Department of Computer Science
University of Cyprus

EPL646 – Advanced Topics in Databases

Lecture 11

Big Data Management I

(Introduction)

Demetris Zeinalipour
http://www.cs.ucy.ac.cy/~dzeina/courses/epl646

Lecture Outline

- ***Big Data Definitions and Background***
- *Big Data Definition by 3V Examples*
  - ***Velocity***
    - *Sensor Monitoring, Network Monitoring, Web2.0 Media, Smartphone Services*
  - ***Volume***
    - *Text<Multimedia<Sciences, Web Data, Filesystems*
  - ***Variety***
    - *The New Database Landscape*
    - *NoSQL (Document Stores, Replication, Consistency, Map-Reduce, Column Stores)*
    - *NewSQL Trends*

Big Data Definitions

- *"Refers to data sets whose **size** and **structure strains** (stretches) the **ability** of commonly used **relational DBMSs** to **capture**, **manage**, and **process** the data within a **tolerable elapsed time**."*
  - *Hoffer, Ramesh, Topi: Modern Database Management, 11E, 2013.*
- *Similar from Wikipedia, Feb. 2013*
  - *"big data is a collection of data sets **so large** and **complex** that it becomes **difficult** to process **using on-hand database management** tools or **traditional data processing** applications."*

Big Data Characteristics

- **Size:** from a few **dozen terabytes** to many **petabytes** in a single database.
- **Data model:** anything from *structured* (relational or tabular) to *semi-structured* (XML or JSON) or even *unstructured* (Web text and log files).
- **Architectures:** highly *parallel* and *distributed* in order to cope with the inherent I/O and CPU limitations.
- **Hardware:** mid-scale *private clouds* (datacenters), offering higher privacy, to *large-scale public clouds*.
- **Functionality:** *operational (OLTP)* and *analytic (OLAP)* functionality *stand-alone* or *as-a-Service.*

Big Data Characteristics

2013 IEEE International Conference on Big Data (IEEE BigData 2013), October 6-9, 2013, Silicon Valley, CA, USA

Computing
Systems
Management
Analytics
Privacy
Search
Mining
Models
Applications
Integration
Web
Security
Software
Architectures
Standards
Cloud/Grid/Stream
Social
Detection
Computational
New
Science
Business
Interfaces
Scale
Studies
Information
High
Programming
Large
Platforms
Novel
Value
research
Variety
Velocity
management
base
Multi-structured
Challenges
User
Support
science
Volume
limited
Pervasive
Society
Complex
Protection
IEEE
Large-scale
Optimization
papers
solicit
years
Cluster
Advanced
Relevant
transforming
Threat
Peer-to-peer
Infrastructure
high-quality
become
International
Real-life
emphasis
significant
Media
Efficiency
include
aspect
Engineering
Experiences
itsel
leading
provides
infrastructure
APT
Energy-efficient
Finance
Enterprises
engineering
beyond
Networks
System
latest
Open
Aspects
Collection/Analytics
topics
Creation
Best
Recommendation
Visualization
using
Project
Service
Government
bases
searching
STORM
Provenance
Hadoop/MapReduce
Policies
disseminating
General
Link
Veracity
original
including
Healthcare
Industry
work-in-progress
Integrity
Practices
Grid
Visualizing
Public
Stream
Scientific
Conference
Autonomic
business
Cloud
society
Deployment
Theoretical
Graph
Emerging
Pre-processing
Intrusion
Acquisition
Preserving
Retailing
new
forum
Development
Modeling
Workflow
Techniques
Foundations
Hardware
Spatiotemporal
Model
Multimedia
Cryptography
Performance
Scalability
Threats
Quality

Wordle.net

Background: Public Clouds

Google's Datacenter in Oregon

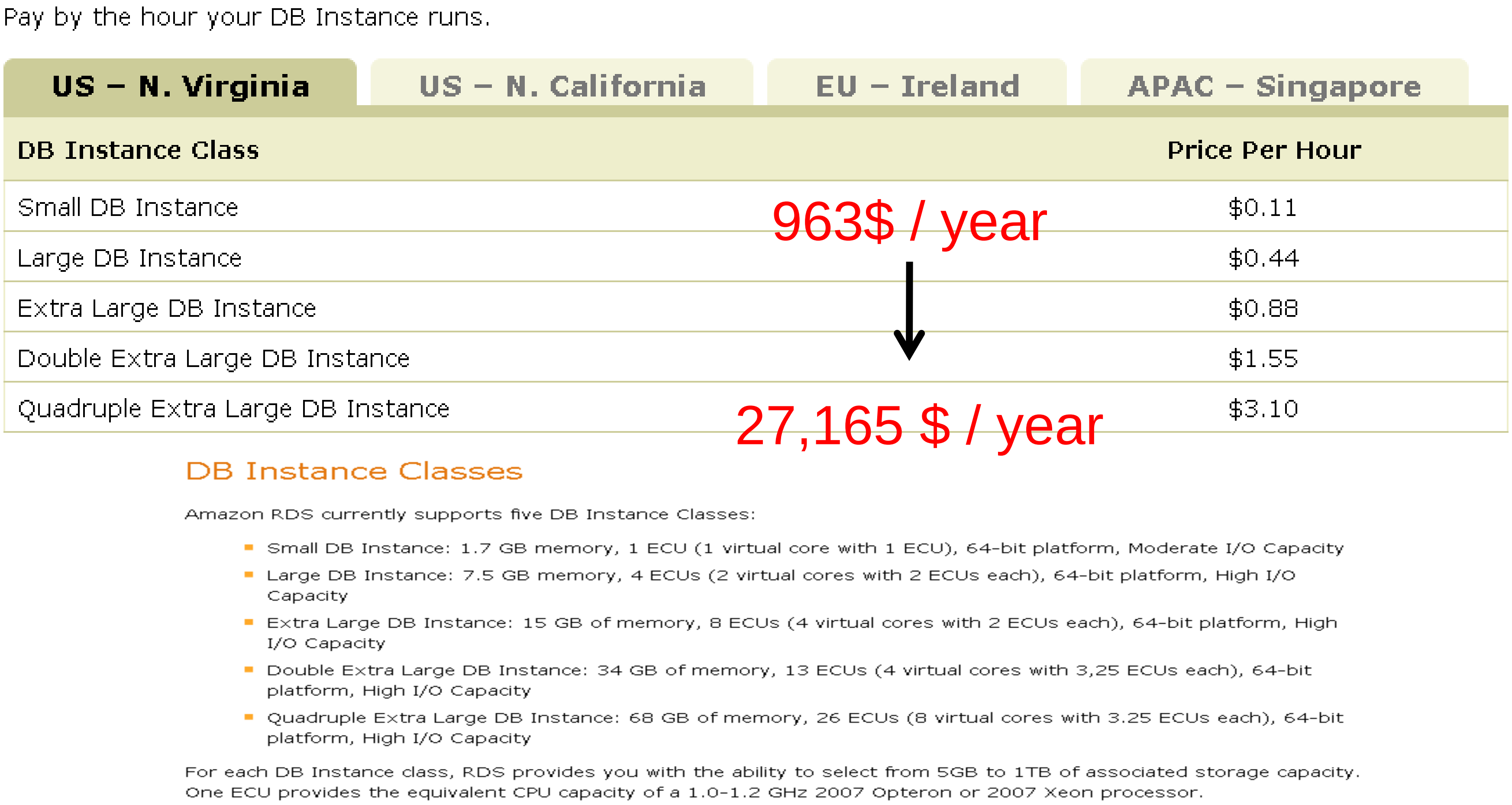
Background: Public Clouds

Microsoft Azure in Chicago

112 containers x 2000 servers = 224,000 servers

Background: *-as-a-Service

To Amazon RDS (Relational Database Service)



Pay by the hour your DB Instance runs.

DB Instance Class	Price Per Hour
Small DB Instance	$0.11
Large DB Instance	$0.44
Extra Large DB Instance	$0.88
Double Extra Large DB Instance	$1.55
Quadruple Extra Large DB Instance	$3.10

963$ / year

↓

27,165 $ / year

DB Instance Classes

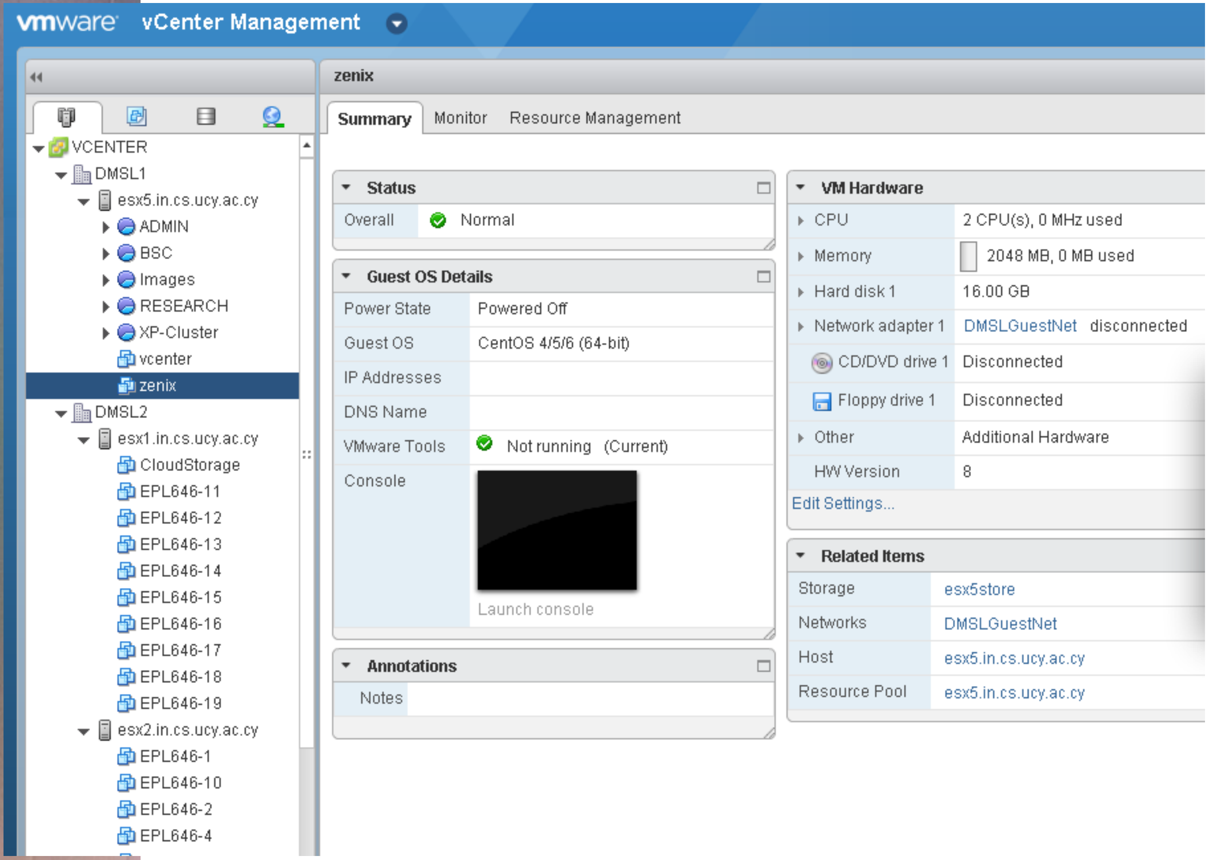
Amazon RDS currently supports five DB Instance Classes:

- Small DB Instance: 1.7 GB memory, 1 ECU (1 virtual core with 1 ECU), 64-bit platform, Moderate I/O Capacity
- Large DB Instance: 7.5 GB memory, 4 ECUs (2 virtual cores with 2 ECUs each), 64-bit platform, High I/O Capacity
- Extra Large DB Instance: 15 GB of memory, 8 ECUs (4 virtual cores with 2 ECUs each), 64-bit platform, High I/O Capacity
- Double Extra Large DB Instance: 34 GB of memory, 13 ECUs (4 virtual cores with 3,25 ECUs each), 64-bit platform, High I/O Capacity
- Quadruple Extra Large DB Instance: 68 GB of memory, 26 ECUs (8 virtual cores with 3.25 ECUs each), 64-bit platform, High I/O Capacity

For each DB Instance class, RDS provides you with the ability to select from 5GB to 1TB of associated storage capacity. One ECU provides the equivalent CPU capacity of a 1.0-1.2 GHz 2007 Opteron or 2007 Xeon processor.

Background: Private Clouds

Our Laboratory Private IaaS



- VCENTER
  - DMSL1
    - esx5.in.cs.ucy.ac.cy
      - ADMIN
      - BSC
      - Images
      - RESEARCH
      - XP-Cluster
      - vcenter
      - zenix
  - DMSL2
    - esx1.in.cs.ucy.ac.cy
      - CloudStorage
      - EPL646-11
      - EPL646-12
      - EPL646-13
      - EPL646-14
      - EPL646-15
      - EPL646-16
      - EPL646-17
      - EPL646-18
      - EPL646-19
    - esx2.in.cs.ucy.ac.cy
      - EPL646-1
      - EPL646-10
      - EPL646-2
      - EPL646-4

zenix

Status

Overall	✓ Normal

Guest OS Details

Power State	Powered Off
Guest OS	CentOS 4/5/6 (64-bit)
IP Addresses	
DNS Name	
VMware Tools	✓ Not running (Current)
Console	Launch console

Annotations

Notes	

VM Hardware

CPU	2 CPU(s), 0 MHz used
Memory	2048 MB, 0 MB used
Hard disk 1	16.00 GB
Network adapter 1	DMSLGuestNet disconnected
CD/DVD drive 1	Disconnected
Floppy drive 1	Disconnected
Other	Additional Hardware
HW Version	8

Edit Settings...

