



EPL646 – Advanced Topics in Databases

Lecture 12

Big Data Management II (NoSQL Databases / CouchDB)

**Chapter 20: Abiteboul et. Al.
+ <http://guide.couchdb.org/>**

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<http://www.cs.ucy.ac.cy/~dzeina/courses/epl646>

Big Data



- *"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: Velocity-Volume-Variety



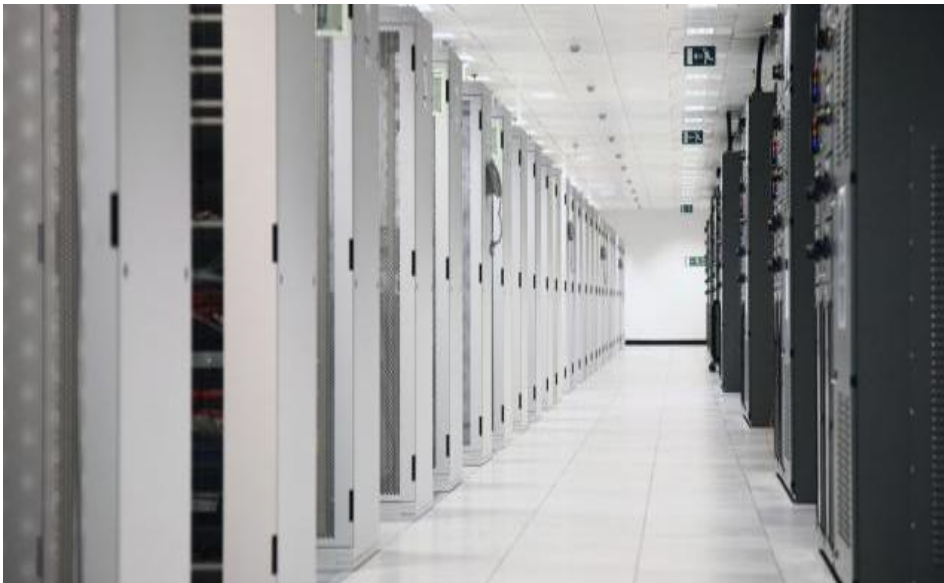
- **Velocity**
 - ***how fast data is being produced and how fast the data must be processed to meet demand.***
 - *How to deal with torrents of data, in near-real time, streaming from **RFID tags** and **smart metering systems**?*
 - *How to **identify fraud** in 5 million trade events created **each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

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!)

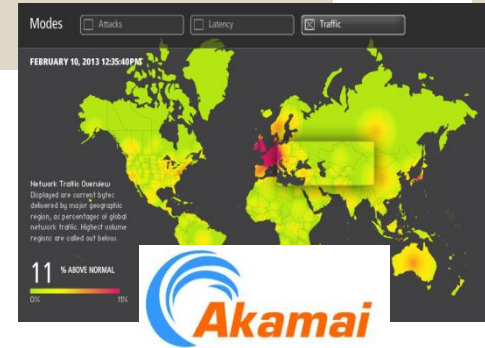
Source: Smart Metering Entity: <http://www.smi-ieso.ca/mdmr>

