Programming the Semantic Web

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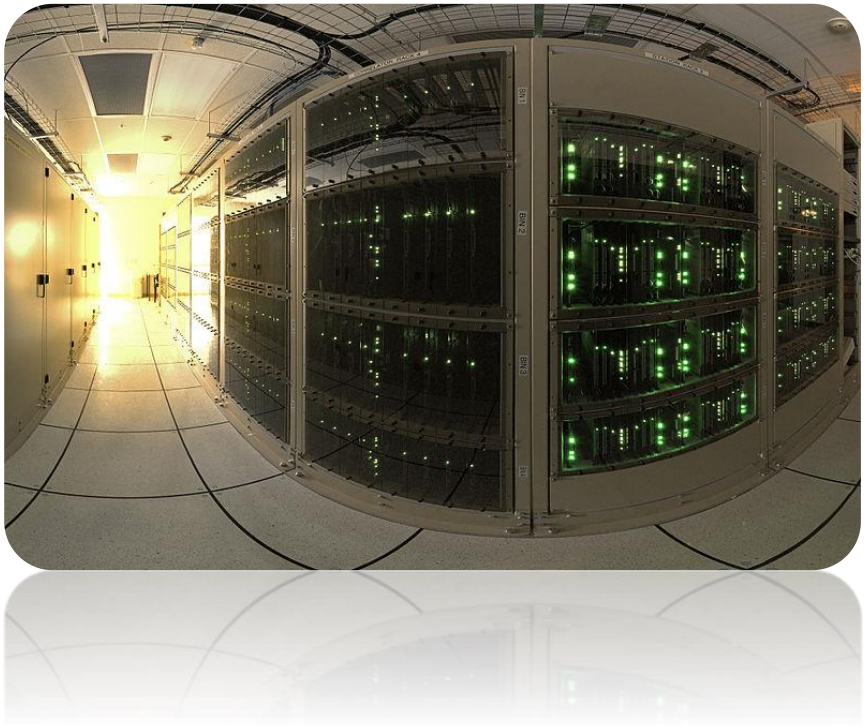
Thomas Gottron, Stefan Schegelmann
& Team

WeST
People and Knowledge Networks

Linked Open Data – Vision of a Web of Data

- „Classic“ Web
  - Linked documents
- Web of Data
  - Linked data entities



Linked Open Data – Vision of a Web of Data

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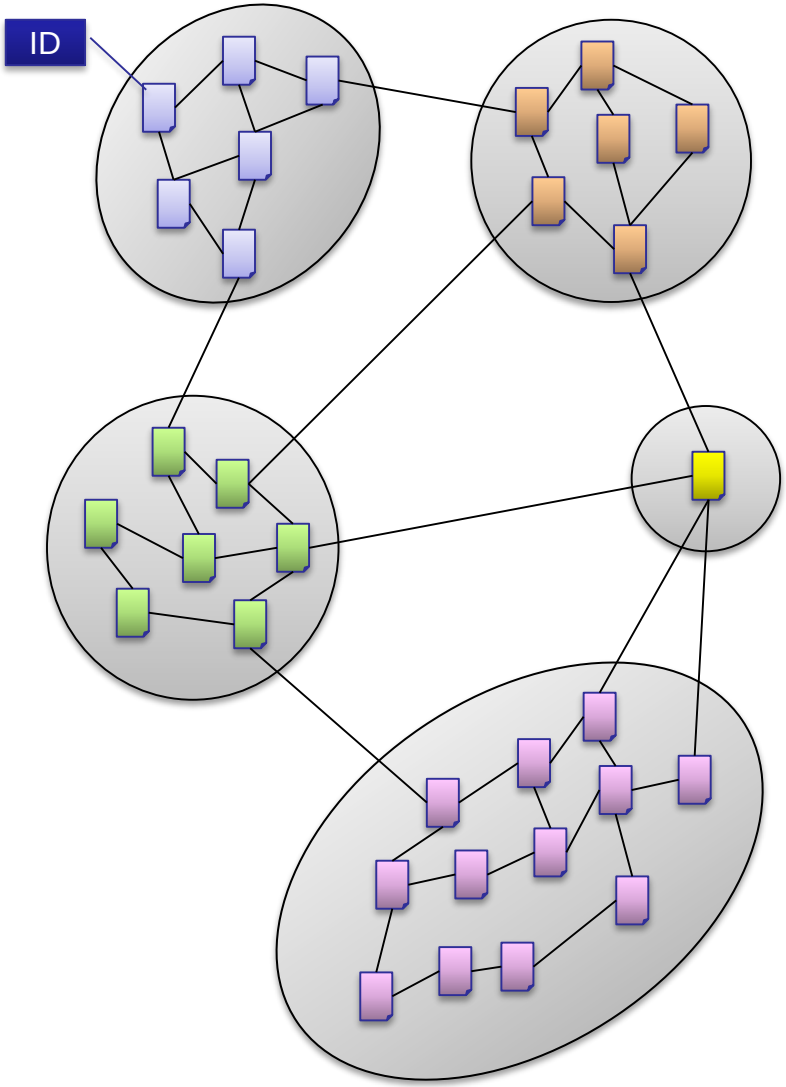
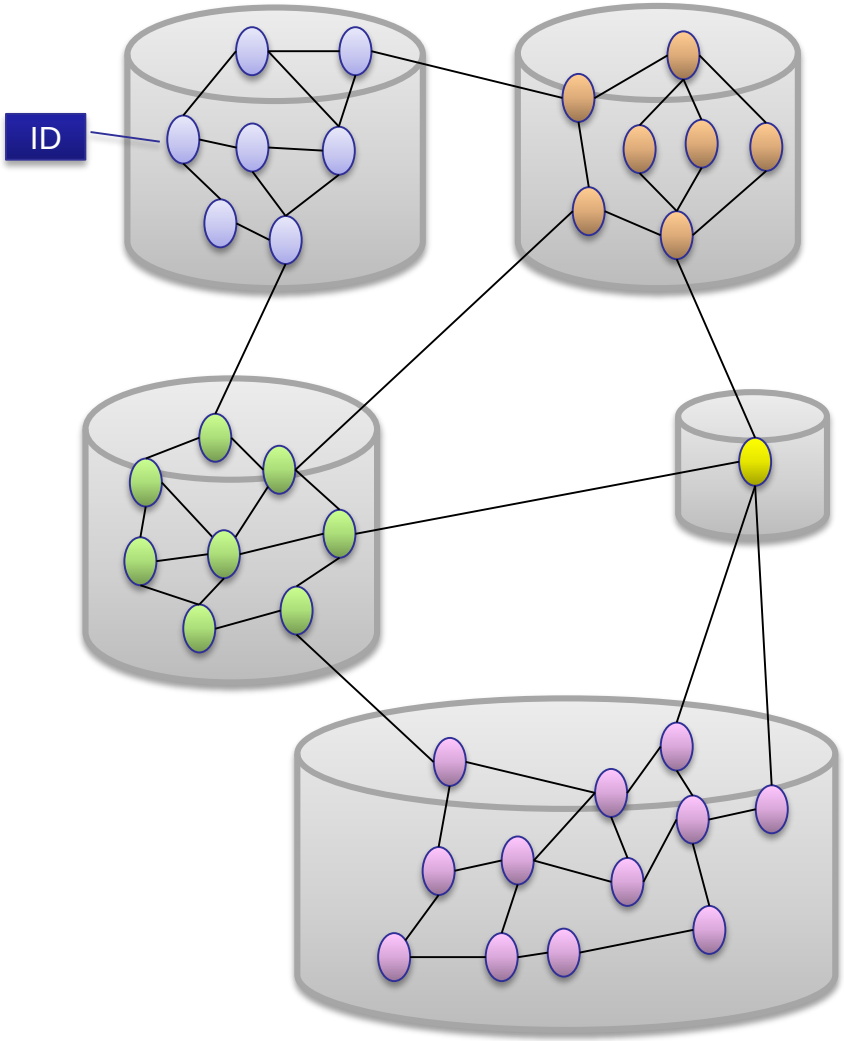


- Web of Data

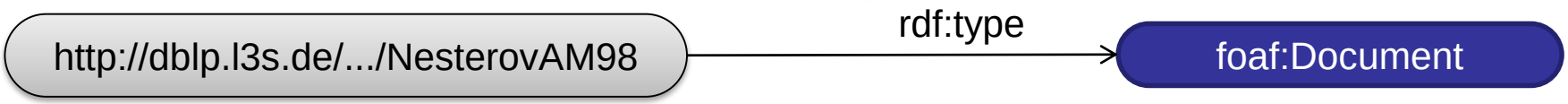


LOD – Base technologies

- IDs: Dereferencable HTTP URIs
- Data Format: RDF
-
-

1 Statement = 1 Tripel

Subject Predicate Object



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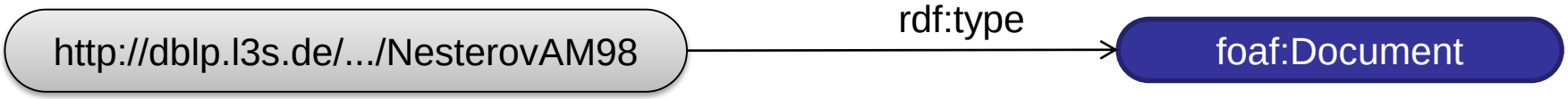
-

rdf:type	= http://www.w3.org/1999/02/22-rdf-syntax-ns#type
foaf:Document	= http://xmlns.com/foaf/0.1/Document



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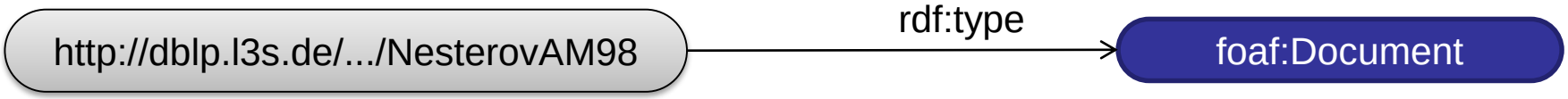

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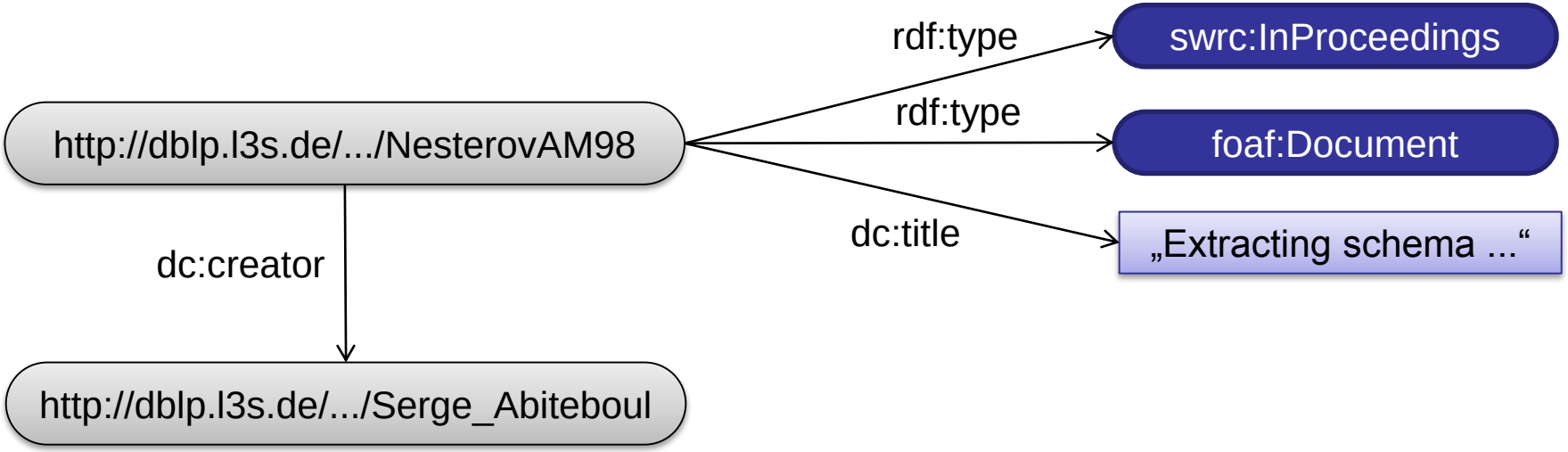

LOD – Base technologies

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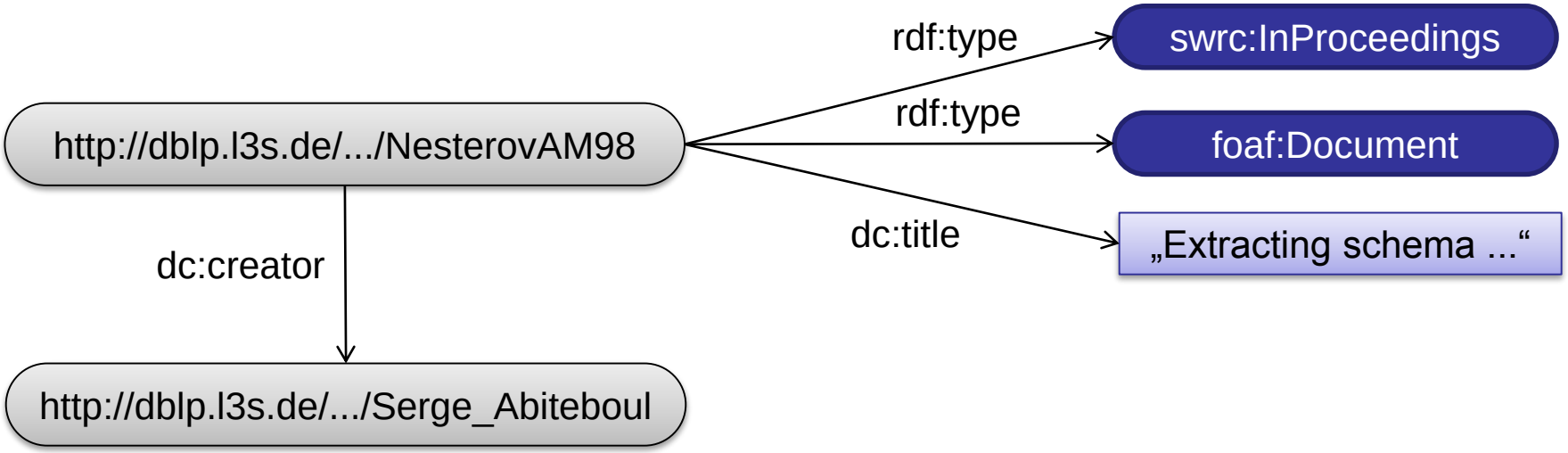
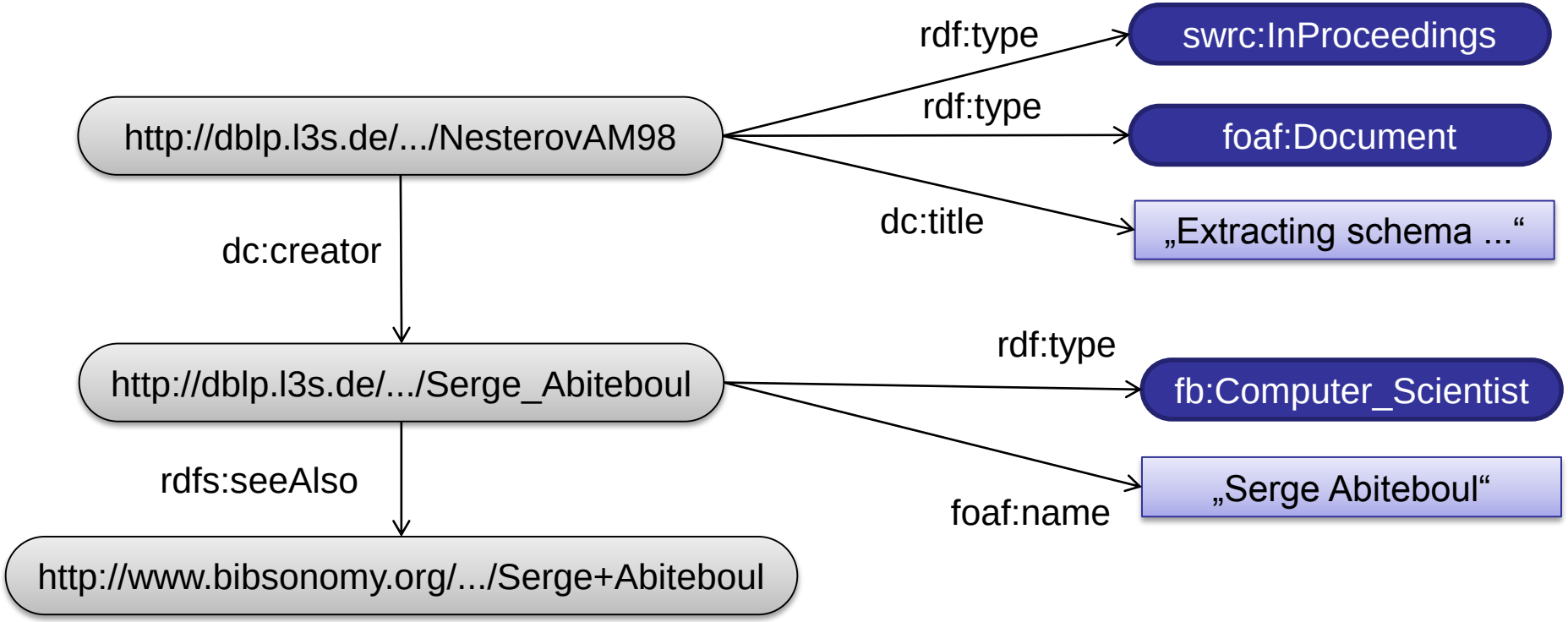
- No schema often / rich schema sometimes
-