Related Items

Storage	esx5store
Networks	DMSLGuestNet
Host	esx5.in.cs.ucy.ac.cy
Resource Pool	esx5.in.cs.ucy.ac.cy

Big Data: Velocity-Volume-Variety

- **Velocity**
  - ***how fast data*** *is being* ***produced*** *and* ***how fast*** *the data must be* ***processed to meet demand****.*
    - *How to deal with torrents of data, in near-real time, streaming from* ***RFID tags*** *and* ***smart metering systems****?*
    - *How to* ***identify fraud*** *in 5 million trade events created* ***each day****?*
    - **Reacting** quickly **enough** to deal with velocity is a **challenge** to most organizations.

Source: IDC. "Big Data Analytics: Future Architectures, Skills and Roadmaps for the CIO," September 2011.

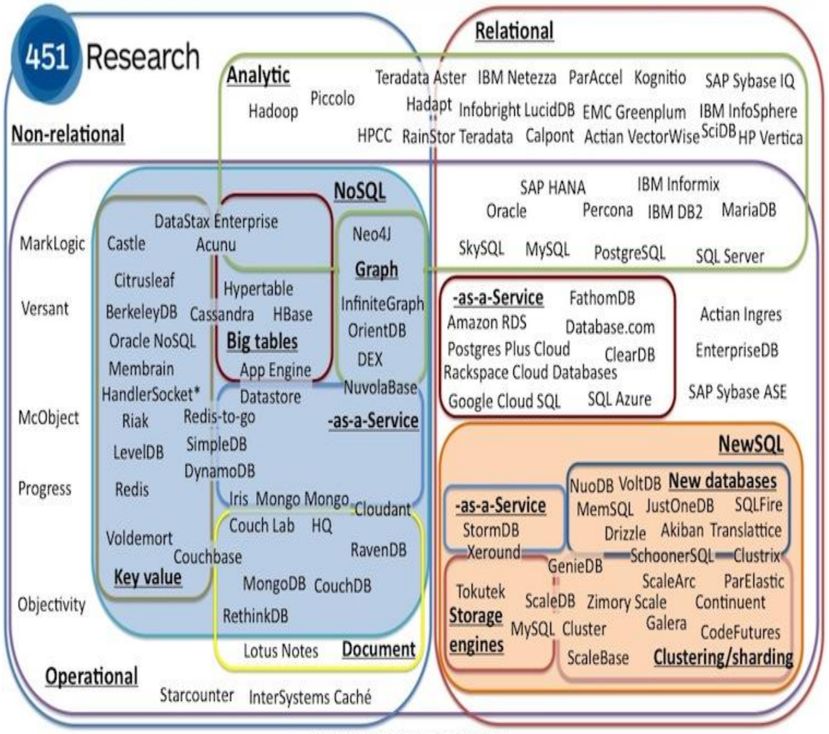
Big Data: Velocity-Volume-Variety

- **Volume**
  - **Past Challenge: Store data.**
    - transaction-based data stored through the years.
    - sensor data being collected
    - Integration with web applications & social media
  - **New Challenge: Create value from data**
    - Turn 12 TB of Tweets each day into a *sentiment analysis* (opinion mining) product.
      - e.g., People feel positive/negative/neutral about brand X.
    - Turn 350 billion annual smart meter readings to knowledge that helps predicting power consumption.

Big Data: Velocity-Volume-Variety

- **Variety:**
  - By some estimates, **80 percent** of an organization's data is **not numeric**!
  - Different data format: *unstructured, structured, semi-structured*
    - text, sensor data, audio, video, click streams, log files, etc.

The evolving database landscape



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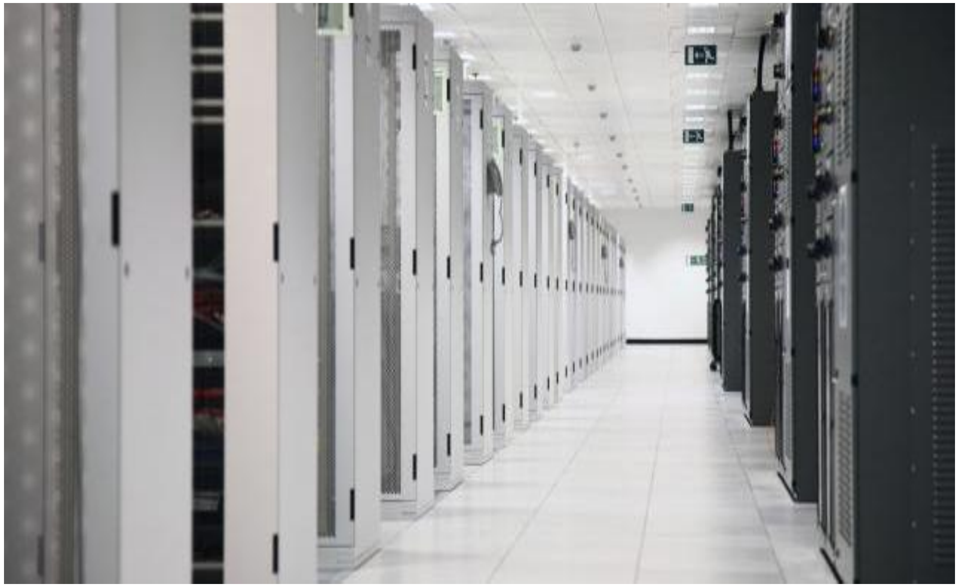
Velocity #1: Smart Meters

- **Smart meter:** records consumption of **electric energy** in **intervals** and communicates that information to the utility for **monitoring** and **billing purposes.**



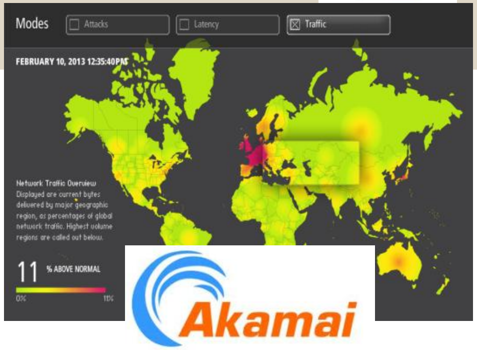
Every 15m

Velocity #1: Smart Meters

- **Ontario's Meter Data Management and Repository (MDM/R):** storing, processing and managing all smart meter data in Ontario, Canada
- **Characteristics:**
  - Provides hourly billing quantity and extensive reports.
  - 4.6 million smart meters.
    - Storage/Bandwidth: 4.6M meters x 0.5K message (typical HTTP) = 2.3 GB / round
  - 110 million meter reads per day
    - on an annual basis, exceeds the number of debit card transactions processed in the **country** (Canada!)

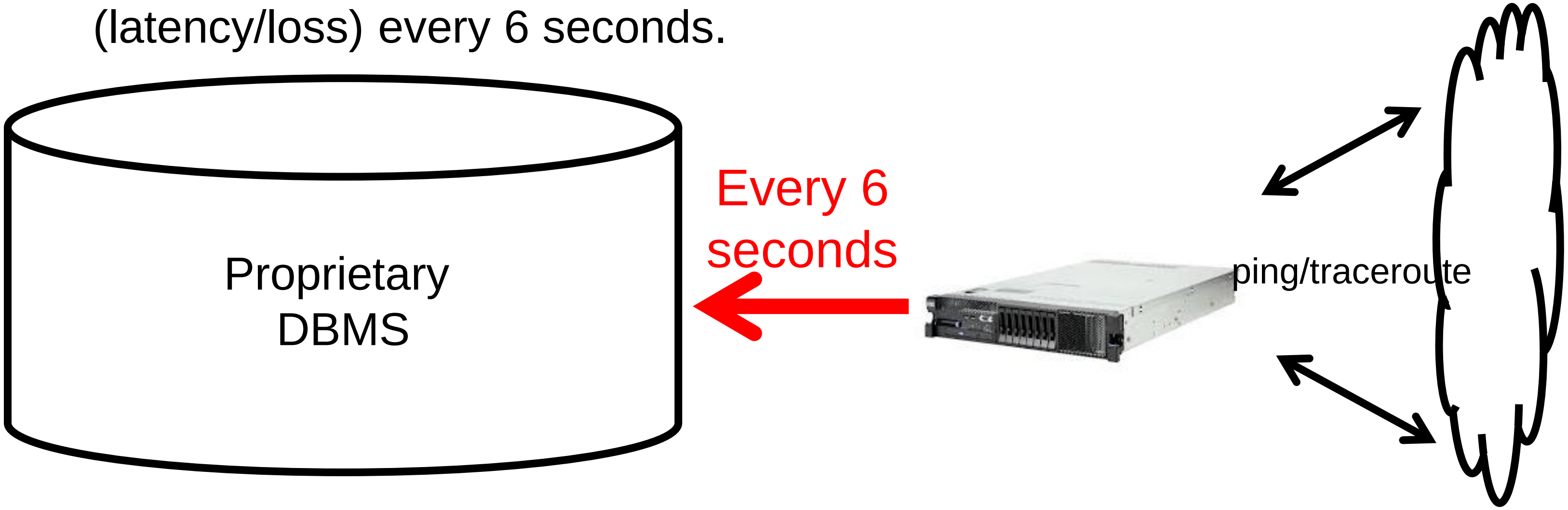
Source: Smart Metering Entity: http://www.smi-ieso.ca/mdmr

Velocity #2: Network Monitoring

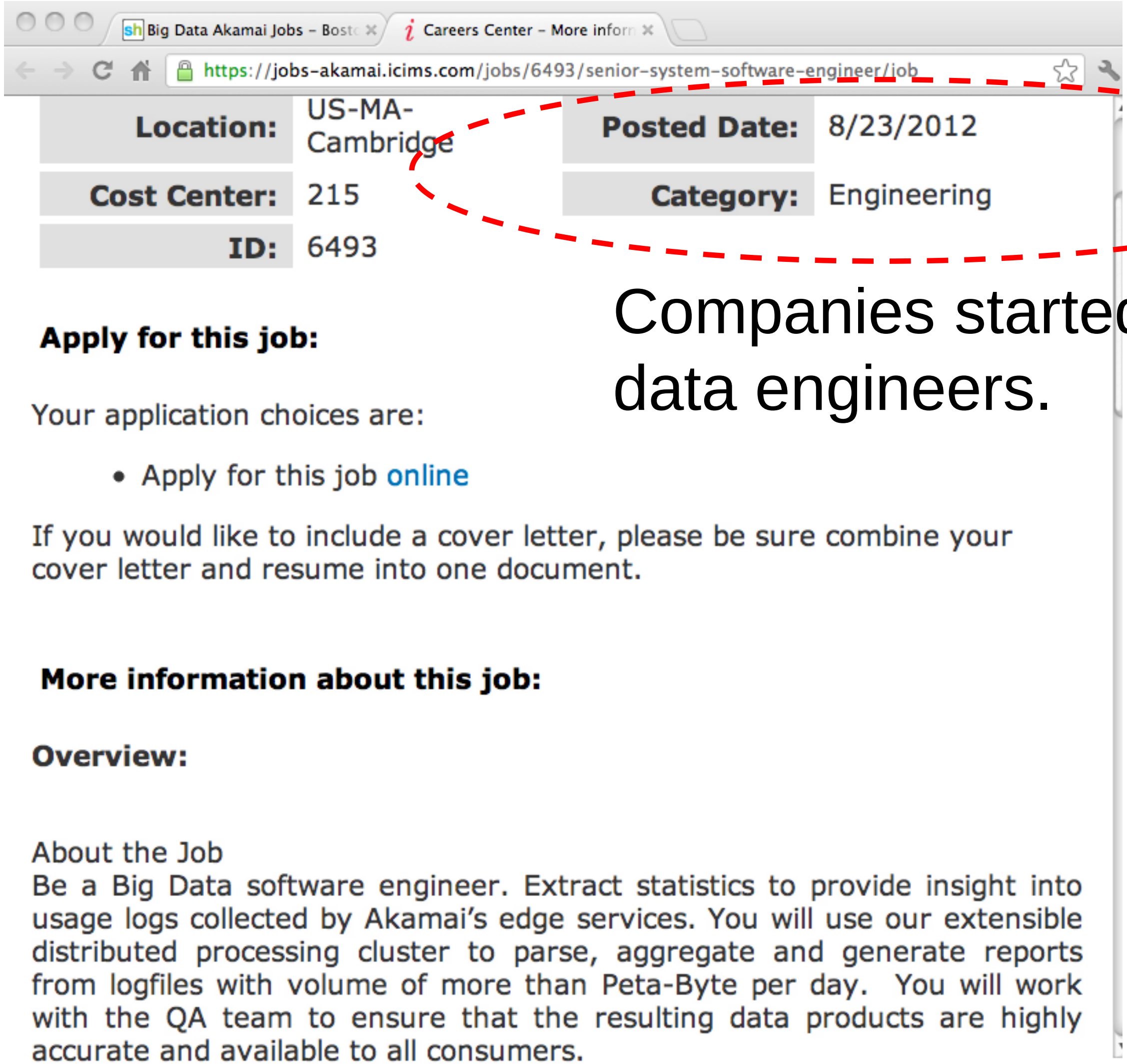


Network Traffic Overview
Displayed are current bytes delivered by major geographic region, as percentages of global network traffic. Highest volume regions are called out below.

