spark/Shark	✓	0	0	0	✓	✓	0	✓	tables	sql-like
2012	Spanner	✓	✓	✓	✓	?	✓	✓	✓	tables	sql-like
2012	Accumulo	✓	✓	✓	record	compat. w/MR	/	0	0	ext. record	nosql
2013	Impala	✓	0	0	0	✓	✓	0	✓	tables	sql-like



Scale was the primary motivation

Bill Howe, UW



Hadoop MapReduce

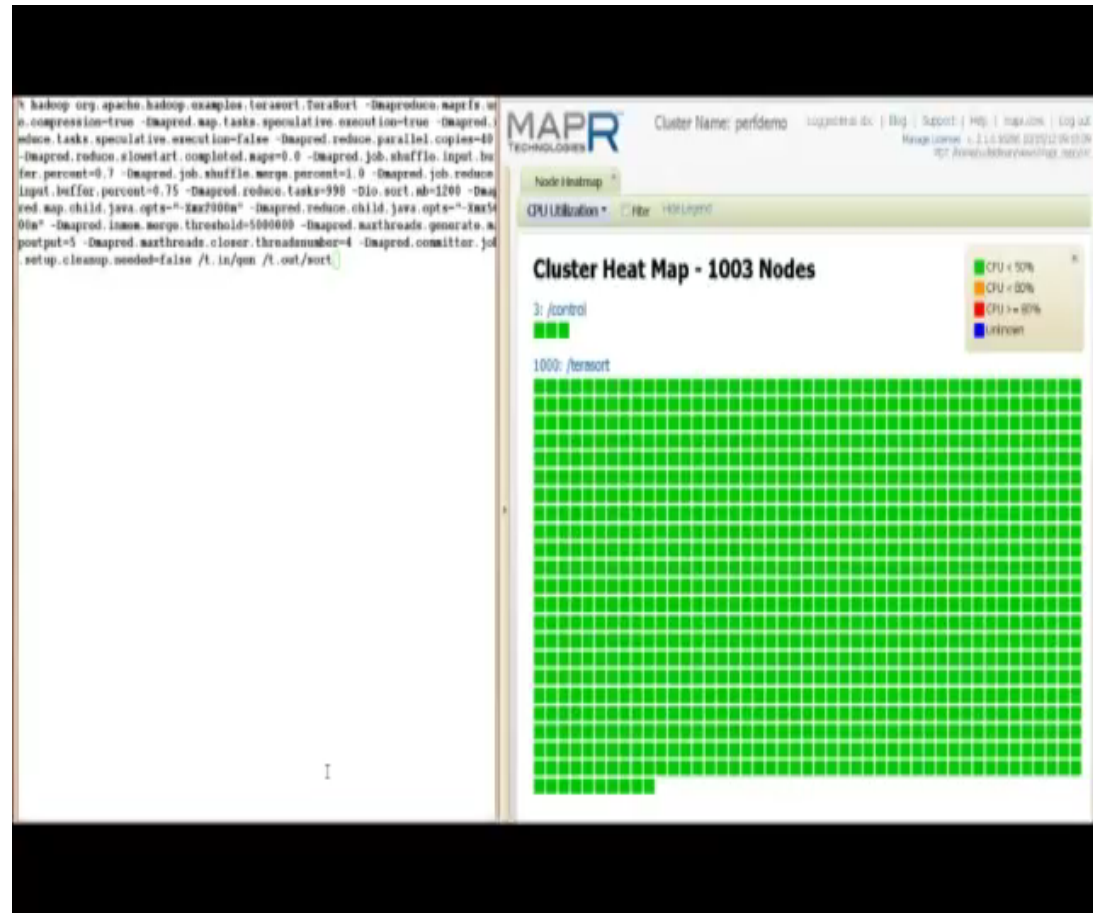
- Distributed batch processing
- Pros
 - Designed to process massive amount of data
 - Mature
 - Low cost
- Cons
 - Not real-time



Hadoop in action

Sorting 1 TB of DATA

- Estimate:
 - read 100MB/s, write 100MB/s
 - no disk seeks, **instant sort**
 - **341 minutes → 5.6 hours**
- The terabyte benchmark winner (2008):
 - 209 seconds (3.48 minutes)
 - 910 nodes x (4 dual-core processors, 4 disks, 8 GB memory)
- October 2012
 - ? see <http://www.youtube.com/watch?v=XbUPlbYxT8g&feature=youtu.be>



Parallel Thinking

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.