Velocity #2: Network Monitoring



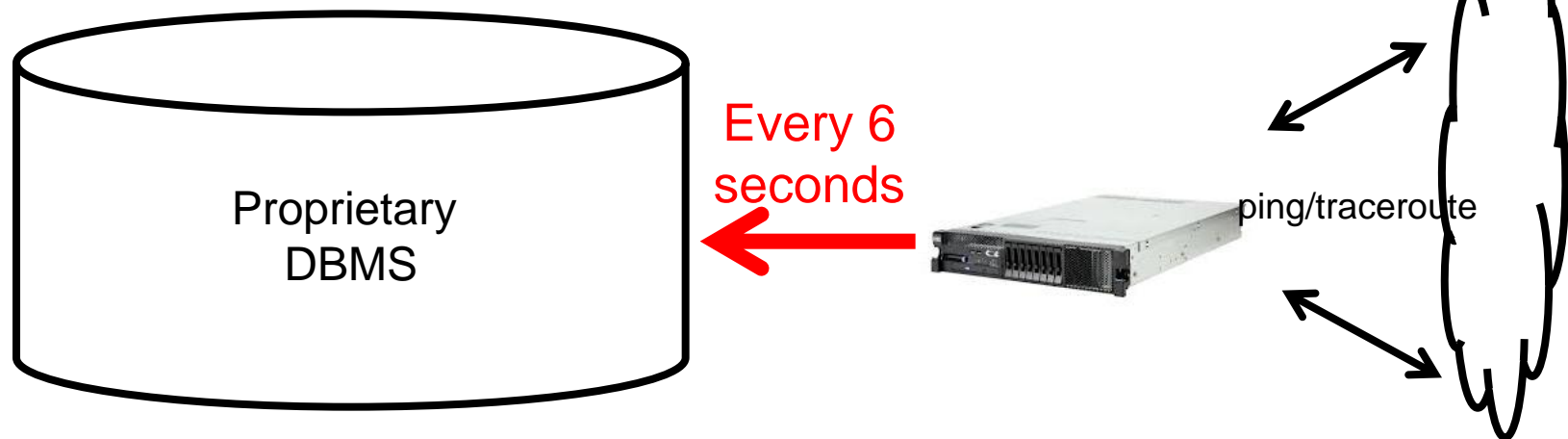
- **Akamai:**

- 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**

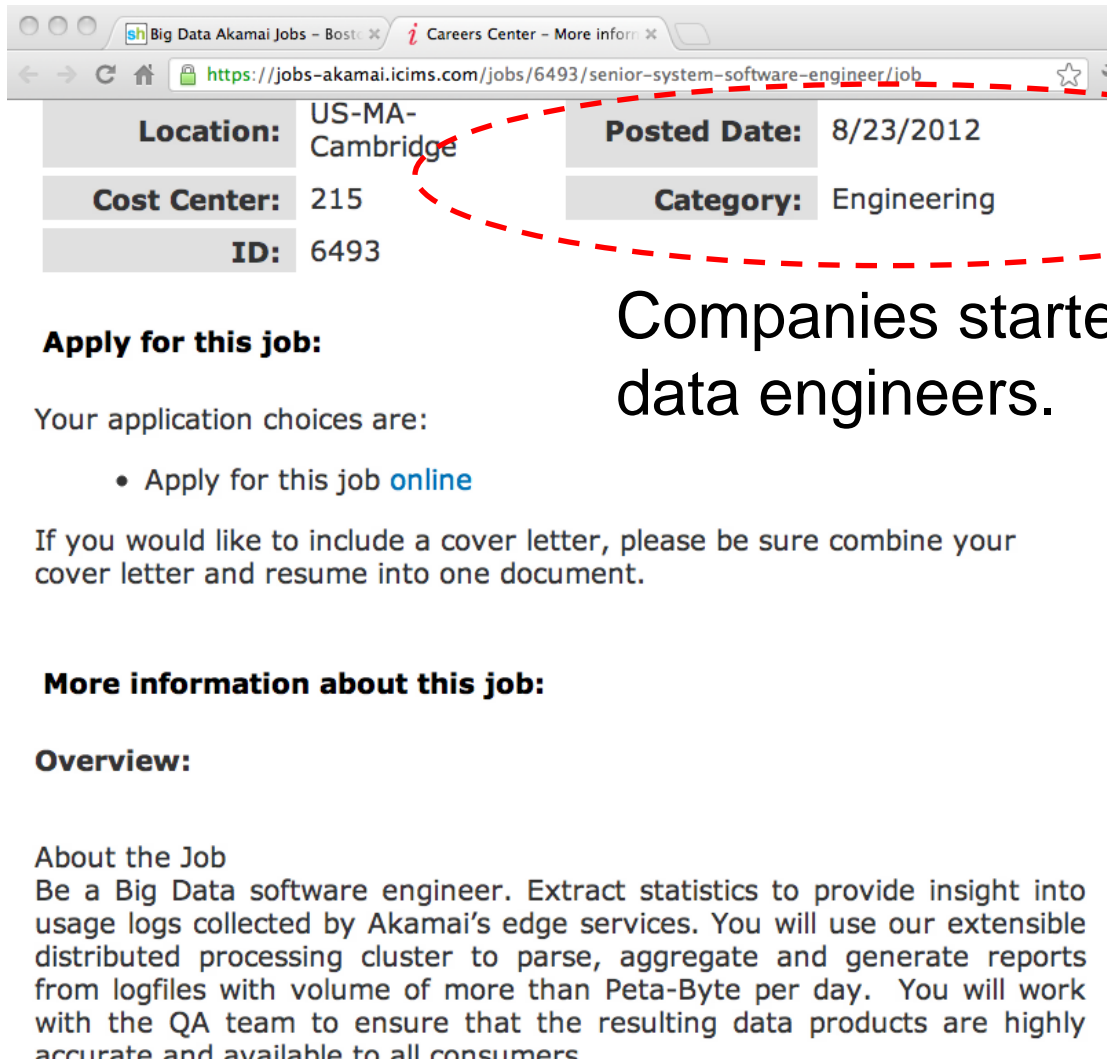


- **How?**

- 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



The screenshot shows a web browser window with two tabs: 'Big Data Akamai Jobs - Boston' and 'Careers Center - More information'. The address bar shows the URL 'https://jobs-akamai.icims.com/jobs/6493/senior-system-software-engineer/job'. The job details are displayed in a table-like format:

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

A red dashed oval highlights the 'Location', 'Posted Date', 'Cost Center', and 'Category' fields. Below the table, the text 'Apply for this job:' is followed by 'Your application choices are:' and a bullet point 'Apply for this job [online](#)'. Below this, a paragraph states: 'If you would like to include a cover letter, please be sure combine your cover letter and resume into one document.' Further down, the section 'More information