- **Akamai:**
  - CDN serving 15-30% of all Web traffic (10TB/sec)
    - One out of every three Global 500® companies
    - All of the top Internet portals
  - Has a picture of the global traffic every **6 seconds**
- **How?**
  - 119,000 servers in 80 countries within over 1,100 networks.
  - Servers report to a proprietary database network health information (latency/loss) every 6 seconds.



Velocity #2: Network Monitoring



Big Data Akamai Jobs – Bosto
Careers Center – More inforr
https://jobs-akamai.icims.com/jobs/6493/senior-system-software-engineer/job

Location:	US-MA-Cambridge	**Posted Date:**	8/23/2012
Cost Center:	215	**Category:**	Engineering
ID:	6493		

Apply for this job:

Your application choices are:

- Apply for this job online

If you would like to include a cover letter, please be sure combine your cover letter and resume into one document.

More information about this job:

Overview:

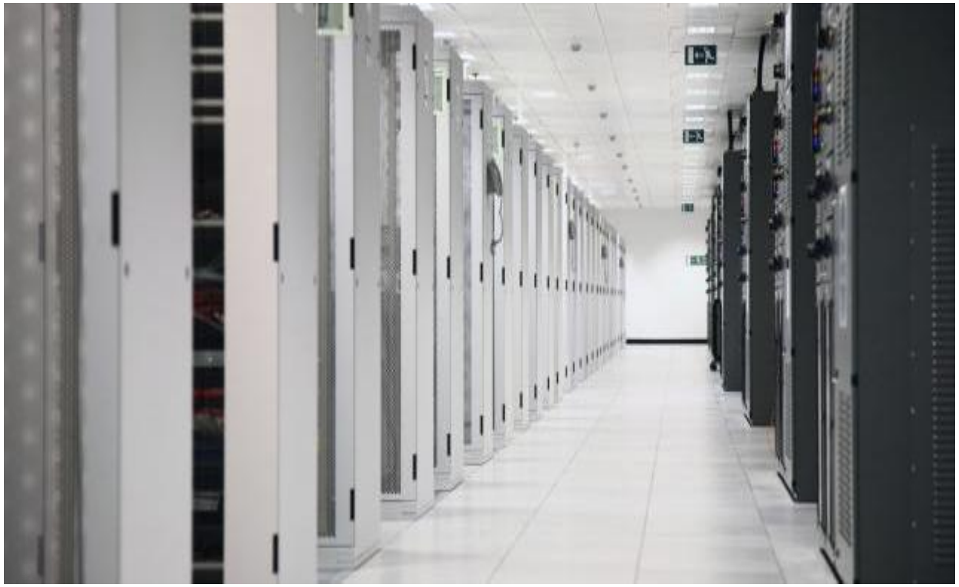
About the Job

Be a Big Data software engineer. Extract statistics to provide insight into usage logs collected by Akamai's edge services. You will use our extensible distributed processing cluster to parse, aggregate and generate reports from logfiles with volume of more than Peta-Byte per day. You will work with the QA team to ensure that the resulting data products are highly accurate and available to all consumers.

Companies started seeking Big data engineers.

Velocity #3: Web2.0 Media

- Analyze online conversations in Social Nets.
- Accelerated responses to marketplace shifts.



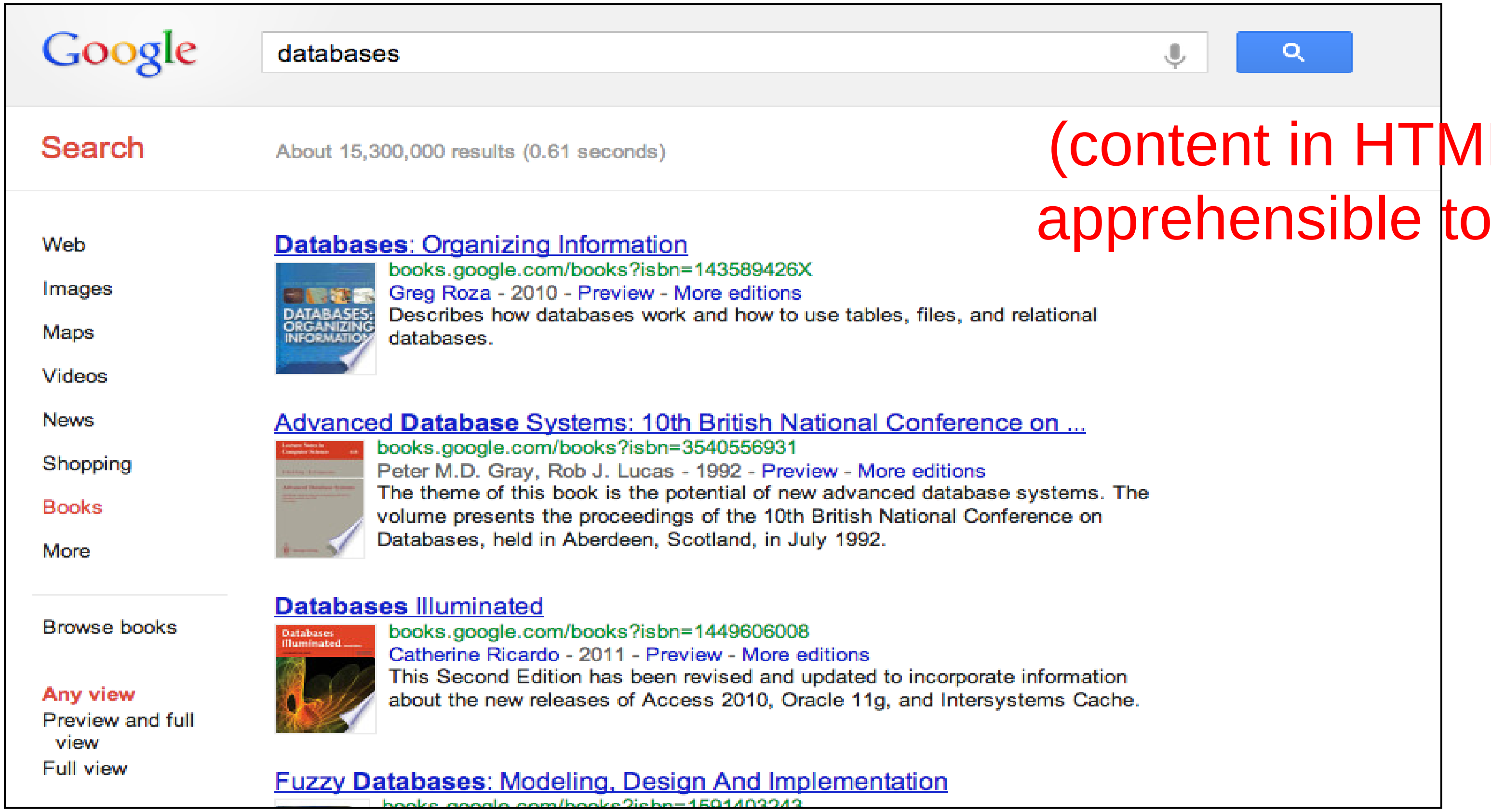
Continously

←

Over Web2.0 protocols

Velocity #3: Web2.0 Media

Web1.0: The Unstructured Web
http://books.google.com/



About 15,300,000 results (0.61 seconds)

Databases: Organizing Information
books.google.com/books?isbn=143589426X
Greg Roza - 2010 - Preview - More editions
Describes how databases work and how to use tables, files, and relational databases.

Advanced **Database** Systems: 10th British National Conference on ...
books.google.com/books?isbn=3540556931
Peter M.D. Gray, Rob J. Lucas - 1992 - Preview - More editions
The theme of this book is the potential of new advanced database systems. The volume presents the proceedings of the 10th British National Conference on Databases, held in Aberdeen, Scotland, in July 1992.

Databases Illuminated
books.google.com/books?isbn=1449606008
Catherine Ricardo - 2011 - Preview - More editions
This Second Edition has been revised and updated to incorporate information about the new releases of Access 2010, Oracle 11g, and Intersystems Cache.

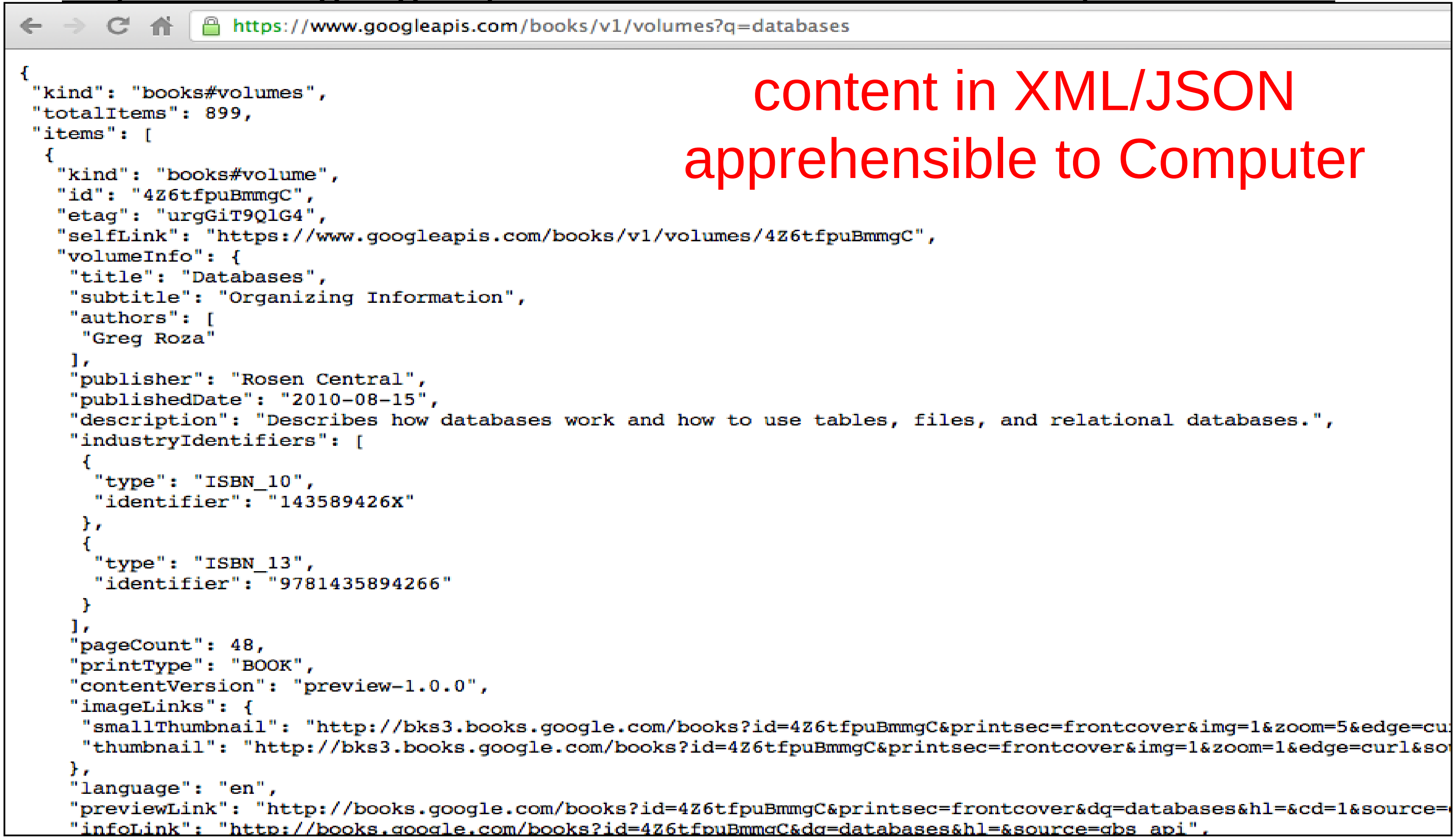
Fuzzy **Databases**: Modeling, Design And Implementation
books.google.com/books?isbn=1591403243

(content in HTML only apprehensible to User)

Velocity #3: Web2.0 Media

Web2.0: The Semi-structured Web!

