

# Usage of **Linked Data**

## Introduction and Application Scenarios

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# Agenda

- 1. Motivation Scenario**
- 2. Linked Data Foundations**
- 3. Introduction to Linked Data**
- 4. Linked Data use case scenarios**

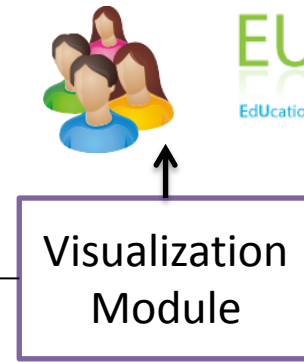
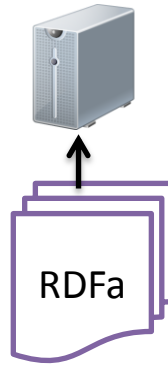
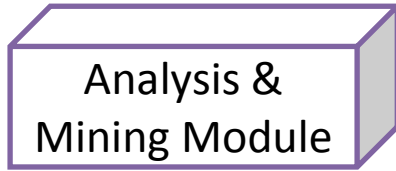
# MOTIVATION SCENARIO

# Music!

- Provision of a music-based portal.
- Bring together a number of disparate components of data-oriented content:
  1. **Musical content** (streaming data & downloads)
  2. **Music and artist metadata**
  3. **Review content**
  4. **Visual content** (pictures of artists & albums)

# Music!

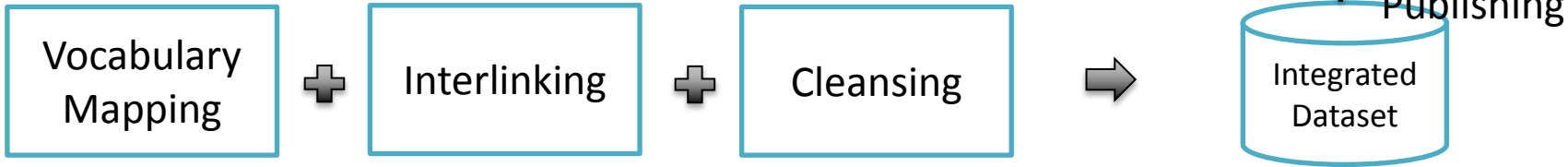
Application



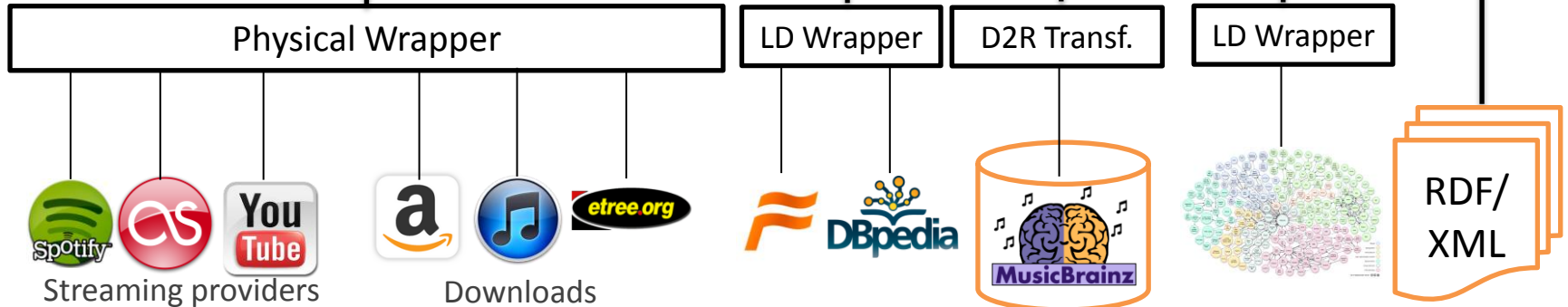
Access



LD Dataset



Data acquisition



Musical Content

Metadata

Other content

# Music!

## Expected Results

- The developer will contribute back the aggregated and interlinked content to the Linked Open Data Cloud.
- Linking of artists will be improved.
- Metadata, visual content and reviews will be improved.
- Links to emerging Web technologies that inherit from semantics: Google RichSnippets, Facebook OpenGraph and schema.org annotation.

# LINKED DATA FOUNDATIONS

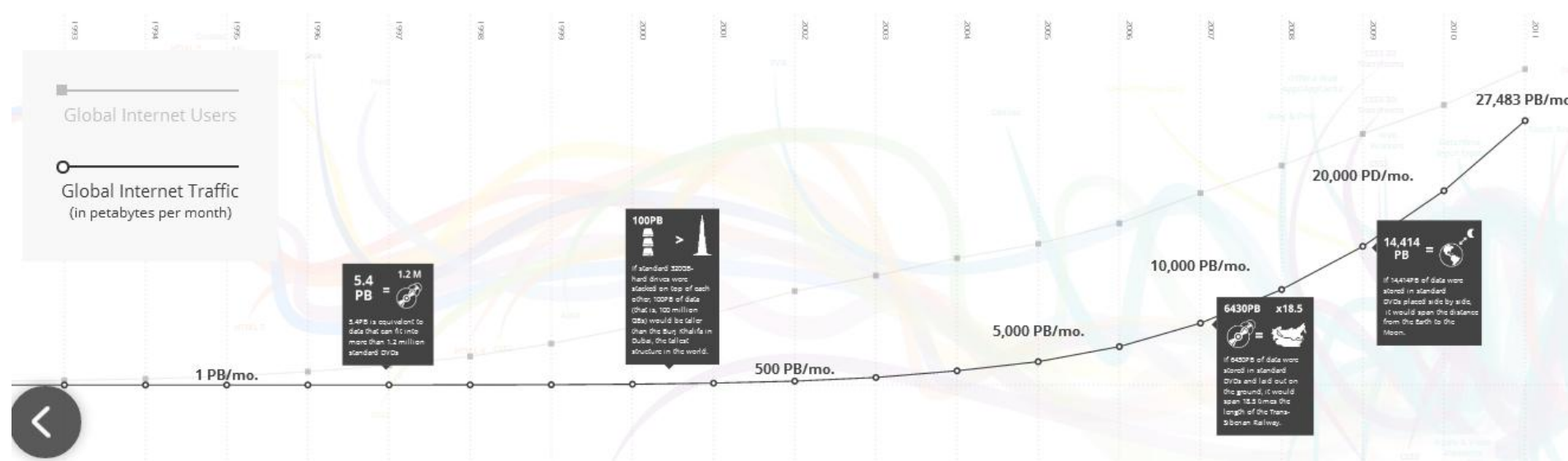
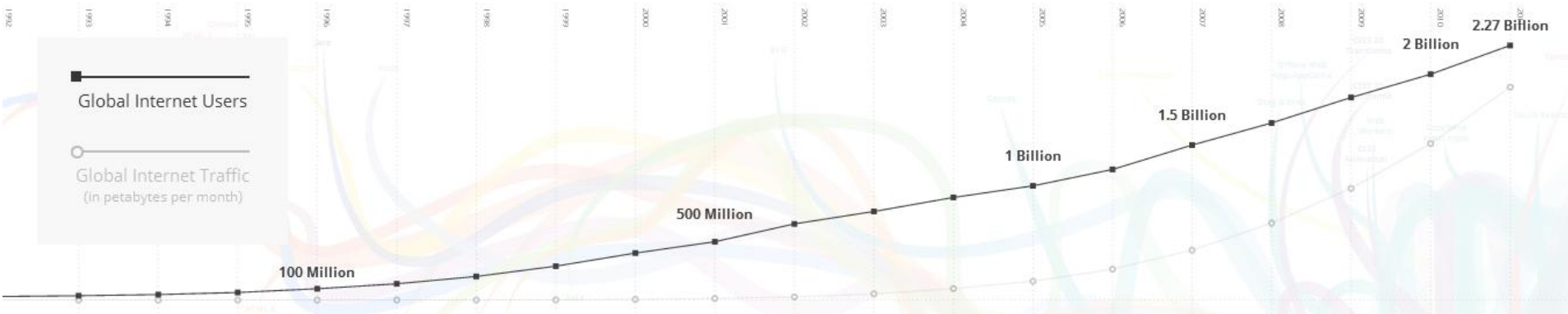
# Internet

- Extension of the technology of **computer networks**.
- The technology supporting the Internet includes the **Internet Protocol (IP)** .
- Each computer on the Internet is assigned an **IP number**.
- Messages can be **routed** from one computer to another.



# Internet

## The growth of the Internet



Source: <http://www.evolutionoftheweb.com>

# The Web

- There is a wealth of information on the Web.
- It is aimed mostly towards consumption by **humans as end-users**:
  - Recognize the meaning behind content and draw conclusions,
  - Infer new knowledge using context and
  - Understand background information.



The image shows a screenshot of the Wikipedia article for Germany. At the top left is the Wikipedia logo, a globe with letters. Below it is the text 'WIKIPEDIA'. To the right is a search bar with 'Germany' entered. Below the search bar is the title 'Germany' and the text 'From Wikipedia, the free encyclopedia'. The main text of the article is visible, starting with 'Germany ( /dʒɜːməni/ ), officially the **Federal Republic of Germany** (German: *Bundesrepublik Deutschland*, pronounced [ˈbʊndəsʁepuˌbliːk ˈdɔʏtʃlant]) is a federal parliamentary republic in west-central Europe. The country consists of 16 states, and its capital and largest city is Berlin. Germany covers an area of 357,021 square kilometres (137,847 sq mi) and has a largely temperate seasonal climate. With 81.8 million inhabitants, it is the most populous member state in the European Union. It is one of the major political powers of the European continent and a technological leader in many fields.

Below the main text are two columns: 'Federal Republic of Germany' with the German flag and coat of arms, and 'Anthem: The third stanza of Lied der Deutschen (Song of the Germans)' with a small globe icon.



[Germany – Wikipedia](#)  
[de.wikipedia.org/wiki/Germany](#)  
**Germany** ist: die englische Bezeichnung für Deutschland. **Germany** (Mondkrater), ein Mondkrater; **Germany** (Rapper), deutscher Rapper. Zudem steht der Name ...

[Germany - Wikipedia, the free encyclopedia](#)  
[en.wikipedia.org/wiki/Germany](#) - Diese Seite übersetzen  
Song of the Germans. Location of **Germany** (dark green)– in Europe (green & dark grey). Location of **Germany** (dark green). – in Europe (green & dark grey) ...  
[Flag of Germany - History of Germany - Geography of Germany - German cuisine](#)

[Tourism in Germany – travel, breaks, holidays](#)  
[www.germany.travel/](#) - Diese Seite übersetzen  
Tourism in **Germany** – travel, breaks, holidays. ... BMWi Logo **Germany**, the travel destination. Towns, cities & culture Towns, cities & culture; Leisure and ...

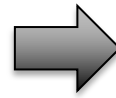
[Startseite: Das Deutschland-Portal](#)  
[www.deutschland.de/](#)  
deutschland.de ist das offizielle und unabhängige Portal der Bundesrepublik Deutschland im Internet. Es bietet in fünf Sprachen eine Sammlung wichtiger ...

# The Web

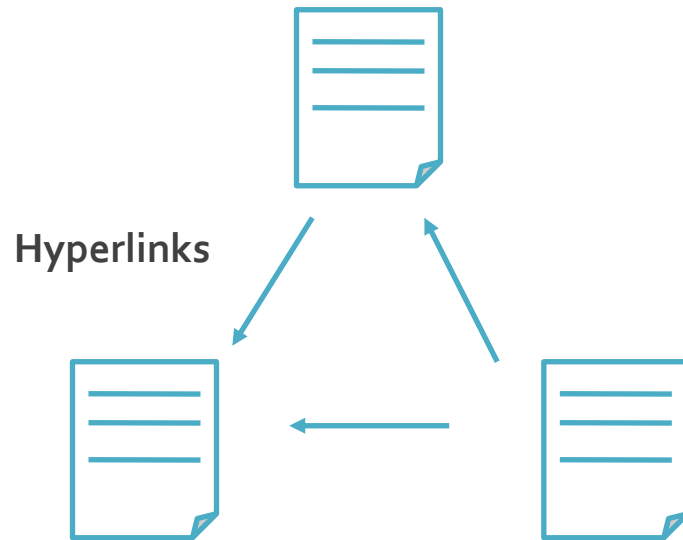
- Billions of diverse documents online, but it is not easily possible to automatically:
  - Retrieve relevant documents.
  - Extract information.
  - Combine information in a meaningful way.
- Idea:
  - Also publish machine processable data on the web.
  - Formulate questions in terms understandable for a machine.
  - Do this in a standardized way so machines can interoperate.
- The Web becomes a **Web of Data**
  - This provides a common framework to share knowledge on the Web across application boundaries.