How many “big”, “medium”, and “small” words are used?

Parallel Thinking

Big = Yellow = 10+ letters

Medium = Red = 5..9 letters

Small = Blue = 2..4 letters

Tiny = Pink = 1 letter

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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 rights, governments are instituted among men, deriving their just powers from the consent of the governed; that whenever a government shall become destructive of these ends, it is the right of the people to alter or abolish it, and to institute new government, laying its foundation on such principles and organizing its powers in such form, as they shall deem most likely to effect their safety and happiness. Prudence indeed

dictate that governments not established should not be changed for light and transient causes; and accordingly our experience and reason shows 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 in 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 a government and to provide new guards for future security. Now has come the patient sufferings of the colonies, and now is the necessity which constrains them to expunge their former systems of government. The history of the present majesty is a history of unremitting injuries and usurpations, among which the least and the most stand single and solitary contradict the uniform tenor of the laws, in which they have direct object the establishment of absolute tyranny over these states. To prove this, let facts be submitted to a candid world, be the truth of which we pledge a faith not unsullied by falsehood.

Parallel thinking

Split the document into chunks and process each chunk on a different computer

Chunk 1

Chunk 2

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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 its foundation on such principles and organizing its 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.

Parallel thinking

Map Task 1
(204 words)

Abridged Declaration of Independence

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

When in the course of human events, it becomes necessary for a people to advance from subordination to 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, liberty, and the pursuit of happiness; that to secure these rights, governments are instituted among men, deriving their just powers 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 its foundation on such principles and organizing its powers 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 the experience of the world has 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 in 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. In the history of the present majesty, a history of unremitting injuries and usurpations, among which we now stand single and solitary, contradict the uniform tenor of the rest of the world, in which no kind of direct object of establishment of absolute tyranny over these states, to prove that the facts are submitted to a candid world, in the truth of which we pledge a faith as unsullied as falsehood.

(key, value)

(yellow, 17)

(red, 77)

(blue, 107)

(pink, 3)

Parallel thinking

Map Task 1
(204 words)

Abridged Declaration of Independence

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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 they have 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 abolish it, and to institute new government, laying its foundation on such principles and organizing its power in such form as to them shall seem most likely to effect their safety and happiness. Prudence indeed will

(key, value)

(yellow, 17)
(red, 77)
(blue, 107)
(pink, 3)

Map Task 2
(190 words)

dictate that governments thus established should not be changed for light and transient causes; and accordingly the experience of the world has shown 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 in 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 their 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 the present majesty is a history of unremitting injuries and usurpations, among which we may not stand 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 that the facts are submitted in a candid world, we have the truth of which we pledge a faith as unsullied as falsehood.

(yellow, 20)
(red, 71)
(blue, 93)
(pink, 6)

Relational Join

Employee

Name	SSN
Sue	999999999
Tony	777777777

Assigned Departments

EmpSSN	DepName
999999999	Accounts
777777777	Sales
777777777	Marketing

Employee ⋈ Assigned Departments

Name	SSN	EmpSSN	DepName
Sue	999999999	999999999	Accounts
Tony	777777777	777777777	Sales
Tony	777777777	777777777	Marketing

Relational join in MR: the trick

Employee

Name	SSN
Sue	9999999999
Tony	7777777777

Assigned Departments

EmpSSN	DepName
9999999999	Accounts
7777777777	Sales
7777777777	Marketing

Relational join in MR: map phase

Employee, Sue, 999999999
Employee, Tony, 777777777
Department, 999999999, Accounts
Department, 777777777, Sales
Department, 777777777, Marketing



Relational join in MR: reduce phase

key=999999999, values=[(Employee, Sue, 999999999),
(Department, 999999999, Accounts)]