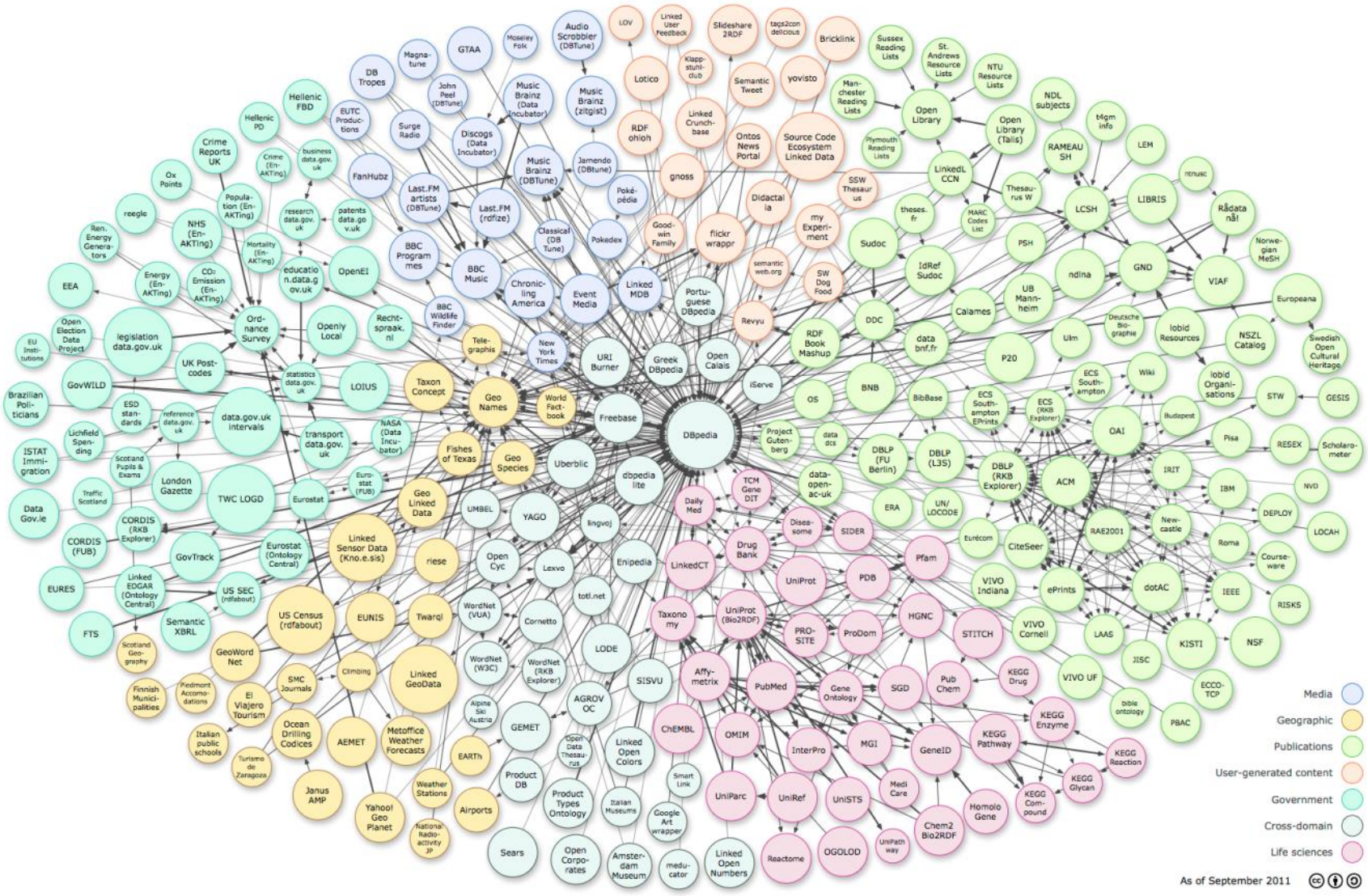


LOD – Base technologies

- IDs: Dereferencable HTTP URIs
- Data Format: RDF
- No schema often / rich schema sometimes
- Links to other data sources



LOD Cloud


DBpedia
Freebase
Geo Names
Geo Species
Geo Linked Data
Linked Sensor Data (Kno.e.sis)
Linked GeoData
Linked Open Colors
Linked Open Numbers
Linked Open Data Thesaurus
Linked User Feedback
Linked Crunchbase
Linked MDB
Linked EDGAR (Ontology Central)
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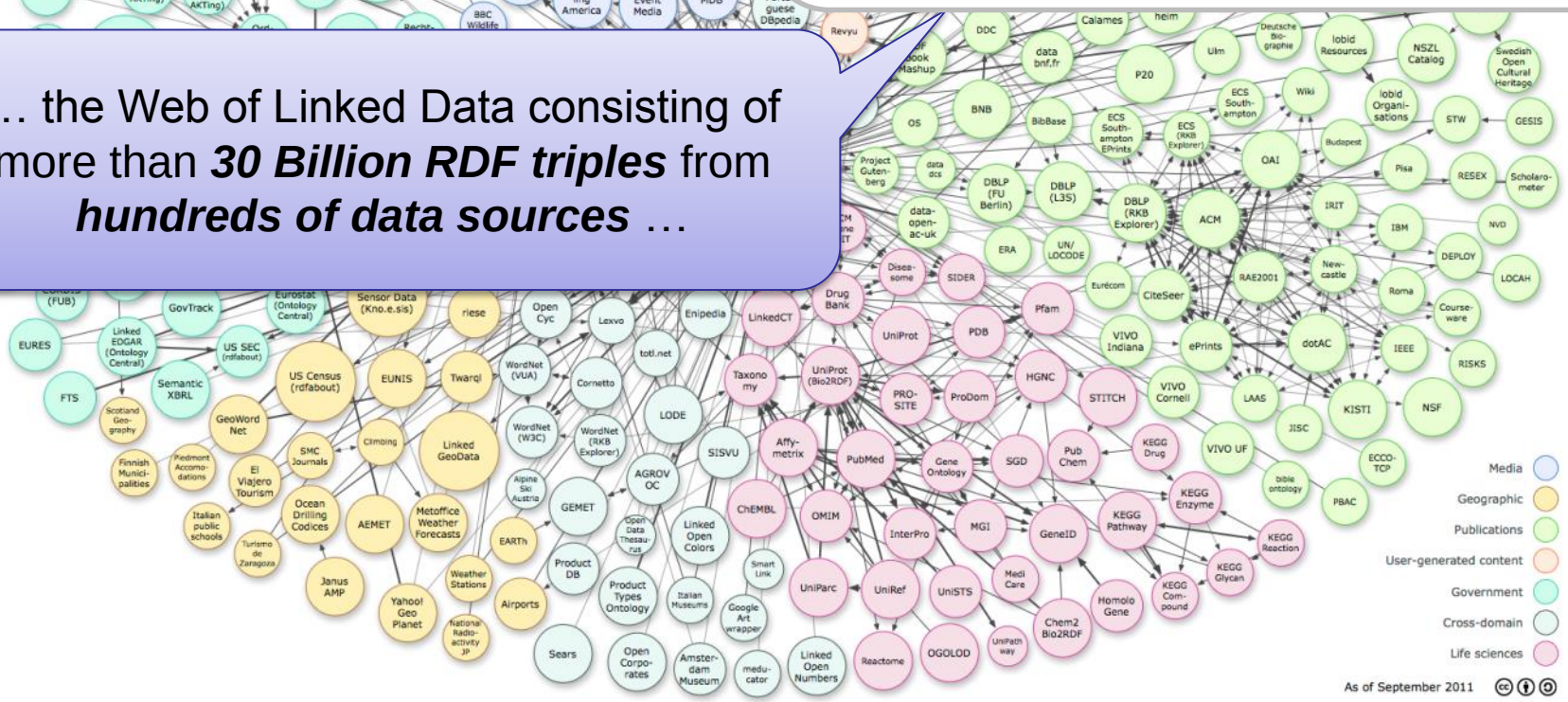
Linked Sensor Data (Kno.e.sis)
Linked User Feedback
Media
Geographic
Publications
User-generated content
Government
Cross-domain
Life sciences
As of September 2011

LOD Cloud

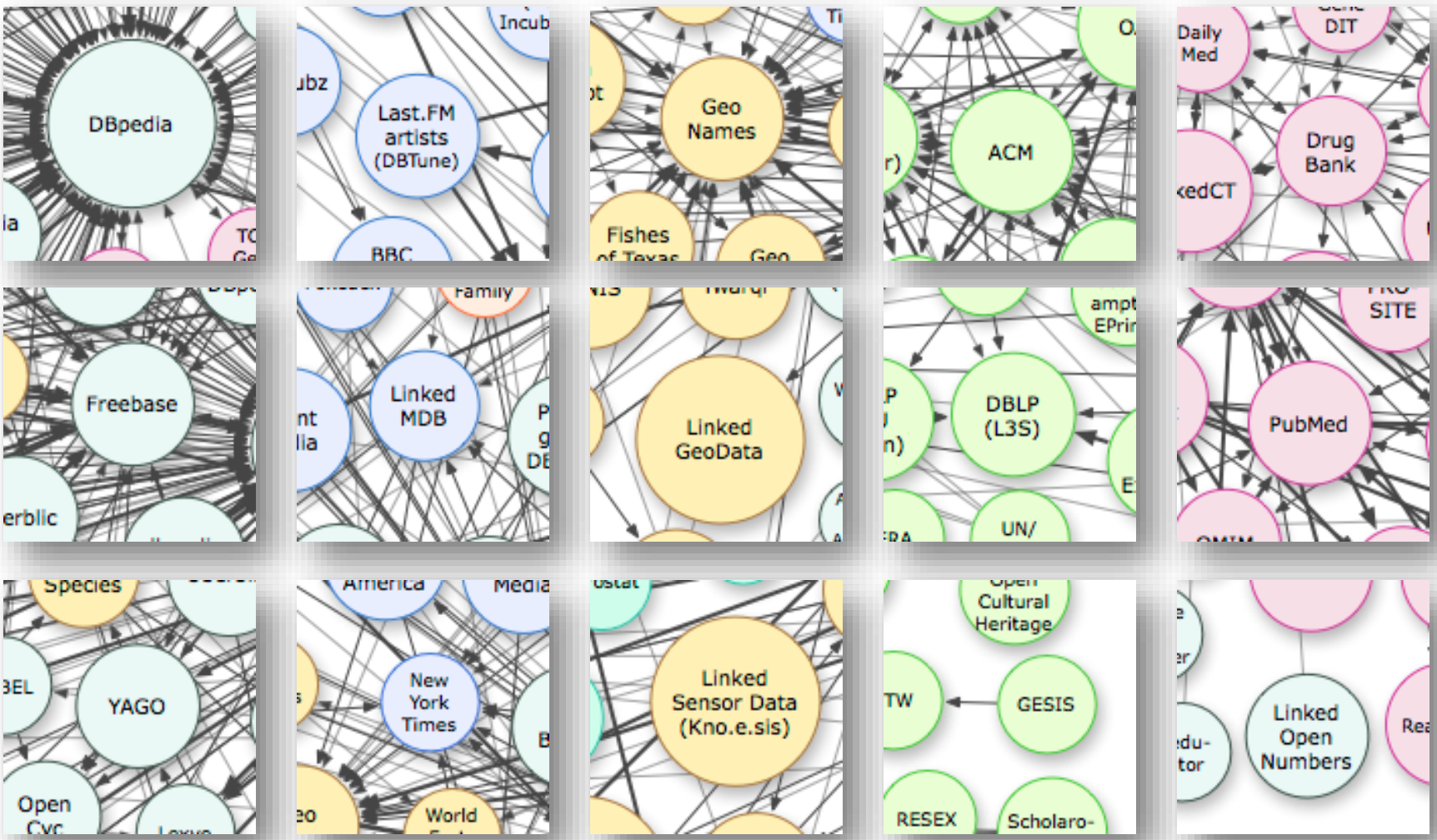
Where's the Data in the Big Data Wave?

Gerhard Weikum
SIGMOD Blog, 6.3.2013
http://wp.sigmod.org/

… the Web of Linked Data consisting of more than ***30 Billion RDF triples*** from ***hundreds of data sources*** …



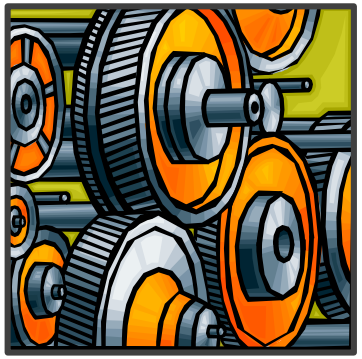
Some „Bubbles“ of the LOD Cloud



Agenda

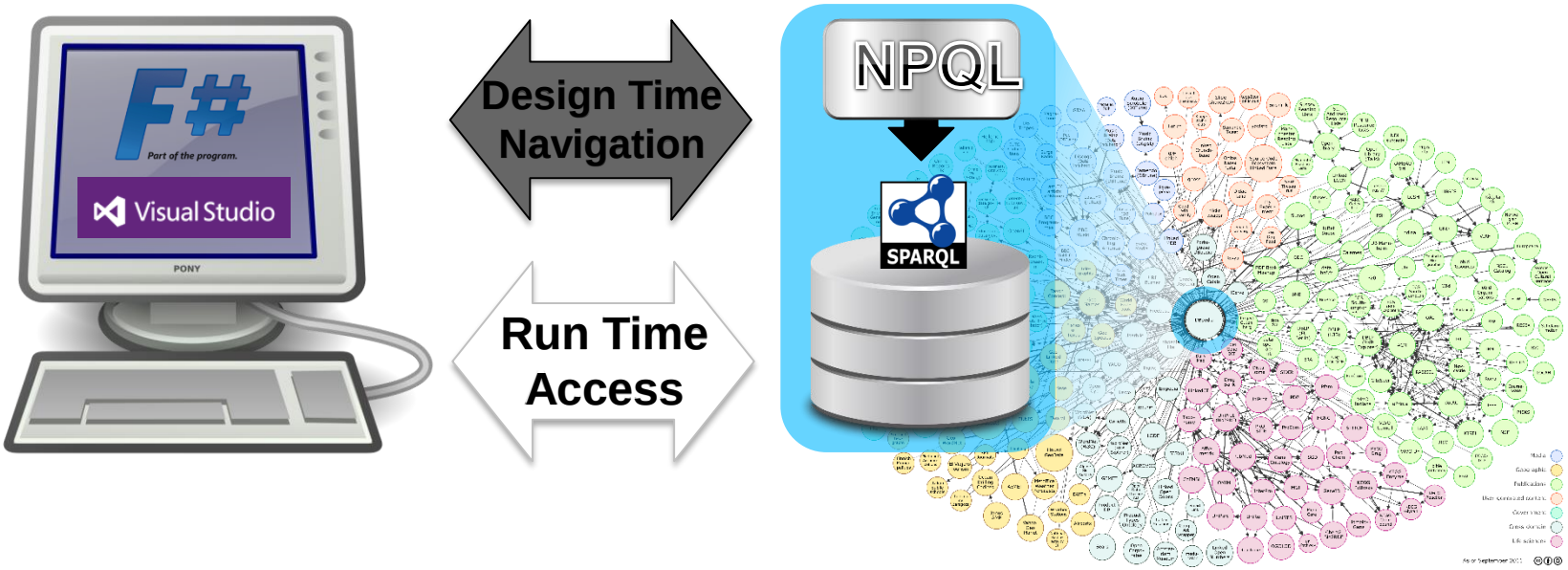
- LiteQ – Language integrated types, extensions and queries for RDF graphs
  - Exploring
  - Programming, Typing

- SchemEX
  - Where do I find relevant data?
  - Efficient construction of a schema-level index

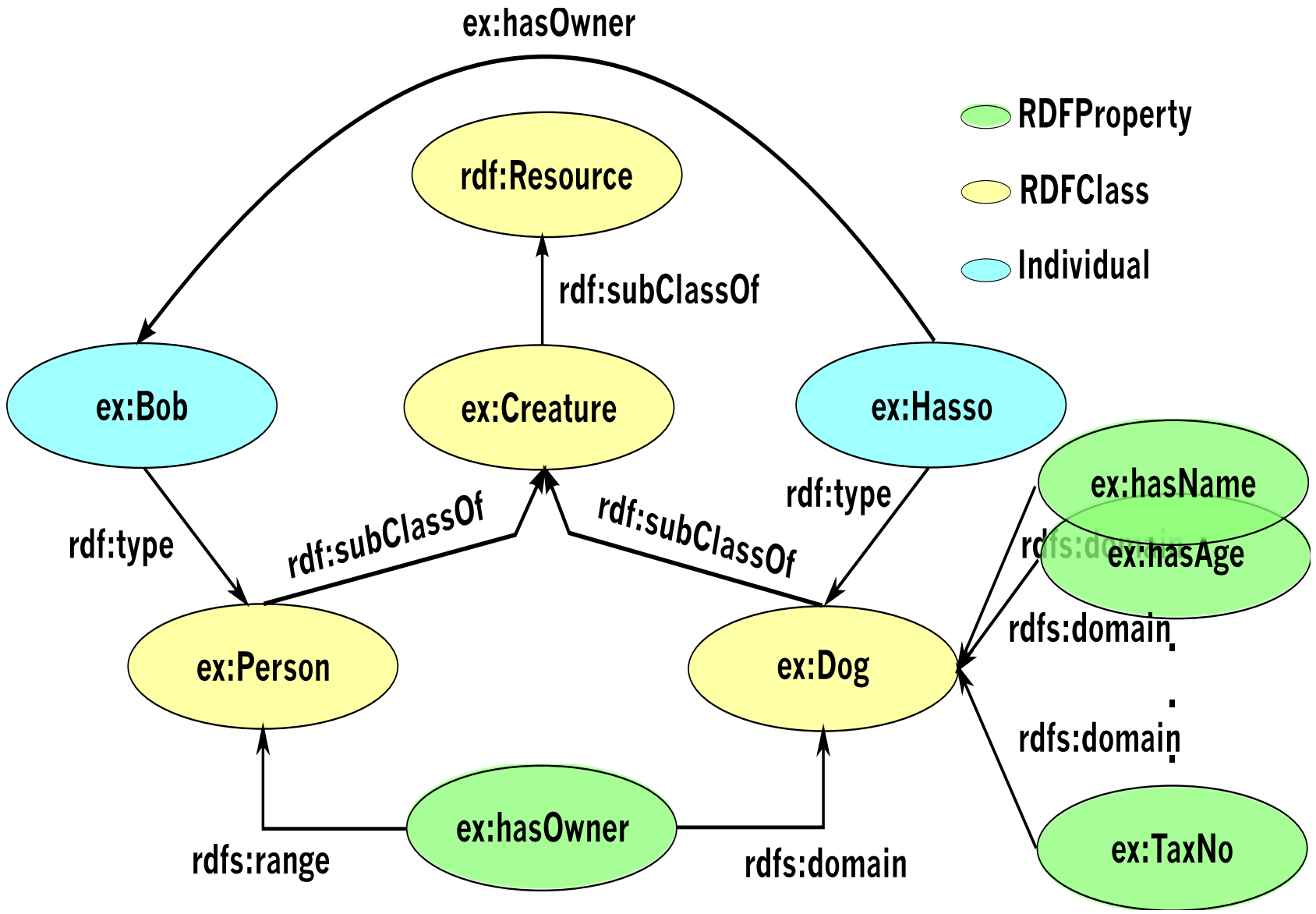


- Application
  - LODatio: Search the LOD cloud
  - Active user support

Motivation


F#
Part of the program.
Visual Studio
PONY
Design Time
Navigation
Run Time
Access
NPQL
SPARQL