# The Web: Evolution

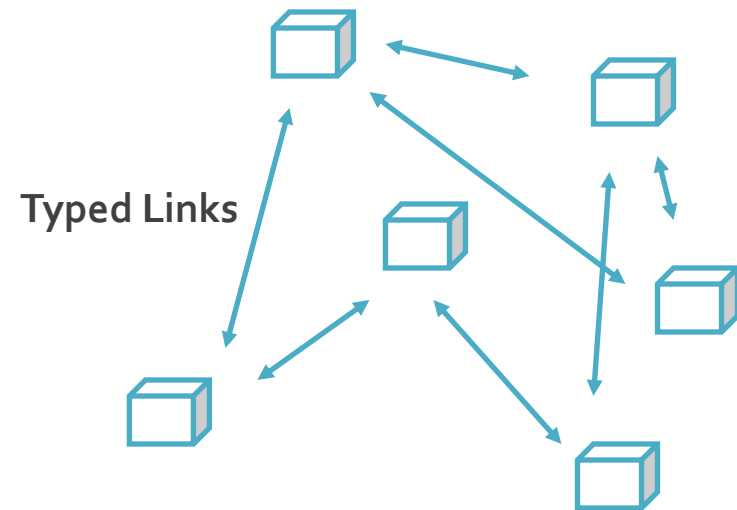
Web of Documents



Web of Data



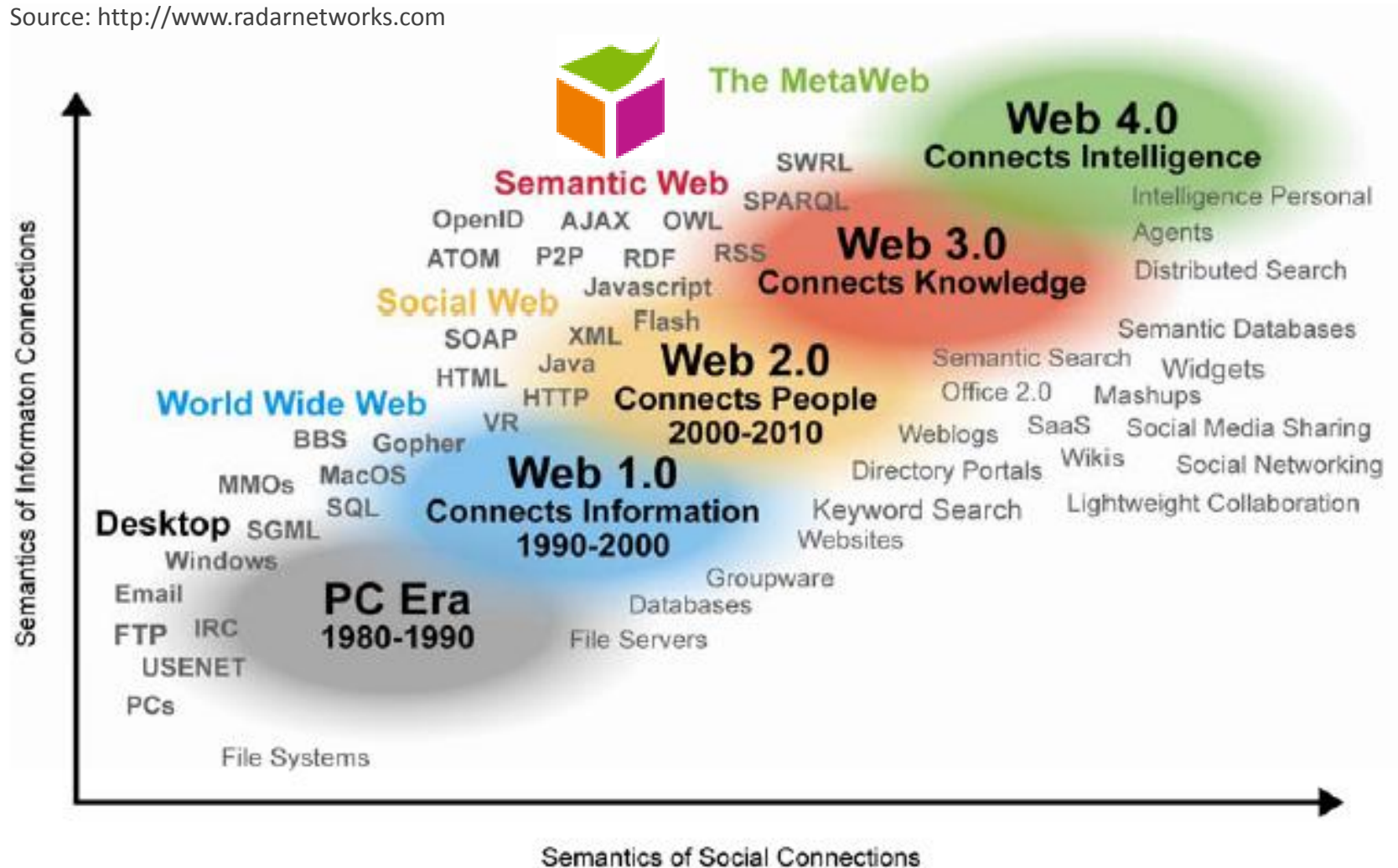
"Documents"



"Things"

# The Web: Evolution

Source: <http://www.radarnetworks.com>



## HTML – HyperText Markup Language

- Language for displaying web pages and other information in a web browser.
- HTML elements consist of **tags** (enclosed in angle brackets), **attributes** and **content**.

## HTTP – Hypertext Transfer Protocol

- Foundation of data communication for the WWW.
- Client-server protocol.
- Every interaction is based on: **request** and **response**.

## Uniform Resource Identifier (URI)

- Compact sequence of characters that identifies an abstract or physical resource.

- **Examples:**

`ldap://[2001:db8::7]/c=GB?objectClass?one`

`mailto:John.Doe@example.com`

`news:comp.infosystems.www.servers.unix`

`tel:+1-816-555-1212`

`telnet://192.0.2.16:80/`

`urn:oasis:names:specification:docbook:dtd:xml:4.1.2`

`http://dbpedia.org/resource/Karlsruhe`

# Describing Data

## Vocabularies

- Collections of defined **relationships** and **classes** of resources.
  - Classes group together similar resources.
- Terms from well-known vocabularies should be **reused** wherever possible.
- New terms should be define only if you can not find required terms in existing vocabularies.



# Describing Data

## Vocabularies

A set of well-known vocabularies has evolved in the Semantic Web community. **Some** of them are:

Vocabulary	Description	Classes and Relationships
Friend-of-a-Friend ( <b>FOAF</b> )	Vocabulary for describing people.	foaf:Person, foaf:Agent, foaf:name, foaf:knows, foaf:member
Dublin Core ( <b>DC</b> )	Defines general metadata attributes.	dc:FileFormat, dc:MediaType, dc:creator, dc:description
Semantically-Interlinked Online Communities ( <b>SIOC</b> )	Vocabulary for representing online communities.	sioc:Community, sioc:Forum, sioc:Post, sioc:follows, sioc:topic
Music Ontology ( <b>MO</b> )	Provides terms for describing artists, albums and tracks.	mo:MusicArtist, mo:MusicGroup, mo:Signal, mo:member, mo:record
Simple Knowledge Organization System ( <b>SKOS</b> )	Vocabulary for representing taxonomies and loosely structured knowledge.	skos:Concept, skos:inScheme, skos:definition, skos:example

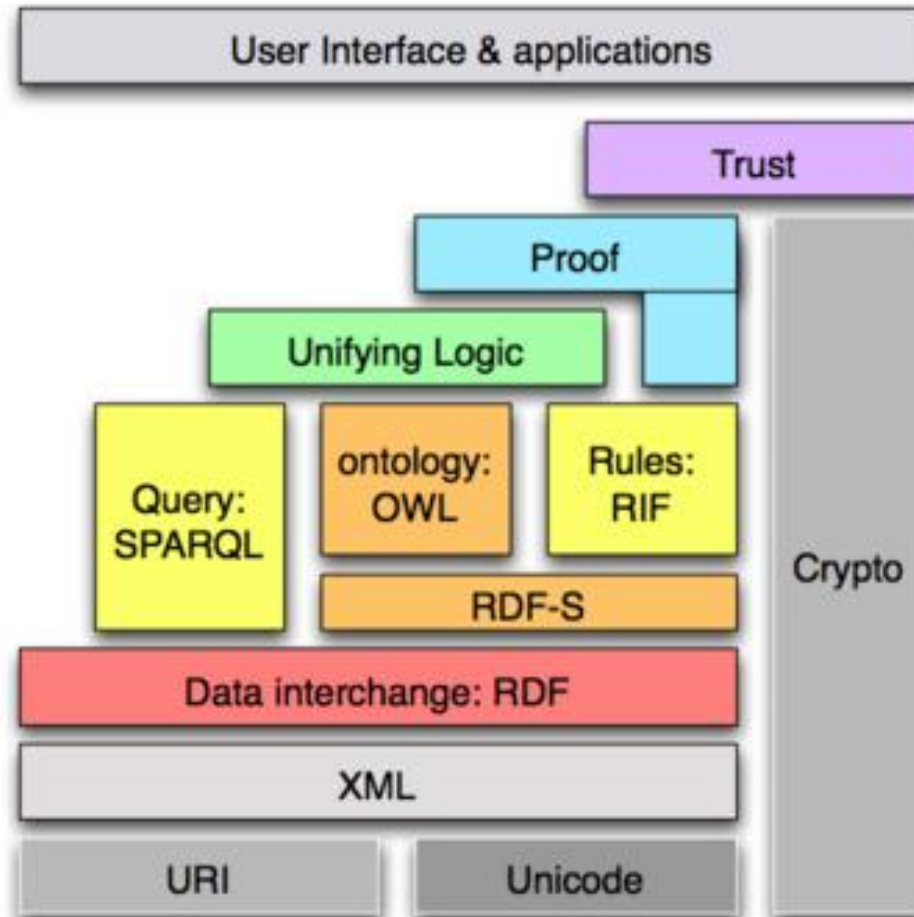
# Describing Data

## Vocabularies

More extensive lists of well-known vocabularies are maintained by:

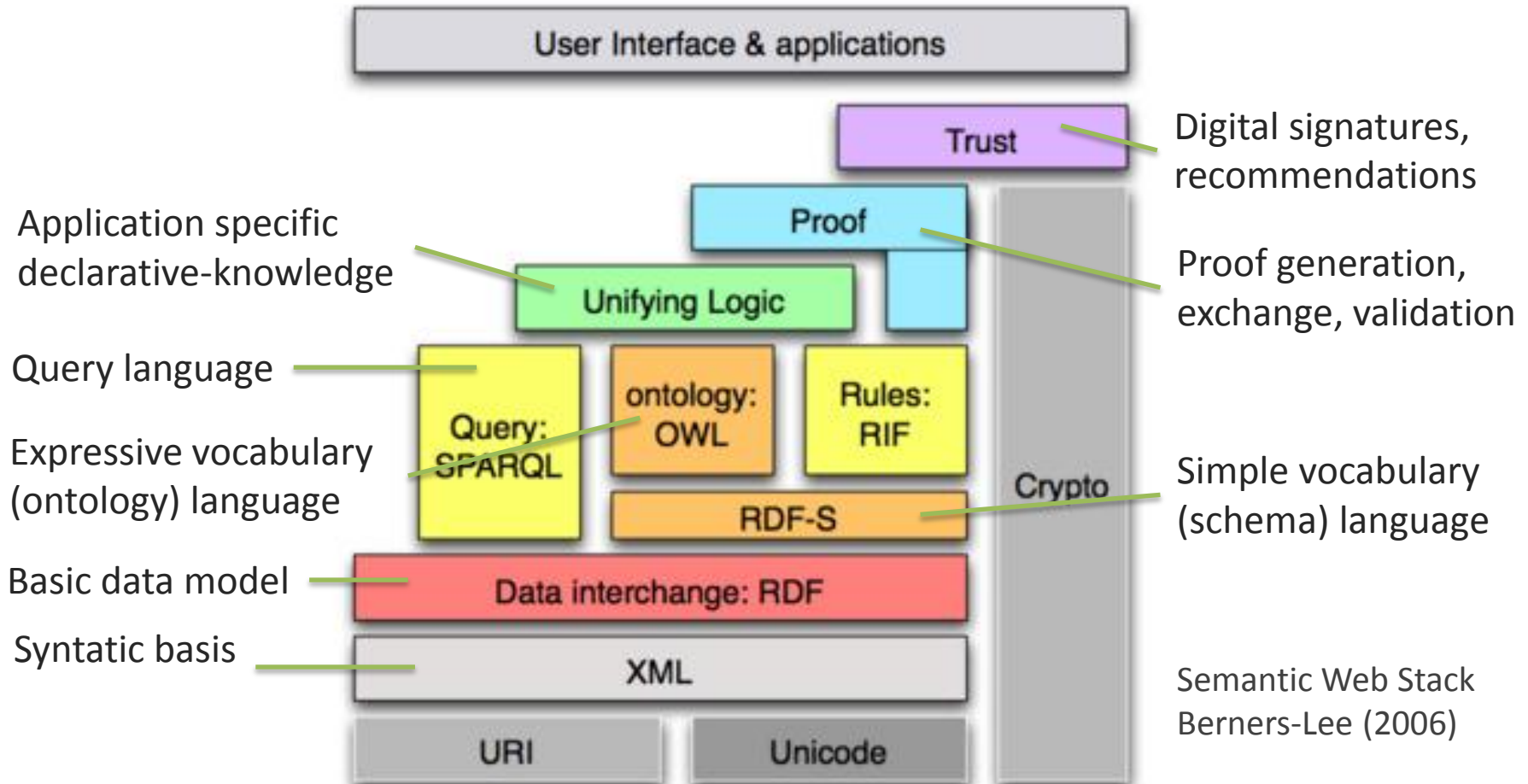
- W3C SWEO Linking Open Data community project  
<http://www.w3.org/wiki/TaskForces/CommunityProjects/LinkingOpenData/CommonVocabularies>
- Mondeca: Linked Open Vocabularies  
<http://labs.mondeca.com/dataset/lov>
- Library Linked Data Incubator Group: Vocabularies in the library domain  
<http://www.w3.org/2005/Incubator/llid/XGR-llid-vocabdataset-20111025>