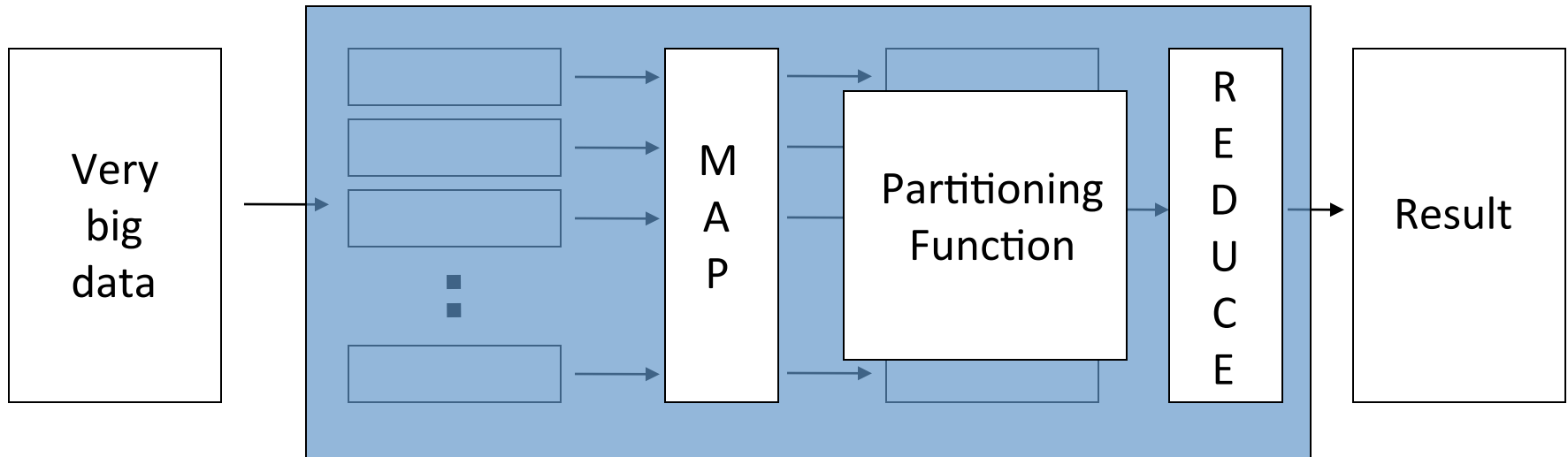
.

key=777777777, values=[(Employee, Tony, 777777777),
(Department, 777777777, Sales),
(Department, 777777777, Marketing)]

MapReduce vs. Databases

- A. Pavlo, et al. "A comparison of approaches to large-scale data analysis," in *SIGMOD '09: Proceedings of the 35th SIGMOD international conference on Management of data*, New York, NY, USA, 2009, pp. 165-178
- Conclusions: ... at the scale of the experiments we conducted, both parallel database systems displayed a significant performance advantage over Hadoop MR in executing a variety of data intensive analysis benchmarks.

Map Reduce



- **Map:**

- Accepts
 - *input* key/value pair
- Emits
 - *intermediate* key/value pair

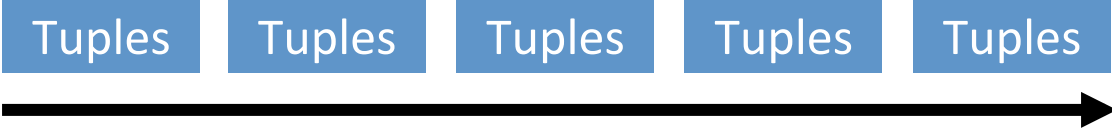
- **Reduce :**

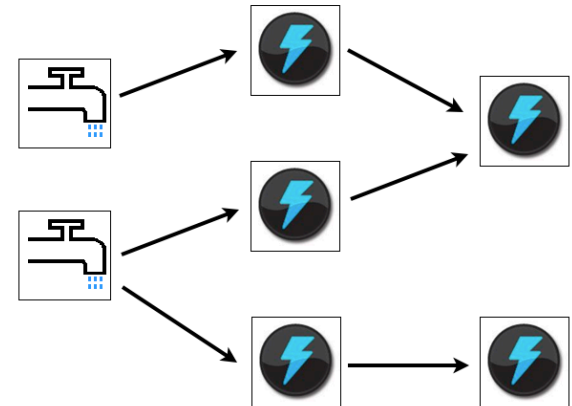
- Accepts
 - *intermediate* key/value* pair
- Emits
 - *output* key/value pair

Real time data analytics

- Apache Storm is a free and open source distributed real time computation system.
 - makes it easy to reliably process unbounded streams of data.
 - simple, can be used with any programming language
- Storm is fast: a benchmark clocked it at over a million tuples processed per second per node.
- Storm integrates with the queueing and database technologies you already use

STORM Concepts

- Streams 
- Spouts: Source of streams
- Bolts: Functions, Filters, Aggregation, Joins, DB R/W
- Topologies: Grouping of Spouts and Bolts