about this job:' is followed by 'Overview:' and 'About the Job'. The 'About the Job' section describes the role of a Big Data software engineer, mentioning the extraction of statistics from usage logs, the use of a distributed processing cluster, and the generation of reports from logfiles with a volume of more than Peta-Byte per day.

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.

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.



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

Human
Generated

- The U.S. Library of Congress (April 2011): **235 TB**
- Ancestry.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>

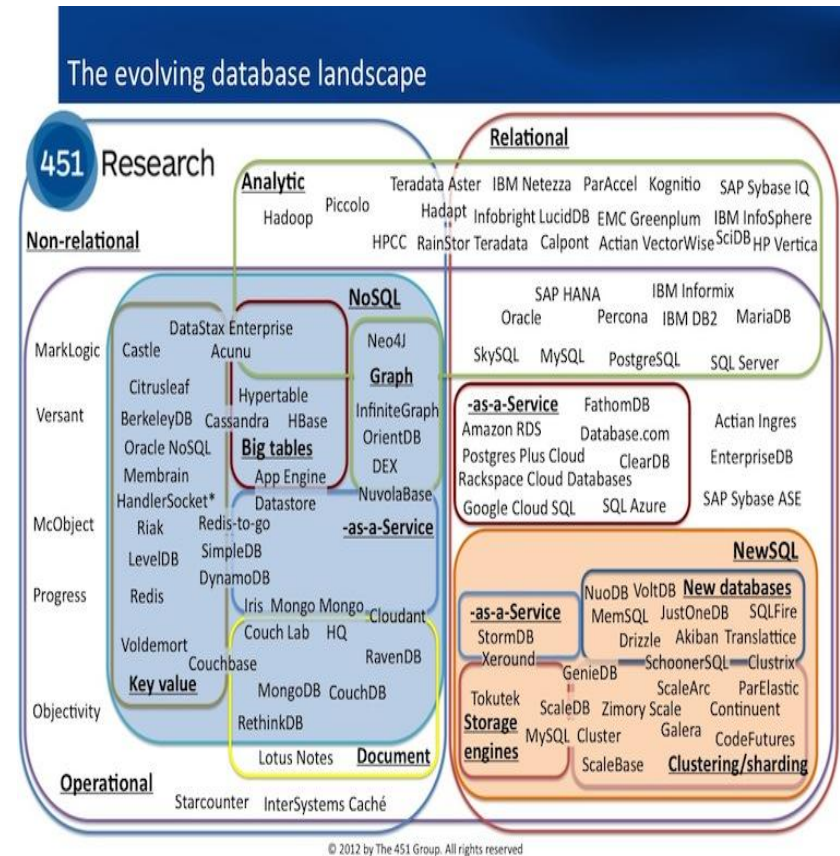
Project name	Table size (TB)	Compression ratio	# Cells (billions)	# Column Families	# Locality Groups	% in memory	Latency-sensitive?
<i>Crawl</i>	800	11%	1000	16	8	0%	No
<i>Crawl</i>	50	33%	200	2	2	0%	No
<i>Google Analytics</i>	20	29%	10	1	1	0%	Yes
<i>Google Analytics</i>	200	14%	80	1	1	0%	Yes
<i>Google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