# Semantics on the Web

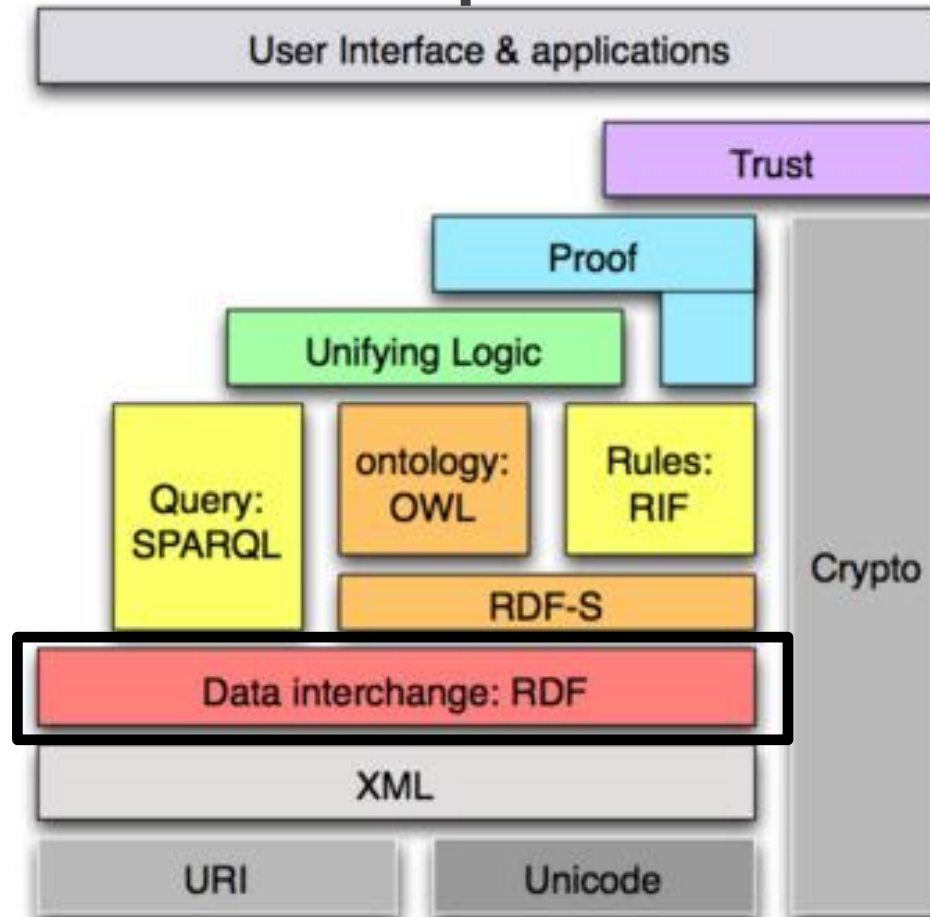


Semantic Web Stack  
Berners-Lee (2006)

# Semantics on the Web



## RDF – Resource Description Framework



Semantic Web Stack  
Berners-Lee (2006)

## RDF – Resource Description Framework

- RDF is the basis layer of the Semantic Web stack ‘layer cake’.
- Basic building block: RDF triple.
  - **Subject** – a resource, which may be identified with a URI.
  - **Predicate** – a URI-identified reused specification of the relationship.
  - **Object** – a resource or literal to which the subject is related.

## RDF – Resource Description Framework (Example)

`<http://musicbrainz.org/artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d#_>`

`<http://www.w3.org/2002/07/owl#sameAs>`

`<http://dbpedia.org/resource/The_Beatles>.`

URIs are given in angle brackets in N-Triples.

`<http://musicbrainz.org/artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d#_>`

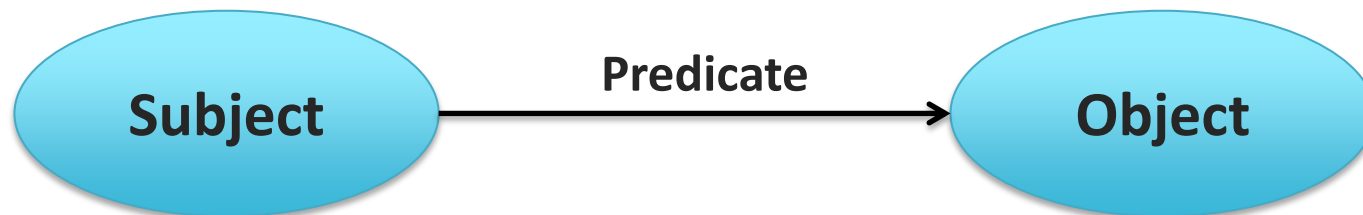
`<http://xmlns.com/foaf/0.1/name>`

`"The Beatles" .` Literals are given in quotes in N-Triples.

In N-Triples every statement is terminated with a full stop.

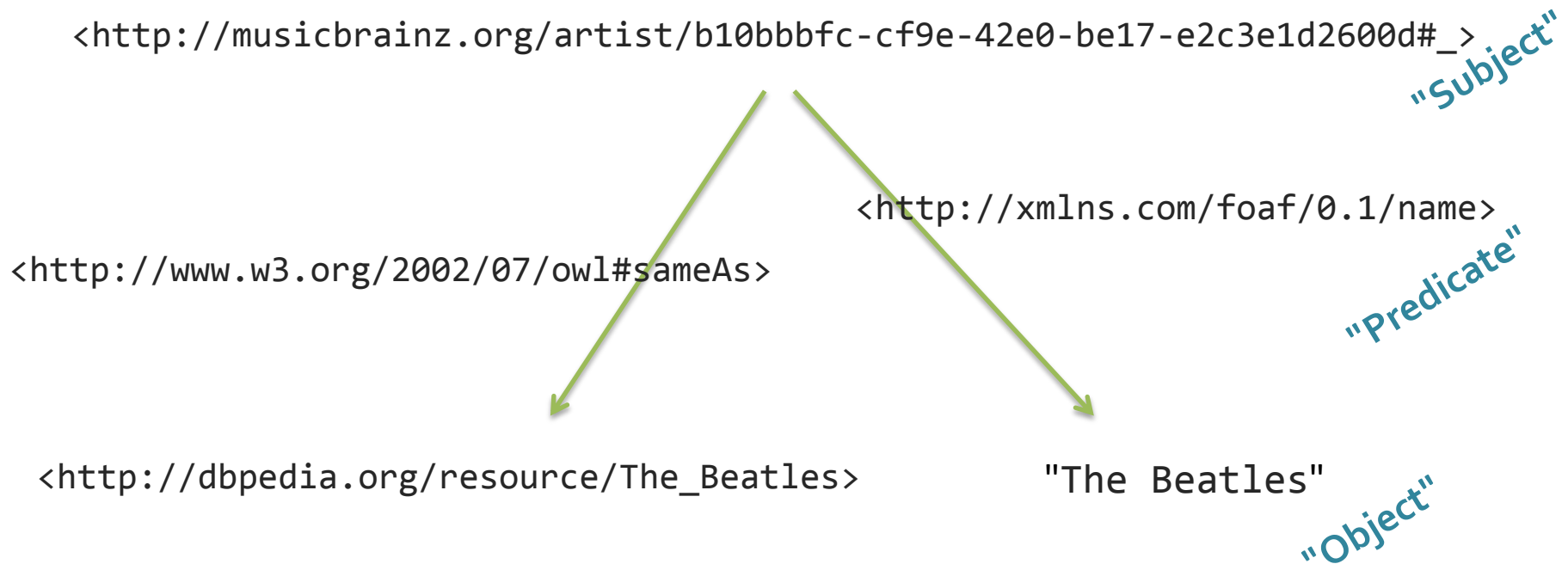
## RDF Graphs

- Every set of RDF assertions can then be drawn and manipulated as a (labelled directed) graph:
  - **Resources** – the subjects and objects are nodes of the graph.
  - **Predicates** – each predicate use becomes a label for an arc, connecting the subject to the object.



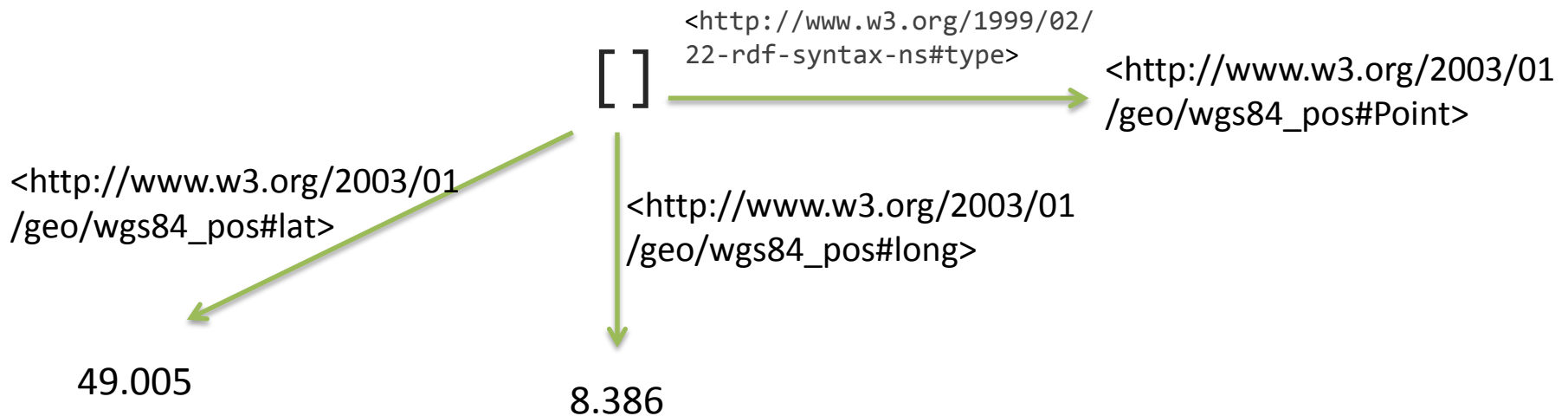


## RDF Graphs (Example)



## RDF Blank Nodes

- RDF graphs can also contain unidentified resources, called *blank nodes*:



- Blank nodes can group related information, but their use in Linked Data is discouraged.

## RDF Turtle

- Turtle is a syntax for RDF more readable.
- Since many URIs share same basis we use **prefixes**:

```
@prefix rdf:<http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
```

```
@prefix rdfs:<http://www.w3.org/2000/01/rdf-schema#>.
```

```
@prefix owl:<http://www.w3.org/2002/07/owl#>.
```

```
@prefix mo:<http://purl.org/ontology/mo/>.
```

```
@prefix dbpedia:<http://dbpedia.org/resource/>.
```

And (sometimes) a unique base:

```
@base <http://musicbrainz.org/artist/>.
```

## RDF Turtle

- Also has a simple *shorthand* for class membership:

```
@base <http://musicbrainz.org/>.
```

```
@prefix mo:<http://purl.org/ontology/mo/>.
```

```
<artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d#_> a mo:MusicGroup.
```

### Is equivalent to:

```
<http://musicbrainz.org/artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d#_>  
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type>  
  <http://purl.org/ontology/mo/MusicGroup>.
```



## RDF Turtle

- When multiple statements apply to **same subject** they can be abbreviated as follows:

```
<artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d#_>
```

```
  rdfs:label "The Beatles"; _____ Same subject
```

```
  owl:sameAs dbpedia:The_Beatles , _____ Same subject &  
  <http://www.bbc.co.uk/music/artists/      predicate  
  b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d#artist> .
```

## RDF Turtle

- Turtle also provides a simple syntax for **datatypes** and **language tags** for literals, respectively:

```
<recording/5098d0a8-d3c3-424e-9367-1f2610724410#_> a mo:Signal;  
    rdfs:label "All You Need Is Love" ;  
    mo:duration "PT3M48S"^^xsd:duration .
```

```
dbpedia:The_Beatles dbpedia-owl:abstract  
    "The Beatles were an English rock band formed (...) "@en,  
    "The Beatles waren eine britische Rockband in den (...) "@de .
```

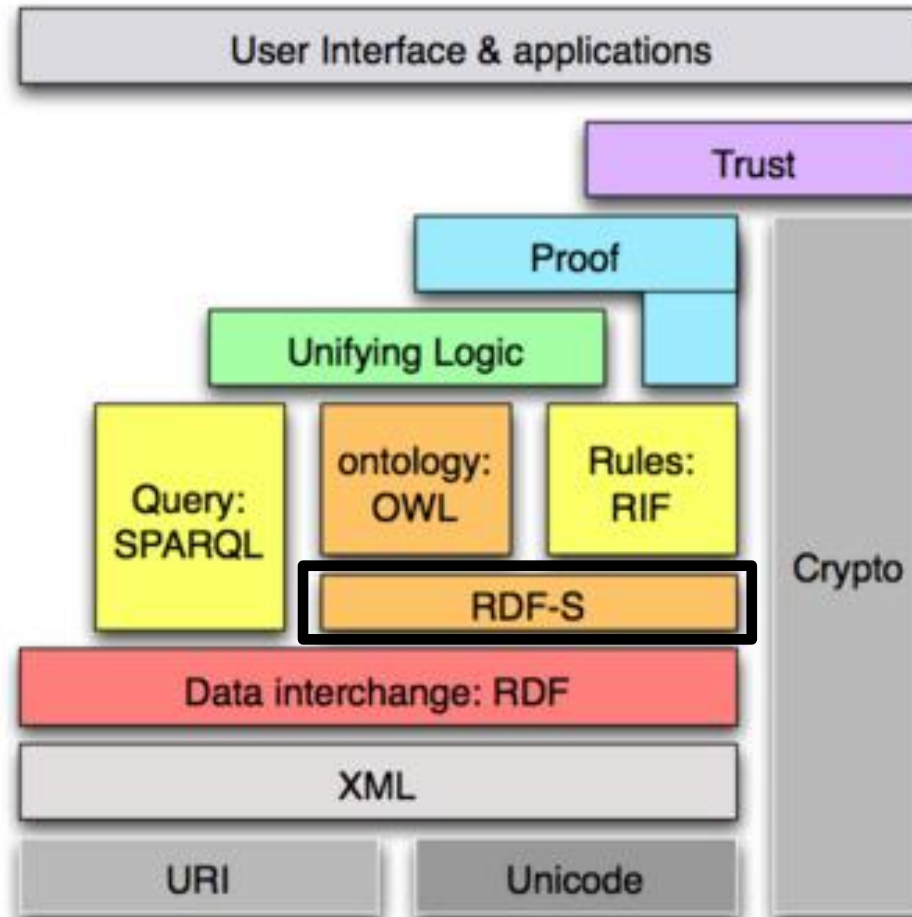
## RDF/XML

- This is most useful for inter-machine communication.
- The primary (recurring) element in encoding assertions (thereby triples) is `rdf:Description`, e.g.:

```
<rdf:Description
  rdf:about="http://musicbrainz.org/artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d#_">
  <foaf:name>The Beatles</foaf:name>
  <owl:sameAs rdf:resource="http://dbpedia.org/resource/The_Beatles">
</rdf:Description>
<rdf:Description
  rdf:about="http://musicbrainz.org/artist/4d5447d7-c61c-4120-ba1b-d7f471d385b9#_">
  <foaf:name>John Lennon</foaf:name>
</rdf:Description>
```