https://www.googleapis.com/books/v1/volumes?q=databases



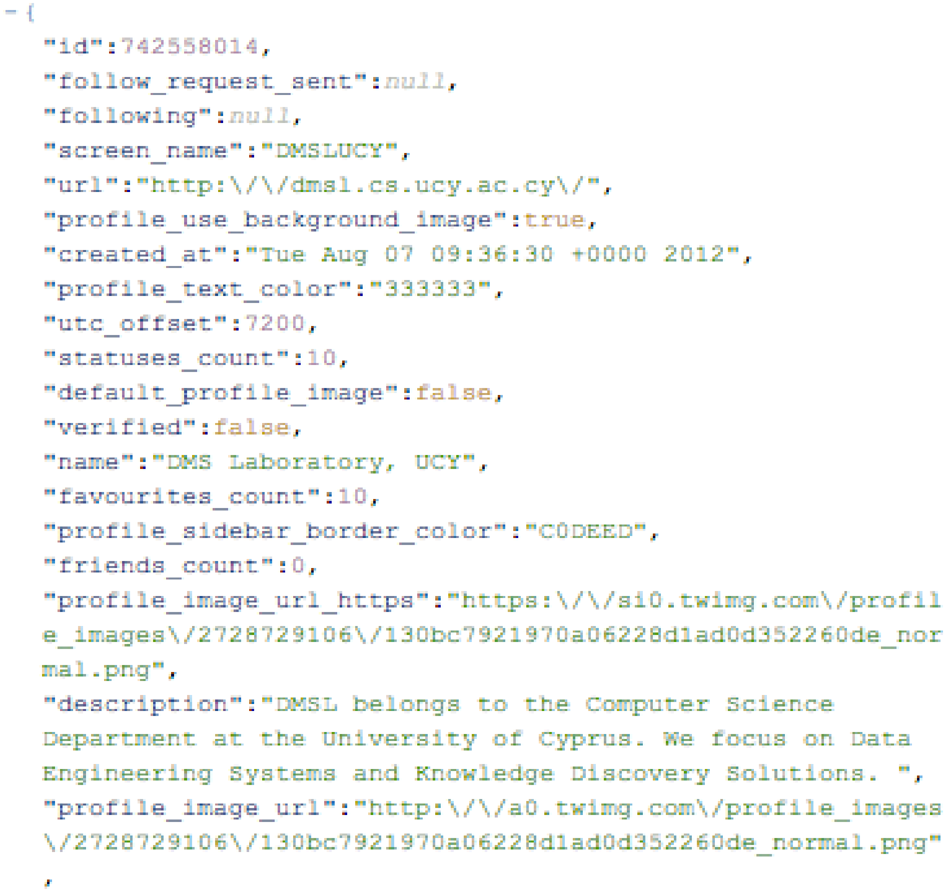
```
{
 "kind": "books#volumes",
 "totalItems": 899,
 "items": [
  {
   "kind": "books#volume",
   "id": "4Z6tfpuBmmgC",
   "etag": "urgGiT9Q1G4",
   "selfLink": "https://www.googleapis.com/books/v1/volumes/4Z6tfpuBmmgC",
   "volumeInfo": {
    "title": "Databases",
    "subtitle": "Organizing Information",
    "authors": [
     "Greg Roza"
    ],
    "publisher": "Rosen Central",
    "publishedDate": "2010-08-15",
    "description": "Describes how databases work and how to use tables, files, and relational databases.",
    "industryIdentifiers": [
     {
      "type": "ISBN_10",
      "identifier": "143589426X"
     },
     {
      "type": "ISBN_13",
      "identifier": "9781435894266"
     }
    ],
    "pageCount": 48,
    "printType": "BOOK",
    "contentVersion": "preview-1.0.0",
    "imageLinks": {
     "smallThumbnail": "http://bks3.books.google.com/books?id=4Z6tfpuBmmgC&printsec=frontcover&img=1&zoom=5&edge=cu
     "thumbnail": "http://bks3.books.google.com/books?id=4Z6tfpuBmmgC&printsec=frontcover&img=1&zoom=1&edge=curl&so
    },
    "language": "en",
    "previewLink": "http://books.google.com/books?id=4Z6tfpuBmmgC&printsec=frontcover&dq=databases&hl=&cd=1&source=
    "infoLink": "http://books.google.com/books?id=4Z6tfpuBmmgC&dq=databases&hl=&source=gbs_api",
```

content in XML/JSON apprehensible to Computer

Velocity #3: Web2.0 Media

Twitter API

https://twitter.com/users/dmslucy.json



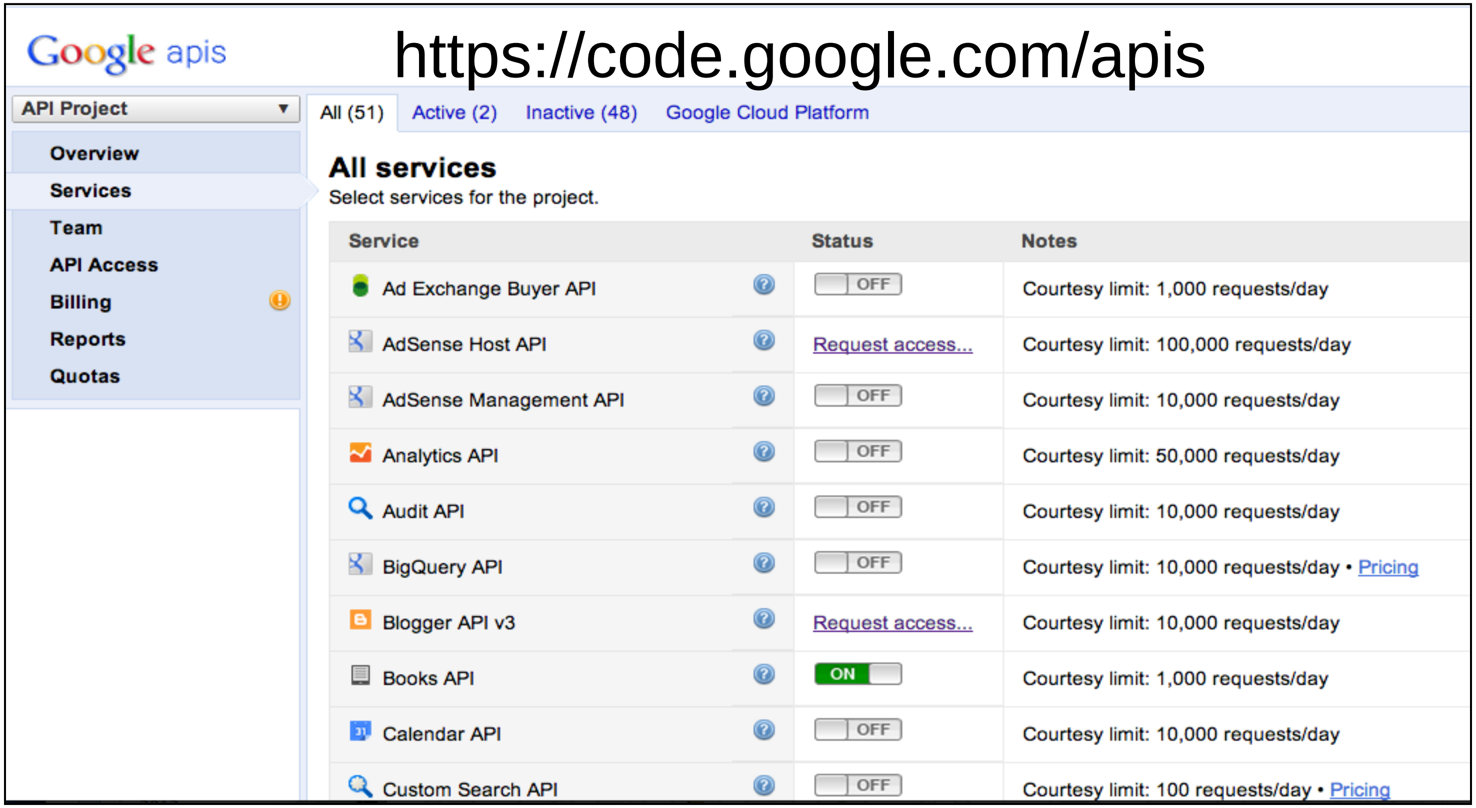
```
- {
    "id":742558014,
    "follow_request_sent":null,
    "following":null,
    "screen_name":"DMSLUCY",
    "url":"http:\/\/dmsl.cs.ucy.ac.cy\/",
    "profile_use_background_image":true,
    "created_at":"Tue Aug 07 09:36:30 +0000 2012",
    "profile_text_color":"333333",
    "utc_offset":7200,
    "statuses_count":10,
    "default_profile_image":false,
    "verified":false,
    "name":"DMS Laboratory, UCY",
    "favourites_count":10,
    "profile_sidebar_border_color":"C0DEED",
    "friends_count":0,
    "profile_image_url_https":"https:\/\/si0.twimg.com\/profil
    e_images\/2728729106\/130bc7921970a06228d1ad0d352260de_nor
    mal.png",
    "description":"DMSL belongs to the Computer Science
    Department at the University of Cyprus. We focus on Data
    Engineering Systems and Knowledge Discovery Solutions. ",
    "profile_image_url":"http:\/\/a0.twimg.com\/profile_images
    \/2728729106\/130bc7921970a06228d1ad0d352260de_normal.png"
    ,
```

Velocity #3: Web2.0 Media

In fact, Web2.0 Services are omnipresent!

(Google, Twitter, Facebook, Youtube, Linkedin, …)

http://www.programmableweb.com/ - 7800 APIs!!! + 6800 Mashups!



https://code.google.com/apis

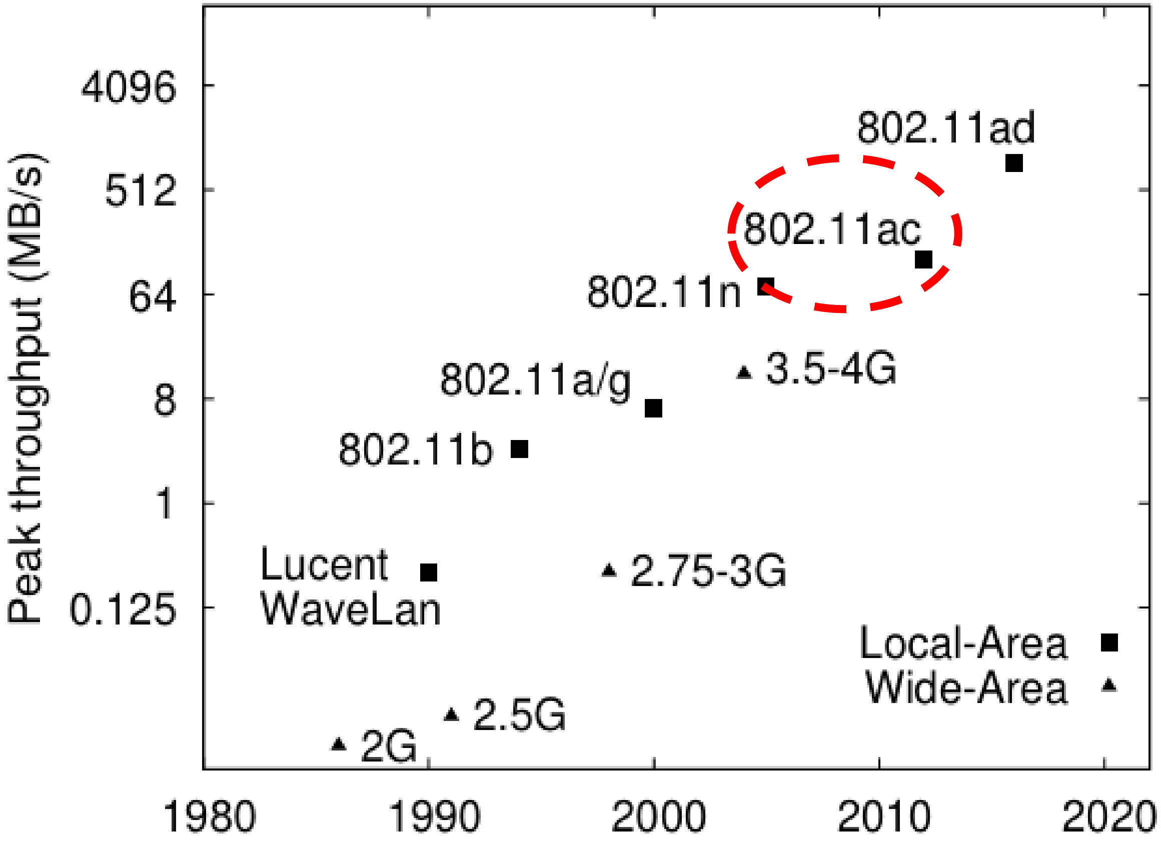
All services

Select services for the project.