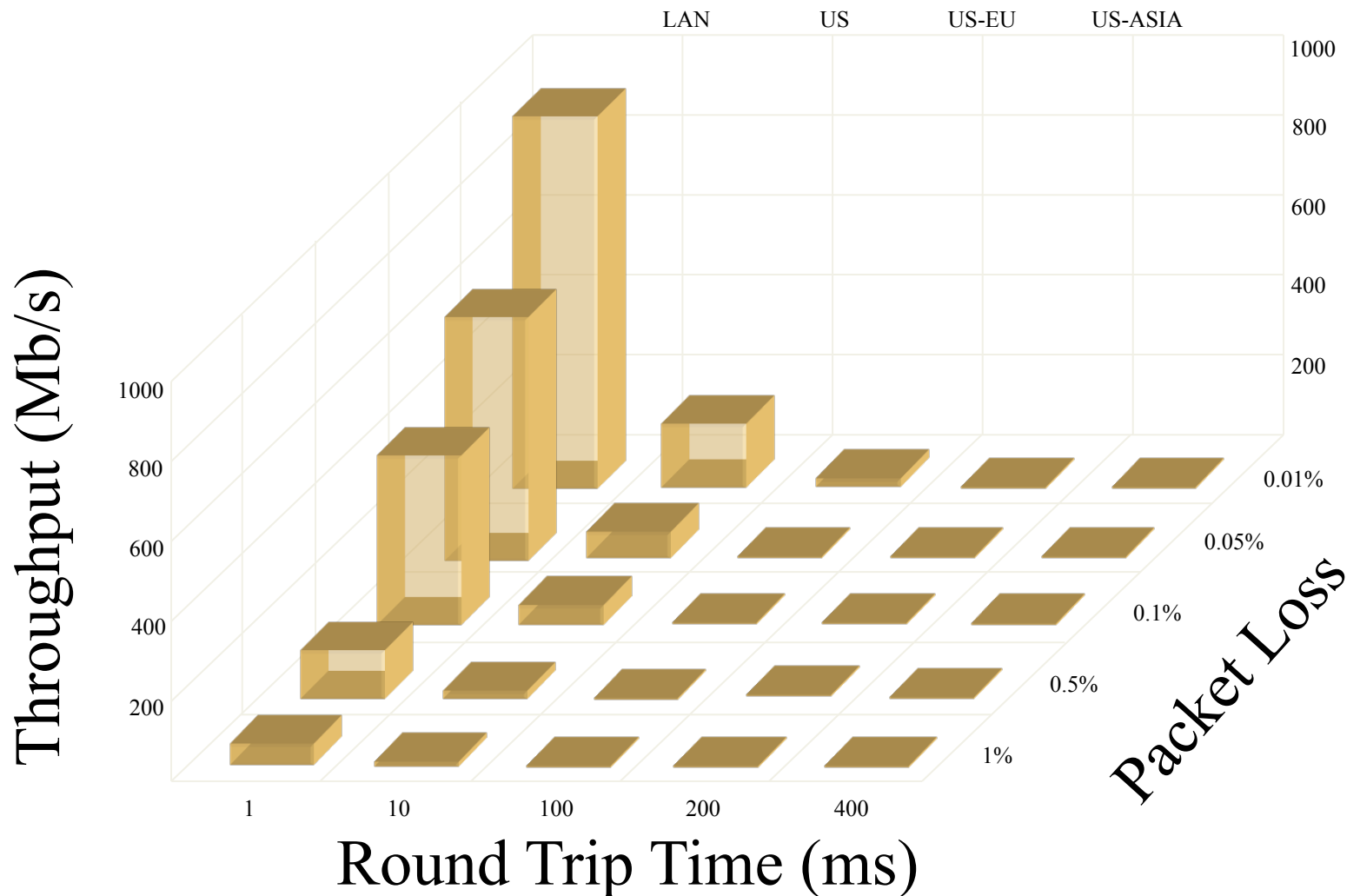
content

- General Introduction
- Definitions
- Data Analytics
- Solutions for Big Data Analytics
- The Network (Internet)
- When to consider BigData solution
- Scientific e-infrastructure – some challenges to overcome

The problem

- TCP Was never designed to move large datasets over wide area high Performance Networks.
- For loading a webpage, TCP is great.
- For sustained data transfer, it is far from ideal.
 - Most of the time even **though the connection itself is good** (let say 45Mbps), transfers are much slower.
 - There are two reason for a slow transfer over fast connections:
 - Latency
 - and packet loss bring TCP-based file transfer to a crawl.