Big Data: Velocity-Volume-Variety



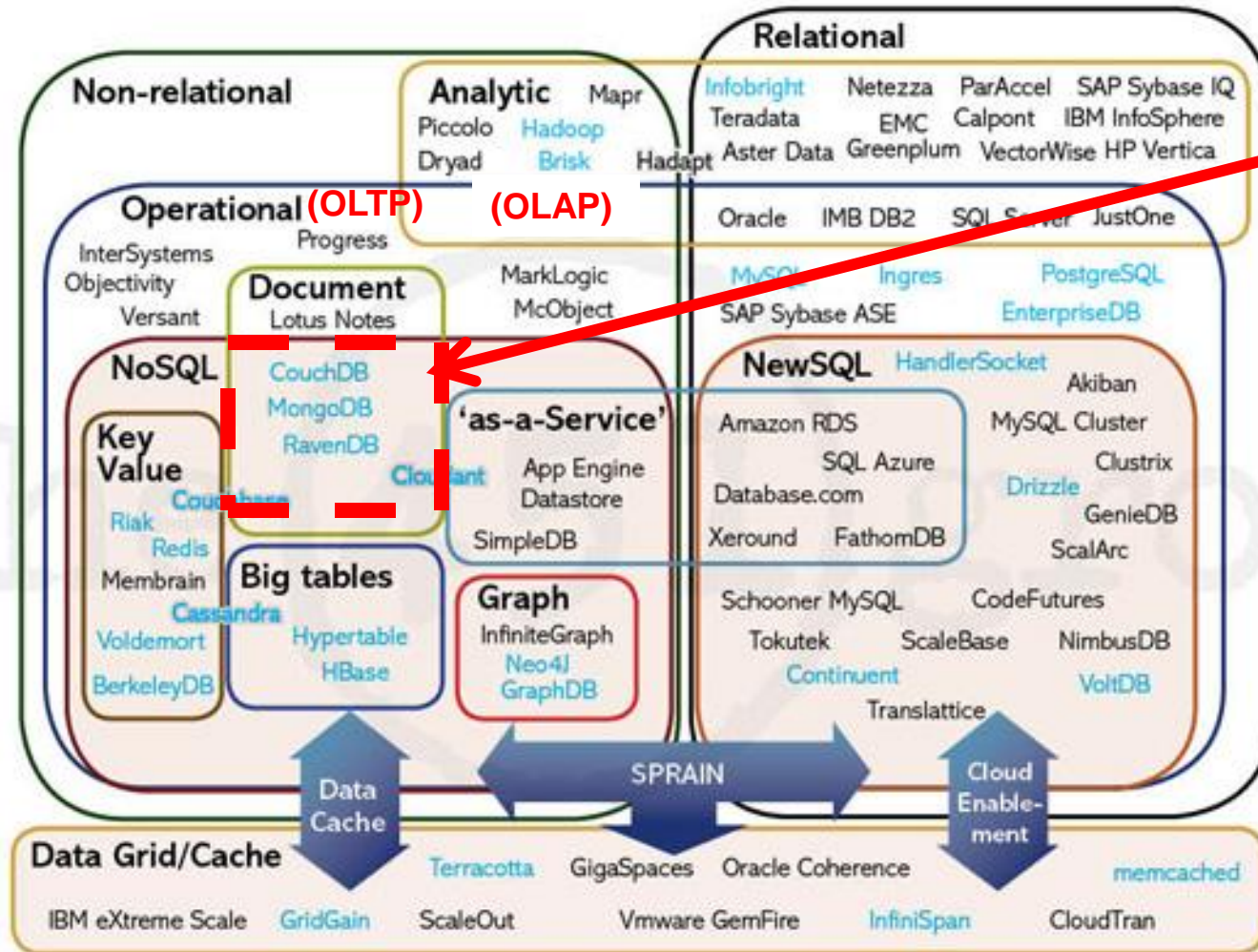
- **Variety:**
 - By some estimates, **80 percent** of an organization's data is **not numeric!**
 - Different data format: *unstructured, structured, semi-structured*
 - text, sensor data, audio, video, click streams, log files, etc.