# Semantics on the Web

## RDF-S – RDF Schema



Semantic Web Stack  
Berners-Lee (2006)



## RDF-S – RDF Schema

Language for two tasks w.r.t. the RDF data model:

- **Expectation** – nominate:
  - the ‘types’, i.e., *classes*, of things we might make assertions about, and
  - the *properties* we might apply, as predicates in these assertions, to capture their relationships.
- **Inference** – given a set of assertions, using these classes and properties, specify what should be inferred about assertions that are *implicitly* made.

## RDF-S – RDF Schema

- **rdf:Property** - Class of RDF properties. Example:  
*mo:member - Indicates a member of a musical group.*
- **rdfs:domain** - States that any resource that has a given property is an instance of one or more classes.  
`mo:member rdfs:domain mo:MusicGroup .`
- **rdfs:range** - States that the values of a property are instances of one or more classes.  
`mo:member rdfs:range foaf:Agent .`

## RDF-S – RDF Schema

Schema `mo:MusicGroup`  
`rdfs:subClassOf`  
`foaf:Group` .

Existing fact  
`<artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d#_>`  
`rdf:type`  
`mo:MusicGroup` .

Inferred  
fact

`<artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d#_>`  
`rdf:type`  
`foaf:Group` .

We *expect* to use this vocabulary to make assertions about music groups.

Having made such an assertion...

***Inferences*** can be drawn that we did not explicitly make

## RDF-S – RDF Schema

Resources and predicates with (limited) **inferences**:

`rdfs:Resource`

`rdfs:Literal`, `rdfs:Datatype`

`rdfs:Class`, `rdfs:subClassOf`

`rdfs:subPropertyOf`

`rdfs:range`, `rdfs:domain`

`rdf:Property` (an instance of `rdfs:Class`)

Some predicates with **NO inferences**:

`rdfs:comment`

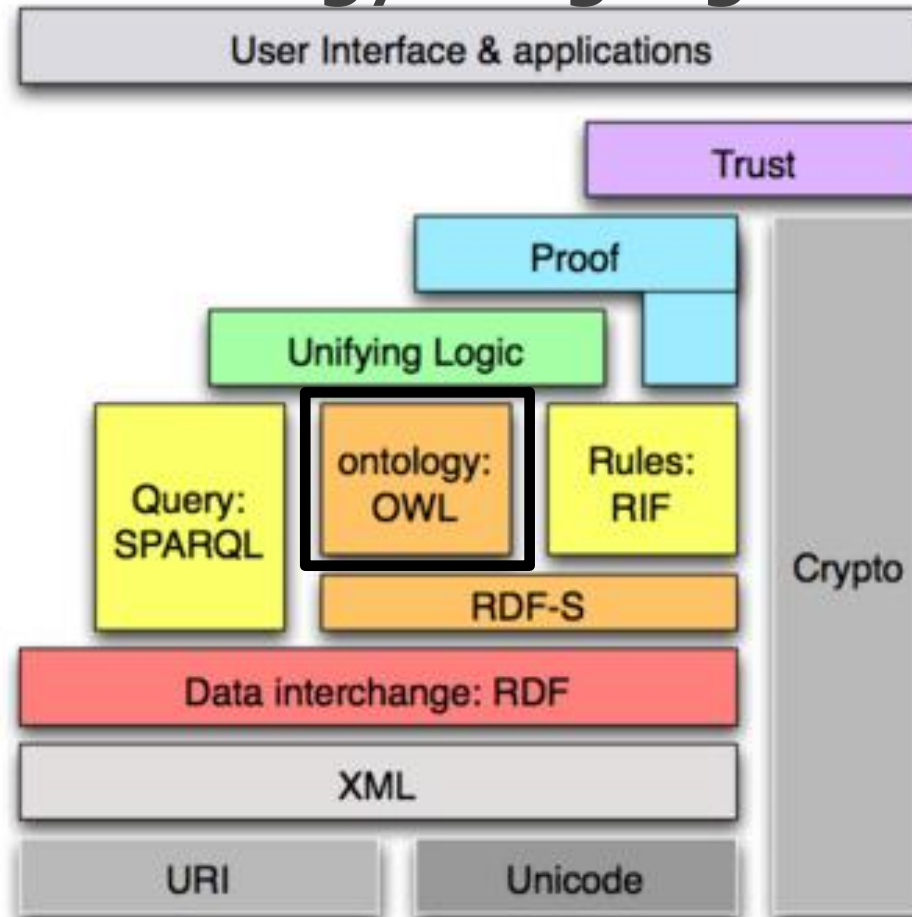
`rdfs:label`

`rdfs:seeAlso`

`rdfs:isDefinedBy`

# Semantics on the Web

## OWL – Web Ontology Language



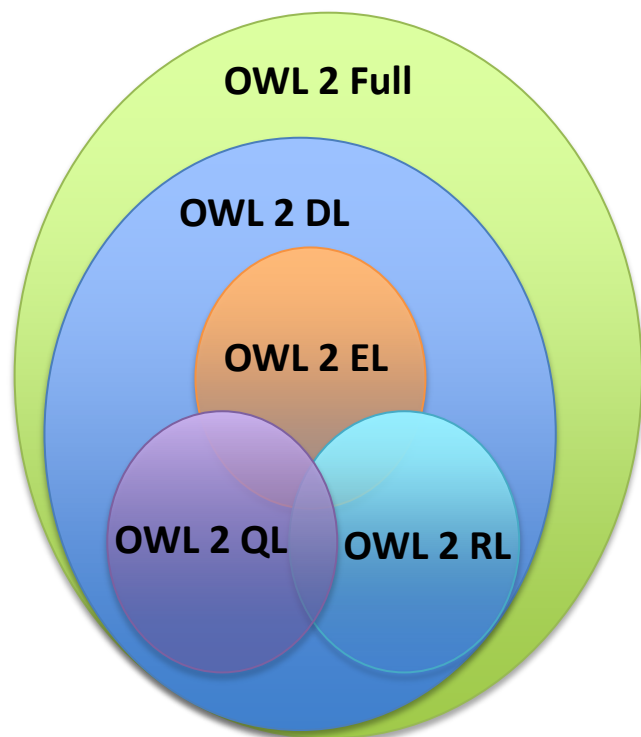
Semantic Web Stack  
Berners-Lee (2006)

## OWL – Web Ontology Language

- RDFS provides a simplified ontological language for defining vocabularies about specific domains.
- Sometimes it is necessary to have access to a wider range of ontological constructs.
- **Web Ontology Language (OWL)** provides more ontological constructs and avoids some of the potential confusion in RDF-S.

## OWL 2.0 – Web Ontology Language 2.0

Extends the DL further, but has three more computable fragments (profiles).



### OWL 2 Full

- Used informally to refer to RDF graphs considered as OWL 2 ontologies and interpreted using the RDF-Based Semantics.

### OWL 2 DL

- Used informally to refer to OWL 2 DL ontologies interpreted using the Direct Semantics.

### OWL 2 EL

- Limited to basic classification, but with polynomial-time reasoning.

### OWL 2 QL

- Designed to be translatable to relational database querying.

### OWL 2 RL

- Designed to be efficiently implementable in rule-based systems.

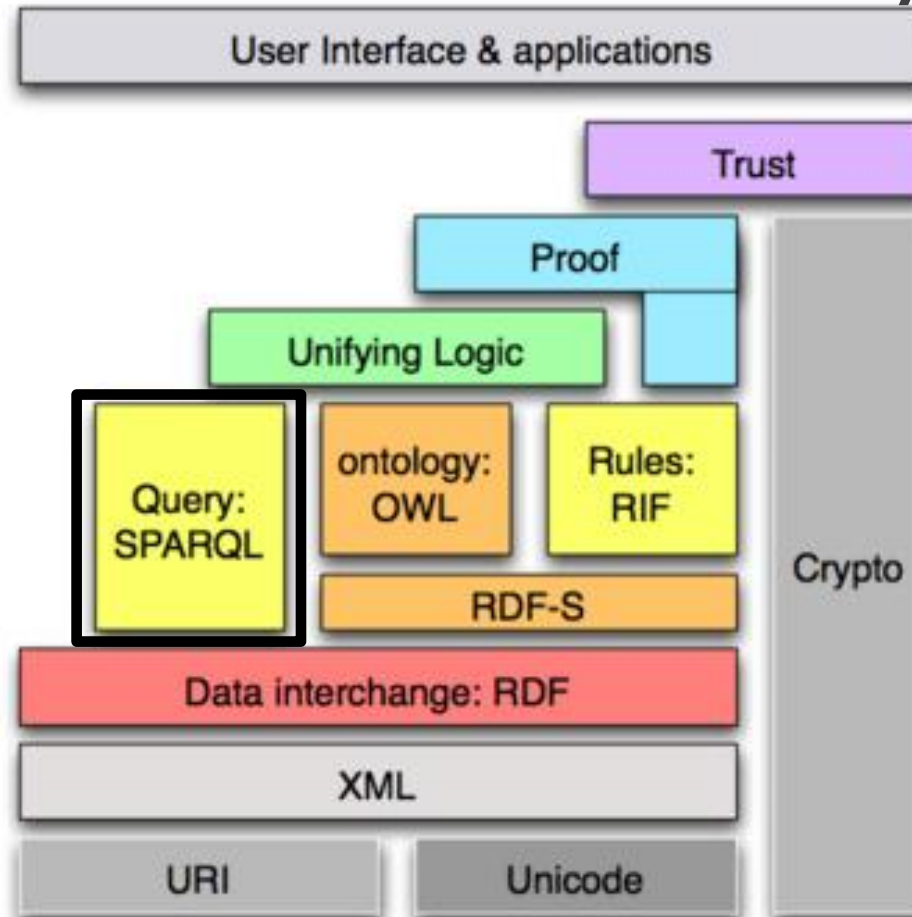
## OWL – Web Ontology Language

OWL is made up of **terms** which provide for:

- **Class construction:** forming new classes from membership of existing ones (e.g., unionOf, intersectionOf, etc.).
- **Property construction:** distinction between OWL ObjectProperties (resources as values) and OWL DatatypeProperties (literals as values).
- **Class axioms:** sub-class, equivalence and disjointness relationships.
- **Property axioms:** sub-property relationship, equivalence and disjointness, and relationships between properties.
- **Individual axioms:** statements about individuals (sameIndividual, differentIndividuals).



## SPARQL – \* Protocol and RDF Query Language



Semantic Web Stack  
Berners-Lee (2006)

## SPARQL – \* Protocol and RDF Query Language

- Query language designed to use a syntax similar to SQL for retrieving data from relational databases.
- Different query forms:
  - **SELECT** returns variables and their bindings directly.
  - **CONSTRUCT** returns a single RDF graph specified by a graph template.
  - **ASK** test whether or not a query pattern has a solution. Returns yes/no.
  - **DESCRIBE** returns a single RDF graph containing RDF data about resources.

## SPARQL – \* Protocol and RDF Query Language

- The syntax of a **SELECT** query is as follows:
  - **SELECT** nominates which components of the matches made against the data should be returned.
  - **FROM** (optional) indicates the sources for the data against which to find matches.
  - **WHERE** defines patterns to match against the data.
  - **ORDER BY** defines a means to order the selected matches.

## SPARQL – \* Protocol and RDF Query Language

*Retrieve the names of the albums and tracks recorded by The Beatles.*

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>
```

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
```

```
PREFIX music-ont: <http://purl.org/ontology/mo/>
```

```
SELECT ?album_name ?track_title
```

```
WHERE {
```

```
  <http://musicbrainz.org/artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d# >
```

```
    foaf:made ?album .
```

```
    ?album dc:title ?album_name ;
```

```
        music-ont:track ?track .
```

```
    ?track dc:title ?track_title . }
```

## SPARQL – \* Protocol and RDF Query Language

### SQL

Based on relations (tables).

The relations (tables) to be matched over should be indicated.

(Retrieval) queries produce a relation from a relation.

### SPARQL

Based on labelled directed graphs.