Example RDF Graph



Programmers Tasks

1. Explore and understand the schema of the data source
   - Find a type that represents dogs
2. Align schema types with programming language type system
   - From dog RDF data type to dog data type in the host programming language
3. Query for instances and instantiate program data types
   - Get all dogs that have an owner

Programmers Tasks vs Our Solution: LITEQ

1. Explore and understand the schema of the data source
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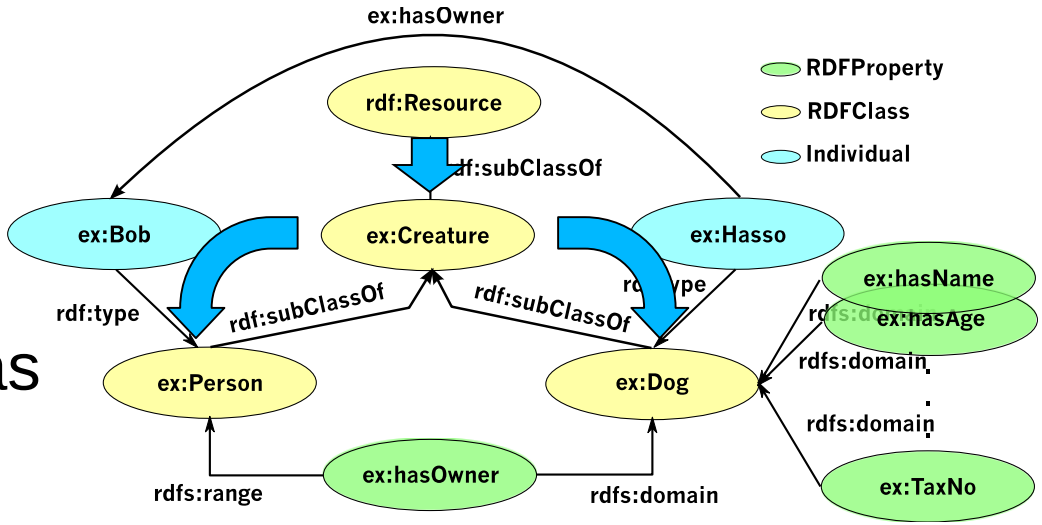
1. Using NPQL (NodePathQueryLanguage) for exploration and definition
2. Type mapping rules for primitive data types
3. Intensional vs Extensional
   - Intensional node path evaluation provides program data types
   - Extensional node path evaluation provides instance data representations

Use NPQL schema query language for navigation

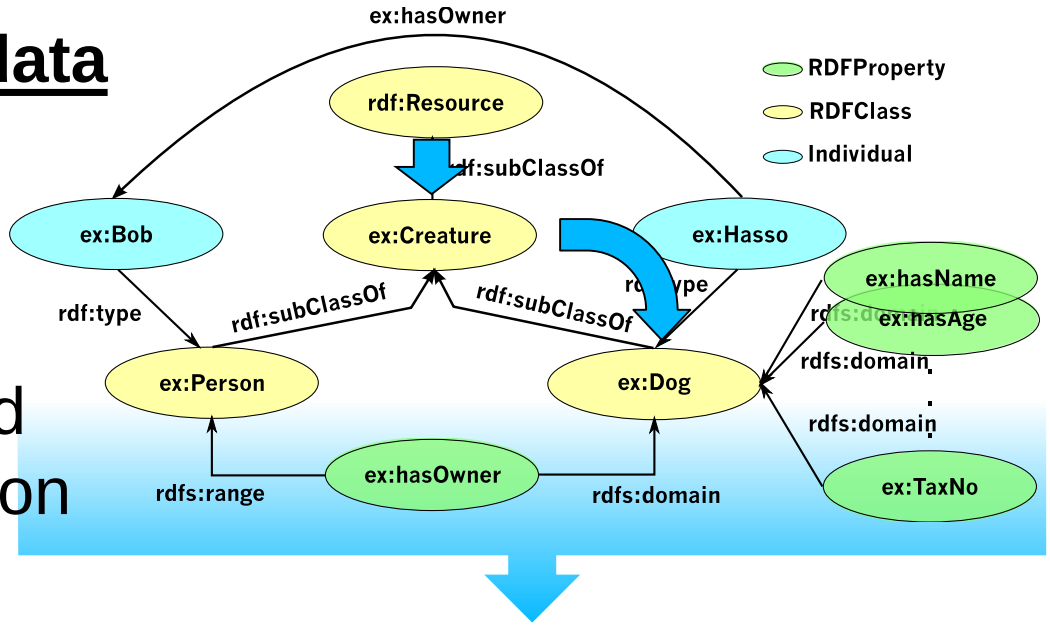


- **<u>Navigating to ex:Dog:</u>**
- Start with rdf:Resource as universal supertype
- Use the subtype navigation operator „>“

rdf:Resource > ex:Creature > ex:Dog

Using NPQL to retrieve type descriptions

- **<u>Retrieving the ex:dog data type</u>**
- Start with the node path from previous example
- Use the intension method to get data type description



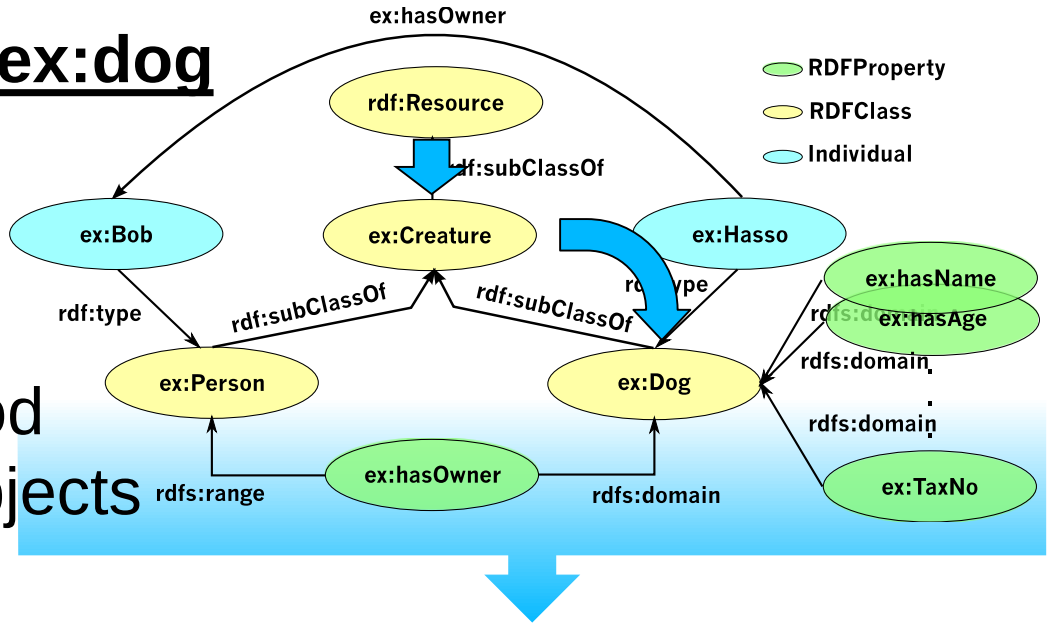

```
type exDog =
        member this.exhasOwner :exPerson =
        member this.exhasName :String =
        member this.exhasAge :String =

                .
                .
        member this.exTaxNo :Integer =
```

... > ex:Creature > ex:Dog -> Intension

Retrieving objects for all ex:dog entities

- Start with the node path from previous example
- Use the extension method to get the set of typed objects



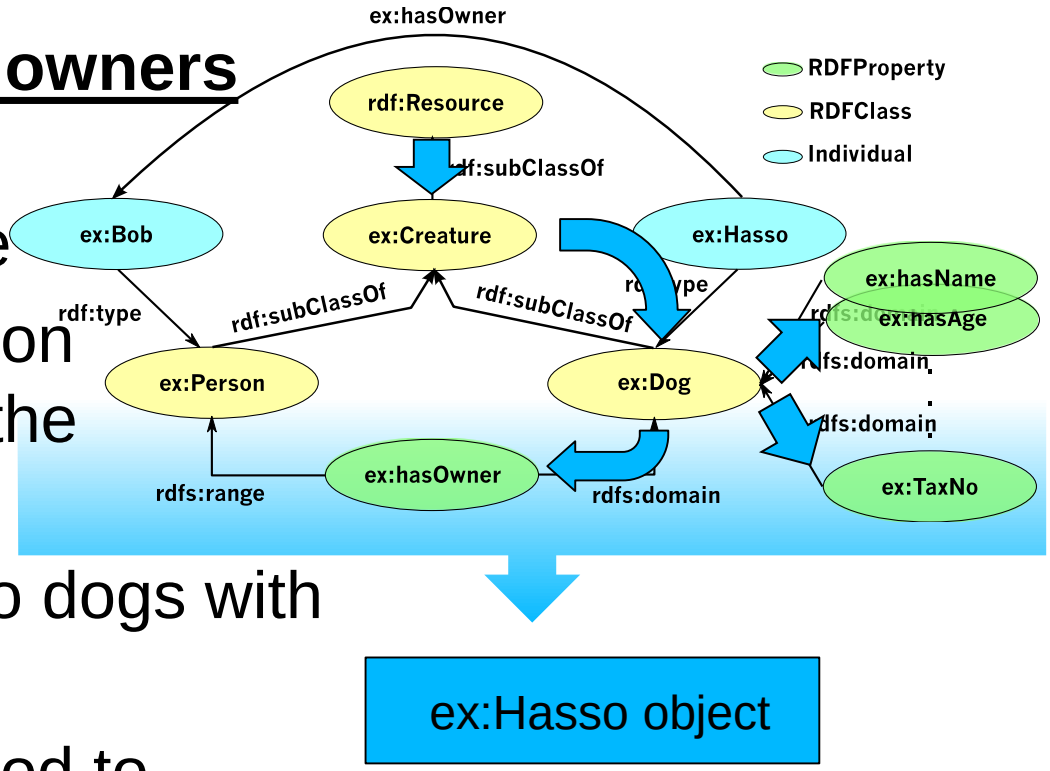
Provides you with the set of objects containing typed objects for all instances of ex:Dog

{exHasso}

... > ex:Creature > ex:Dog -> Extension

Using NPQL to define Instances

- **<u>Retrieve all dogs with owners</u>**
- Use the known path to navigate to the dog type
- Use the property selection operator "<-" to restrict the dog data type
- Restrict dog data type to dogs with ex:hasOwner property
- Use the extension method to retrieve all dog instances with an owner



ex:Hasso object

... > ex:Dog <- ex:hasOwner -> Extension

Using LITEQ in Visual Studio

- Line 5: define a datacontext object
- Line 6: Use the datacontext object to define pet data type
  - Navigate to pet
  - Choose ex:hasOwner property

```
4
5   let dataContext = Uniko.West.LITEQTypeProvider.RdfDataProvider<"D:\\work2\\svn_west\\RDF-TP-V2\\LiteqTypeProvider\\bin\\Debug\\TestData.ttl", 100, 100>.GetDataContext()
6   let somedata = dataContext.
7
8       http://example.org/ns#Animal
9       http://example.org/ns#Cat
10      http://example.org/ns#CatPet
11      http://example.org/ns#Creature
12      http://example.org/ns#Dog
13      http://example.org/ns#DogPet
14      http://example.org/ns#Person
15      http://example.org/ns#Pet
16      http://example.org/ns#Supertype
17
18
19
20
```

Eigenschaft Uniko.West.LITEQTypeProvider.RdfDataProvider<...>.RdfService.http://example.org/ns#Animal: Uniko.West.LITEQTypeProvider.RdfDataProvider<...>.RdfService.MyTestGraph.http://example.org/ns#Supertype.http://example.org/ns#SupertypeTypeNav.http://example.org/ns#Creature.http://example.org/ns#CreatureTypeNav.http://example.org/ns#Animal

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6   let somedata = dataContext.``http://example.org/ns#Animal``.
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```

individuals
properties
subtypes

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http://example.org/ns#Dog
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```

- http://example.org/ns#hasAge
- http://example.org/ns#hasName
- http://example.org/ns#hasOwner

Using LITEQ to define types

- The intensional semantic of LITEQ node paths supports data type definition in the host programming language

```
type dog =rdfResource > exCreature > exDog → Intension
```

Intensional semantics:

```
type exDog=
   inherit exCreature
   hasOwner : exPerson
```

Using LITEQ to define types

Using LITEQ to retrieve objects

- The extensional semantic of LITEQ node paths supports query and retrieval of sets of typed objects

```
let dogs =rdfResource > exCreature > exDog → Extension
```

Extensional semantics:
{ex:Hasso,…}

Using LITEQ to define type conditions

- LITEQ data types in the host programming language can be used to define type condidtions, e.g. in method heads
- LITEQ data types are generated in a pre-compile step, they behave like manually implemented types
- compile-time and run-time type-checking is supported

```
let payTax(dogWithOwner : exDog←hasOwner) = …
```

Type conditions for function (method) arguments

Using Type Condidtions

Scenario:

- Get all dogs
- Iterate over the set of dogs
- Call paytax method for all dogs with owners

```
let dogs = rdfResource > exCreature > exDog → Extension
let payTax(dogWithOwner : exDog←hasOwner)  = …
for dog in dogs do
match dog with
| :? exDog ← hasOwner as dogWithOwner -> payTax dog
| _ -> ()
```

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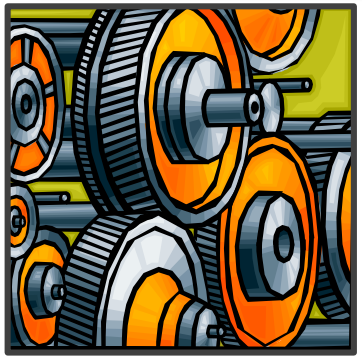
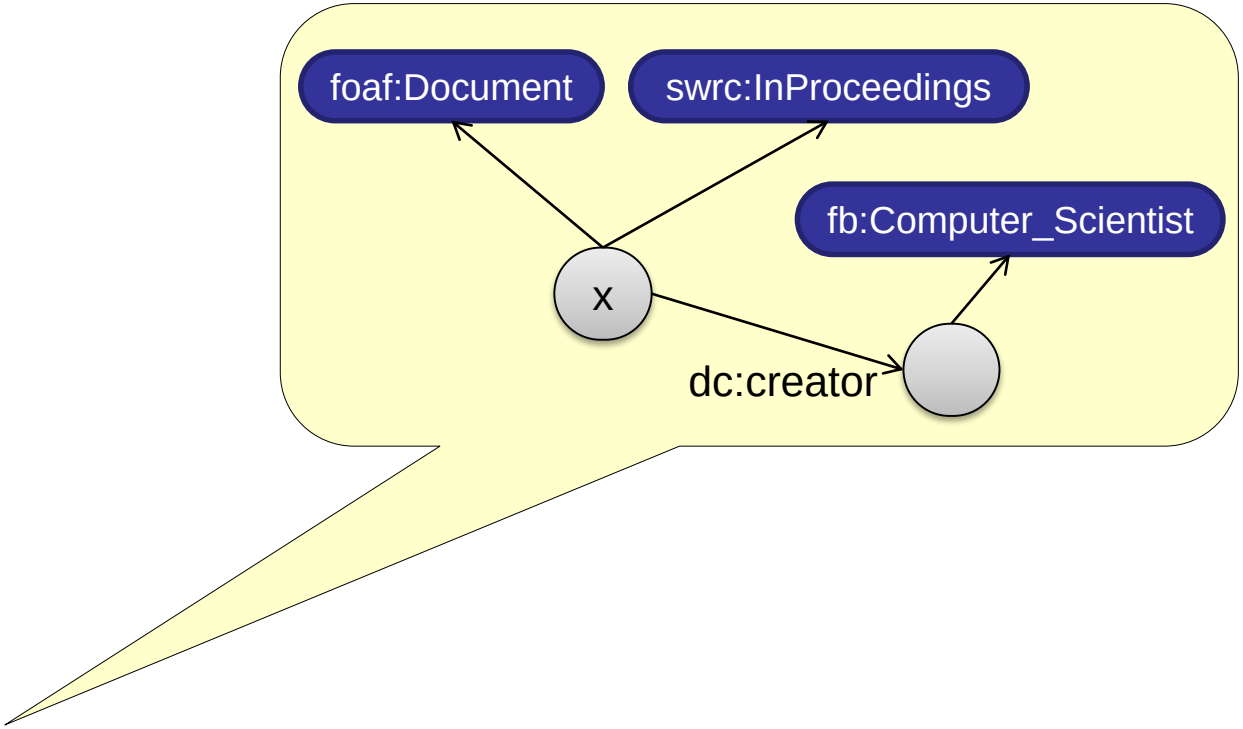


- Application
  - LODatio: Search the LOD cloud
  - Active user support

Searching the LOD cloud???



Searching the LOD cloud???