EPL646: Part B



Distributed/Web/Cloud DBs/Dstores



Lecture
Focus

Venn
Diagram by
451 group

<http://xeround.com/blog/2011/04/newsq-cloud-database-as-a-service>

Lecture Outline

(Introduction to Semi-structured Data)



- Intro to Web2.0 & JSON Data Interchange Format
- JSON Key-Value Data Model
- CouchDB: A JSON Database (written in Erlang)
 - Using Command Line CURL/ Web-based FUTON
 - CouchDB Architecture (Btrees, Filesystem, Replication)
 - REST Principles
 - Creating DBs, Adding Docs, Updating Docs, Deleting Docs, _ID and _REV issues, Multi-Version CC (MVCC)
 - Querying Data with (Materialized) Views (Map-Reduce style in Javascript)
 - Replication and Scalability Issues

Web 2.0: The Structured Web



DBLP: <http://www.informatik.uni-trier.de/>

[Numerous sites already allow downloading remote repositories in structured form (e.g., XML)]

Links

- Computer Science Organizations: [ACM](#) ([DL](#) / [SIGMOD](#) / [SIGIR](#)), [IEEE Computer Society](#) ([DL](#)), [IEEE Xplore](#), [IFIP](#), ...
- Related Services: [Google Scholar](#), [MS Academic Search](#), [CiteSeer/ CiteSeerX](#), [CS BibTeX](#) (DBLP), [io-port.net](#), [CoRR](#), [HAL](#), [NZ-DL](#), [Zentralblatt MATH](#), [MathSciNet](#), [Erdős Number Proj.](#), [Math Genealogy Proj.](#), [BibSonomy](#), [CiteULike](#), [ScientificCommons](#), [Libra](#), [Arnetminer](#), [RePEc](#), ...

Schloss Dagstuhl and DBLP join forces

A joint cooperation between [Schloss Dagstuhl](#) and Trier University/DBLP aims at strengthening the documentation of research publications in Informatics in a comprehensive, transparent, and open accessible way. ...
([news](#)) - ([project page](#))

XML

You may download **DBLP XML records** from <http://dblp.uni-trier.de/xml/> - a simple DTD is available. The paper "[DBLP - Some Lessons Learned](#)" documents technical details of this XML file. In the appendix "[DBLP XML Requests](#)" you may find the description of a primitive DBLP API.

New Design

On the host [Trier II](#) we are testing a new design for the DBLP website ...

2 100 000

DBLP now lists more than 2.1 million (> 2²¹) publications. More [Statistics about DBLP](#)

JSON: Web 2.0 Data Interchange Format

(JSON: The Fat-free XML)



- The initial vision for XML was to provide a data-**interchange language** to enable **machine-to-machine** communication.
 - However, XML is not well suited to data-interchange as the elements are **taking up to much space**.
- **JSON (JavaScript Object Notation)**
 - RFC4627: a lightweight, text-based, language-independent data interchange format.
- Web services providers nowadays offer their web services in JSON (e.g., Google APIs, Twitter API)
 - The objective of this lecture is to see how to store/query such data with a specialized document store, titled CouchDB (other: MongoDB (open), RavenDB (open))¹²⁻¹⁶

JSON: Web 2.0 Data Interchange Format (Google Books)



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

The screenshot shows the Google Books search results for the query "databases". The search bar at the top shows the query and the number of results (About 15,300,000 results in 0.61 seconds). The left sidebar contains navigation links: Web, Images, Maps, Videos, News, Shopping, Books (highlighted in red), and More. Below these are links for "Browse books" and "Any view" (with sub-links for "Preview and full view" and "Full view"). The main content area displays three search results:

- 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.