Assumes a default graph.  
(The FROM clause populates this with specific identified subgraphs).

SPARQL SELECT queries produce a relation from a graph.  
CONSTRUCT queries (considered later) produce a graph from a graph.

## SPARQL – \* Protocol and RDF Query Language

- SPARQL 1.1 provides graph update operations:
  - **INSERT DATA:** adds explicit triples, given inline.
  - **DELETE DATA:** removes explicit triples, given inline.
  - **DELETE/INSERT WHERE:** updates based on triples calculated from WHERE clause (as in SELECT and CONSTRUCT).
  - **LOAD:** reads the content of a document into a graph.
  - **COPY/MOVE/APPEND:** manipulates at named graph level.
  - **CLEAR/DROP:** removes all triples in one or more graph.

## SPARQL – \* Protocol and RDF Query Language

*Insert the following albums recorded by The Beatles into the graph*

*[http://myFavGroups/The\\_Beatles](http://myFavGroups/The_Beatles)*

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>
```

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
```

```
INSERT DATA { GRAPH <http://myFavGroups/The\_Beatles> {  
<http://musicbrainz.org/artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d#>  
  foaf:made <http://musicbrainz.org/release/3a685770-7326-34fc-9f18-e5f5626f3dc5#> ,  
  <http://musicbrainz.org/release/cb6f8798-d51e-4fa5-a4d1-2c0602bfe1b6#> .  
  
<http://musicbrainz.org/release/3a685770-7326-34fc-9f18-e5f5626f3dc5#>  
  dc:title "Please Please Me".  
  
<http://musicbrainz.org/release/cb6f8798-d51e-4fa5-a4d1-2c0602bfe1b6#>  
  dc:title "Something New". } }
```

## SPARQL – \* Protocol and RDF Query Language

*Delete all the information about the album Casualties of The Beatles.*

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>
```

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
```

```
DELETE { ?album ?predicate ?object . }
```

```
WHERE {
```

```
<http://musicbrainz.org/artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d>
```

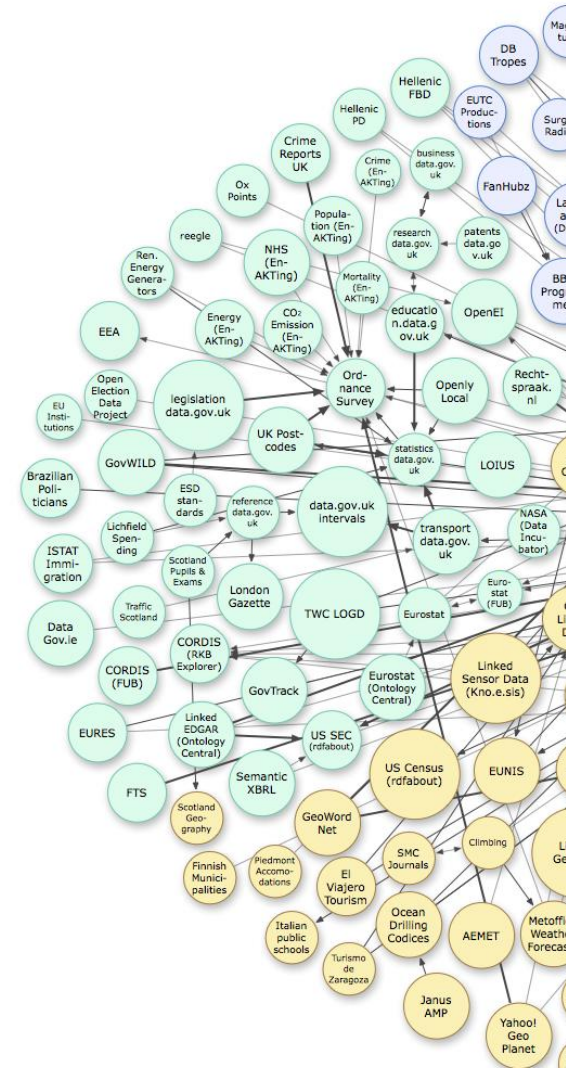
```
    foaf:made ?album .
```

```
?album dc:title "Casualties";
```

```
    ?predicate ?object .}
```

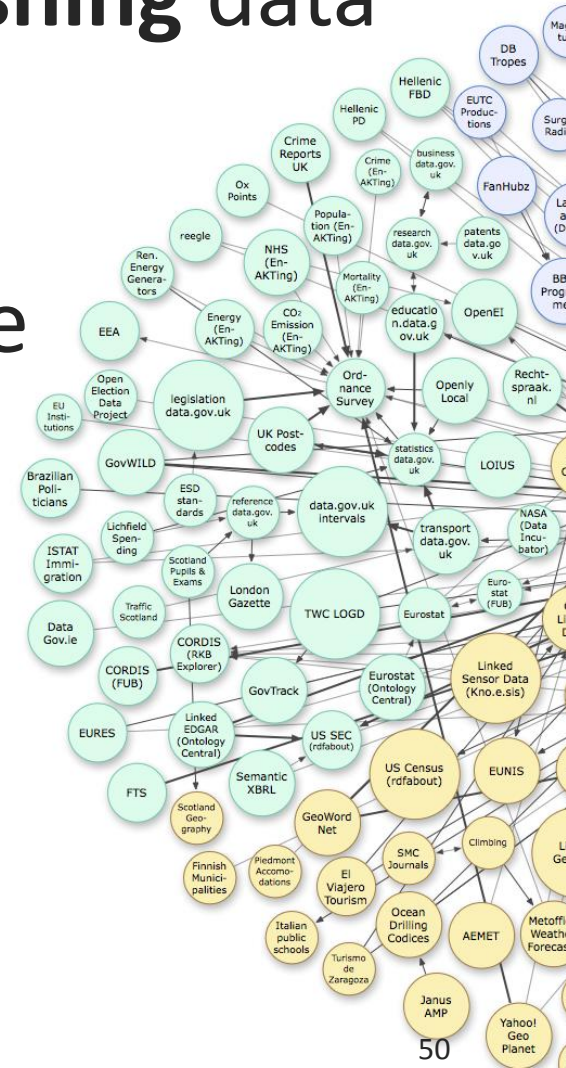


# INTRODUCTION TO: LINKED DATA



# Linked Data

- Set of best practices for **publishing** data on the Web.
- Data from different knowledge domains, self-described, linked and accessible.
- Follows 4 simple principles...



# Linked Data Principles

1. Use URIs as **names** for things.
2. Use HTTP URIs so that users can **look up** those names.
3. When someone looks up a URI, **provide useful information**, using the standards (RDF\*, SPARQL).
4. Include links to other URIs, so that users can **discover** more things.

# Linked Data Principles

## 1. Use URIs as **names** for things.

- A foundational issue in Linked Data was the distinction of URIs for **object documents** that might describe them.

# Linked Data Principles

## 2. Use HTTP URIs so user can **look up** those names.

- HTTP allows a second way to distinguish real-world objects from documents.
- Best practice says HTTP 303 and Location header should be used.

3. When someone looks up a URI, **provide useful information**, using the standards (RDF\*, SPARQL, Turtle<sup>1</sup>).

- While RDF/XML should be the default for look-up.
  - RDFa annotations in HTML are now also standard.
- SPARQL endpoint for queries are encouraged, or a dump of the whole dataset.

<sup>1</sup> To become a standard.

3. When someone looks up a URI, **provide useful information**, using the standards (RDF\*, SPARQL, Turtle<sup>1</sup>).

## What to return for a URI?

- **Immediate description:** triples where the URI is the subject.
- **Backlinks:** triples where the URI is the object.
- **Related descriptions:** information of interest in typical usage scenarios.
- **Metadata:** information as author and licensing information.
- **Syntax:** RDF descriptions as RDF/XML and human-readable formats.

Source: *How to Publish Linked Data on The Web* - Chris Bizer, Richard Cyganiak, Tom Heath.

# Linked Data Principles

4. Include links to other URIs, so that users can **discover** more things.

There are several ways to reuse URIs:

- direct **reuse**
  - (OWL) **sameAs**
  - (RDFS) **seeAlso**
- } Instance Level
- direct **reuse** of class/property
  - (RDFS) **sub-class/-property**
  - (OWL) **equivalent** class/property
  - SKOS **broad match**
- } Schema Level



# Linked Data 5 Star


- ★ Data is available on the Web.
- ★★ Data is available as machine-readable structured data.
- ★★★ Non-proprietary formats are used.
- ★★★★ Individual data identified with open standards.
- ★★★★★ Data is linked to other data provider.

# Linked Data 5 Star

## Example:

My Data

**THE BEATLES**



"John Lennon"

"Paul McCartney"

"George Harrison"

"Ringo Starr"

Please Please Me - 1963 • With The Beatles - 1963  
A Hard Day's Night - 1964 • Beatles For Sale - 1964  
Help! - 1965 • Rubber Soul - 1965  
Revolver - 1966  
Sgt. Pepper's Lonely Hearts Club Band - 1967  
White Album - 1968  
Abbey Road - 1969  
Magical Mystery Tour - 1967  
Yellow Submarine - 1969  
Let It Be - 1970  
Past Masters - 1988


# Linked Data 5 Star



## Data is available on the Web

My Data

**THE BEATLES**



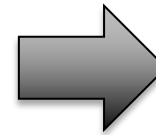
"John Lennon"

"Paul McCartney"

"George Harrison"

"Ringo Starr"

Please Please Me - 1963 • With The Beatles - 1963  
A Hard Day's Night - 1964 • Beatles For Sale - 1964  
Help! - 1965 • Rubber Soul - 1965  
Revolver - 1966  
Sgt. Pepper's Lonely Hearts Club Band - 1967  
White Album - 1968  
Abbey Road - 1969  
Magical Mystery Tour - 1967  
Yellow Submarine - 1969  
Let It Be - 1970  
Past Masters - 1988



It can be retrieved using HTTP.

# Linked Data 5 Star



## Data is available as machine-readable structured data

My Data

"The Beatles"	<a href="http://upload.wikimedia.org/wikipedia/commons/thumb/d/df/The_Fabs.JPG/600px-The_Fabs.JPG">http://upload.wikimedia.org/wikipedia/commons/thumb/d/df/The_Fabs.JPG/600px-The_Fabs.JPG</a>
"John Lennon"	
"Paul McCartney"	Please Please Me – 1963 A Hard Day's Night – 1964
"George Harrison"	Help! – 1965 Revolver – 1966
"Ringo Starr"	...

Machine-readable data:



Images



Scanned Information



Plain text or ...

(to continue on the next slide)

# Linked Data 5 Star



## Non-proprietary formats are used

### My Data

```
<schema "http://www.example.com/2012/XMLMyMusic"
version= "1.0" >
<band>
  <name>The Beatles</name>
  <member>John Lennon</member>
  <member>Paul McCartney</member>
  <member>George Harrison</member>
  <member>Ringo Starr</member>
  <picture>http://upload.wikimedia.org/wikipedia/common
s/thumb/d/df/The_Fabs.JPG/600px-
The_Fabs.JPG</picture>
  <album year=1963>Please Please Me</album>
  <album year=1964>A Hard Day's Night</album>
  <album year=1965>Help!</album>
  <album year=1966>Revolver</album>
  ...
</band>
```

# Linked Data 5 Star



## Individual data identified with open standards

### My Data

```
<schema
"http://www.example.com/2012/XMLMyMusic"
version="1.0" >
<band>
  <name>http://musicbrainz.org/artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d</name>
  <member>http://musicbrainz.org/artist/4d5447d7-c61c-4120-ba1b-d7f471d385b9</member>
  ...

  <album
year=1963>http://musicbrainz.org/release/5f3ba07b-4a24-4cd5-b8ad-95ba0fcebec1</album>
  ...
</band>
```

URI: Uniform Resource Identifier

- Data is uniquely **identified**

→ The Beatles

→ John Lennon

→ Revolver

- **Dissambiguation**

In this context, "Revolver" is an album! Not a gun.