Service	Status	Notes
Ad Exchange Buyer API	OFF	Courtesy limit: 1,000 requests/day
AdSense Host API	Request access...	Courtesy limit: 100,000 requests/day
AdSense Management API	OFF	Courtesy limit: 10,000 requests/day
Analytics API	OFF	Courtesy limit: 50,000 requests/day
Audit API	OFF	Courtesy limit: 10,000 requests/day
BigQuery API	OFF	Courtesy limit: 10,000 requests/day • Pricing
Blogger API v3	Request access...	Courtesy limit: 10,000 requests/day
Books API	ON	Courtesy limit: 1,000 requests/day
Calendar API	OFF	Courtesy limit: 10,000 requests/day
Custom Search API	OFF	Courtesy limit: 100 requests/day • Pricing

Velocity #4: Smartphone Services

Wireless Data Transfer Rates



4G ITU peak rates:

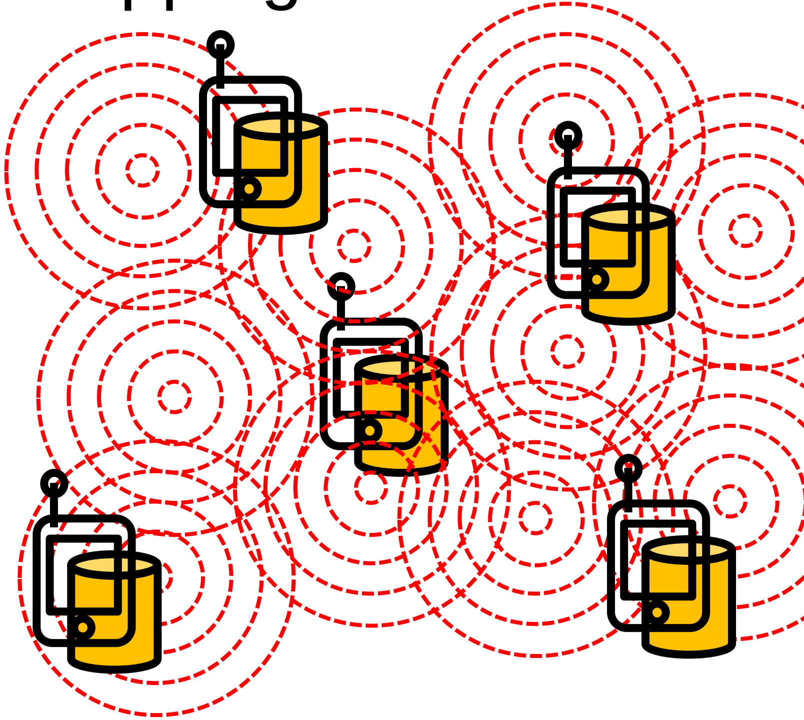
•100 Mbps (high mobility, such as trains and cars)

•1Gbps (low mobility, such as pedestrians and stationary users)

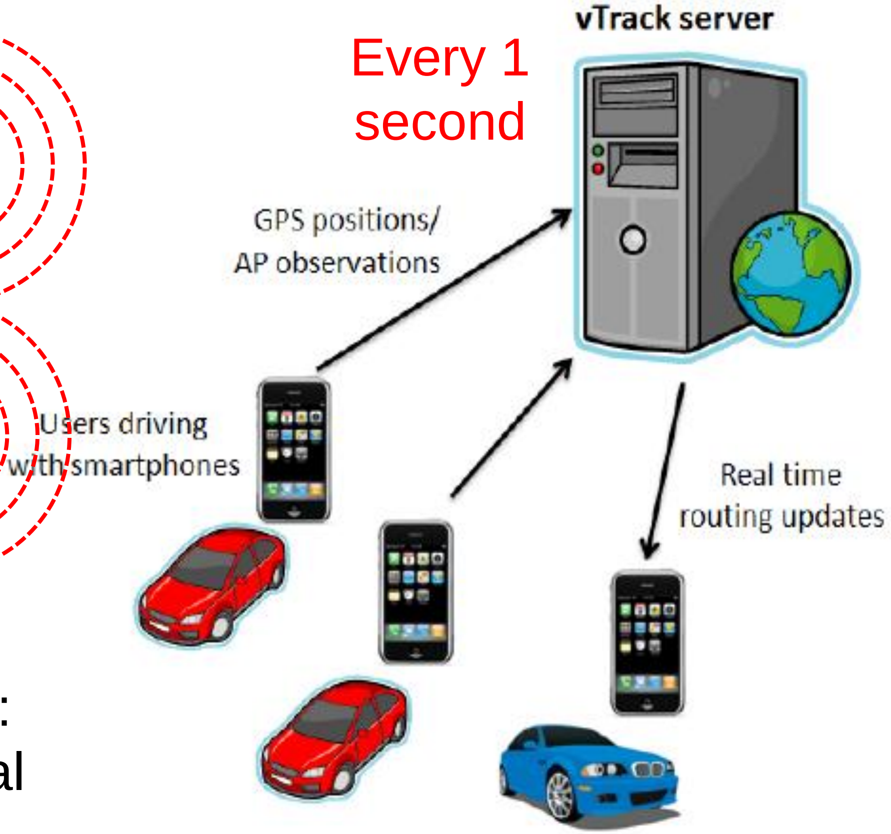
*Plot Courtesy of H. Kim, N. Agrawal, and C. Ungureanu, "Revisiting Storage for Smartphones", The 10th USENIX Conference on File and Storage Technologies (FAST'12), San Jose, CA, February 2012. *** Best Paper Award ****

Velocity #4: Smartphone Services

Mapping the Road traffic by collecting WiFi signals.



Every 1 second



Received Signal Strength (RSS):
power present in WiFi radio signal

Graphics courtesy of: A .Thiagarajan et. al. “Vtrack: Accurate, Energy-Aware Road Traffic Delay Estimation using Mobile Phones, In Sensys’09, pages 85-98. ACM, (Best Paper) MIT’s CarTel Group

Velocity #4: Smartphone Services

Request Format (request.json)

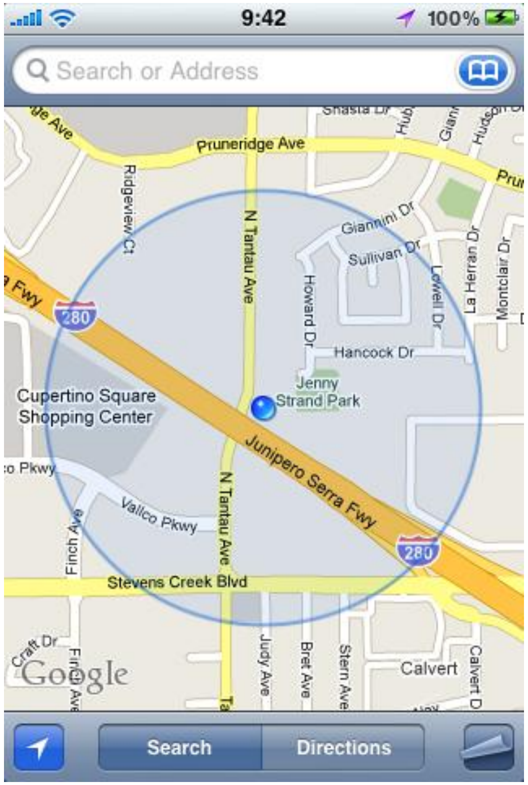
```
{
 "homeMobileCountryCode": 310,
 "homeMobileNetworkCode": 260,
 "radioType": "gsm",
 "carrier": "T-Mobile",
 "cellTowers": [
  {
   "cellId": 39627456,
   "locationAreaCode": 40495,
   "mobileCountryCode": 310,
   "mobileNetworkCode": 260,
   "age": 0,
   "signalStrength": -95
  }
 ],

}
```

```
"wifiAccessPoints": [
 {
  "macAddress": "01:23:45:67:89:AB",
  "signalStrength": 8,
  "age": 0,
  "signalToNoiseRatio": -65,
  "channel": 8
 },
 {
  "macAddress": "01:23:45:67:89:AC",
  "signalStrength": 4,
  "age": 0
 }
]
```

Response Format

The response format is also JSON.

```
{
  "location": {
  "latitude": 51.0,
  "longitude": -0.1,
  },
  "accuracy": 1200.4,
}
```



Will be discussing some furtherin-house applications in a while

Volume #1: Text<Multimedia<Sciences

- **From the TB-era to the PB-era.**

Human Generated

- The U.S. Library of Congress (April 2011): **235 TB**
- Anchestry.com: Genealogical data **600 TB**

Multimedia/ Streaming

- **Games:** World of Warcraft uses **1.3 PB** of storage to maintain its game.
- **Internet Video:** will account for 61% of total Internet Data by 2015 (**966 Exabytes** or nearly 1 **Zettabyte!)**

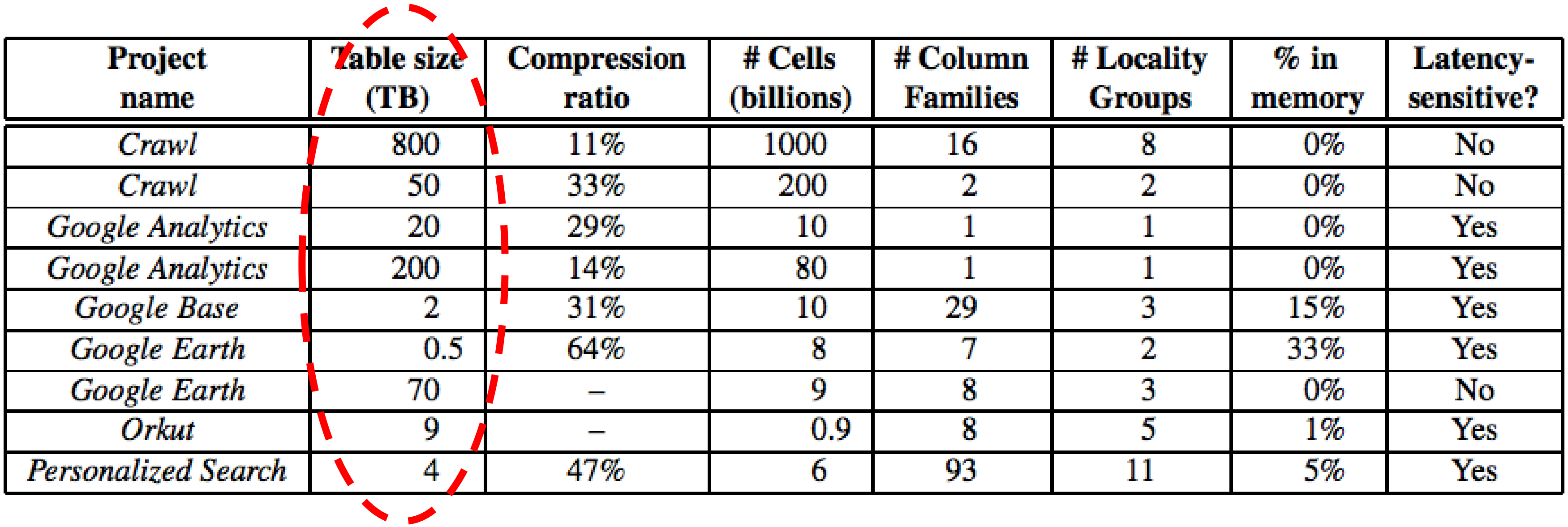
Sciences/ Sensors

- **Climate science:** The German Climate Computing Centre (DKRZ) has a storage capacity of **60 PB** of climate data.
- **Physics:** The experiments in the Large Hadron Collider produce about **15 PB** of data per year, which is distributed over the LHC Computing Grid (Our department is part of the EGEE – Enabling Grids for E-sciencE, now EGI - European Grid Infrastructure).

Source: Petabyte, from Wikipedia: http://en.wikipedia.org/wiki/Petabyte

Volume #2: Web Data

Google Volume (in 2006)
IDC: The total amount of global data is expected to grow to 2.7 zettabytes during 2012. This is 48% up from 2011. http://en.wikipedia.org/wiki/Zettabyte

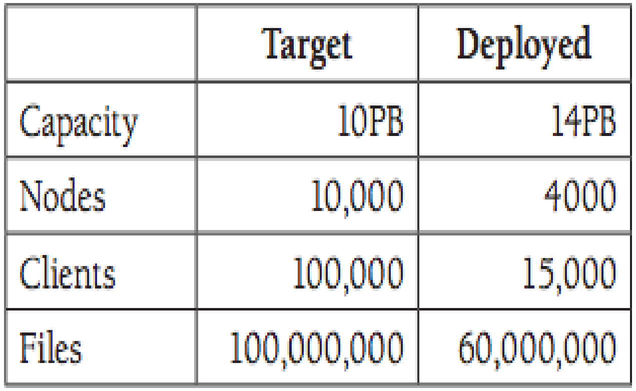


Project name	Table size (TB)	Compression ratio	# Cells (billions)	# Column Families	# Locality Groups	% in memory	Latency-sensitive?
Crawl	800	11%	1000	16	8	0%	No
Crawl	50	33%	200	2	2	0%	No
Google Analytics	20	29%	10	1	1	0%	Yes
Google Analytics	200	14%	80	1	1	0%	Yes
Google Base	2	31%	10	29	3	15%	Yes
Google Earth	0.5	64%	8	7	2	33%	Yes
Google Earth	70	–	9	8	3	0%	No
Orkut	9	–	0.9	8	5	1%	Yes
Personalized Search	4	47%	6	93	11	5%	Yes

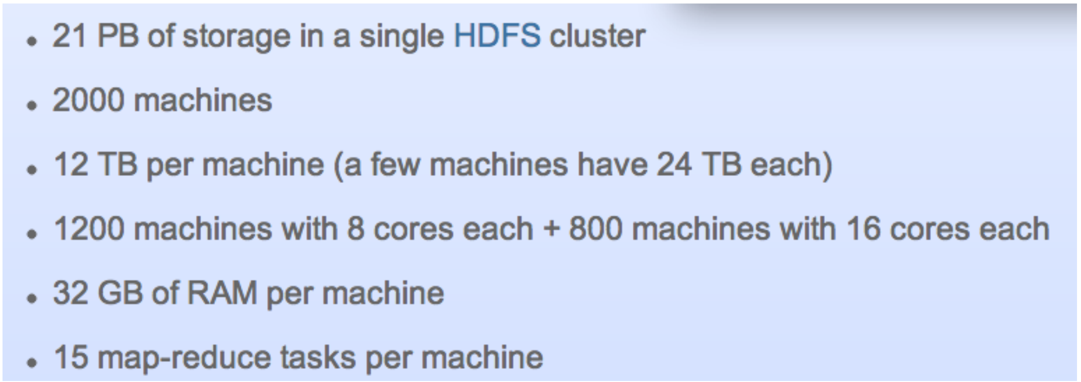
Bigtable: A Distributed Storage System for Structured Data,
OSDI'06: Seventh Symposium on Operating System Design and Implementation, Seattle, WA, November, 2006.