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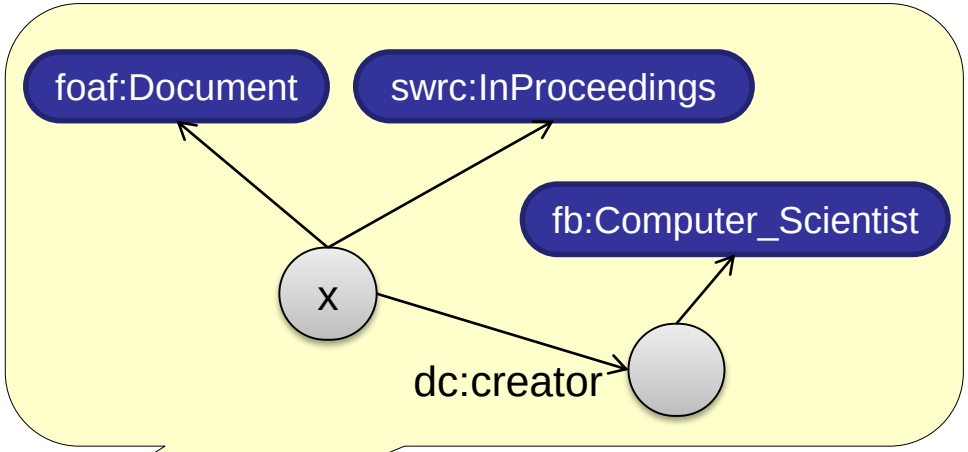
SELECT ?x
WHERE {
   ?x rdf:type foaf:Document .
   ?x rdf:type swrc:InProceedings .
   ?x dc:creator ?y .
   ?y rdf:type fb:Computer_Scientist
}
```



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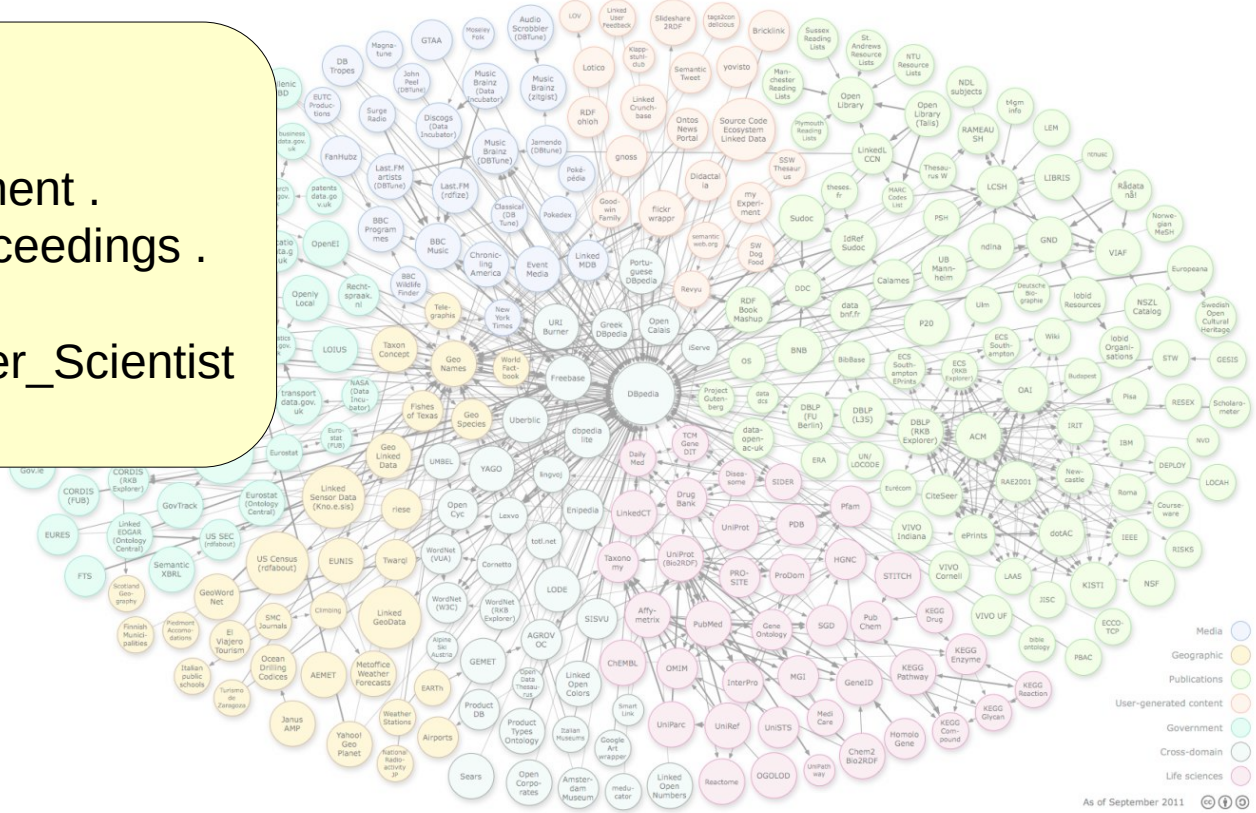

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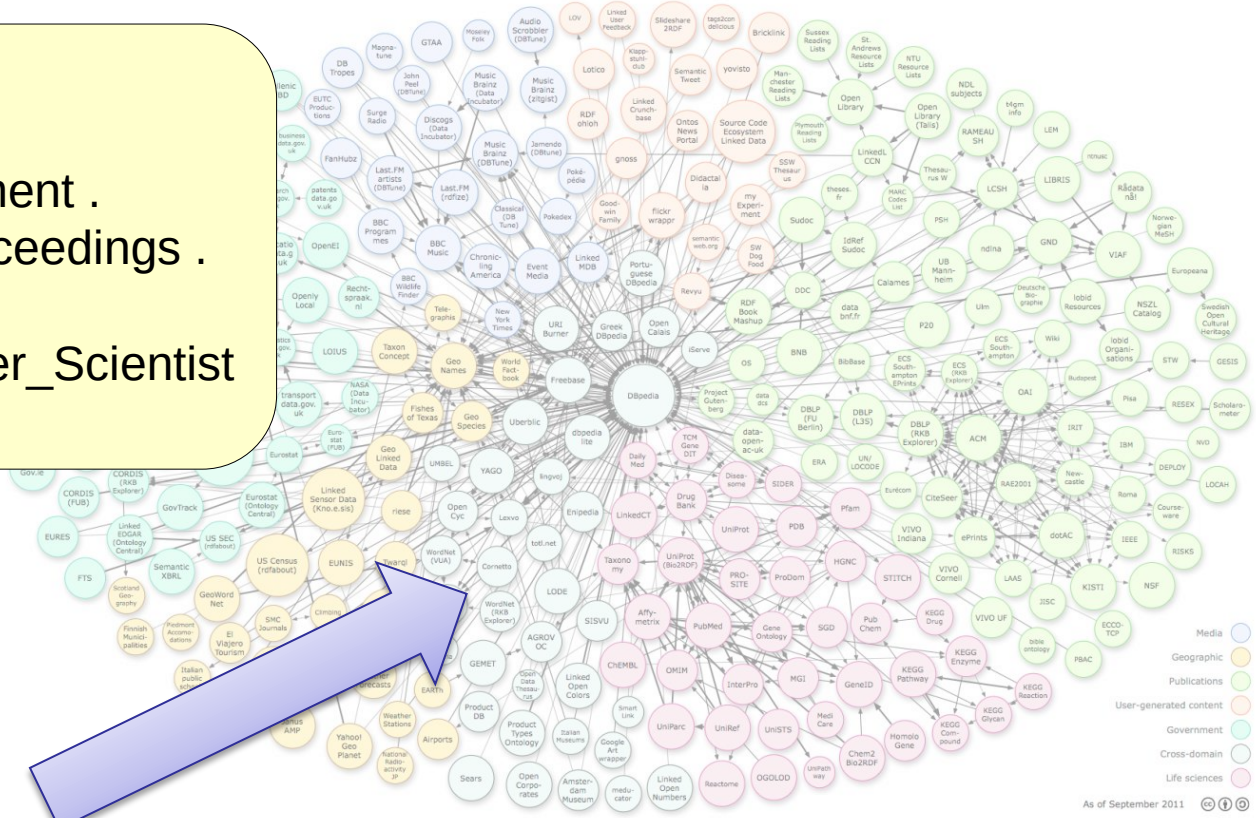

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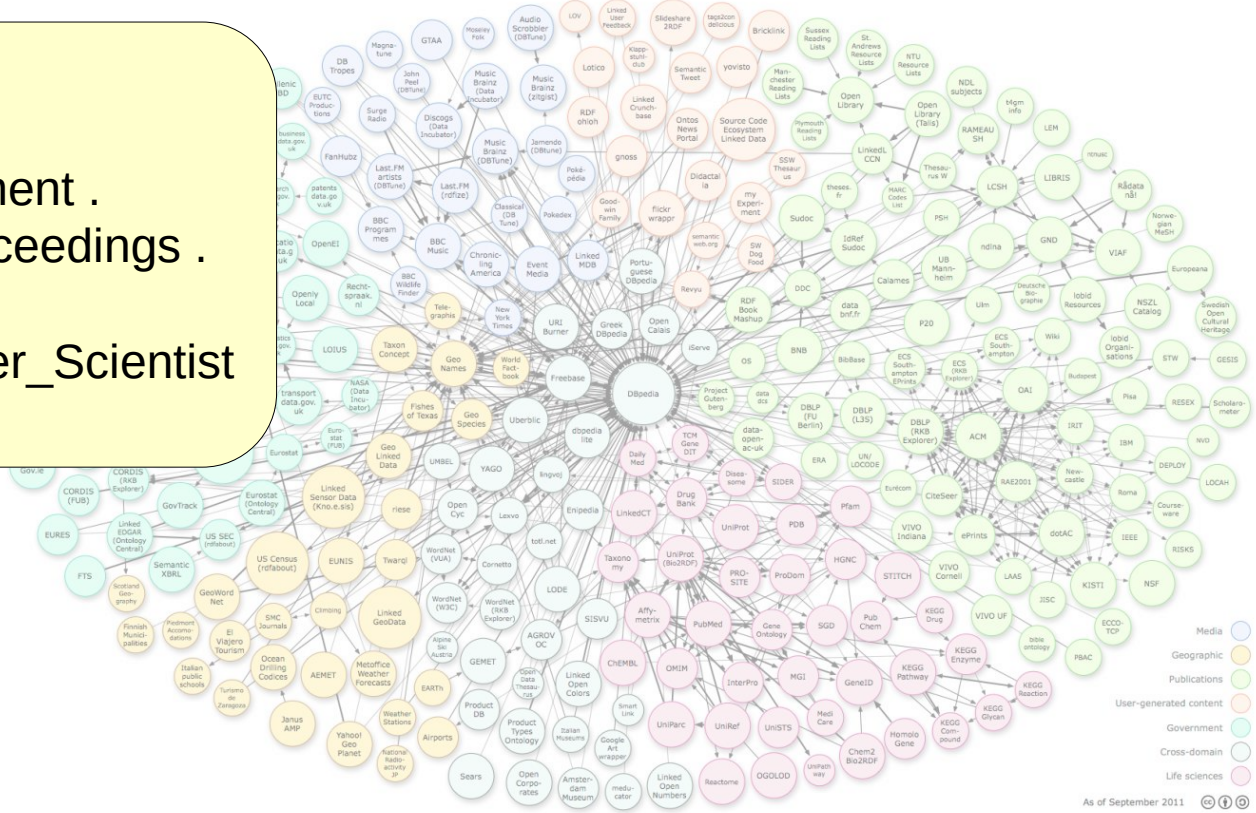

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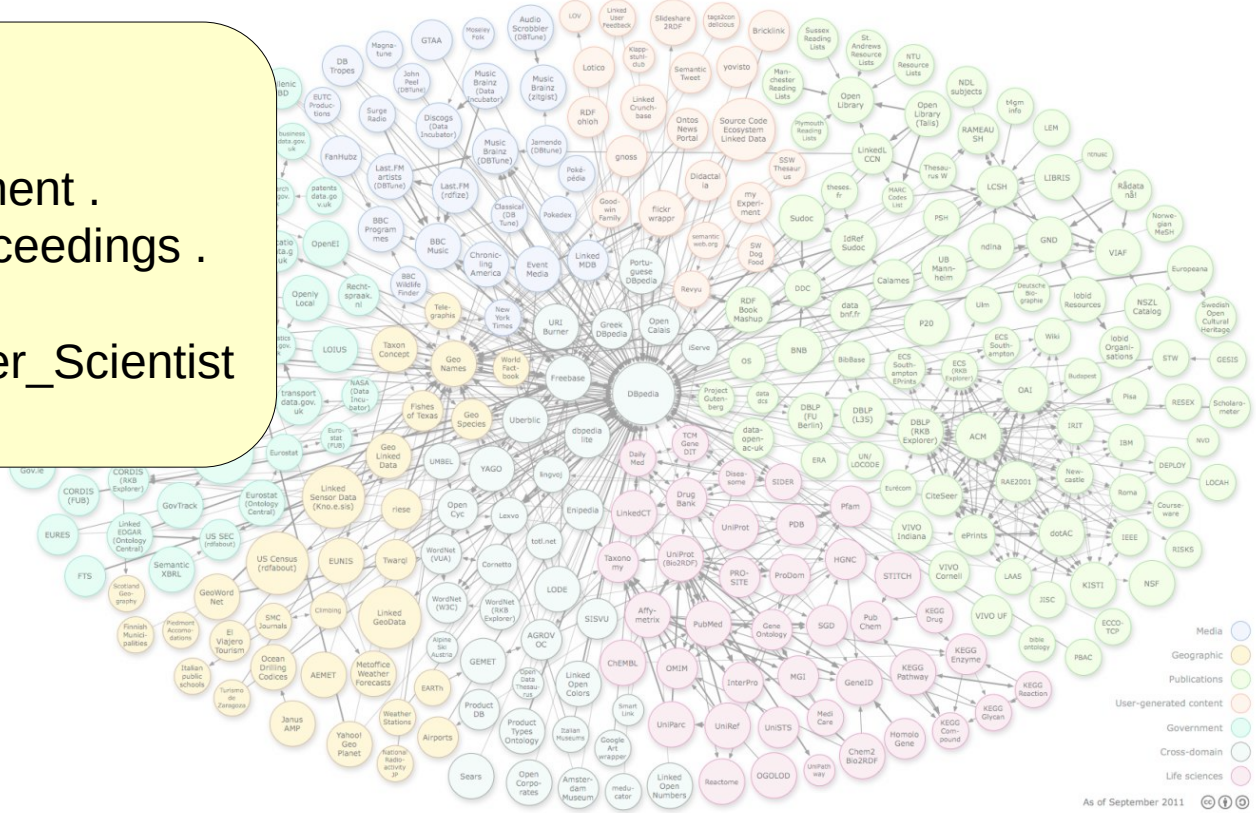

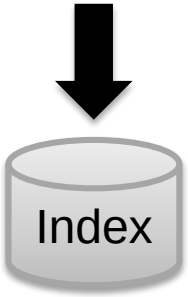

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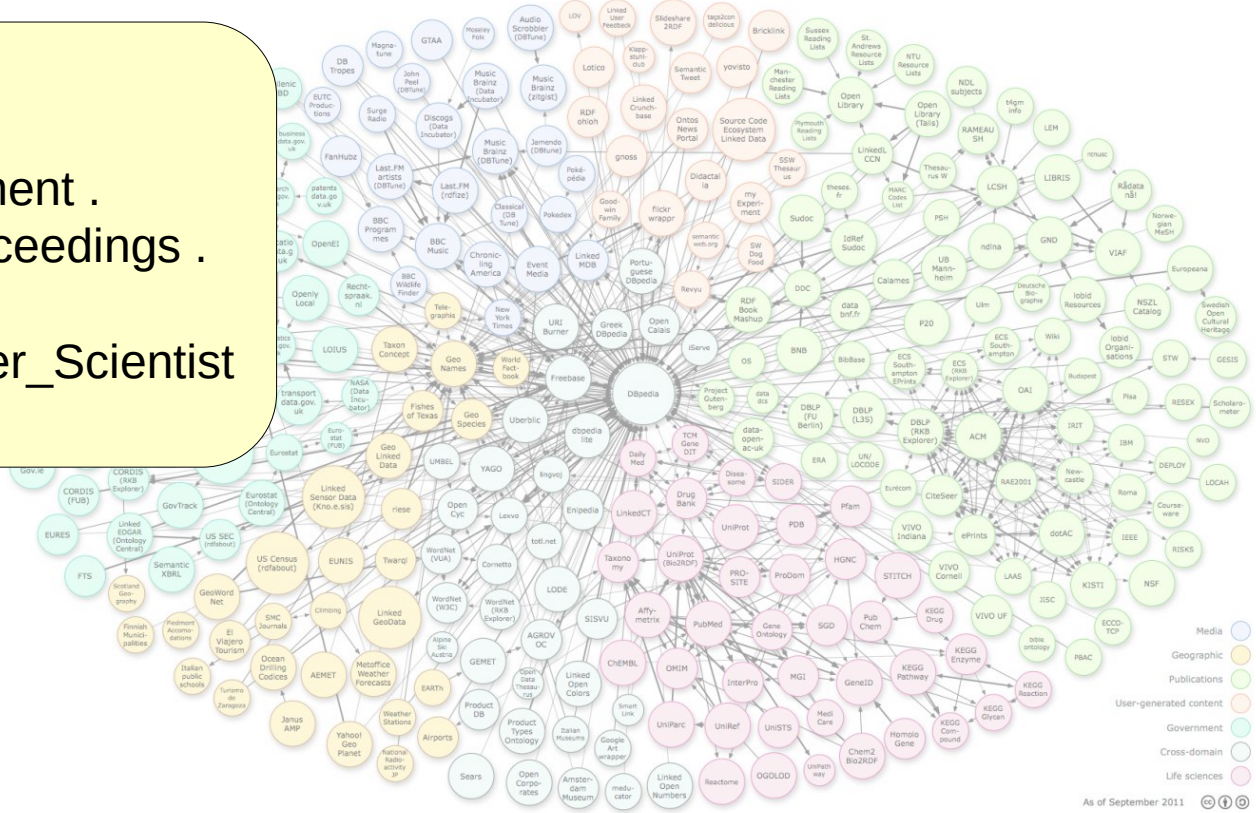

Where?

Index

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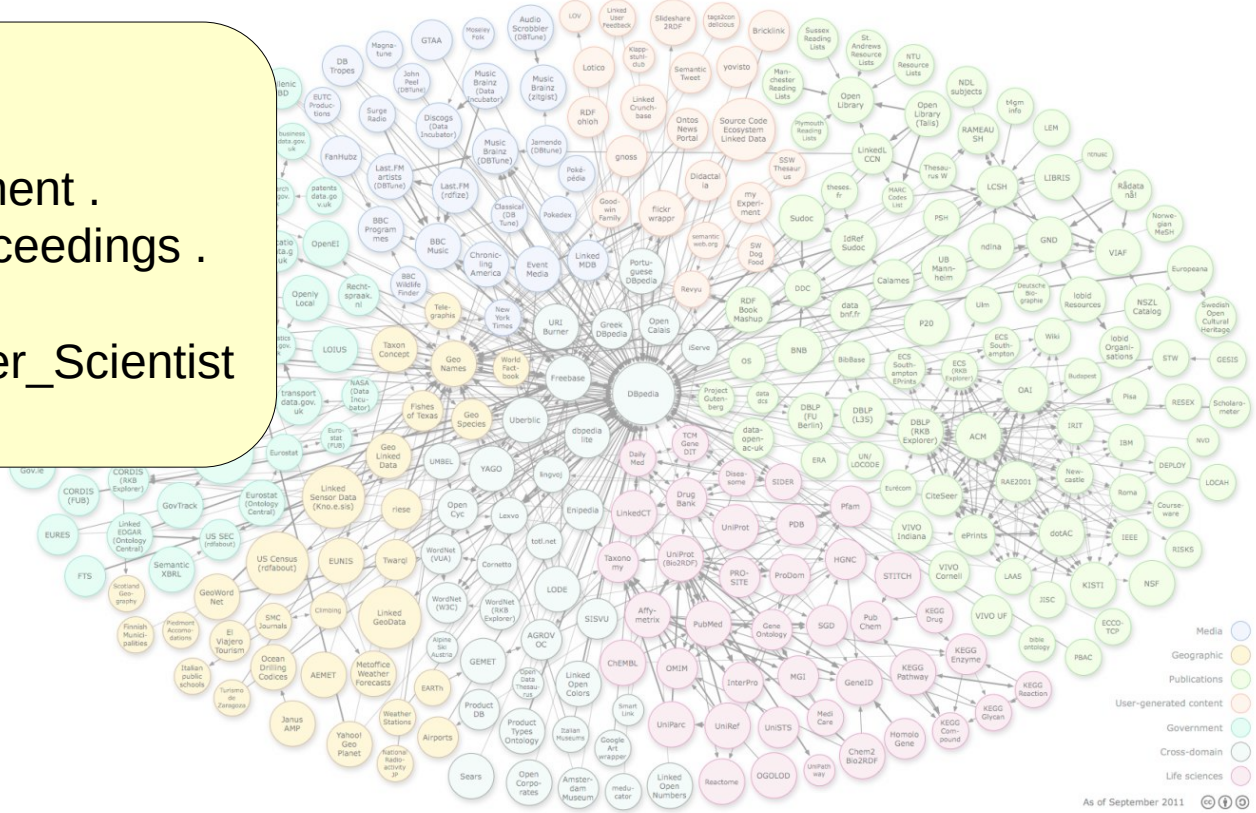

Where?

Index

- ACM
- DBLP

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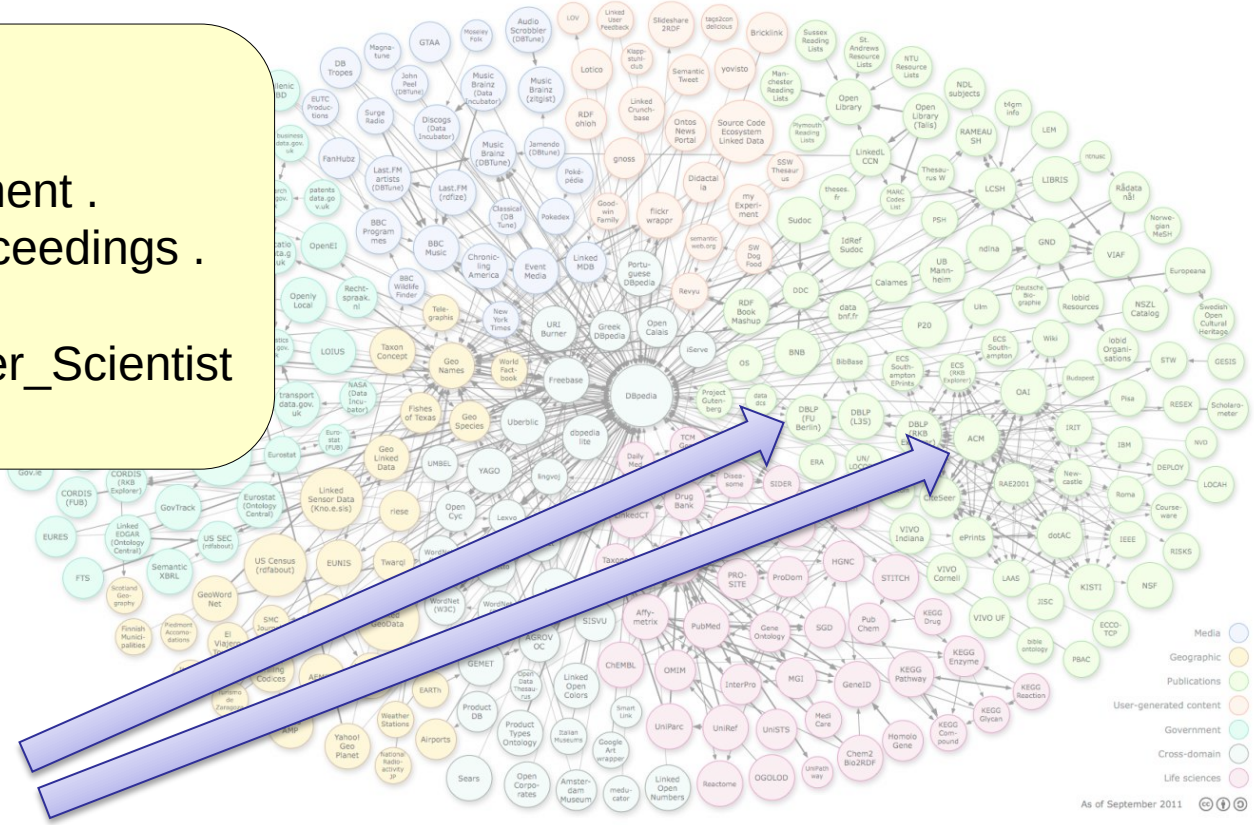
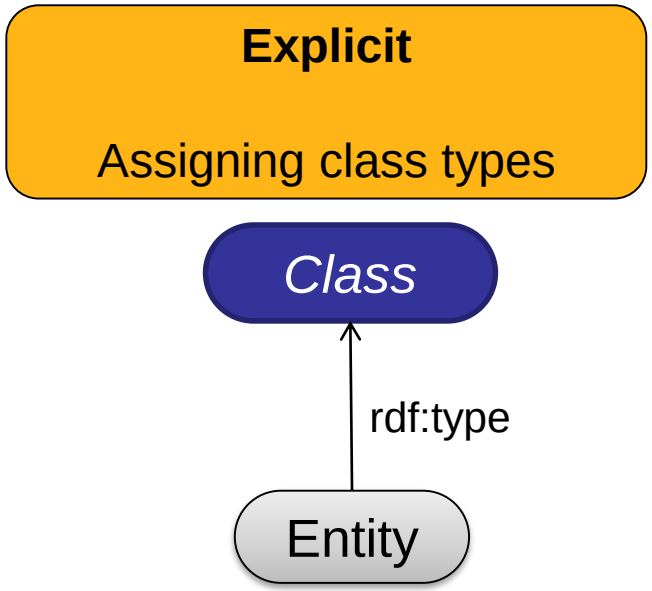


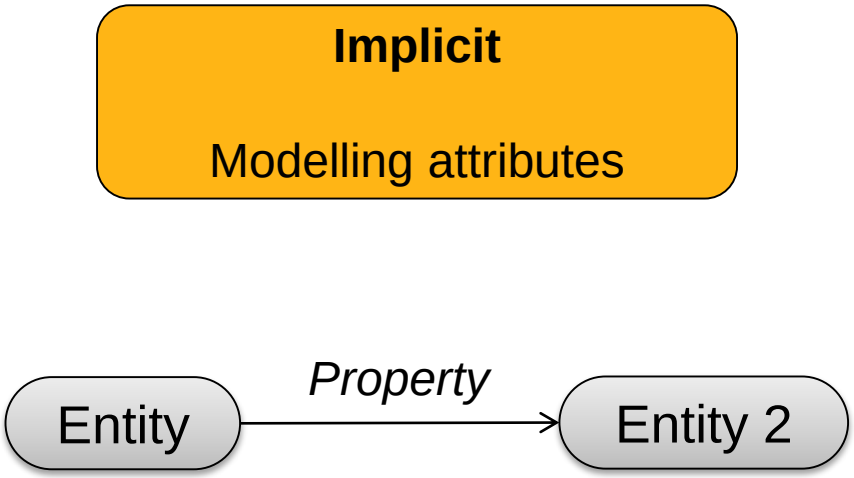
Where?

Index

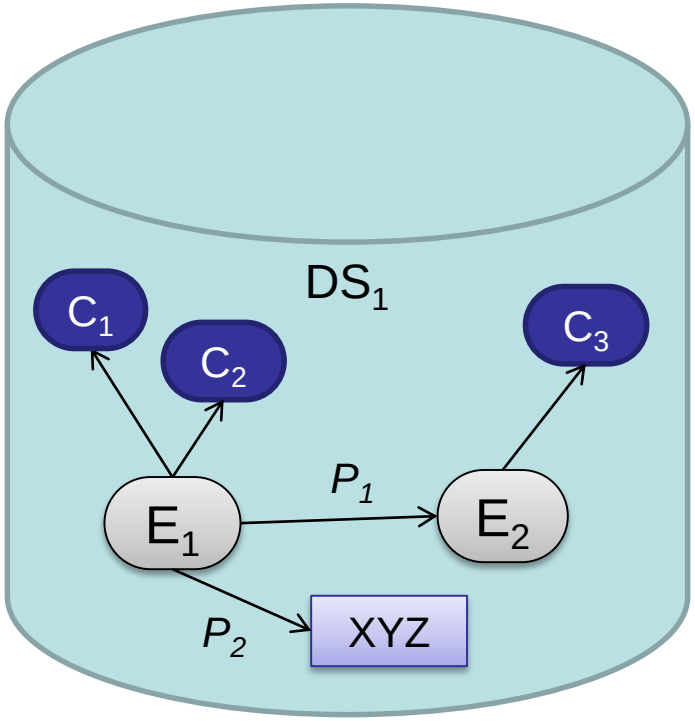
- ACM
- DBLP

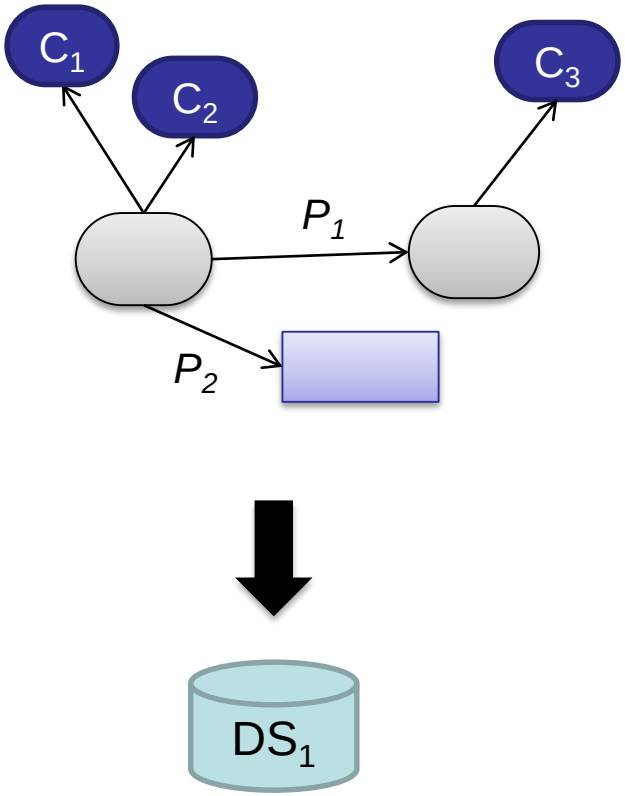
- Schema information on LOD





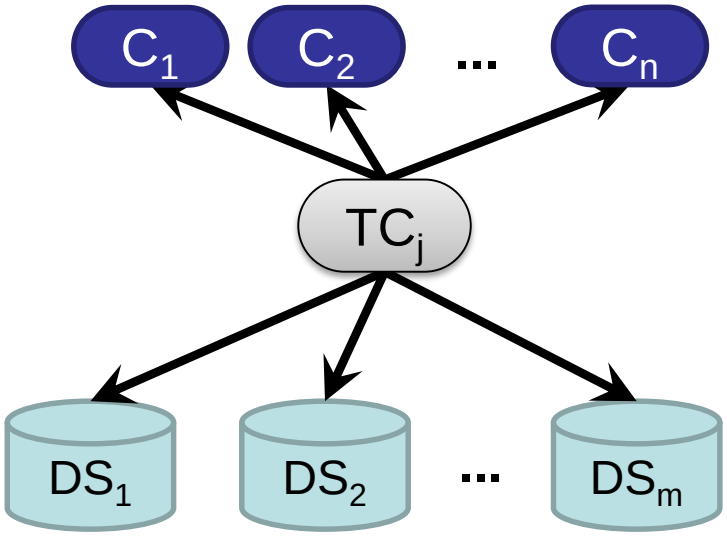
Schema-level index



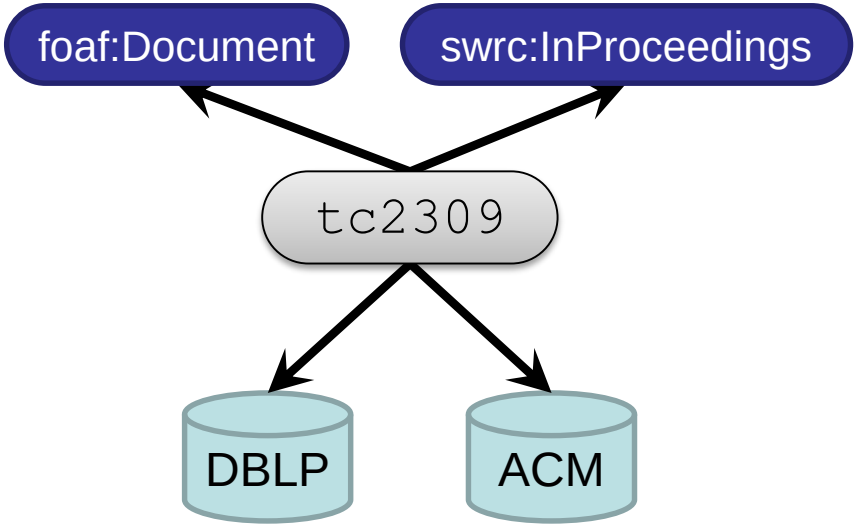


Typecluster

- Entities with the same *Set* of types

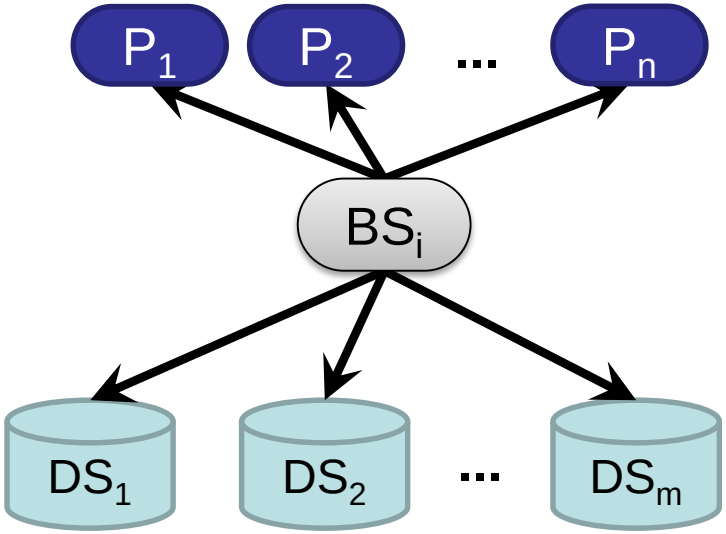


Typecluster: Example

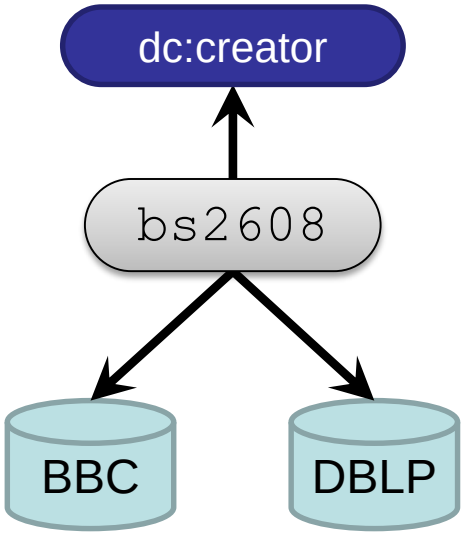


Bi-Simulation

- Entities are equivalent, if they refer with the same attributes to equivalent entities
- Restriction: 1-Bi-Simulation



Bi-Simulation: Example



SchemEX: Combination TC and Bi-Simulation

- Partition of TC based on 1-Bi-Simulation with restrictions on the destination TC

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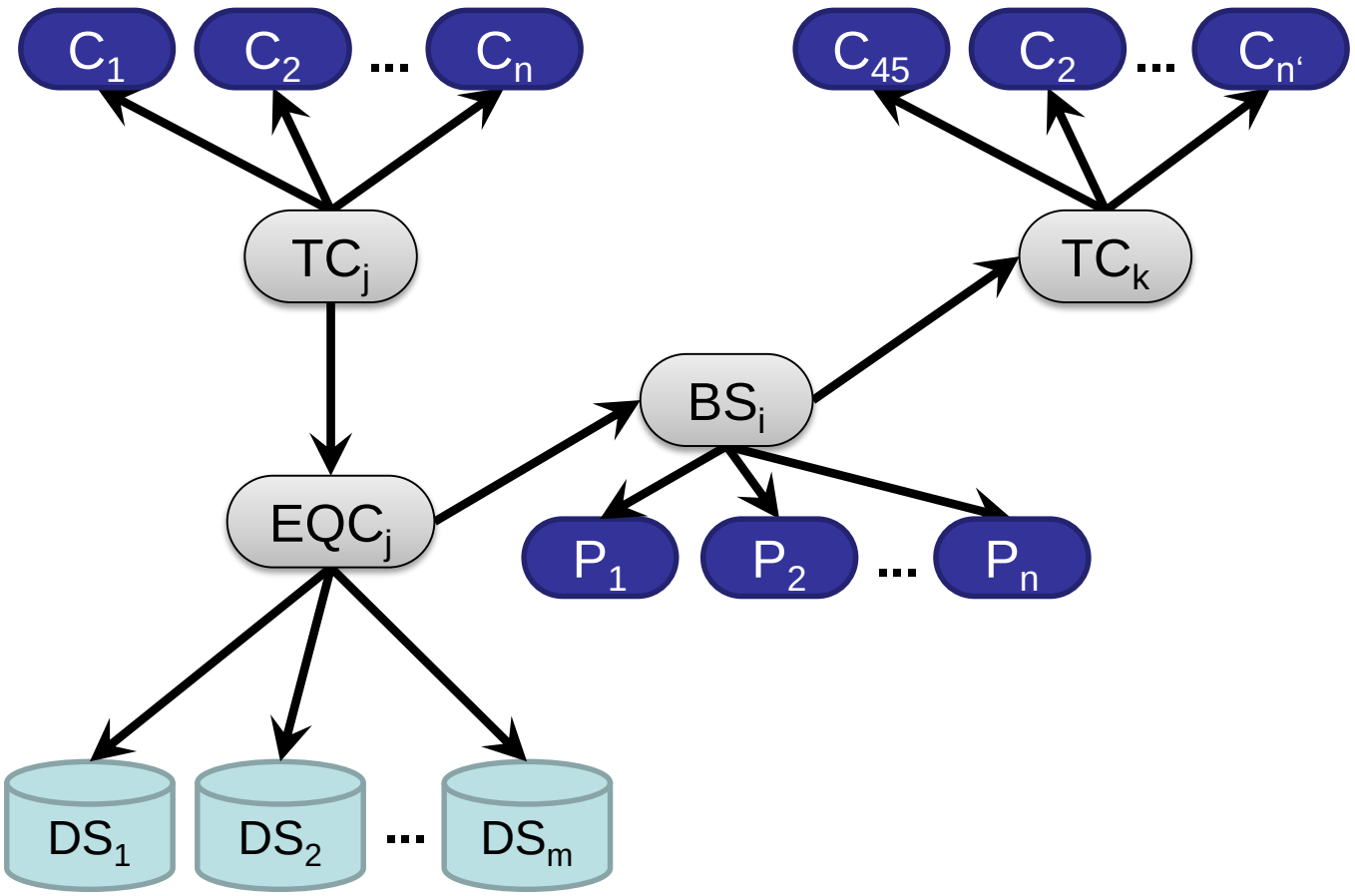

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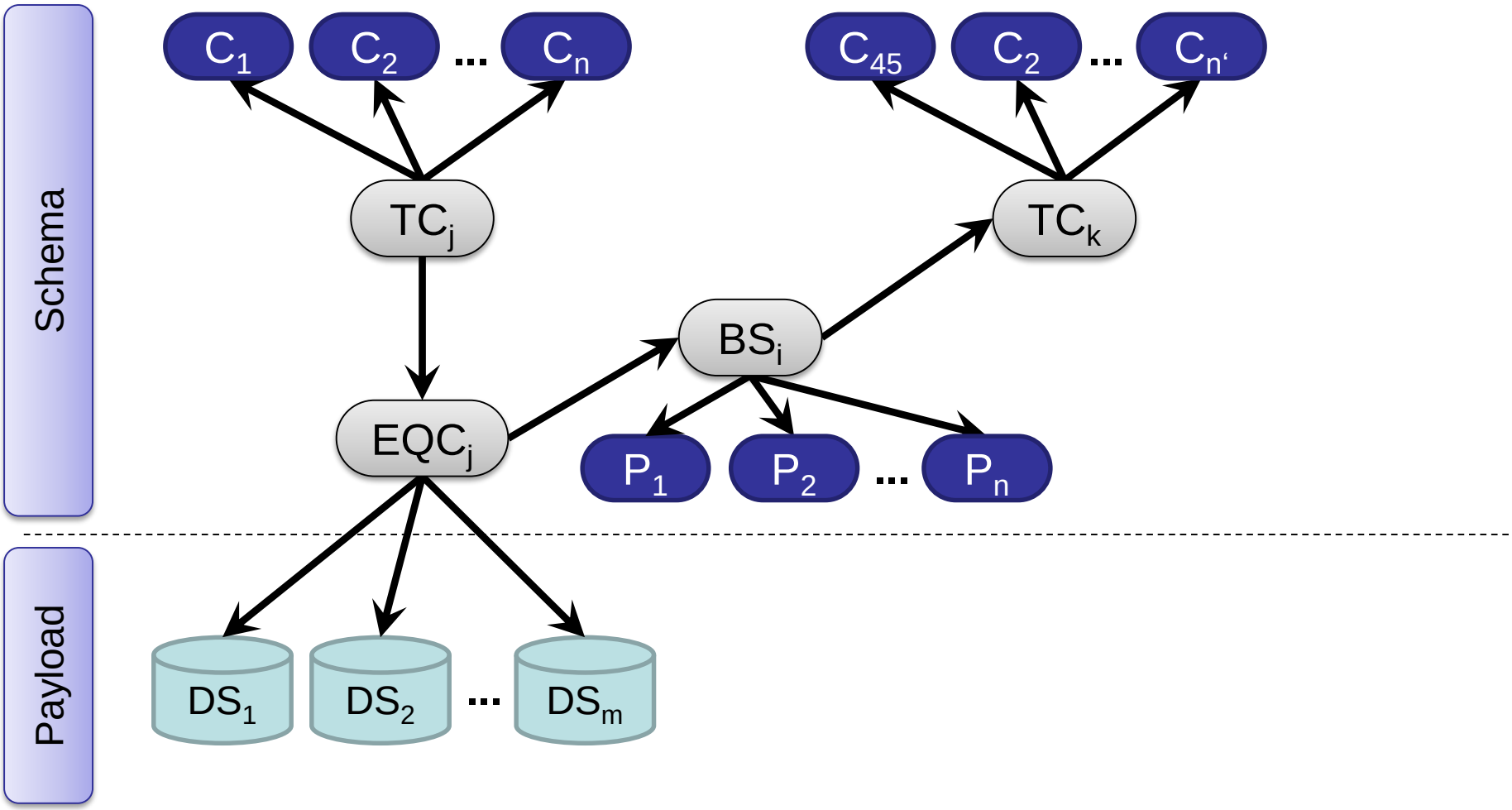

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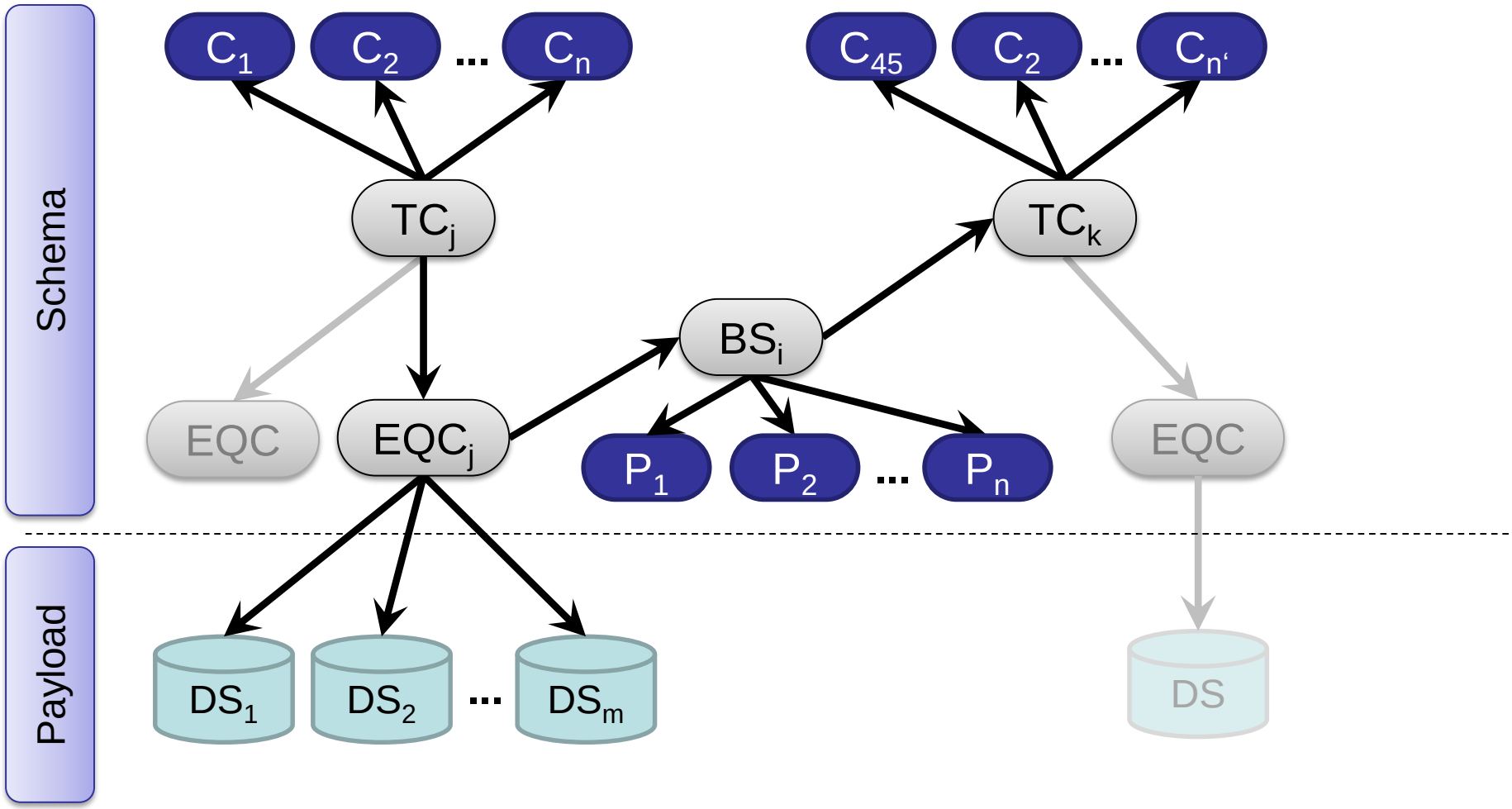

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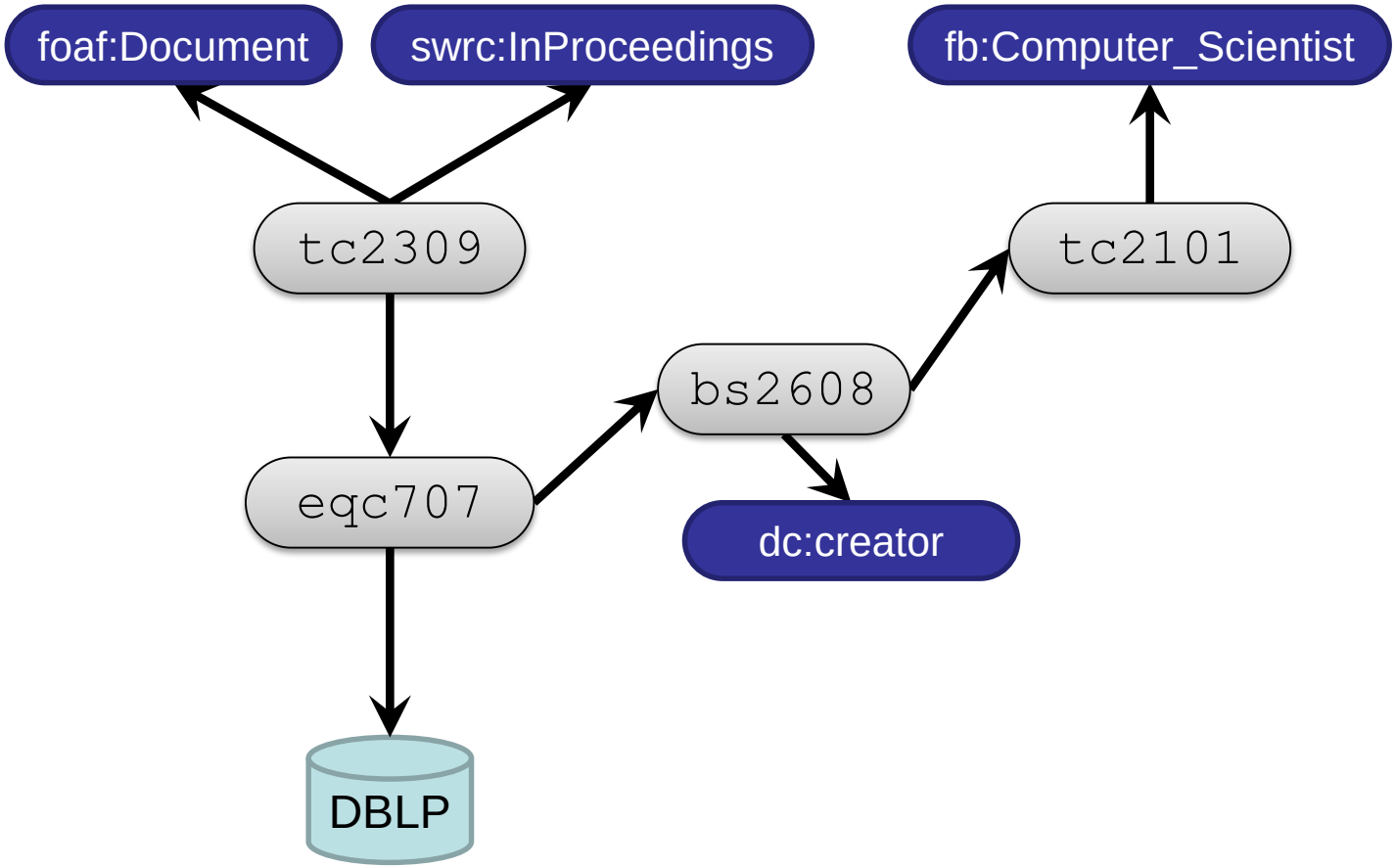

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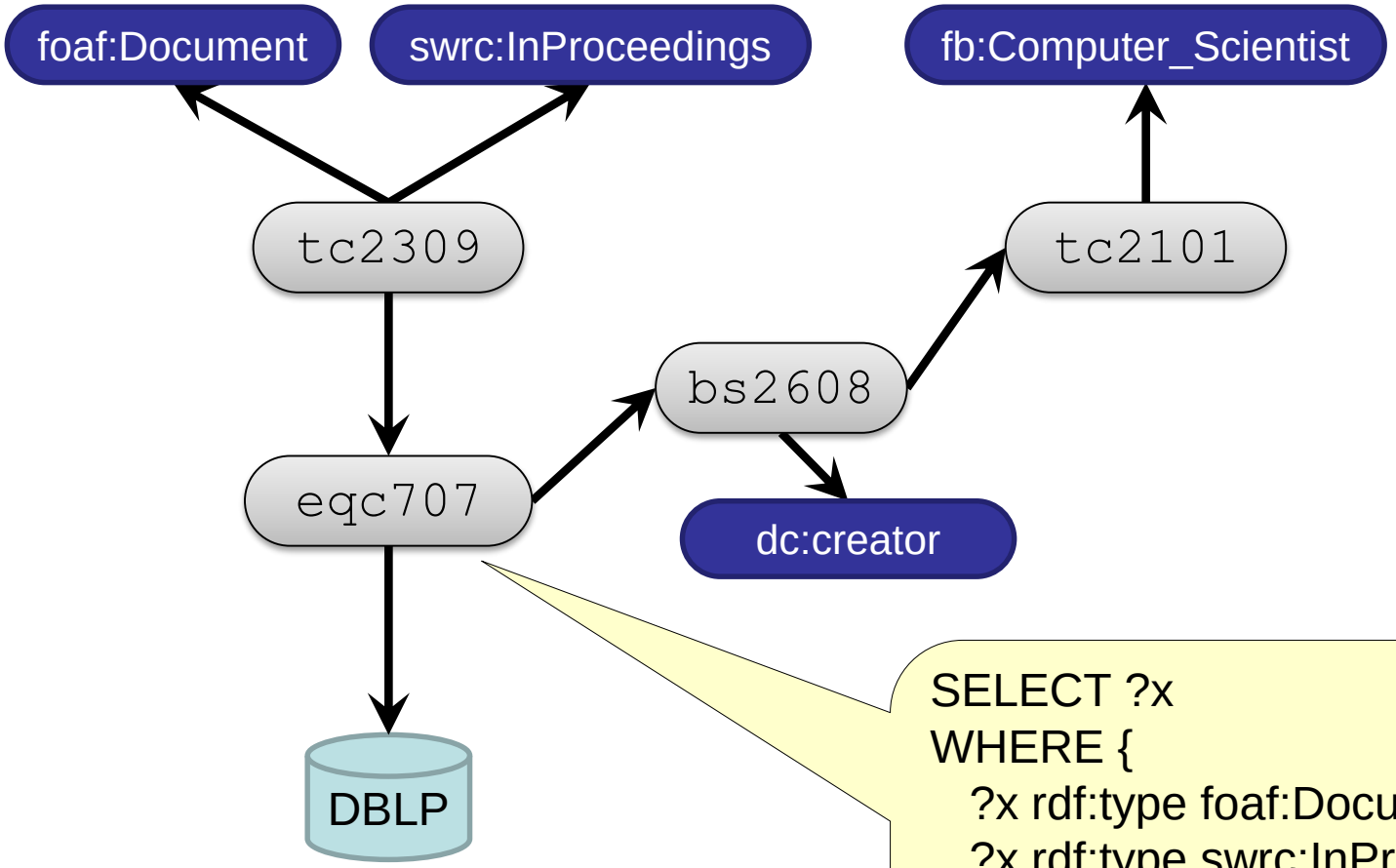