# Linked Data 5 Star



## Data is linked to other data provider

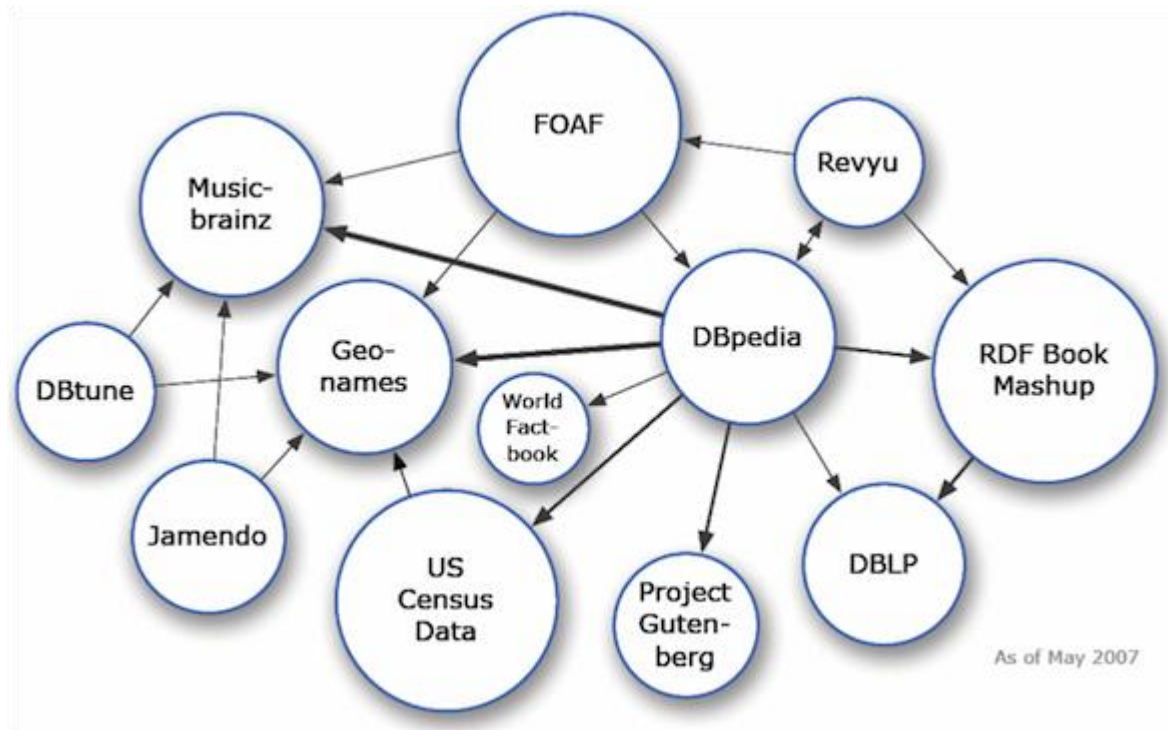
```
<schema
"http://www.example.com/2012/XMLMyMusic"
version="1.0" >
<band>
  <name>http://musicbrainz.org/artist/b10bbbfc-cf9e-42e0-be17-e2c3e1d2600d</name>
  <member>http://musicbrainz.org/artist/4d5447d7-c61c-4120-ba1b-d7f471d385b9</member>
  ...
  <album
year=1963>http://musicbrainz.org/release/5f3ba07b-4a24-4cd5-b8ad-95ba0fcebec1</album>
  ...
  <seeAlso>http://dbpedia.org/resource/The\_Beatles
  </seeAlso>
</band>
```

[http://dbpedia.org/resource/The\\_Beatles](http://dbpedia.org/resource/The_Beatles)