Volume #3: Big Data File Systems

- ***Big Data Filesystems: How Big?***
- Results from 2010:



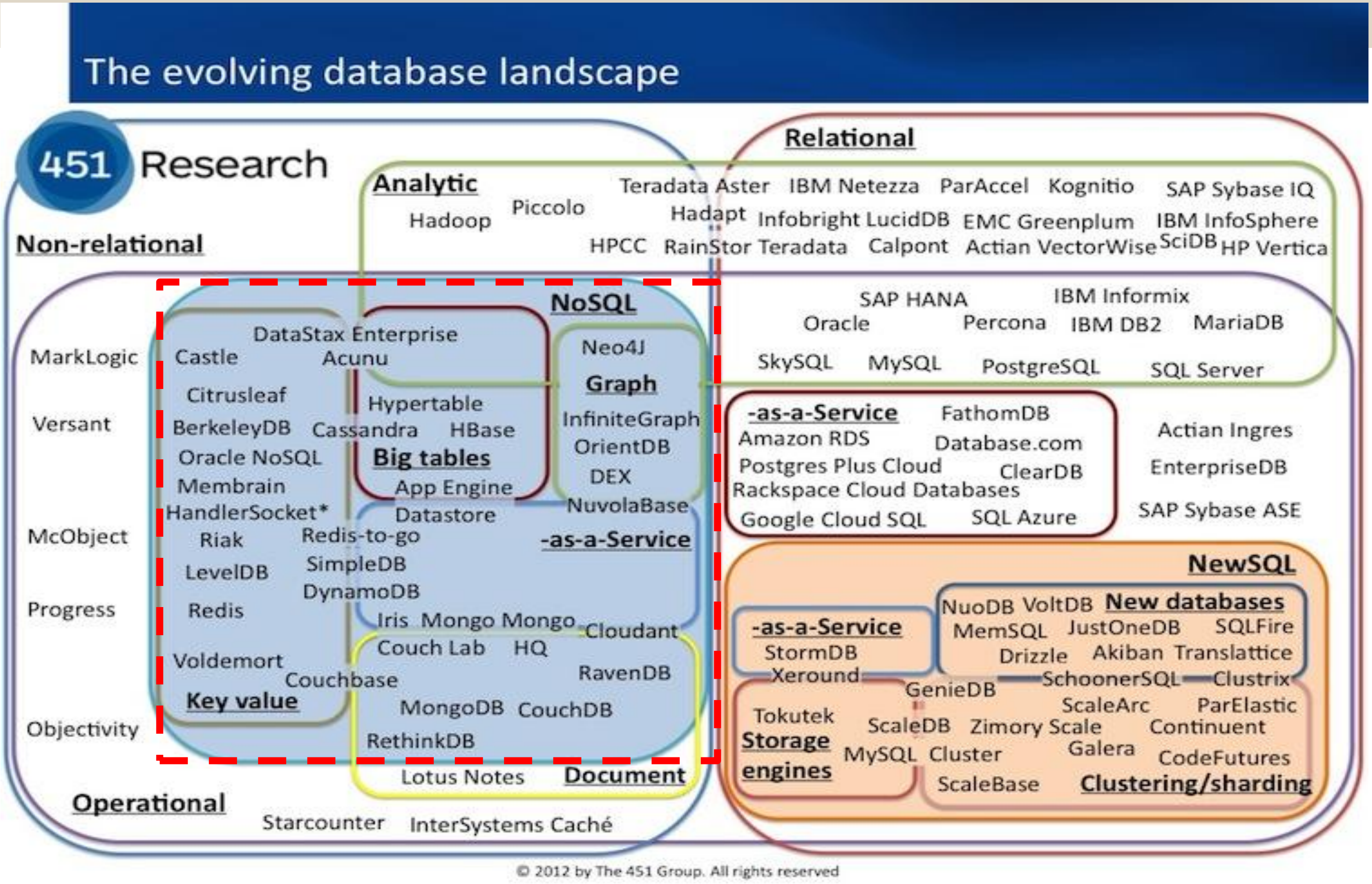
	Target	Deployed
Capacity	10PB	14PB
Nodes	10,000	4000
Clients	100,000	15,000
Files	100,000,000	60,000,000



- 21 PB of storage in a single HDFS cluster
- 2000 machines
- 12 TB per machine (a few machines have 24 TB each)
- 1200 machines with 8 cores each + 800 machines with 16 cores each
- 32 GB of RAM per machine
- 15 map-reduce tasks per machine

HDFS scalability: the limits to growth
http://static.usenix.org/publications/login/2010-04/openpdfs/shvachko.pdf

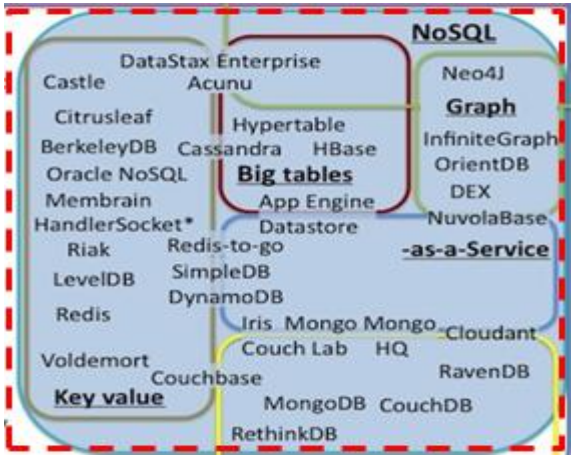
Variety Overview



451 Research, Matthew Aslett, http://goo.gl/GYcEx

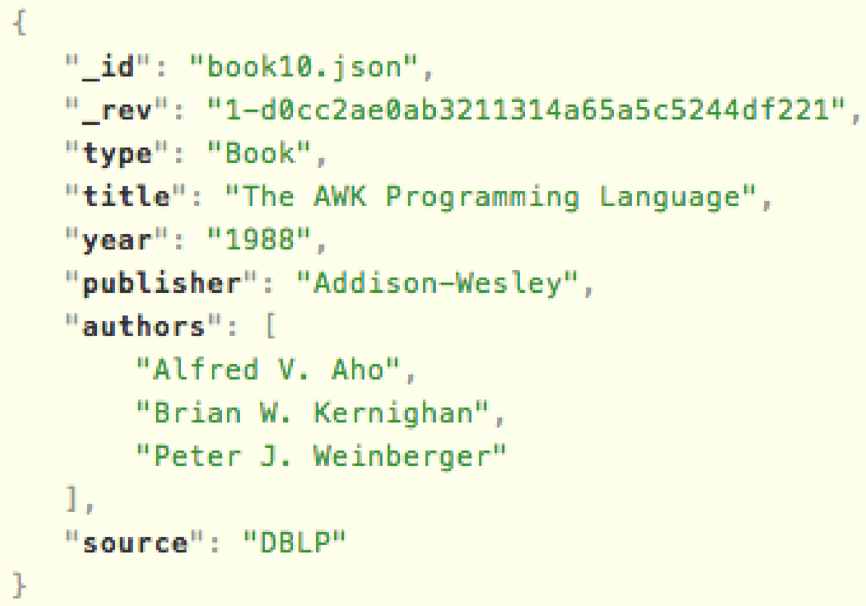
Variety #1: NoSQL

- ***NoSQL ("not only SQL")*** *is a broad class of database management systems identified by n**on-adherence** to the widely used **relational database management system model.***
- **NoSQL** databases are **NOT built** primarily on **tables**, and generally **DO NOT** use SQL for data.
- NoSQL => Not Relational!
  - Key Value (e.g., BerkeleyDB – emb, Oracle NoSQL - Distributed)
  - Document Stores (e.g., JSON stores)
  - BigTables (i.e., Column-stores)
  - Graph Databases (e.g., FlockDB)
  - … potentially much longer list but I will only focus on a few trends



Variety #1: NoSQL / Document Stores

Document in CouchDB

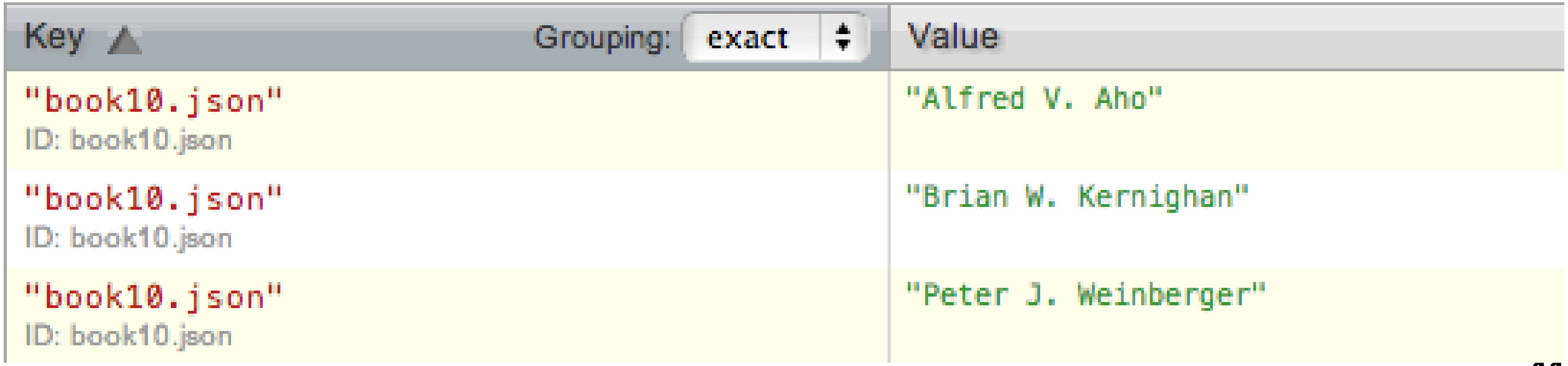


```
{
   "_id": "book10.json",
   "_rev": "1-d0cc2ae0ab3211314a65a5c5244df221",
   "type": "Book",
   "title": "The AWK Programming Language",
   "year": "1988",
   "publisher": "Addison-Wesley",
   "authors": [
       "Alfred V. Aho",
       "Brian W. Kernighan",
       "Peter J. Weinberger"
   ],
   "source": "DBLP"
}
```

Map Function

```
function(doc) {
    for (i in doc.authors) {
      author = doc.authors[i];
      emit(doc._id, author);
    }
}
```

Results (through REST/HTTP or Futon)

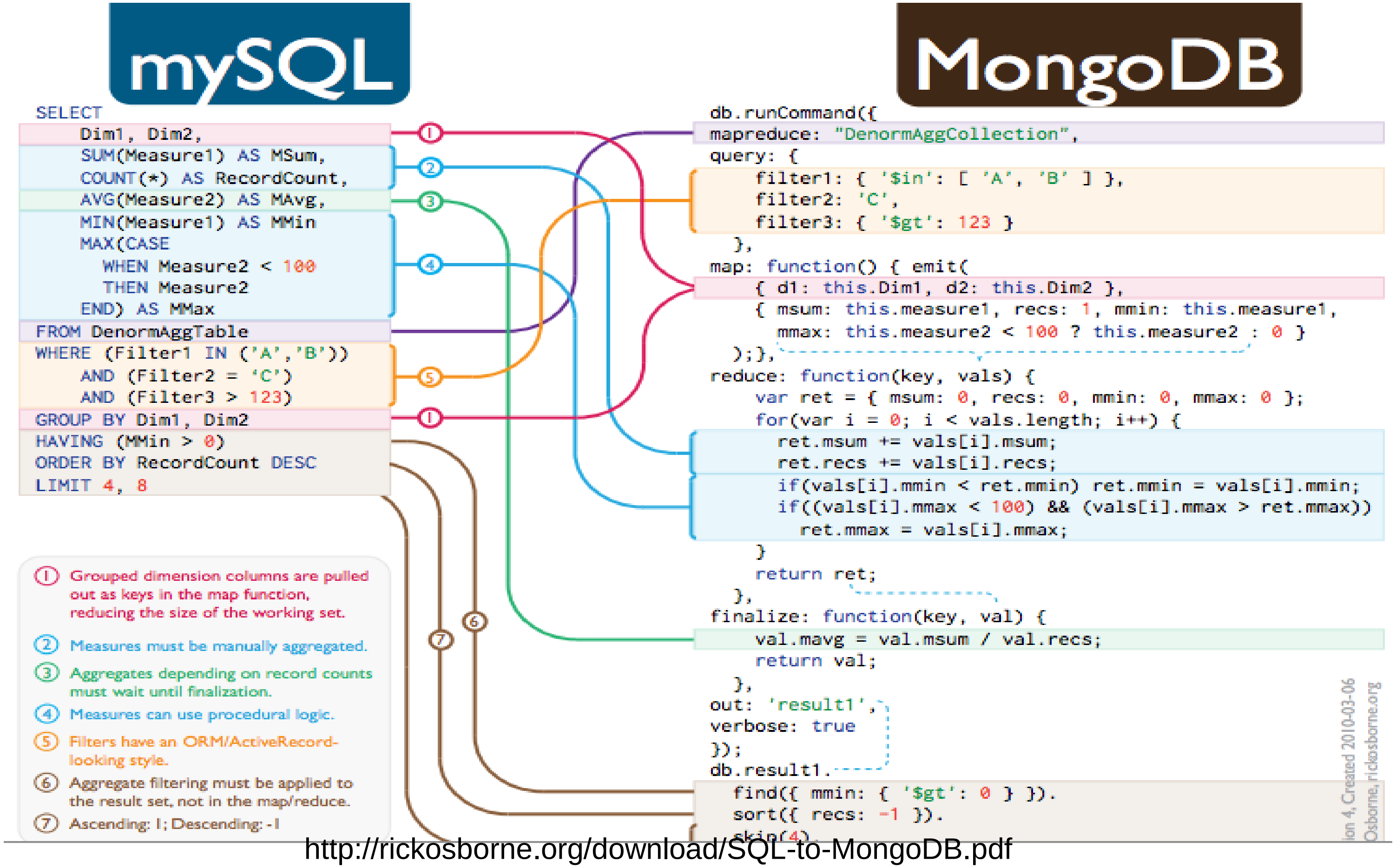


Grouping: exact

Key ▲	Value
"book10.json" ID: book10.json	"Alfred V. Aho"
"book10.json" ID: book10.json	"Brian W. Kernighan"
"book10.json" ID: book10.json	"Peter J. Weinberger"