Below the third result, the title "Fuzzy Databases: Modeling, Design And Implementation" is partially visible.

(content in HTML only
apprehensible to User)

JSON: Web 2.0 Data Interchange Format (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\\profile_images\\2728729106\\130bc7921970a06228d1ad0d352260de_normal.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"
}
```

JSON: Web 2.0 Data Interchange Format (Google Geolocation API)



```
curl -d @request.json -H "Content-Type: application/json" -i  
"https://www.googleapis.com/geolocation/v1/geolocate?key=YOURKEY"
```

Request Format (request.json)

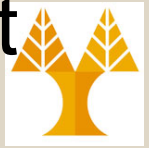
```
{  
  "homeMobileCountryCode": 310,  
  "homeMobileNetworkCode": 260,  
  "radioType": "gsm",  
  "carrier": "T-Mobile",  
  "cellTowers": [  
    {  
      "cellId": 39627456,  
      "locationAreaCode": 40495,  
      "mobileCountryCode": 310,  
      "mobileNetworkCode": 260,  
      "age": 0,  
      "signalStrength": -95  
    },  
    {  
      "cellId": 39627457,  
      "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,  
}
```

JSON: Web 2.0 Data Interchange Format (Other Google APIs)



In fact, Web2.0 Services are omnipresent!

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

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

Google apis <https://code.google.com/apis>

API Project All (51) Active (2) Inactive (48) Google Cloud Platform

Overview
Services
Team
API Access
Billing
Reports
Quotas

All services
Select services for the project.

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

The JSON Key-Value Data Model



At the core: key-value construct

Basic example:

```
"title": "The Social network"
```

Atomic data types: character strings, integers, floating-point number and Booleans (`true` or `false`). Non-string values need not be surrounded by `""`.

```
"year": 2010
```

The JSON Key-Value Data Model



Complex values: objects

An *object* is an unordered set of name/value pairs.

Json does not care about types (everything is essentially text)

The types can be distinct, and a key can only appear once.

```
{"last_name": "Fincher", "first_name": "David"}
```

A object can be used as the (complex) value component of a key-value construct:

```
"director": {  
  "last_name": "Fincher",  
  "first_name": "David",  
  "birth_date": 1962  
}
```

The JSON Key-Value Data Model



Complex values: arrays

An array is an ordered collection of values that need not be of the same type.

```
"actors": [ "Eisenberg", "Mara", "Garfield", "Timberlake" ]
```

A *document* is an object. It can be represented with an unbounded nesting of array and object constructs