# Linked Data Cloud

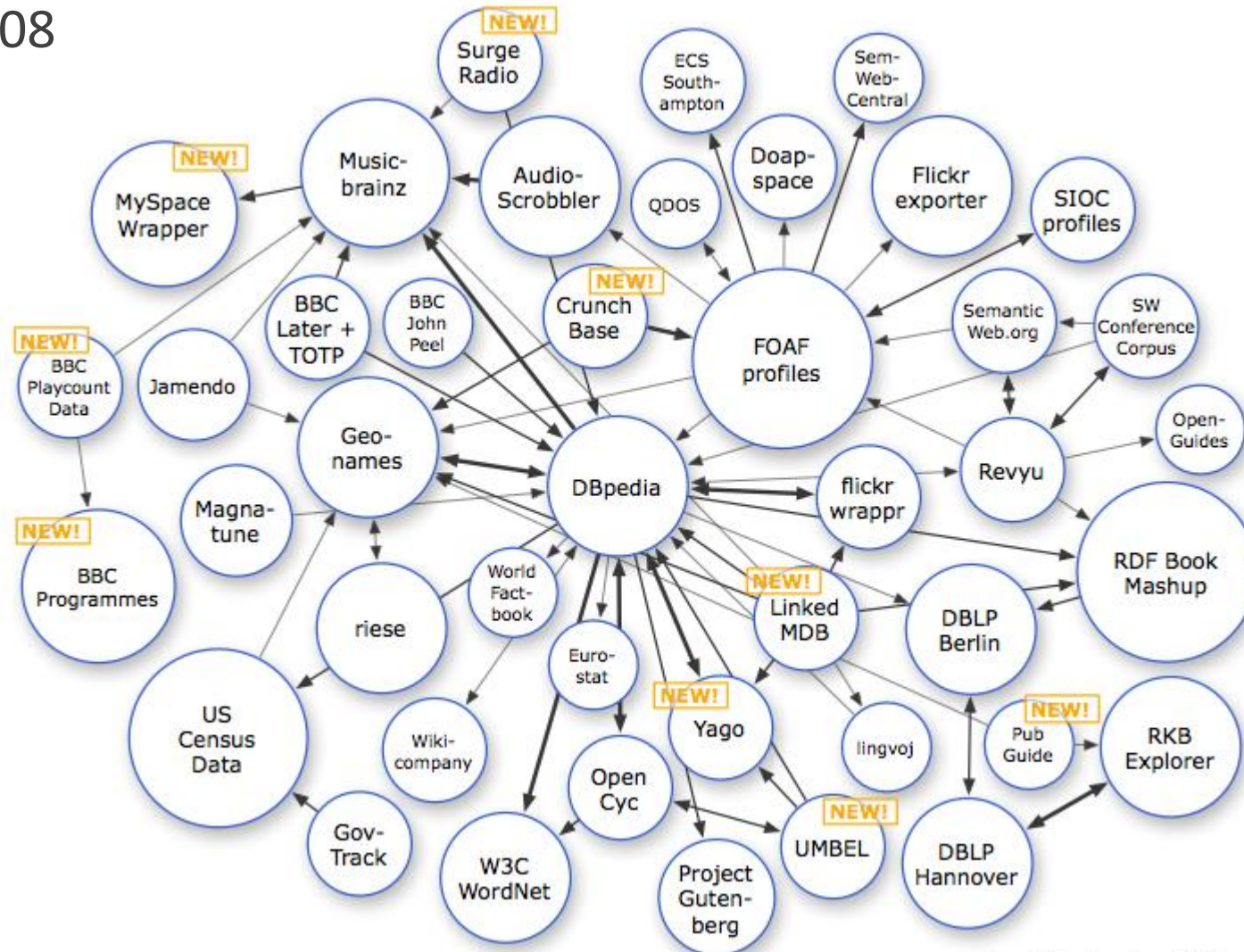
2007





# Linked Data Cloud

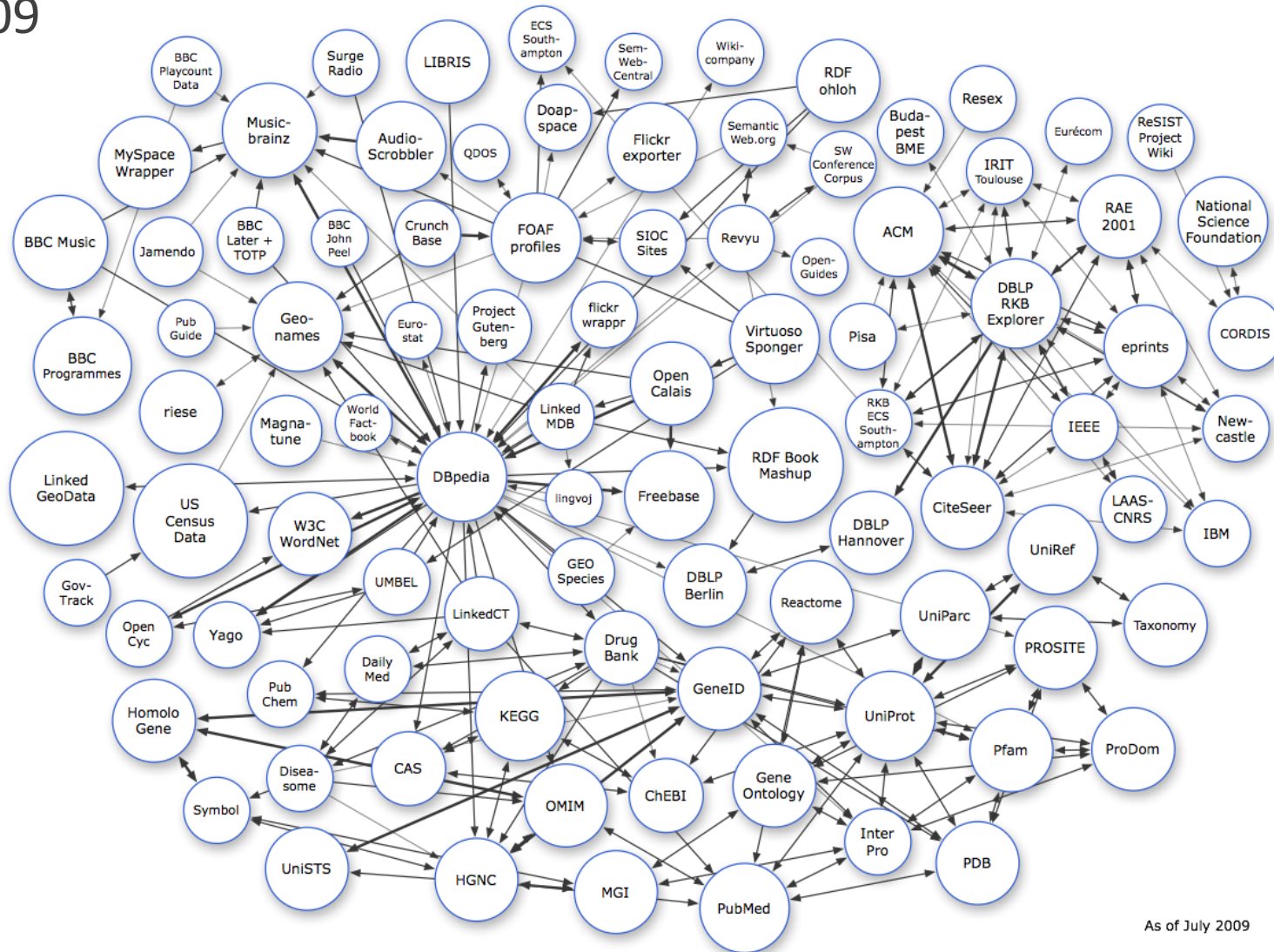
2008



As of September 2008

# Linked Data Cloud

2009

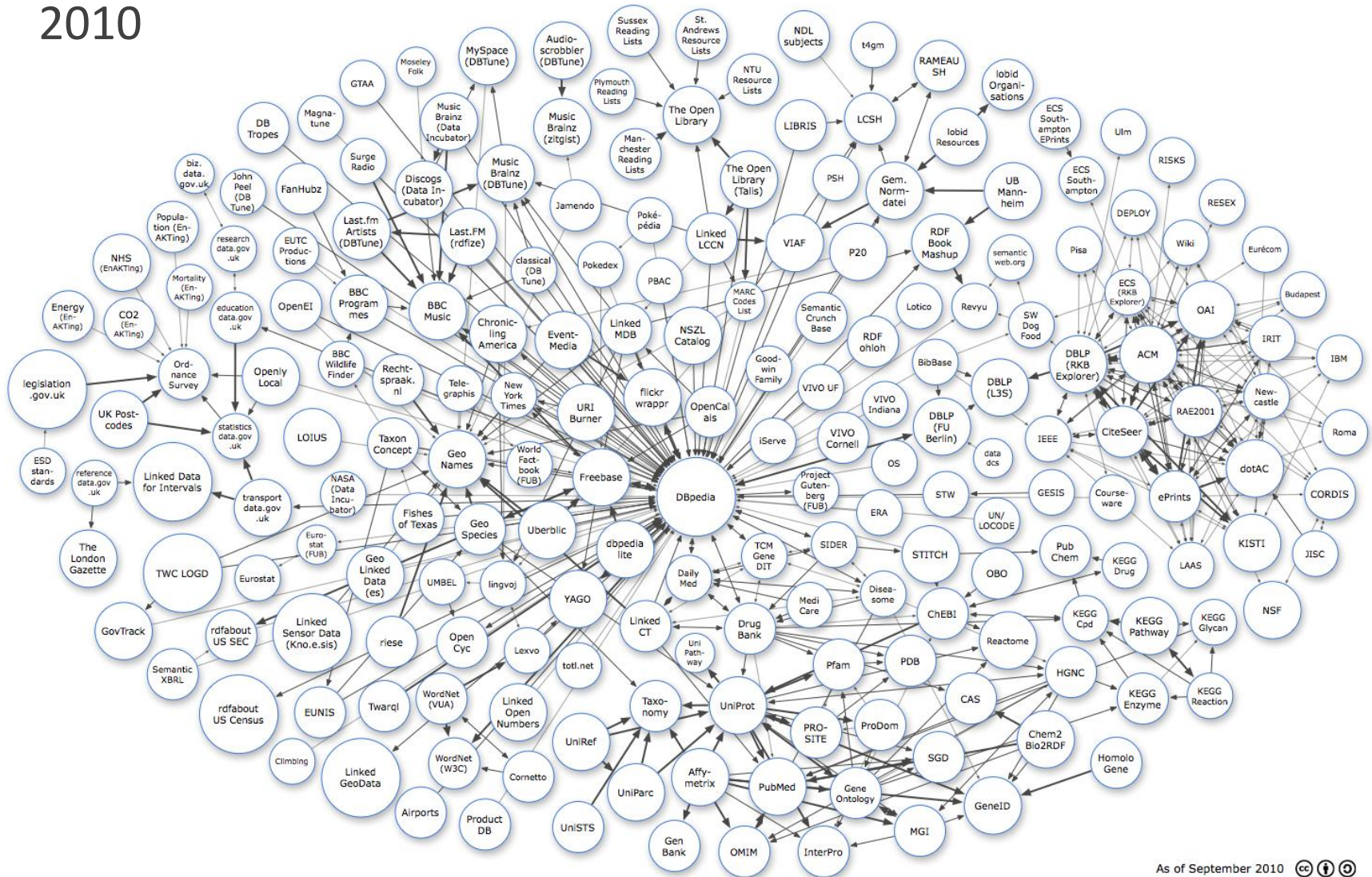


As of July 2009



# Linked Data Cloud

2010



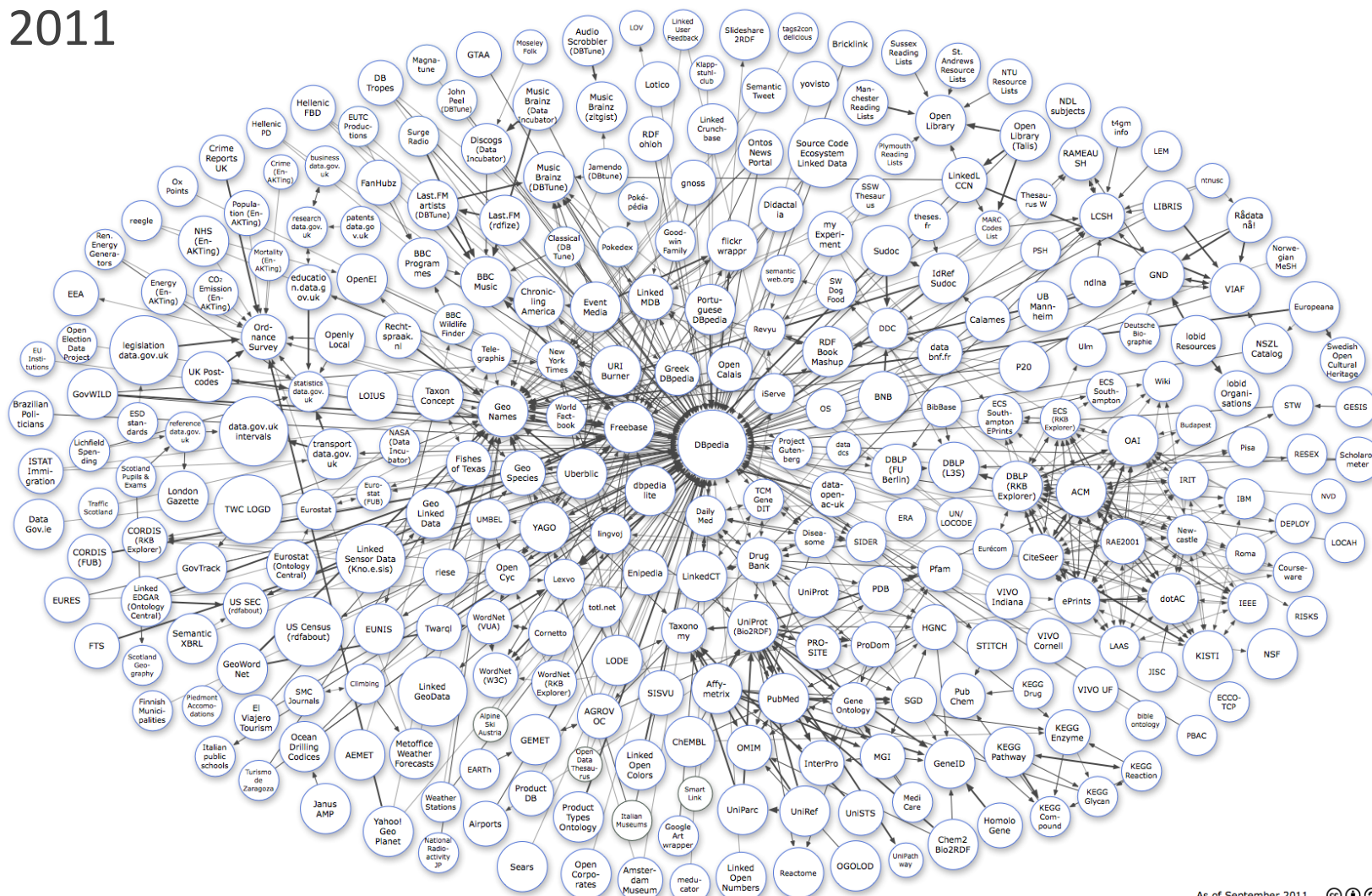
As of September 2010





# Linked Data Cloud

2011



As of September 2011

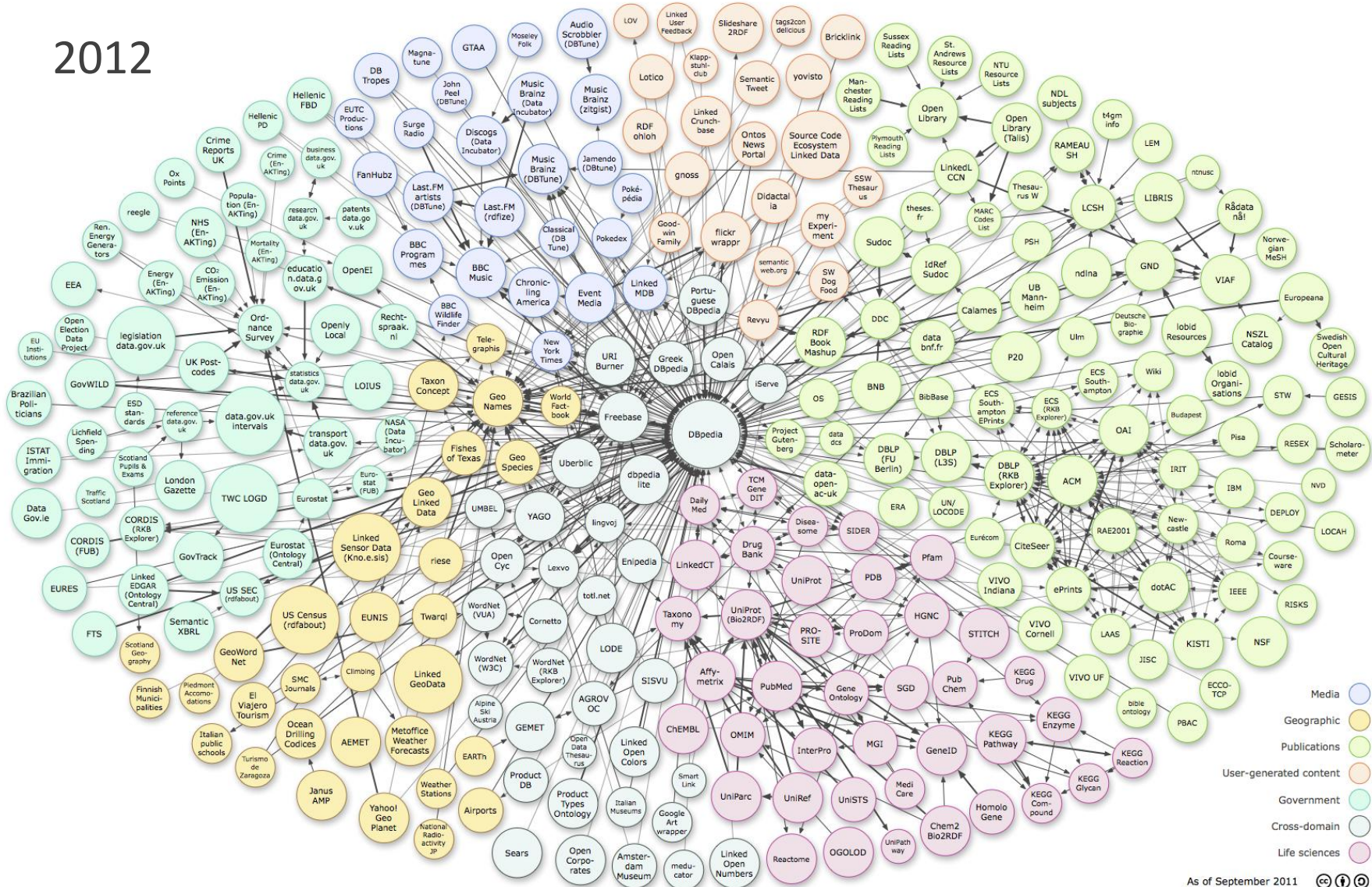




# Linked Data Cloud



2012



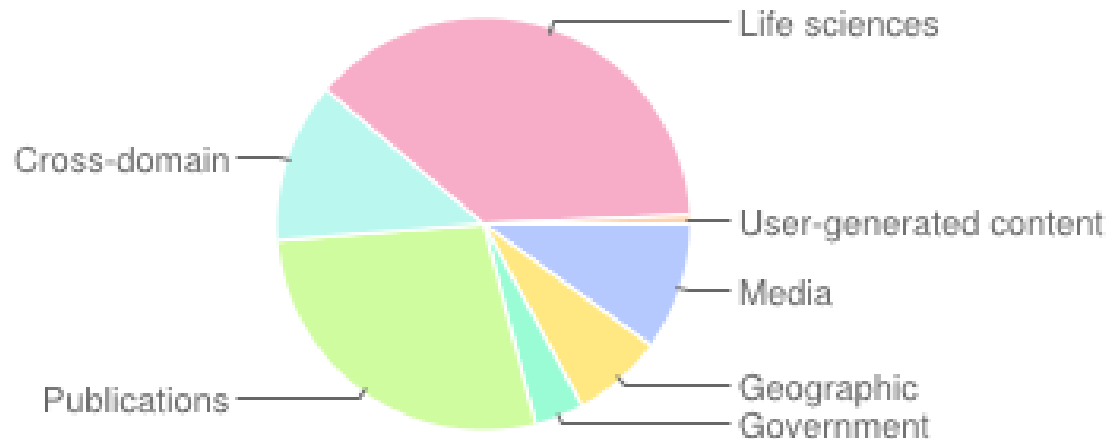
As of September 2011



# State of the LOD Cloud<sup>1</sup>

- Total Datasets:  
**295**

- Total Triples:  
**31,634,213,770**



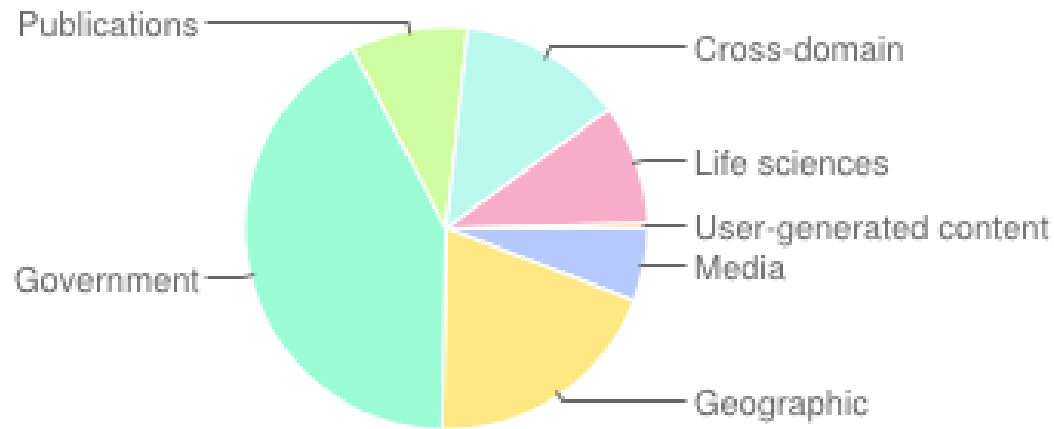
Distribution of triples by domain

<sup>1</sup> Version 0.3, 09/19/2011

<http://www4.wiwiss.fu-berlin.de/lodcloud/state>

# State of the LOD Cloud<sup>1</sup>

- Total (Out-)Links:  
**503,998,829**



Distribution of links by domain

<sup>1</sup> Version 0.3, 09/19/2011

<http://www4.wiwiss.fu-berlin.de/lodcloud/state>

# Exploring the Web of Data

- **Linked Data browsers**
- **Linked Data mashups**
- **Search engines**



# Linked Data Browsers

## Marbles

The screenshot shows the Marbles browser interface for the profile of Tim Berners-Lee. The browser address bar displays the URL `http://www.w3.org/People/Berners-Lee/card#i`. The profile page includes a title "Tim Berners-Lee", a URL `http://www.w3.org/1999/02/22-rdf-syntax-ns#type`, and various properties such as `name`, `image`, `homepage`, `works`, `name`, `Open name`, and `birth name`. Each property is accompanied by a list of values, often with small colored circles representing different data sources. A photograph of Tim Berners-Lee is displayed under the `image` property. At the bottom, a "Sources" section lists the URLs of the data sources used to populate the profile, including `http://www.w3.org/People/Berners-Lee/` and `http://www.w3.org/1999/02/22-rdf-syntax-ns#type`.

<http://marbles.sourceforge.net>

# Linked Data Mashup

## Revyu.com

**ReVYU.COM**  
ReView ANYTHING

[Home](#) | [Browse Things](#) | [Search Things](#) | [Browse People](#)  
[Login/Register](#) | [New Review](#)

### Broken Flowers


**Links**  
Homepage: <http://www.brokenflowersmovie.com/>  
See Also: [http://en.wikipedia.org/wiki/Broken\\_flowers](http://en.wikipedia.org/wiki/Broken_flowers)

**Tags**  
[bill-murray](#) [film](#) [jessica-lange](#) [jim-jarmusch](#) [julie-delpy](#) [movie](#) [sharon-stone](#)

**Reviews (1)**  
★★★★★ [by tom on 30 Jan 2007](#)

Broken Flowers provides a fantastic vehicle for a classic deadpan Bill Murray performance. The film centers around his character Don, who one day receives a letter from an ex-girlfriend, telling him he has a teenage son. The letter is unsigned, so (with encouragement from his neighbour) he sets off round the country, visiting each the exes who could be the mother of his son. Predictably they're all different in personality and life situation, giving plenty of raw material for awkward silences and dubious encounters. This is great viewing for any Bill Murray fans, or anyone who likes their humour intelligent and a little bit quirky. The soundtrack is also excellent, and deserves a separate review.