```
SELECT ?x
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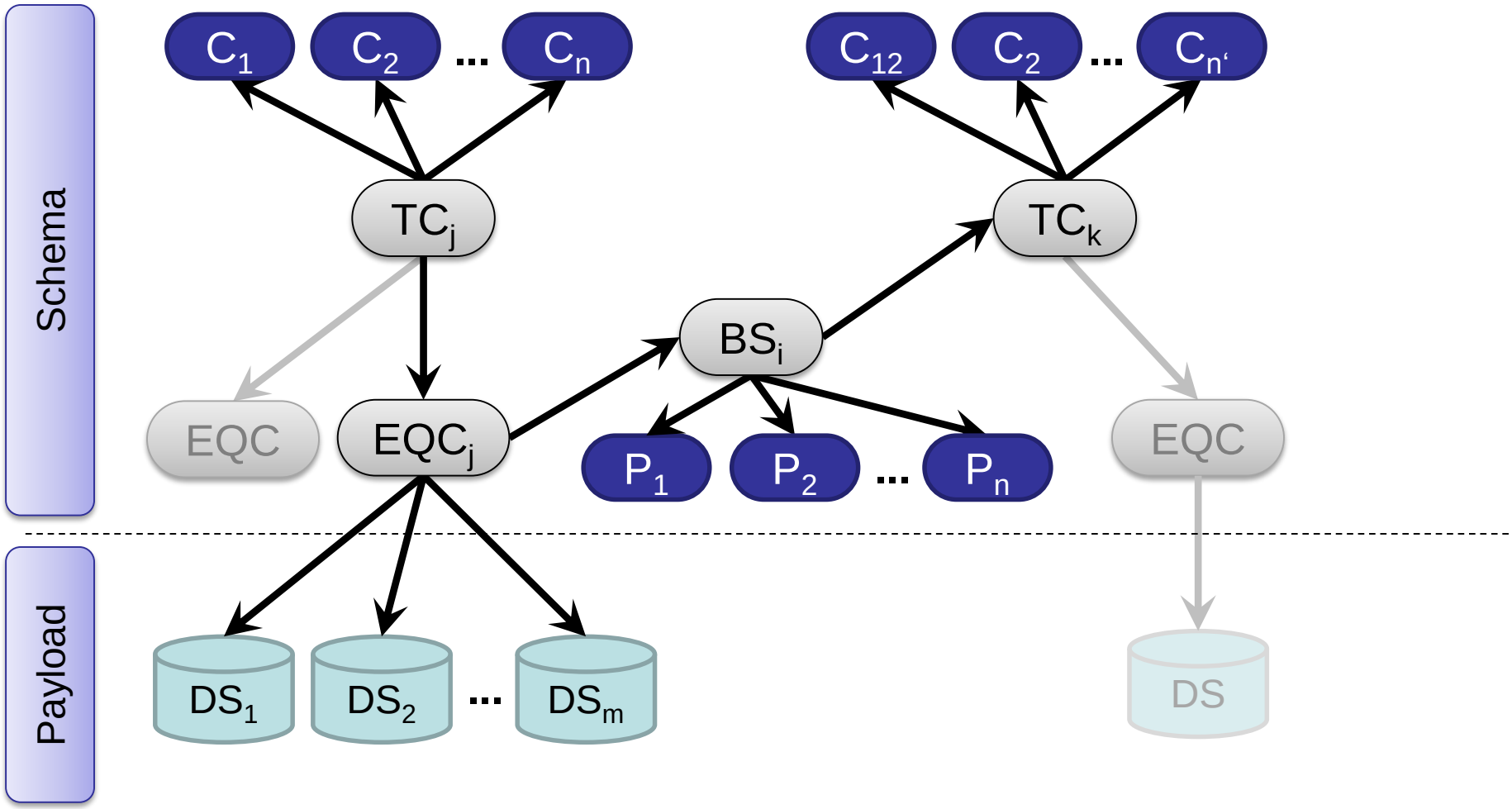
```

- Precise computation: Brute-Force



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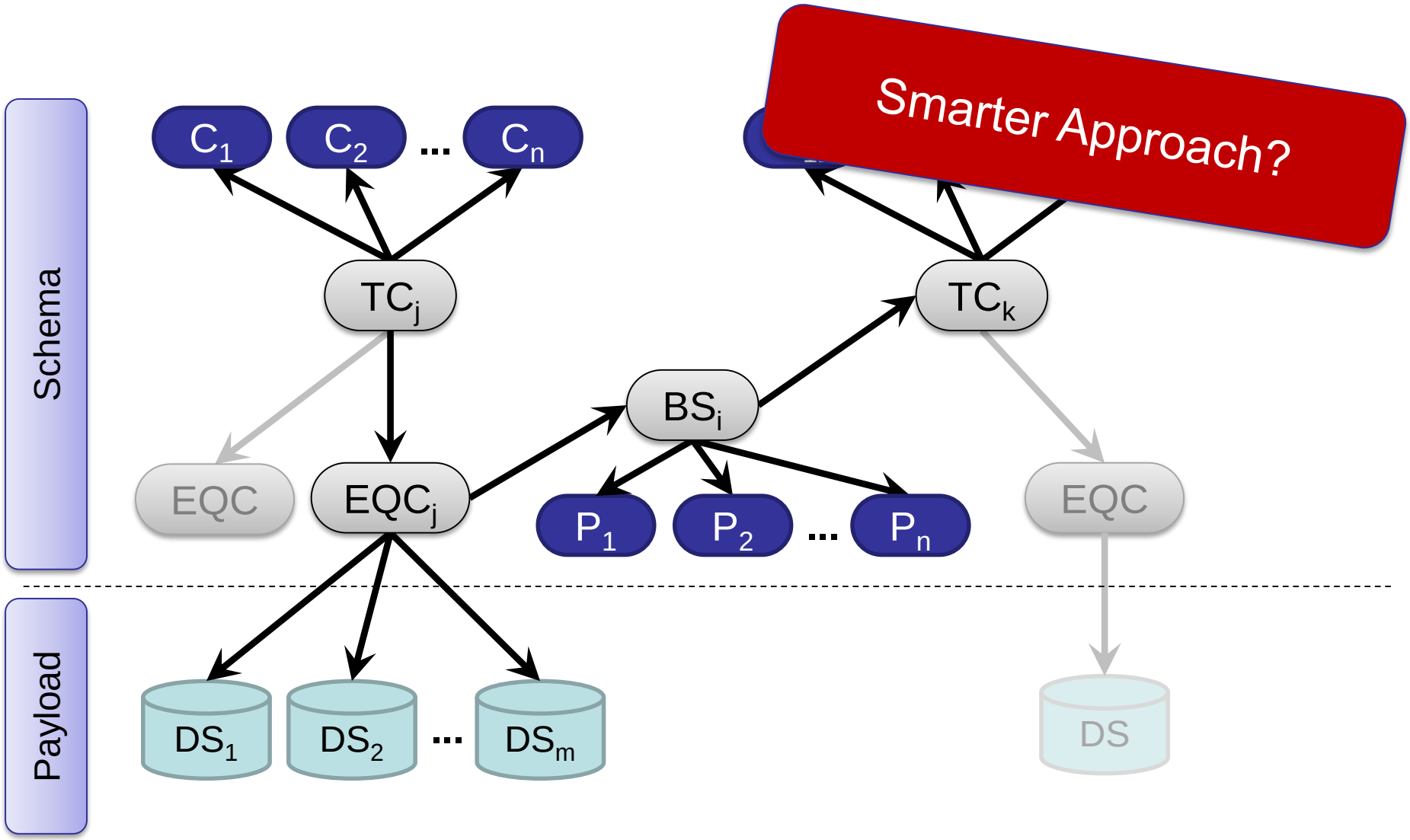
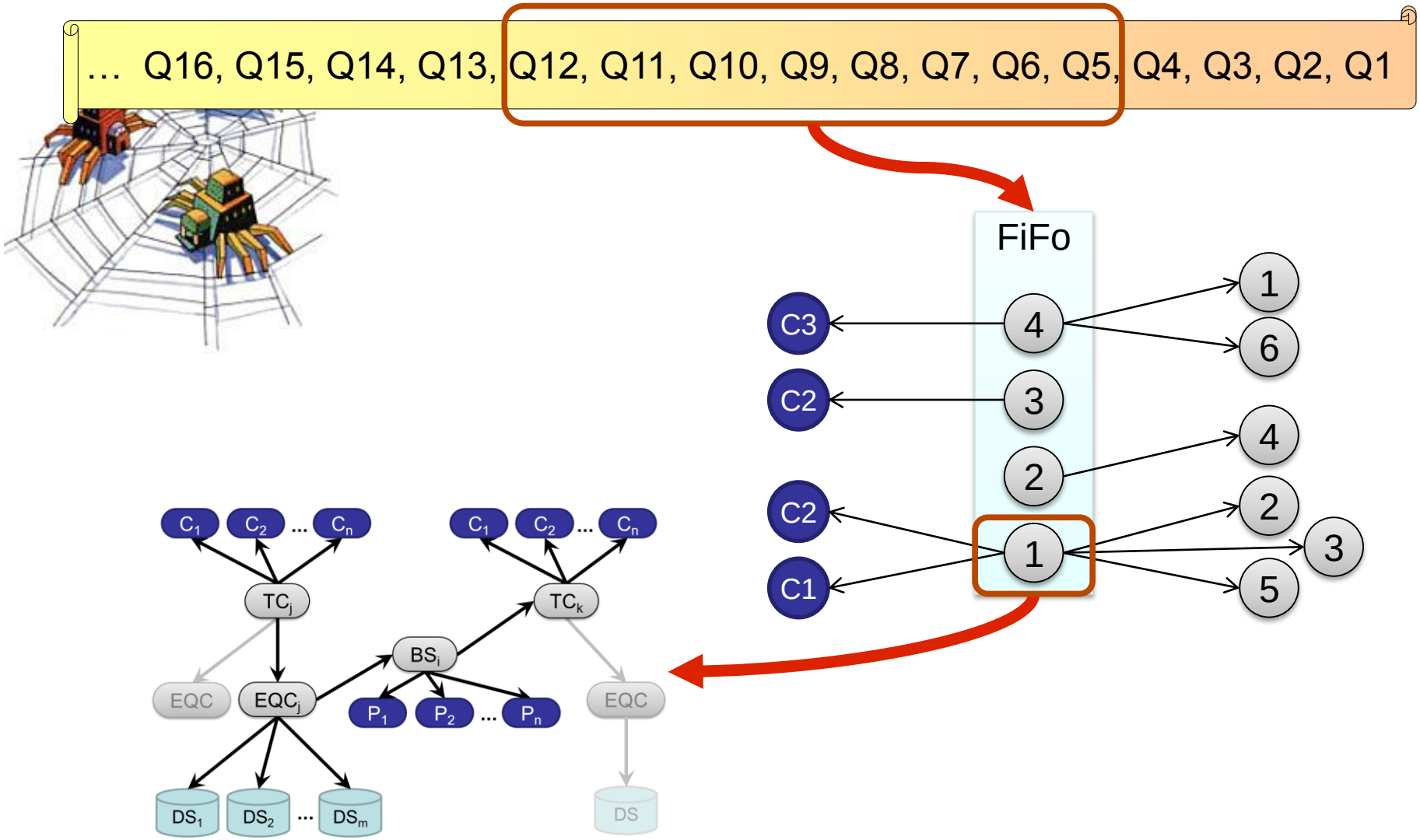
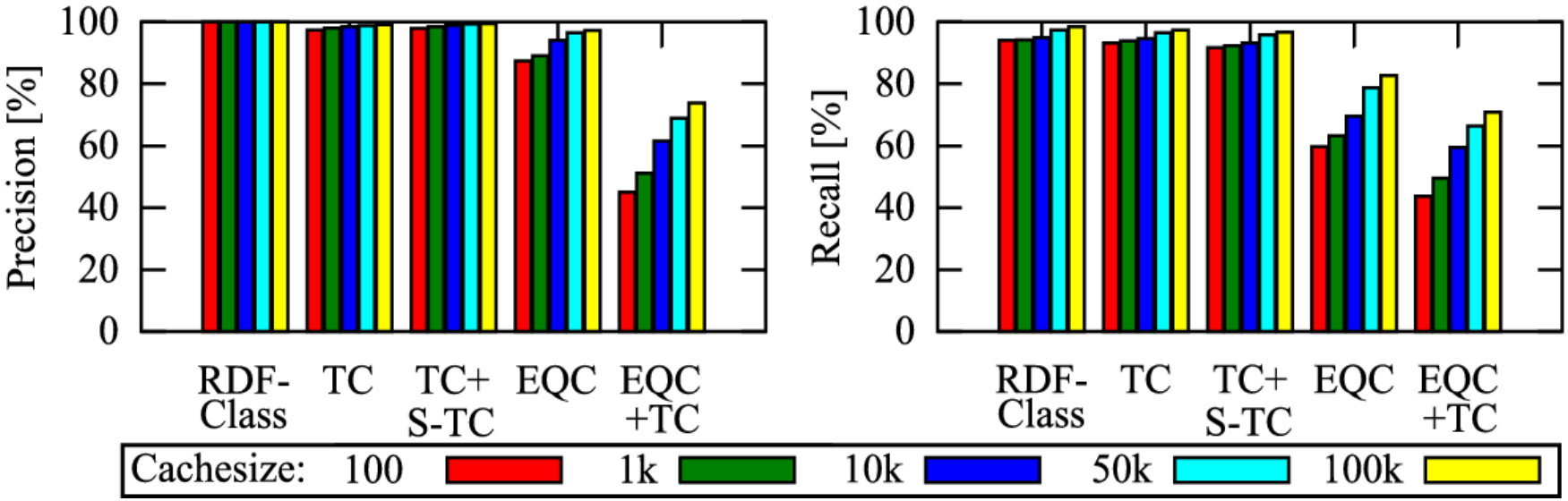


- LOD Crawler: Stream of n-Quads (triple + data source)



Quality of Approximated Index

- Stream-based computation vs. brute force
  - Data set of 11 Mio. tripel



SchemEX @ BTC 2011

- SchemEX
  - Allows complex queries (Star, Chain)
  - Scalable computation
  - High quality

- Index over BTC 2011 data
  - 2.17 billion tripel
  - Index: 55 million tripel

- Commodity hardware
  - VM: 1 Core, 4 GB RAM
  - Throughput: 39.500 tripel / second
  - Computation of full index: 15h

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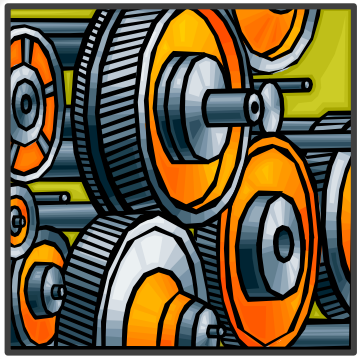
1. Place
BTC 2011

Agenda

- LiteQ – Language integrated types, extensions and queries for RDF graphs
  - Exploring
  - Programming, Typing

- SchemEX
  - Where do I find relevant data?
  - Efficient construction of a schema-level index



- Application
  - LODatio: Search the LOD cloud
  - Active user support

SPARQL queries on LOD ???