```
{
  "title": "The Social network",
  "year": "2010",
  "director": { "last_name": "Fincher",
                "first_name": "David" },
  "actors": [
    { "first_name": "Jesse", "last_name": "Eisenberg" },
    { "first_name": "Rooney", "last_name": "Mara" }
  ]
}
```


CouchDB: A JSON Database



What is CouchDB?

"a database that completely embraces the web"

A system representative of the “NoSQL” trend.

- ① a semi-structured data model, based on JSON;
 - ② no schema;
 - ③ *structured materialized views* produced from document collections;
 - ④ views defined with the MAPREDUCE paradigm, allowing both a parallel computation and incremental maintenance of their content;
 - ⑤ distributed data management techniques: consistent hashing, support for data replication and reconciliation, horizontal scalability, parallel computing, etc.
- conflict resolution



CouchDB

relax

<http://couchdb.apache.org/>

CouchDB: FUTON Web Admin GUI



Futon: A Web-based front-end for administering CouchDB

The screenshot shows the CouchDB Futon web interface in a browser window. The address bar shows the URL `127.0.0.1:5984/_utils/`. The main heading is "Overview". Below it is a "+ Create Database ..." button. A table lists the databases:

Name	Size	Number of Documents	Update Seq
_replicator	4.1 KB	1	1
_users	4.1 KB	1	1
books	3.7 MB	1557	1563
movies	4.1 KB	1	1
twitter	4.1 KB	1	1

Below the table, it says "Showing 1-5 of 5 databases". Navigation links include "← Previous Page", "Rows per page: 10", and "Next Page →". On the right side, there is a sidebar with the CouchDB logo and the text "relax". Below the logo is a "Tools" section with a menu: Overview (selected), Configuration, Replicator, Status, and Verify Installation. At the bottom of the sidebar, it says "For Developers: Test Suite".

CouchDB: FUTON Web Admin GUI



Editing records (documents) with Futon

← → ↺ 🏠 127.0.0.1:5984/_utils/database.html?books/_all_docs

Overview > books

+ New Document ⓘ Security... Jump to: View: Stale views ☐

⌘ Compact & Cleanup... ⌘ Delete Database...

Key ▲	Value
"_design/examples" ID: _design/examples	{rev: "4-ab4f0d8f5340146bdc32a78e137f0a9"}