Variety #1: NoSQL / Document Stores

For a real app we could envision much more complex queries.



```
SELECT
    Dim1, Dim2,
    SUM(Measure1) AS MSum,
    COUNT(*) AS RecordCount,
    AVG(Measure2) AS MAvg,
    MIN(Measure1) AS MMin
    MAX(CASE
      WHEN Measure2 < 100
      THEN Measure2
    END) AS MMax
FROM DenormAggTable
WHERE (Filter1 IN ('A','B'))
    AND (Filter2 = 'C')
    AND (Filter3 > 123)
GROUP BY Dim1, Dim2
HAVING (MMin > 0)
ORDER BY RecordCount DESC
LIMIT 4, 8
```

```
db.runCommand({
mapreduce: "DenormAggCollection",
query: {
    filter1: { '$in': [ 'A', 'B' ] },
    filter2: 'C',
    filter3: { '$gt': 123 }
  },
map: function() { emit(
    { d1: this.Dim1, d2: this.Dim2 },
    { msum: this.measure1, recs: 1, mmin: this.measure1,
      mmax: this.measure2 < 100 ? this.measure2 : 0 }
  );},
reduce: function(key, vals) {
    var ret = { msum: 0, recs: 0, mmin: 0, mmax: 0 };
    for(var i = 0; i < vals.length; i++) {
      ret.msum += vals[i].msum;
      ret.recs += vals[i].recs;
      if(vals[i].mmin < ret.mmin) ret.mmin = vals[i].mmin;
      if((vals[i].mmax < 100) && (vals[i].mmax > ret.mmax))
        ret.mmax = vals[i].mmax;
    }
    return ret;
  },
finalize: function(key, val) {
    val.mavg = val.msum / val.recs;
    return val;
  },
out: 'result1',
verbose: true
});
db.result1.
  find({ mmin: { '$gt': 0 } }).
  sort({ recs: -1 }).
  skip(4).
```

1. Grouped dimension columns are pulled out as keys in the map function, reducing the size of the working set.
2. Measures must be manually aggregated.
3. Aggregates depending on record counts must wait until finalization.
4. Measures can use procedural logic.
5. Filters have an ORM/ActiveRecord-looking style.
6. Aggregate filtering must be applied to the result set, not in the map/reduce.
7. Ascending: 1; Descending: -1

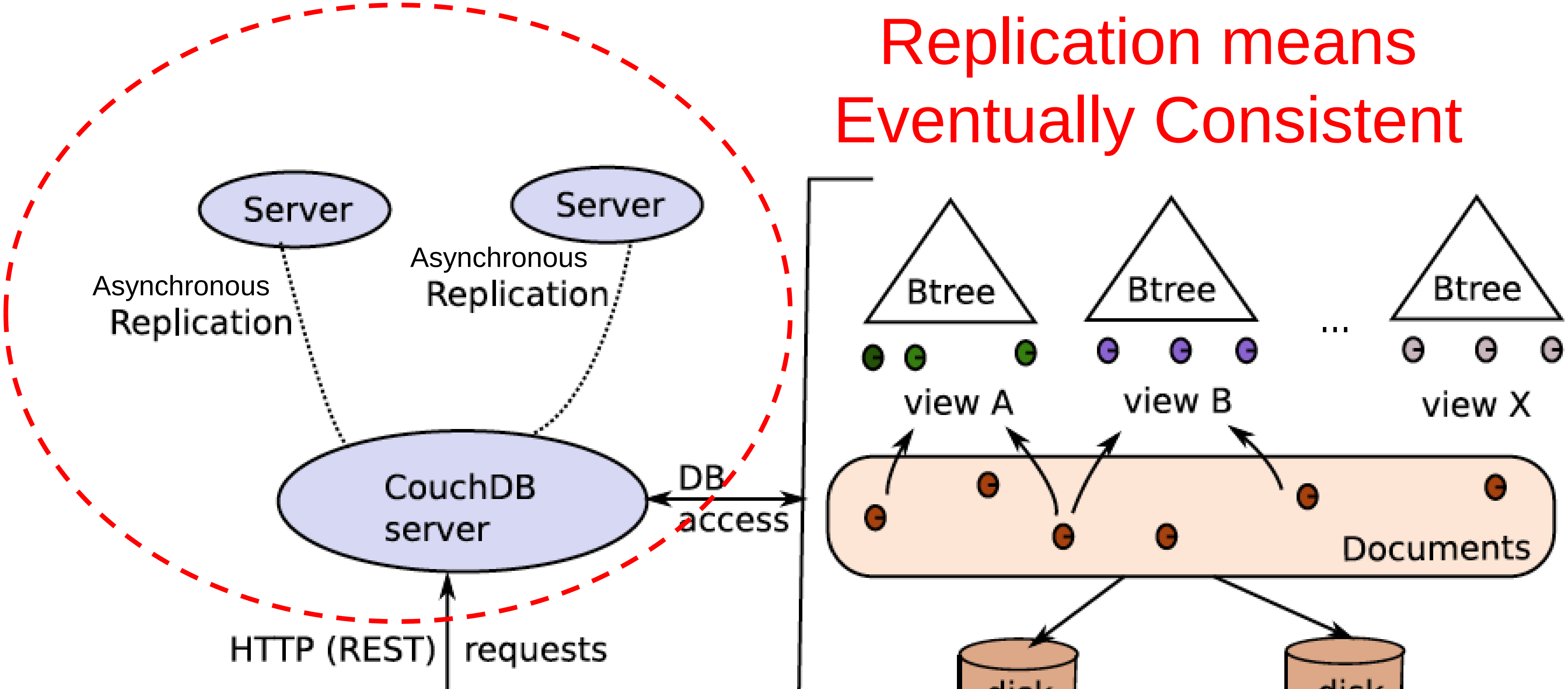
ion 4, Created 2010-03-06
Osborne, rickosborne.org

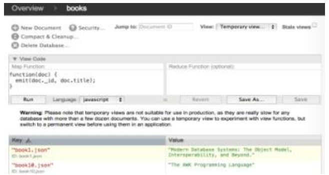
http://rickosborne.org/download/SQL-to-MongoDB.pdf

Variety #1: NoSQL / Replication

Architecture of CouchDB

Asynchronous Replication means Eventually Consistent



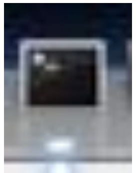


```
function(doc) {
  emit(doc._id, doc.title);
}
```

Warning: Please note that temporary views are not suitable for use in production, as they are really slow for any database with more than a few dozen documents. You can use a temporary view to experiment with view functions, but switch to a permanent view before using them in an application.

Key	Value
"book1.json" ID: book1.json	"Modern Database Systems: The Object Model, Interoperability, and Beyond."
"book10.json" ID: book10.json	"The AWK Programming Language"

Client application



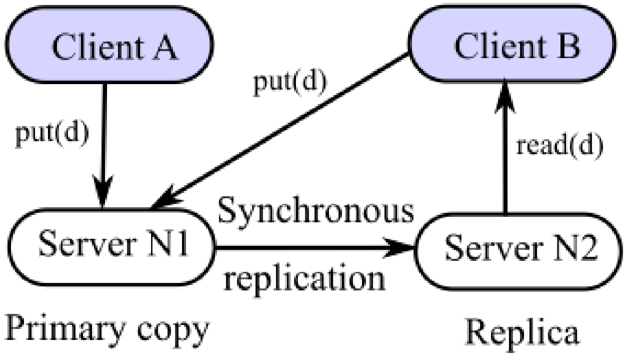
Variety #1: NoSQL / Consistency ☹

SQL RDBMSs

(Most) NoSQL DBMSs

Some illustrative scenarios

Strongly consistent!



a) Eager replication with primary copy

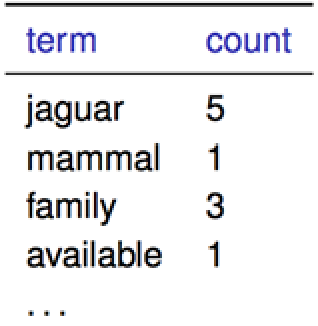
ntually
tent!

Variety #2: NoSQL / Map Reduce Analytics

- ***Map-Reduce:*** *a* ***programming model for processing*** *large data sets (Not online like Warehouses ☹).*
  - *Invented by Google! "MapReduce: Simplified Data Processing on Large Clusters, Jeffrey Dean and Sanjay Ghemawat, OSDI'04: Sixth Symposium on Operating System Design and Implementation,San Francisco, CA, December, 2004."*
  - *Can be implemented in any language (Java, example nex)*
- ***Hadoop:*** *Apache's open-source* ***software framework*** *that supports* ***data-intensive distributed applications***
  - *Derived from Google's MapReduce + Google File System (GFS) papers.*
  - *Enables applications to work with thousands of computation-independent computers and petabytes of data.*
  - Download: http://hadoop.apache.org/

Variety #2: NoSQL / Map Reduce Analytics

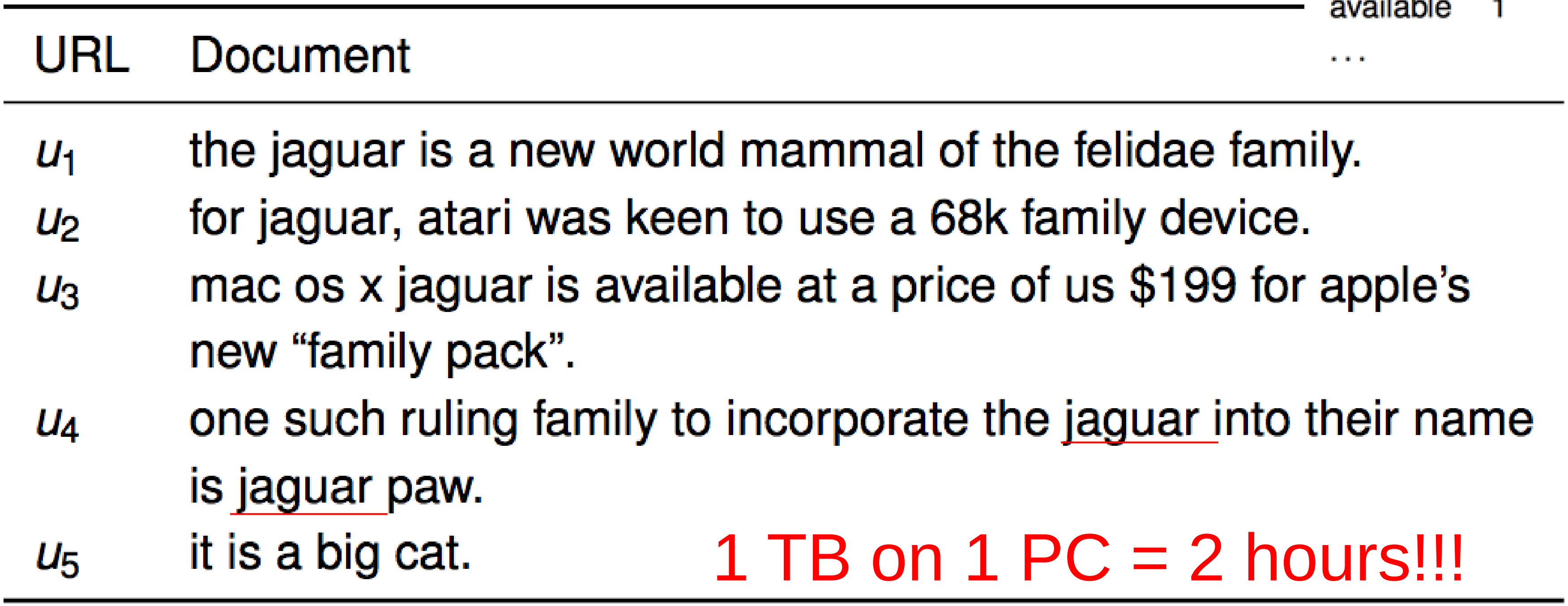
Example: term count in MapReduce (input)



term	count
jaguar	5
mammal	1
family	3
available	1
. . .	