What do you think of **Broken Flowers**? [Write Your Own Review...](#)

**Broken Flowers**  
  
directed by [Jim Jarmusch](#)  
[RDF Metadata About Broken Flowers](#)  
[Write a Review of Broken Flowers](#)  
[Add to del.icio.us](#)

Revyu.com: [Contact](#) | [Credits](#) | [Privacy Policy](#) | [Disclaimer](#)

<http://revyu.com>

# Linked Data Mashup

## DBPedia Mobile



Pictures from revyu.com



<http://wiki.dbpedia.org/DBpediaMobile>

# Linked Data Mashup

## SIGMA

**SIGMA**  
SEMANTIC INFORMATION MASHUP

Help About Forum

Version: 1.1.33

tim berners-lee [Add More Info](#) [Start New](#) [Order](#) [Options](#) [Use it](#)

**Tim Berners-Lee**

picture:  [9,11,12,14,15,17,18,19,20] [9,10,13]

**given name:** Tim [1,11,12,14,15,17,18,19,20]

**family name:** Berners-Lee [1,11,12,14,15,17,18,19,20]

**comment:** Sir Timothy John "Tim" Berners-Lee, OM, KBE, FRS, FEng, FRSA (born 8 June 1955, also known as "TimBL"), is a British engineer and computer scientist and MIT professor credited with inventing the World Wide Web, making the first proposal for it in March 1989. On 25 December 1990, with the help of Robert Cailliau and a young student at CERN, he implemented the first successful communication between an HTTP client and server via the Internet.

[hide value](#) [just this value](#) [which sources](#) [reject sources](#)

Sir Timothy John Berners-Lee, OM, KBE, FRS ist ein britischer Informatiker. Er ist der Erfinder der HTML (Hypertext Markup Language) und der Begründer des World Wide Web. Heute steht er dem World Wide Web Consortium (W3C) vor und ist Professor am Massachusetts Institute of Technology (MIT). [9,13,10]

蒂莫西·约翰·“蒂姆”·伯纳斯-李爵士，OM，KBE，FRS，FEng，FRSA（Sir Timothy John "Tim" Berners-Lee，1955年6月8日 - ），生於英國倫敦，是万维网的发明者，現任麻省理工學院正教授。1990年12月25日，在罗伯特·卡里奥与CERN的一名年轻学生的帮助下，他成功地通过Internet实现了HTTP代理与服务器的第一次通讯。他是监视万维网发展的万维网联盟（總部位於麻省理工學院）的主席。2009年4月，他在华盛顿成为美国国家科学院院士。 [9,13,10]

**is creator of:** [Tabulator](#) [9,10,11,12,13,14,15,17,18,19,20]

**alternate:** [http://rdf.freebase.com/rdf/en.tim\\_berners-lee](http://rdf.freebase.com/rdf/en.tim_berners-lee) [6]

**author name:** vicente181096 [5]

**author url:** <http://www.slideshare.net/vicente181096> [5]

**admins:** 1124331582,500054654,220400,512158401,808970553,1502271052,695398126 [3]

**birth year:** 1955-01-01 00:00:00 [9]

Sources (20)  Approved (0)  Rejected (0)

- 1 [Tim Berners-Lee - Wikiped...](#) 12 facts | 2011-05-19  
[http://en.wikipedia.org/wiki/Tim\\_Berners-...](http://en.wikipedia.org/wiki/Tim_Berners-...)
- 2 [Tim Berners-Lee: Biograp...](#) 9 facts | 2011-05-19  
<http://www.answers.com/topic/tim-berners-...>
- 3 [Untitled document](#) 10 facts | 2011-05-24  
<http://www.time.com/time/magazine/article...>
- 4 [Tim Berners-Lee](#) 2 facts | 2011-05-19  
[http://schools-wikipedia.org/wp/t/Tim\\_Ber...](http://schools-wikipedia.org/wp/t/Tim_Ber...)
- 5 [Untitled document](#) 14 facts | 2011-01-13  
<http://www.slideshare.net/api/oembed/1?format=xml&su...>
- 6 [Tim Berners-Lee facts - ...](#) 4 facts | 2011-02-23  
[http://www.freebase.com/view/en/tim\\_berne...](http://www.freebase.com/view/en/tim_berne...)
- 7 [SIOC profile for "http://..."](#) 2016 facts | 2011-02-10  
<http://ws.sioc-project.org/mediawiki/mediawiki.php?...>
- 8 [Untitled document](#) 4 facts | 2011-02-03  
<http://linkeddata.uriburner.com/sparql?default-grap...>
- 9 [About: Tim Berners-Lee](#) 130 facts | 2011-05-18  
[http://dbpedia.org/page/Tim\\_Berners-Lee](http://dbpedia.org/page/Tim_Berners-Lee)
- 10 [Untitled document](#) 218 facts | 2011-01-10  
<http://linkeddata.uriburner.com/sparql?default-grap...>
- 11 [Tim Berners-Lee](#) 130 facts | 2011-05-23  
[http://dbpedia.org/8890/resource/Tim\\_Berners-Lee](http://dbpedia.org/8890/resource/Tim_Berners-Lee)
- 12 [Timothy Berners-Lee](#) 137 facts | 2011-05-18  
[http://dbpedia.org/resource/Tim\\_Berners-Lee](http://dbpedia.org/resource/Tim_Berners-Lee)
- 13 [About: Timothy Berners-L...](#) 224 facts | 2011-02-03  
<http://linkeddata.uriburner.com/about/html/http://d...>
- 14 [Untitled document](#) 137 facts | 2011-05-18  
[http://dbpedia.org/data/Tim\\_Berners-Lee.xml](http://dbpedia.org/data/Tim_Berners-Lee.xml)
- 15 [Untitled document](#) 136 facts | 2011-05-19  
[http://dbpedia.org/data/Tim\\_Berners-Lee.n3](http://dbpedia.org/data/Tim_Berners-Lee.n3)
- 16 [Berners-Lee, Tim: bibli...](#) 42 facts | 2011-01-14

<http://sig.ma>

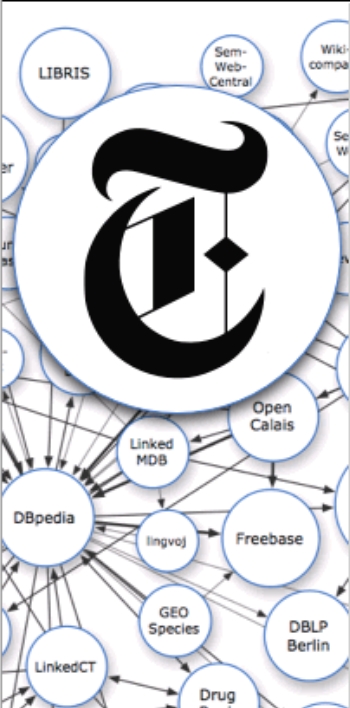


# Linked Data Search Engines

## NYTimes

The New York Times View Application Source

## Linked Open Data BETA




LIBRIS Sem-Web-Central Wiki compa  
Open Calais  
Linked MDB  
DBpedia Ingvj Freebase  
GEO Species DBLP Berlin  
LinkedCT Drug Bank

### Alumni In The News

Enter a school name below and see our coverage of that school's alumni.

---



**George Miller**  
Attorney  
Born: May 17, 1945


### San Francisco State University

- Congress Considers Concussion Protections - September 24, 2010
- EDITORIAL; Fairness for Older Workers - September 14, 2010
- EDITORIAL; Saving the Teachers - May 06, 2010
- House Bill Would Assure Workers Paid Sick Days - November 04, 2009
- EDITORIAL; Preventing Age Discrimination - October 13, 2009
- OP-ED COLUMNIST; Someday, a Bill Will Pass - September 17, 2009
- Obama Plan to End Role of Banks in Federal Student Loans Wins Support - July 11, 2009
- House Unveils Health Bill, Minus Key Details - June 20, 2009
- Democrats Nearing Consensus on Health - June 10, 2009
- U.S. Charges 7 Accused of Ties To Bonannos - August 29, 2008

Please note that portions of this application rely on user generated data from external sources. It is hoped but not guaranteed that this data is accurate.

[About This Page](#) | [Copyright 2009 The New York Times Company](#) | [Terms of Service](#) | [Privacy Policy](#) | [Work for Us](#)

<http://data.nytimes.com/schools/schools.html>



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# Some Application Scenarios

## BBC

The screenshot shows the BBC Music website interface. At the top, there's a navigation bar with 'BBC' logo, 'Sign in', and various menu items like 'News', 'Sport', 'Weather', 'iPlayer', 'TV', 'Radio', 'More...', 'London 2012', and a search bar. Below this is a 'MUSIC' section with sub-links for 'HOME', 'SHOWCASE', 'REVIEWS', and 'GENRES'. A search bar for 'Search By Artist...' is also present. The main content area features a large video player for 'The Beatles' with a play button. Below the video, there's a section titled 'Brian Epstein Finds The Beatles' with a brief description. To the right, there's a 'Share This Page' section with social media buttons for Facebook and Twitter, and a 'BBC Music Showcase' section with a 'BBC MUSIC SHOWCASE' button. At the bottom right, there's a 'Latest Tracks Played On The BBC' section listing tracks like 'Twist & Shout', 'Tomorrow Never Knows', 'She Loves You', and 'Sgt Pepper's Lonely Hearts/With A Little Help'. A carousel at the bottom shows related content like 'Ringo Starr on the Beatles...' and 'The Beatles and Brian...'. The BBC logo is visible in the top left corner of the page.

# Some Application Scenarios

## LinkedGeoData.org



This faceted Linked Geo Data browser is based on data obtained from the [OpenStreetMap project](#) (released under [CC-BY-SA](#)) and was developed by [AKSW research group](#).

Search results powered by Nominatim

four search was: 'berlin'

1. **Berlin**
2. **Berlin**  
Deutschland, Europe
3. **Berlin**  
Coos, New Hampshire, United States of America
4. **Berlin**  
Berlin, Stadt, Mitte, Berlin, Deutschland, Europe
5. **Berlin**  
Worcester County, Maryland, United States of America
6. **Berlin**  
Hartford, Connecticut, United States of America
7. **Berlin**  
LaMoure, North Dakota, United States of America
8. **Berlin**  
Coos, New Hampshire, United States of America
9. **Berlin**  
Camden, New Jersey, United States of America
10. **Berlin**

**View**  
[node:697335603](#)  
[Edit on OpenStreetMap](#)

Name	
Description	
Image	
Source_ref	
natural	stone
historic	monument

# Some Application Scenarios

## Linked Government Data: USA

An Official Web Site of the United States Government Tuesday, May 24, 2011 Text: A+ A- A Share

**DATA.GOV**  
EMPOWERING PEOPLE

HOME DATA APPS COMMUNITY METRICS OPEN DATA SITES GALLERY WHAT'S NEW

### Earthquake and Tsunami Datasets and Information

- Worldwide M1+ Earthquakes, Past 7 Days
- RadNet Map Interface for Near-Real-Time Radiation Monitoring Data
- Search other related datasets
- World Earthquake Interactive Map Demo

SEARCH OUR CATALOGS

Search our catalogs.. SEARCH

### WORLDWIDE M1+ EARTHQUAKES, PAST 7 DAYS

Real-time, worldwide earthquake list for the past 7 days

### DATA AND APPS

- 389,714 raw and geospatial datasets
- 977 government apps
- 236 citizen-developed apps

### COMMUNITIES

Come explore, discuss, meet others in the same field, and develop the data and apps in the community that you care about. Join in the

### OPEN GOVERNMENT

Latest News: Japanese Earthquake and Radiation Data



# Some Application Scenarios

## Linked Government Data: UK

The screenshot shows the data.gov.uk website. At the top, there is a black navigation bar with the HM Government logo on the left and a 'Log in or sign up' link on the right. Below this is a white header area with the 'data.gov.uk BETA' logo and the tagline 'Opening up government'. A search bar with the placeholder text 'What are you looking for?' and a green 'Search' button is positioned to the right of the logo. A green navigation menu contains links for 'Data', 'Apps', 'Ideas', 'Forum', 'Wiki', 'Blogs', 'Linked Data', 'Resources', and 'About'. The main content area is divided into several sections. On the left, there is a vertical list of links: 'Call for dataset requests', 'Instructions for data publishers', 'Public Data Corporation', and 'Met office data'. The central part of the page features a large image of a data table with a green overlay that reads 'Instructions for data publishers' and 'Calling all data publishers - new guide to publishing to data.gov.uk'. To the right of this image, there is a section titled 'Over 6,900 datasets to view' and 'Inside Government Data', which includes a paragraph of text and three expandable links: 'Government spend over £25,000, by department', 'Who does what in Whitehall - and how much are they paid?', and 'Hospitality, gifts and expenses'. Below this section is a 'Share this' button with social media icons for Twitter, Facebook, and LinkedIn. At the bottom of the page, there is a dark grey bar with the text 'Facts, figures, apps and more'. This bar contains three columns: 'Find data of interest' with a description and a green image, 'Apps' with a description and a blue image, and 'Tags' with a list of tags: 'health (2,328)', 'care (1,646)', 'transparency (1,594)', and 'communities (1,318)'.

# Summary

In this chapter we studied:

- **The Web** and its evolution.
- Web technology basics: **HTTP, HTML, URI**.
- **Vocabularies** to describe data.
- The **Semantic Web stack**: RDF, RDF-S, OWL, SPARQL.
- **Linked Data** concept and principles.
- Evolution of the **LOD cloud**.
- Browsers, mashups and search engines to **explore the Web of Data**.
- Some **application** scenarios.



@euclid\_project