"book1.json" ID: book1.json	{rev: "1-410c67caca526b476abc72e73b003605"}
"book10.json" ID: book10.json	{rev: "1-d0cc2ae0ab3211314a65a5c5244df221"}
"book100.json" ID: book100.json	{rev: "1-2cfe83eea8cad920cfd66755ac78b46f"}
"book1000.json"	{rev: "1-7681da7415571ed392393b99734c86d8"}

CouchDB in a Nutshell



CouchDB in a nutshell

A **document**, **web-oriented** data system.

Document oriented. Document are complex and autonomous pieces of information. Can store files, functions, any type of media. But no references.

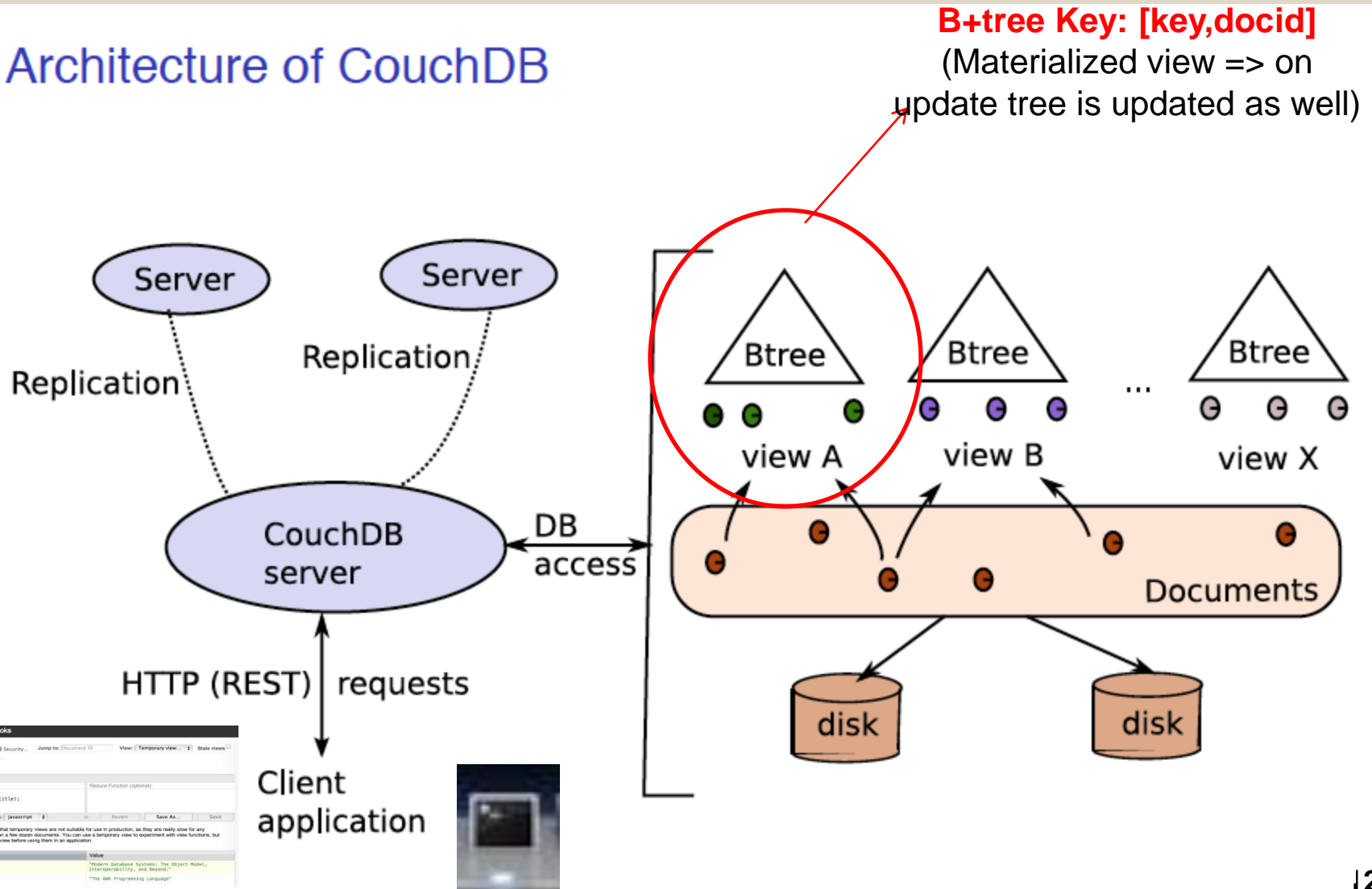
Typical functionalities of document application: versioning, replication, synchronization, restructuring.

Web-oriented. A document is a **resource** in the Web sense – it has a URI, and can be manipulated via HTTP (REST architecture).

CouchDB: A JSON Database (Architecture)



Architecture of CouchDB



CouchDB: Filesystem Layout (Datastores and Materialized Views)



Index of /Users/dzeina/Li

Name	Size	Date
[parent directory]		
.books_design/		10/29/12 11
.delete/		10/23/12 3
.movies_design/		10/23/12 4
_replicator.couch	4.1 kB	10/23/12 9
_users.couch	4.1 kB	10/23/12 9:40:05 AM
books.couch	3.7 MB	10/29/12 11:41:48 AM
booksreplica.couch	764 kB	10/29/12 11:41:48 AM
movies.couch	4.1 kB	10/23/12 3:40:27 PM
twitter.couch	4.1 kB	10/23/12 10:50:02 AM

Index of /Users/dzeina/Library/Application S

Name	Size	Date Modified
[parent directory]		
1fb02d640d642a6272bfa5334d2e3f42.view	188 kB	10/29/12 11:18:59 AM
20ab140f1492382baf3aafb426f2d7.view	56.1 kB	10/23/12 4:12:14 PM
33abe94d1a00f46506f2c0b015540db1.view	8.1 kB	10/29/12 11:19:29 AM
3b5f338a51e55052f5513da8a6bd64a8.view	216 kB	10/23/12 4:52:51 PM
451385d5ae51196393f2ceb3a2b780fa.view	4.1 kB	10/29/12 11:19:29 AM
45b8fde80881d168a44595ff5cc90ea1.view	16.1 kB	10/29/12 11:48:33 AM
5ccddad630dd20ffd2b6fb4833080772.view	4.1 kB	10/23/12 4:58:52 PM
64a3e2d25cf3876b0fa55d78c50d7f0b.view	72.1 kB	10/29/12 11:48:33 AM
6ba736a20feacba97c220a4b7f3e02e3.view	132 kB	10/29/12 11:45:02 AM
6da619412b8ffa95126c11d2b21d27cc.view	504 kB	10/23/12 4:09:13 PM
6fac50850cee7de2f185090669defd68.view	4.1 kB	10/23/12 11:21:22 PM
70419c9fa523e611895f53b01ac694e0.view	204 kB	10/23/12 4:59:53 PM