Count the distinct words in all documents

cat *.txt | sort | uniq -c



URL	Document
u_1	the jaguar is a new world mammal of the felidae family.
u_2	for jaguar, atari was keen to use a 68k family device.
u_3	mac os x jaguar is available at a price of us $199 for apple's new "family pack".
u_4	one such ruling family to incorporate the jaguar into their name is jaguar paw.
u_5	it is a big cat.

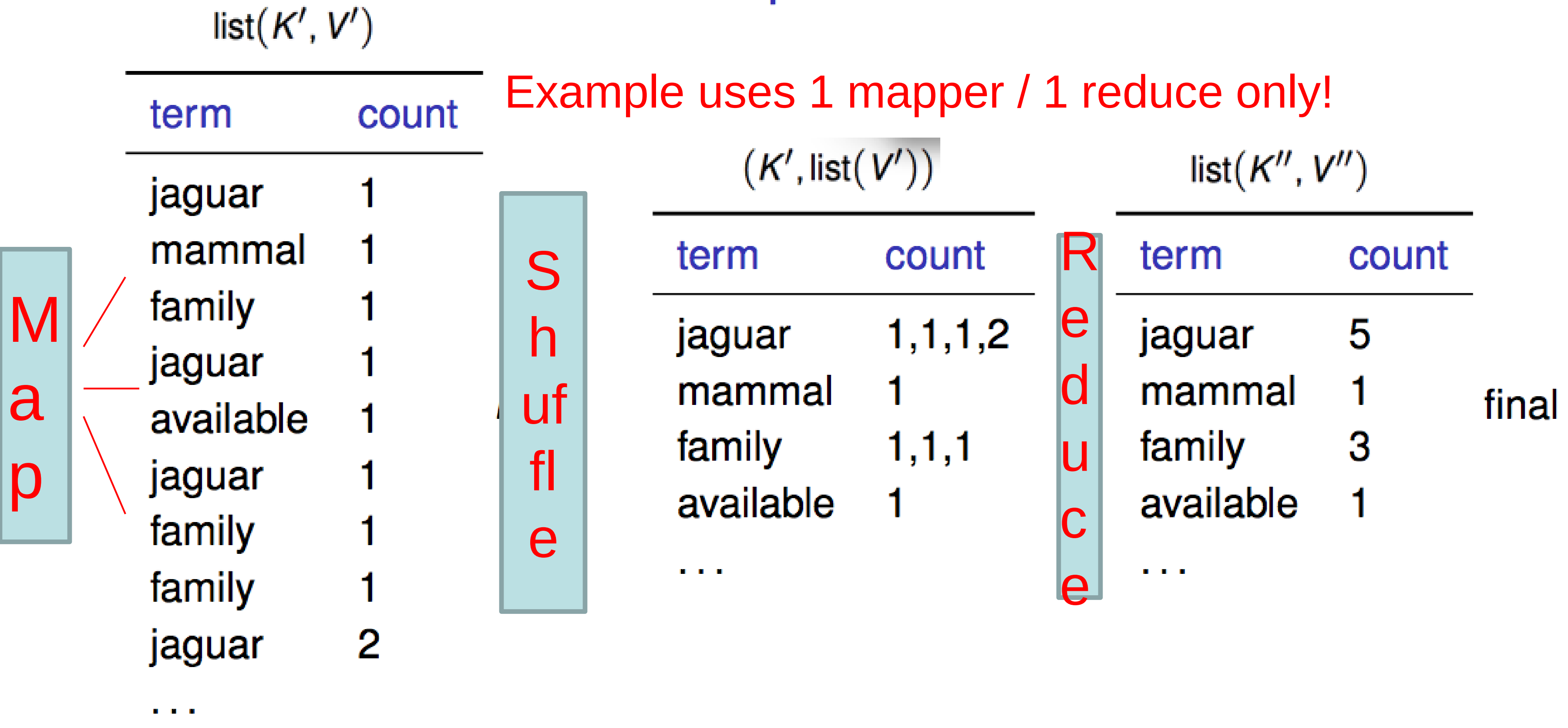
1 TB on 1 PC = 2 hours!!!

1TB on 100 PCs = 1min!!!

Variety #2: NoSQL / Map Reduce Analytics

Example: term count in MapReduce

Example uses 1 mapper / 1 reduce only!



list(K', V')

term	count
jaguar	1
mammal	1
family	1
jaguar	1
available	1
jaguar	1
family	1
family	1
jaguar	2
. . .	

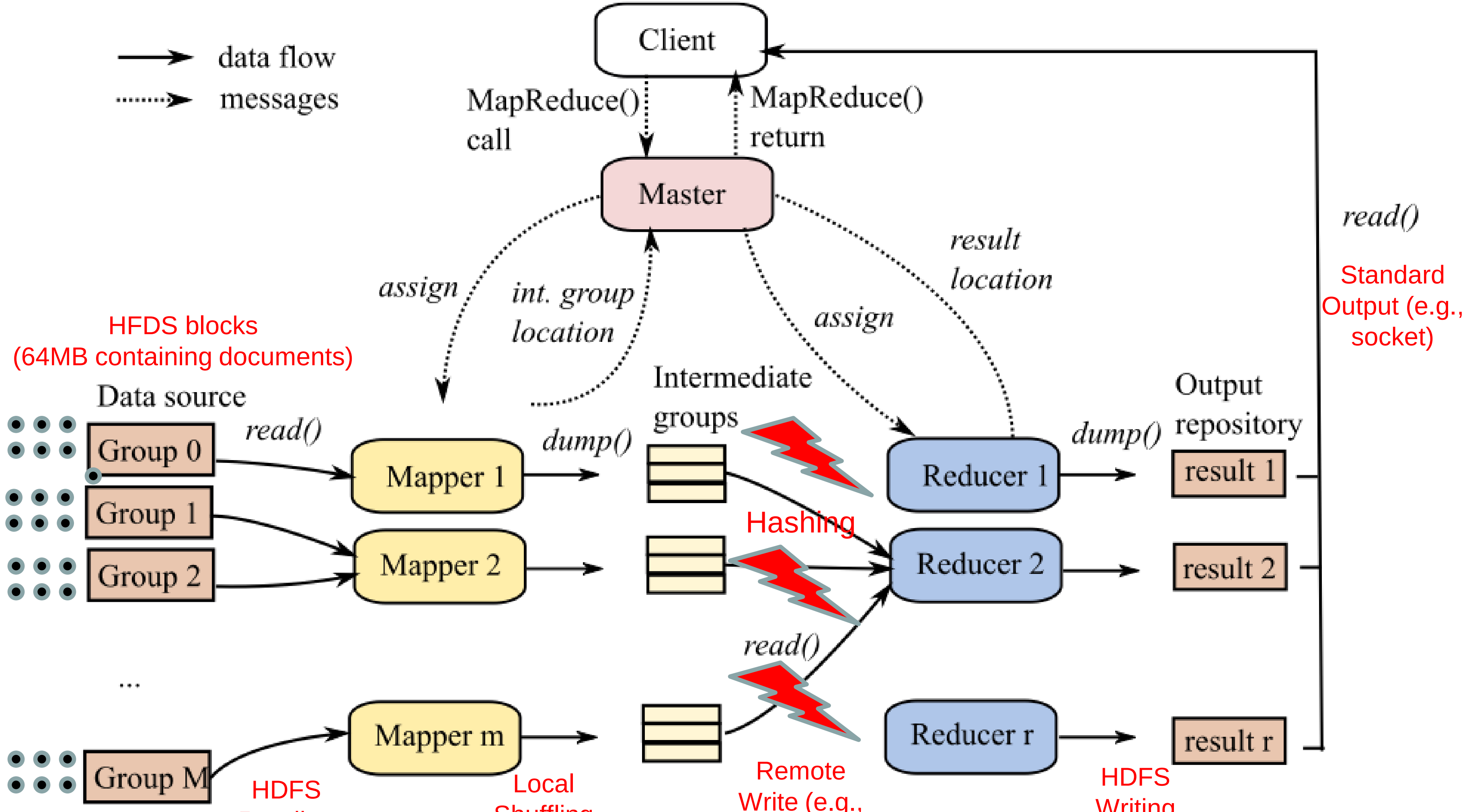
$(K', \text{list}(V'))$

term	count
jaguar	1,1,1,2
mammal	1
family	1,1,1
available	1
. . .	

list(K'', V'')

term	count
jaguar	5
mammal	1
family	3
available	1
. . .	

Variety #2: NoSQL / Map Reduce Analytics



Variety #3: NoSQL / Column Stores

- A **column-oriented DBMS** is a database management system (DBMS) that **stores data tables** as sections of **columns rather than as rows**, like most relational DBMSs

Row-Store OLTP-workloads!

1,Smith,Joe,40000;
2,Jones,Mary,50000;
3,Johnson,Cathy,44000;

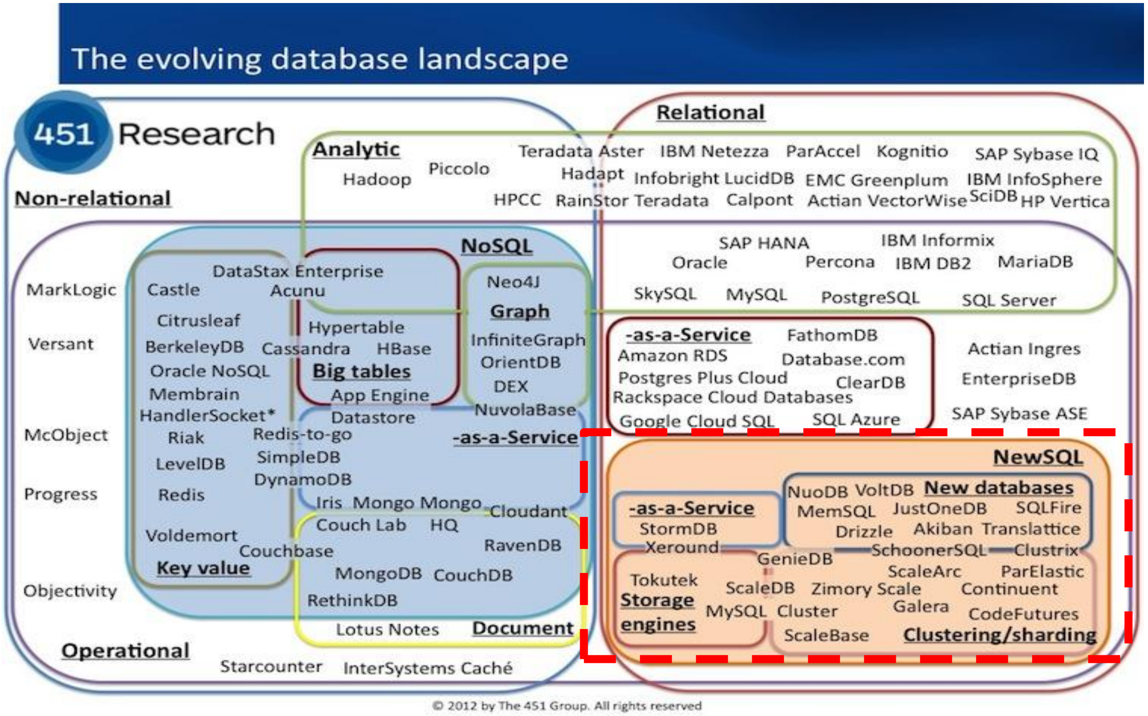
Column-Store OLAP-workloads!

1,2,3;
Smith,Jones,Johnson;
Joe,Mary,Cathy;
40000,50000,44000;

- Suggested for data warehouses, customer relationship management (CRM) systems and other ad-hoc inquiry systems **where aggregates or scans are carried out over large numbers** of **similar data items**

Variety #4: NewSQL

- ***"NewSQL"** is a class of modern relational database management systems that seek to provide the **same scalable performance** of **NoSQL** systems for **OLTP** workloads while still maintaining the **ACID guarantees (i.e., offering transactions)** of a traditional DBMS.*



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NewSQL= NoSQL+Transactions

Variety #4: NewSQL

Google's Trajectory

- **(2003) Google GFS Paper (SOSP'03)**
  - **Objective:** Create a Google-scale Filesystem
  - Apache HDFS is GFS open-source implementation.
- **(2004) Google's Map-Reduce Paper (OSDI'04)**
  - **Objective:** Enable big-data analytics over non-tabular data (e.g., XML or text) … with the assistance of GFS.
  - Apache's MapReduce: An open source implementation of the paper
- **(2006) Google BigTable Paper (OSDI'06)**
  - **Objective:** Enable big-data analytics over tabular data (i.e., tables)
  - (2008) Apache's Hbase: An open-source implementation of the paper
  - (2010): Facebook Messaging moves from Cassandra to HBase
- (2012) Google's F1 RDBMS (SIGMOD'12) & Spanner Storage Papers **(OSDI'12)**

HYPERTABLE INC APACHE HBASE Cassandra