TCP Throughput vs RTT and Packet Loss



Source: Yunhong Gu, 2007, experiments over wide area 1G.

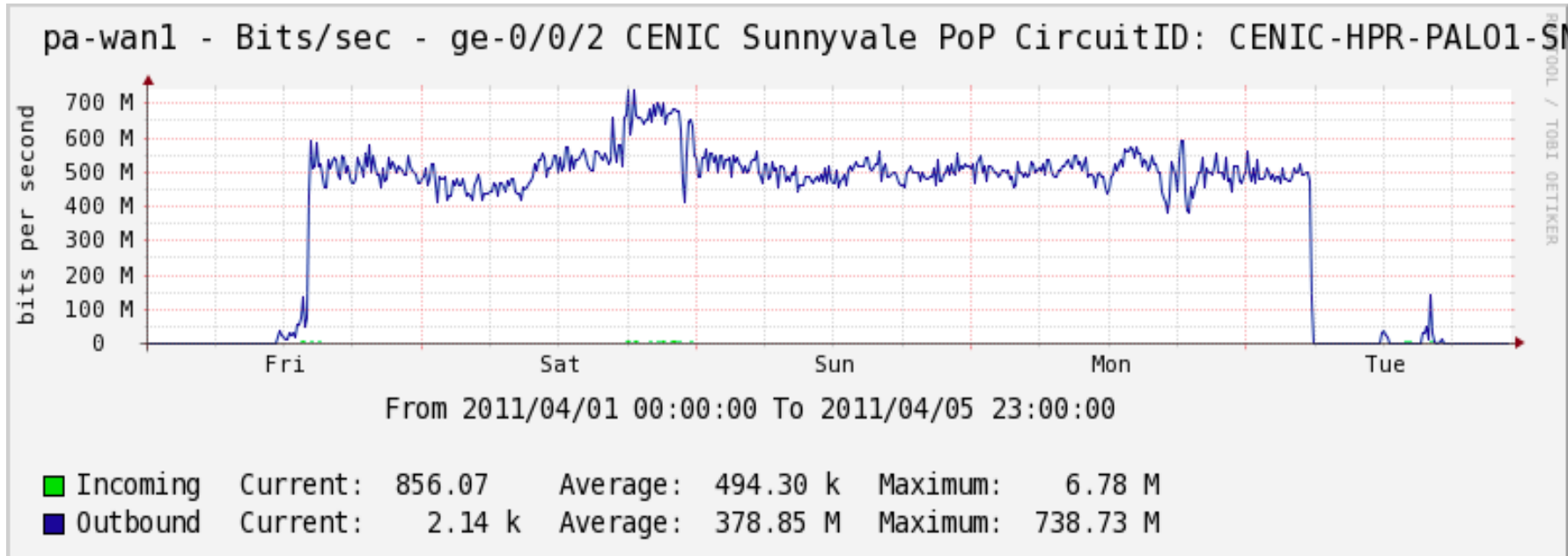
The solutions

- Use parallel TCP streams
 - GridFTP
- Use specialized network protocols
 - UDT, FAST, etc.
- Use RAID to stripe data across disks to improve throughput when reading
- These techniques are well understood in HEP, astronomy, but not yet in biology

Moving 113GB of Bio-mirror Data

- | Site | RTT | TCP | UDT | TCP/UDT | Km |
|--------|-----|-------------|-----|---------|--------|
| NCSA | 10 | 139 | 139 | 1 | 200 |
| Purdue | 17 | 125 | 125 | 1 | 500 |
| ORNL | 25 | 361 | 120 | 3 | 1,200 |
| TACC | 37 | 616 | 120 | 55 | 2,000 |
| SDSC | 65 | 750 | 475 | 1.6 | 3,300 |
| CSTNET | 274 | 3722 | 304 | 12 | 12,000 |
- GridFTP TCP and UDT transfer times for 113 GB from gridip.bio-mirror.net/biomirror/blast/ (Indiana USA).
 - All TCP and UDT times in minutes.
 - Source: <http://gridip.bio-mirror.net/biomirror/>

Case study: CGI 60 genomes



- Trace by Complete Genomics showing performance of moving 60 complete human genomes from Mountain View to Chicago using the open source Sector/UDT.
- Approximately **18 TB at about 0.5 Mbs on 1G link**.