```
SELECT ?x
WHERE {
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   ?x dc:creator ?y .
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}
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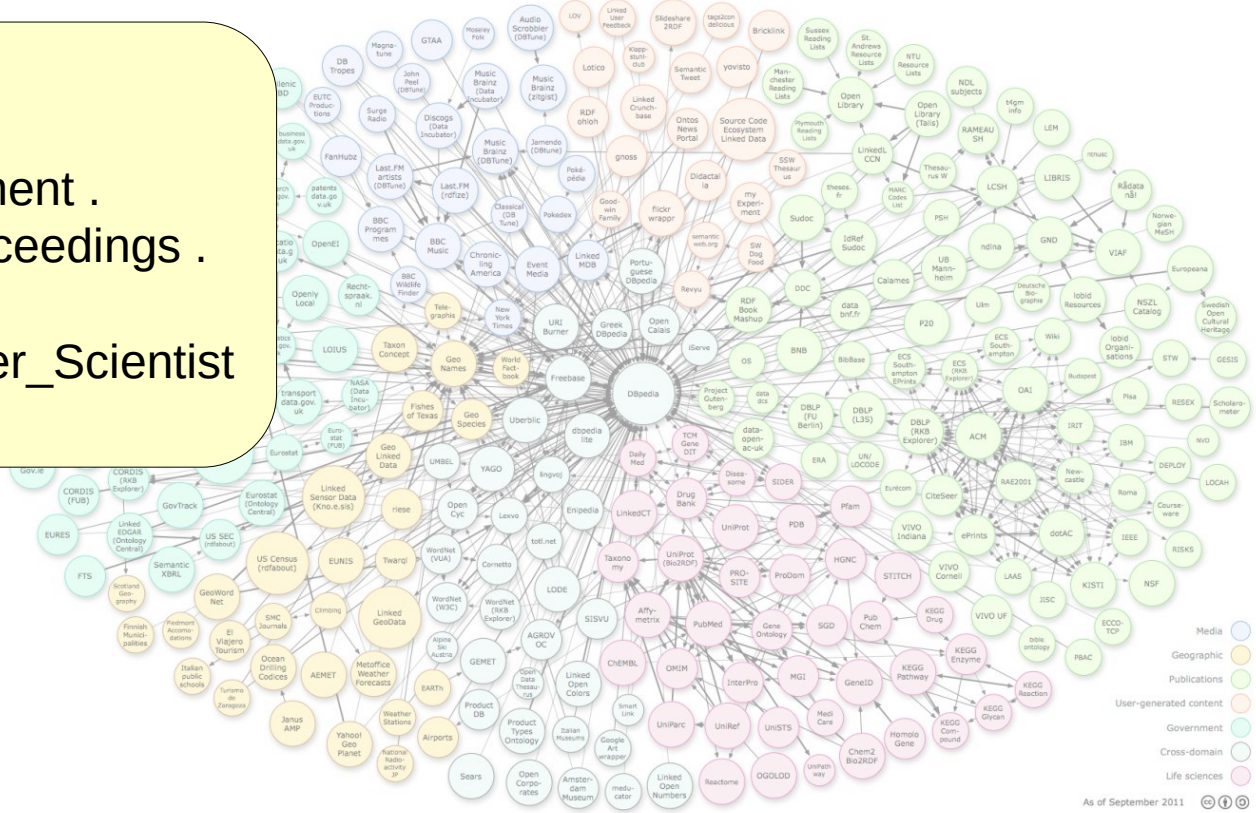

Where?

Index

- ACM
- DBLP

SPARQL queries on LOD ???

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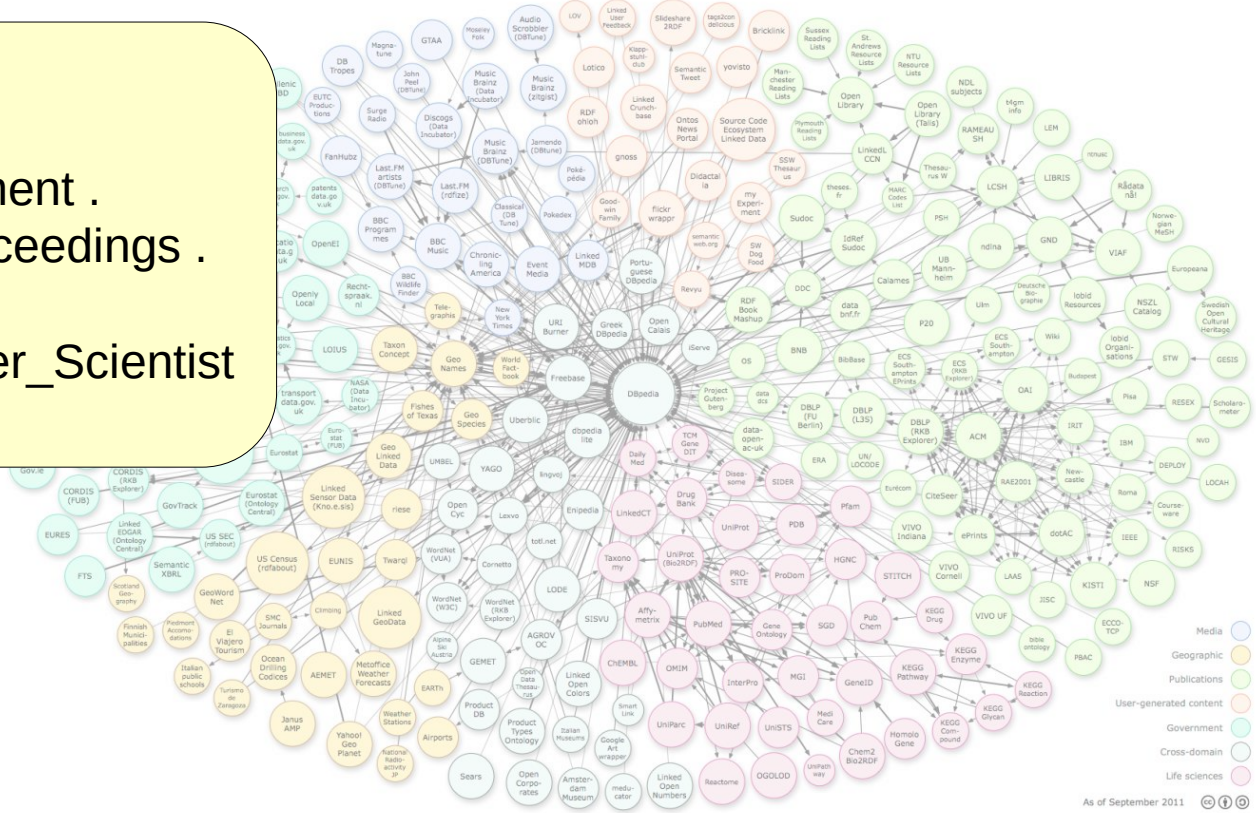

Where?