How FedEx Has More Bandwidth Than the Internet—and When That'll Change

- If you're looking to transfer hundreds of gigabytes of data, it's still—weirdly—faster to ship hard drives via FedEx than it is to transfer the files over the internet.
- “ Cisco estimates that total internet traffic currently averages **167 terabits per second**. FedEx has a fleet of 654 aircraft with a lift capacity of 26.5 million pounds daily. A solid-state laptop drive weighs about 78 grams and can hold up to a terabyte. That means FedEx is capable of transferring 150 exabytes of data per day, or 14 petabits per second—**almost a hundred times the current throughput of the internet.**

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When to Consider a Big Data Solution

User point of view

- You're limited by your **current platform** or **environment** because you can't process the **amount** of data that you want to process
- You want to involve **new sources of data** in the analytics, but you can't, because it **doesn't fit into schema-defined rows and columns** without sacrificing fidelity or the richness of the data
- You need to ingest data as **quickly as possible** and need to work with a schema-on-demand

When to Consider a Big Data Solution

- You're forced into a **schema-on-write** approach (the schema must be created before data is loaded),
 - but you need to ingest data quickly, or perhaps in a discovery process,
 - and want the cost benefits of a **schema-on-read** approach (data is simply copied to the file store, and no special transformation is needed) until you know that you've got something that's ready for analysis?
- The data arriving **too fast** at your organization's doorstep for the current analytics platform to handle

When to Consider a Big Data Solution

- You want to analyse not just raw structured data, but also **semi-structured** and **unstructured data** from a wide variety of sources
- you're not satisfied with the effectiveness of your algorithms or models
 - when all, or most, of the data needs to be analysed
 - or when a sampling of the data isn't going to be nearly as effective

When to Consider a Big Data Solution

- you aren't completely sure where the investigation will take you, and you want **elasticity of compute, storage**, and the types of analytics that will be pursued—all of these became useful as we added more sources and new methods

If your answers to any of these questions are “yes,” you need to consider a Big Data solution.

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Scientific e-infrastructure – some challenges to overcome

- Collection
 - How can we make sure that data are **collected together** with the **information** necessary **to re- use them**?
- Trust
 - How can we **make informed judgements** about whether certain data are **authentic** and can be **trusted**?
 - How can we judge which **repositories** we can **trust**? How can **appropriate access** and use of resources be granted or controlled

Scientific e-infrastructure – some challenges to overcome

- Usability
 - How can we move to a situation **where non-specialists can overcome** the barriers and be able to start sensible work on unfamiliar data
- Interoperability
 - How can we implement **interoperability within disciplines** and move to an overarching multi-disciplinary way of understanding and using data?
 - How can we **find unfamiliar** but relevant data resources **beyond simple keyword searches**, but involving a deeper probing into the data
 - How can **automated tools** find the information needed to tackle data

Scientific e-infrastructure – some challenges to overcome

- Diversity
 - How do we overcome the problems of diversity – heterogeneity of data, but also of backgrounds and data-sharing cultures in the scientific community?
 - How do we deal with **the diversity of data repositories** and access rules – within or between disciplines, and within or across national borders?
- Security
 - How can we **guarantee data integrity**?
 - How can we avoid **data poisoning** by individuals or groups intending to bias them in their interest?

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Scientific e-infrastructure – a wish list

- **Open deposit**, allowing user-community centres to store data easily
- **Bit-stream preservation**, ensuring that data authenticity will be guaranteed for a specified number of years
- **Format and content migration**, executing CPU-intensive transformations on large data sets at the command of the communities

Scientific e-infrastructure – a wish list

- **Persistent identification**, allowing data centres to register a huge amount of markers to track the origins and characteristics of the information
- **Metadata support** to allow effective management, use and understanding
- **Maintaining proper access rights** as the basis of all trust
- **A variety of access and curation services** that will vary between scientific disciplines and over time

Scientific e-infrastructure – a wish list

- **Execution services** that allow a large group of researchers to operate on the stored data
- **High reliability**, so researchers can count on its availability
- **Regular quality assessment** to ensure adherence to all agreements
- **Distributed and collaborative** authentication, authorisation and accounting
- **A high degree of interoperability** at format and semantic level

- Realtime Analytics for Big Data: A Facebook Case Study
 - <http://www.youtube.com/watch?v=viPRny0nq3o>