Index

0 hits

SPARQL queries on LOD ???

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   ?x dc:creator ?y .
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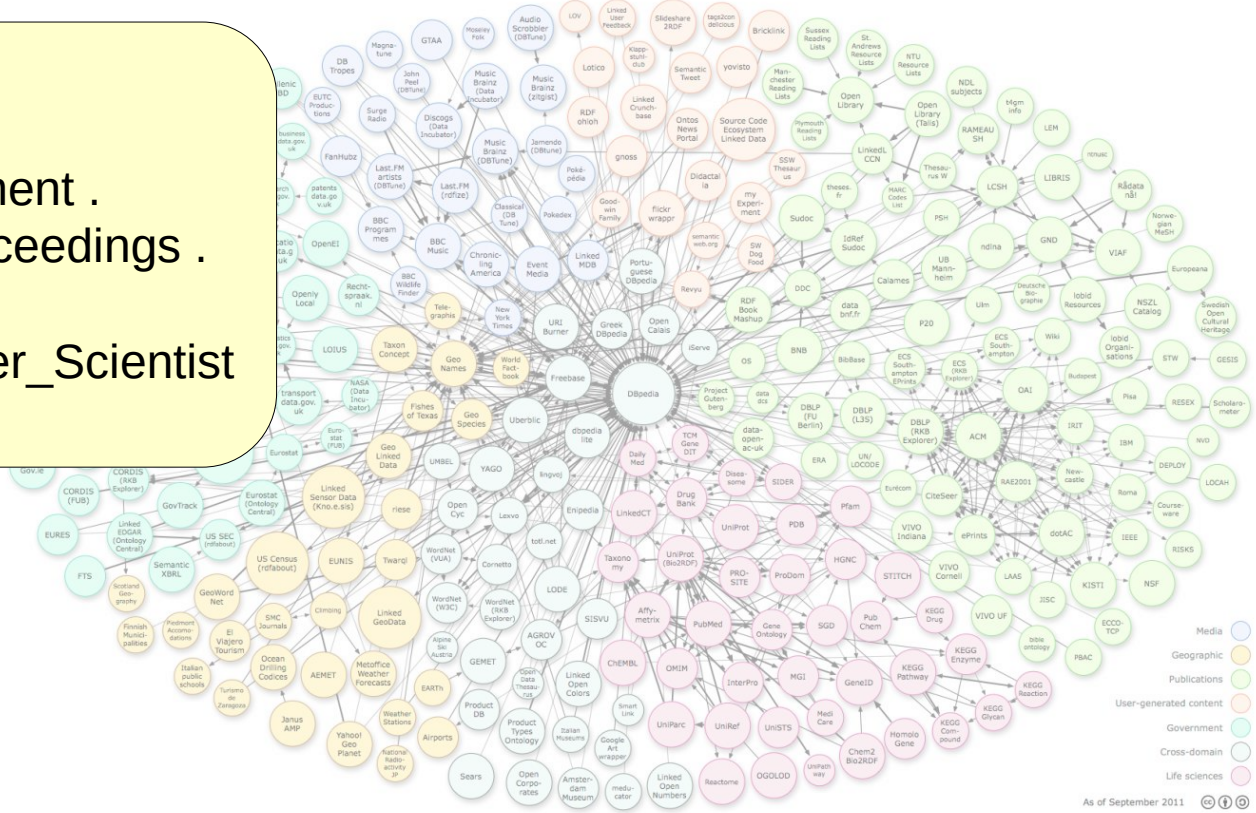

Where?

Index

1.000 hits

SPARQL queries on LOD ???

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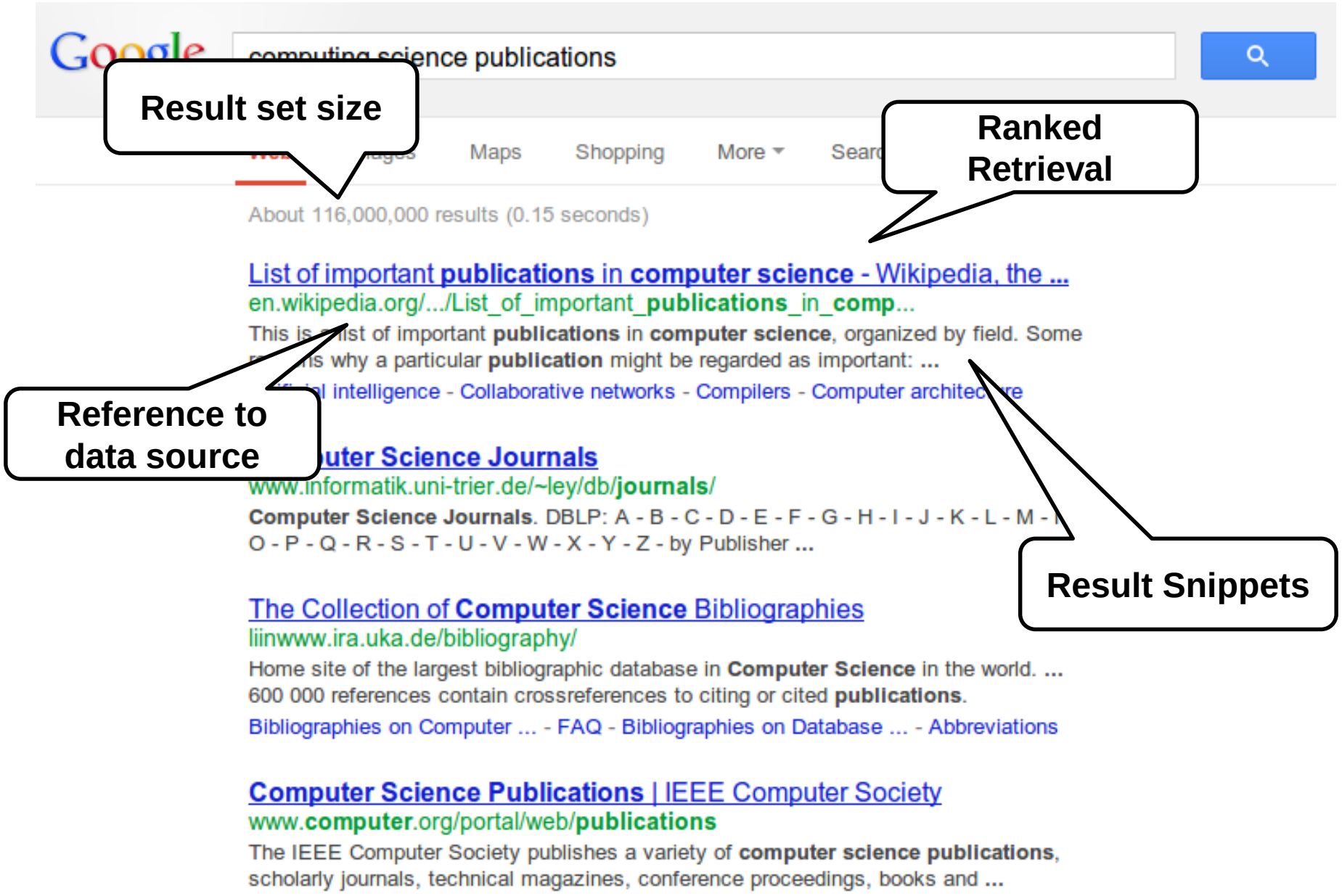
}
```

Where?

Index

Inspiration from web search engines ...



Inspiration from web search engines ...

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Related Queries

Gooooooooooogle ›

1 2 3 4 5 6 7 8 9 10 **Next**

lodatio

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX swrc: <http://swrc.ontoware.org/ontology#>
PREFIX dc: <http://purl.org/dc/elements/1.1/>
SELECT ?x
WHERE {
        ?x rdf:type foaf:Document .
        ?x dc:author ?y .
        ?y rdf:type foaf:Person .
}
```

Send Query

Did you mean?

Remove: ?y rdf:type foaf:Person Try this query

Remove: ?x dc:author ?y Try this query

Remove: ?x rdf:type foaf:Document Try this query

9 datasources with 9 instances

(1.668 seconds)

http://www4.wiwiss.fu-berlin.de/bizer/foaf.rdf (1 instances)

http://www4.wiwiss.fu-berlin.de/bizer/foaf.rdf (1 instances)

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- D2R Server - Publishing Releational Databases on the Semantic Web.

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- The TriQL.P Browser: Filtering Information using Context-, Content- and Rating-Based Trust Policies.

Page 1 of 1

Related Queries

Add: ?x dc11:title ?unknown1458 Try this query

WeST People and Knowledge Networks

Examples:

txn:authority

Try it!

po:Genre

Try it!

po:Series po:genre po:Genre

Try it!

More examples

lodatio

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PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
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SELECT ?x
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Send Query

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Result set size

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Send Query

Did you mean?

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Remove: ?x dc:author ?y Try this query

Remove: ?x rdf:type foaf:Document Try this query

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Ranked Retrieval

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```

Send Query

Did you mean?

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Page 1 of 1

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lodatio

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Send Query

Did you mean?

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Page 1 of 1

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Examples:

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lodatio

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```

Send Query

Did you mean?

Did you mean?

Remove: ?y rdf:type foaf:Person Try this query

Remove: ?x dc:author ?y Try this query

Remove: ?x rdf:type foaf:Document Try this query

Result set size

Ranked Retrieval

9 datasources with 9 instances

(1.668 seconds)

http://www4.wiwiss.fu-berlin.de/bizer/foaf.rdf (1 instances)

http://www4.wiwiss.fu-berlin.de/bizer/foaf.rdf (1 instances)

http://www4.wiwiss.fu-berlin.de/is-group/data/events/Event1 (1 instances)

http://www4.wiwiss.fu-berlin.de/is-group/data/events/Event3 (1 instances)

Reference to data source

http://www4.wiwiss.fu-berlin.de/is-group/data/persons/Person6 (1 instances)

http://www4.wiwiss.fu-berlin.de/is-group/data/persons/Person6 (1 instances)

http://www4.wiwiss.fu-berlin.de/is-group/data/persons/Person7 (1 instances)

http://www4.wiwiss.fu-berlin.de/is-group/data/publications/Publication2 (1 instances)

- D2R Server - Publishing Releational Databases on the Semantic Web.

Result Snippets

http://www4.wiwiss.fu-berlin.de/is-group/data/publications/Publication3 (1 instances)

- The TriQL.P Browser: Filtering Information using Context-, Content- and Rating-Based Trust Policies.

Page 1 of 1

Related Queries

Related Queries

Add: ?x dc11:title ?unknown1458 Try this query

Examples:

txn:authority

Try it!

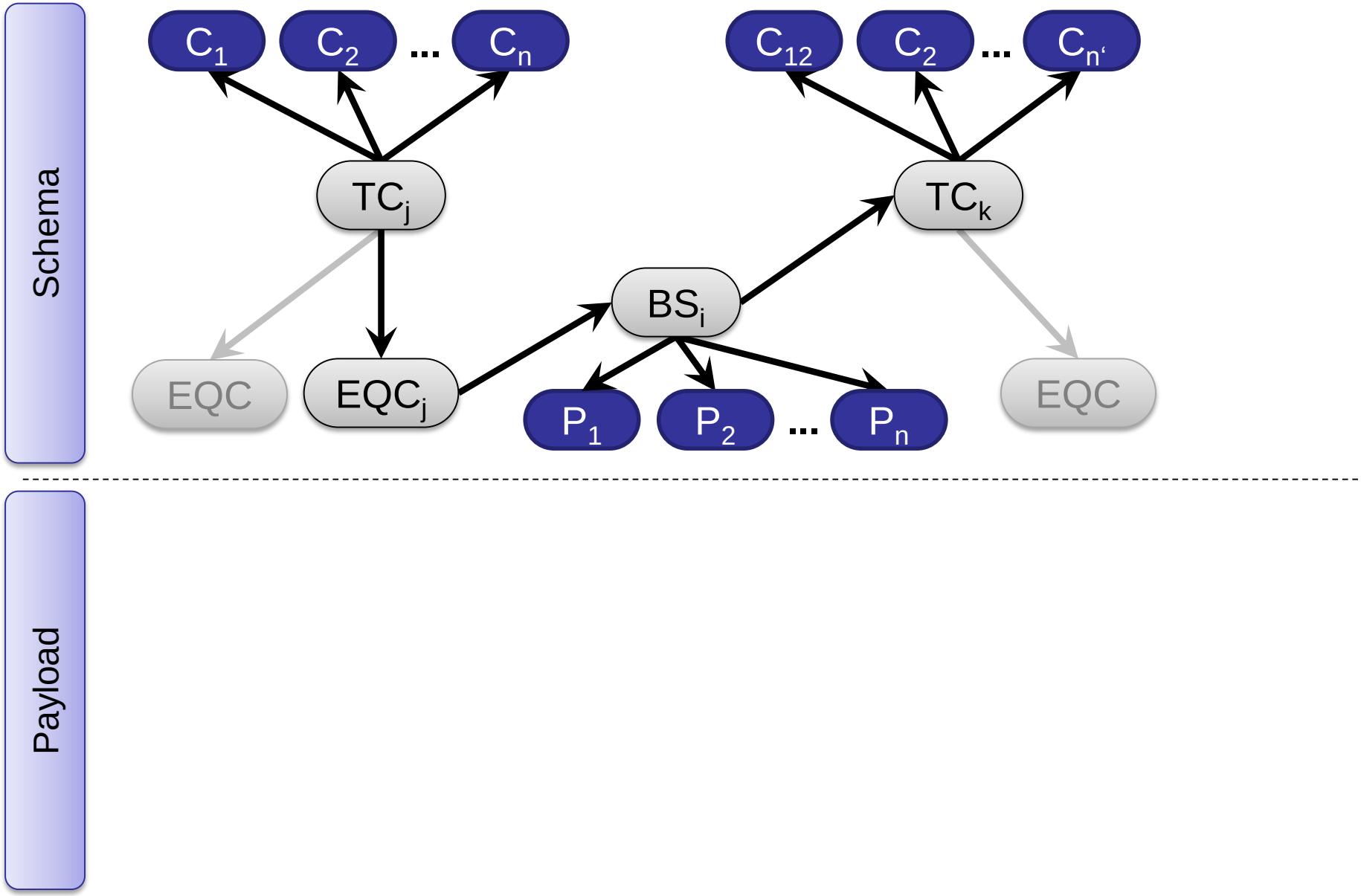
po:Genre

Try it!

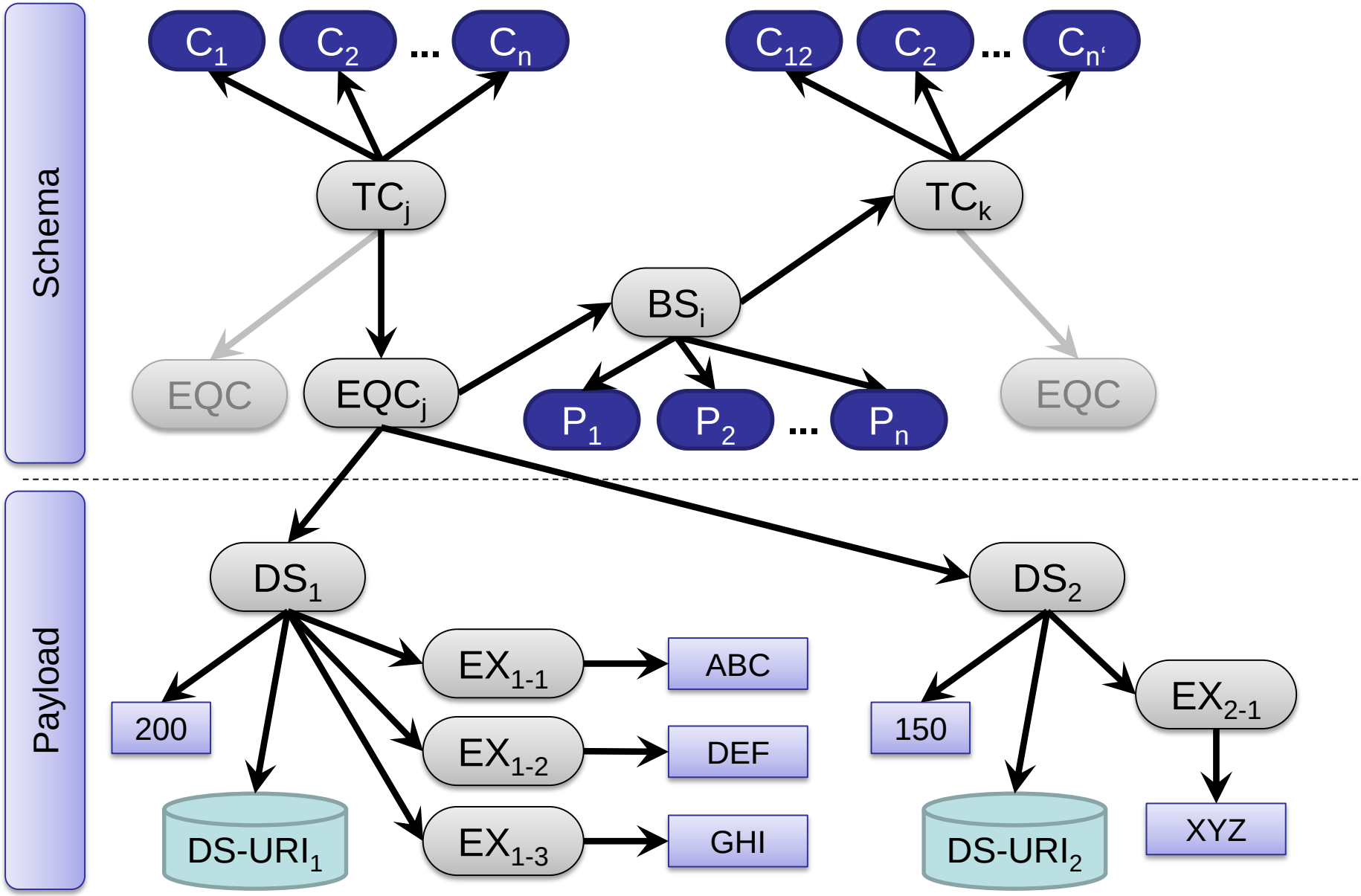
po:Genre

More examples

LODatio: Extending the Payload

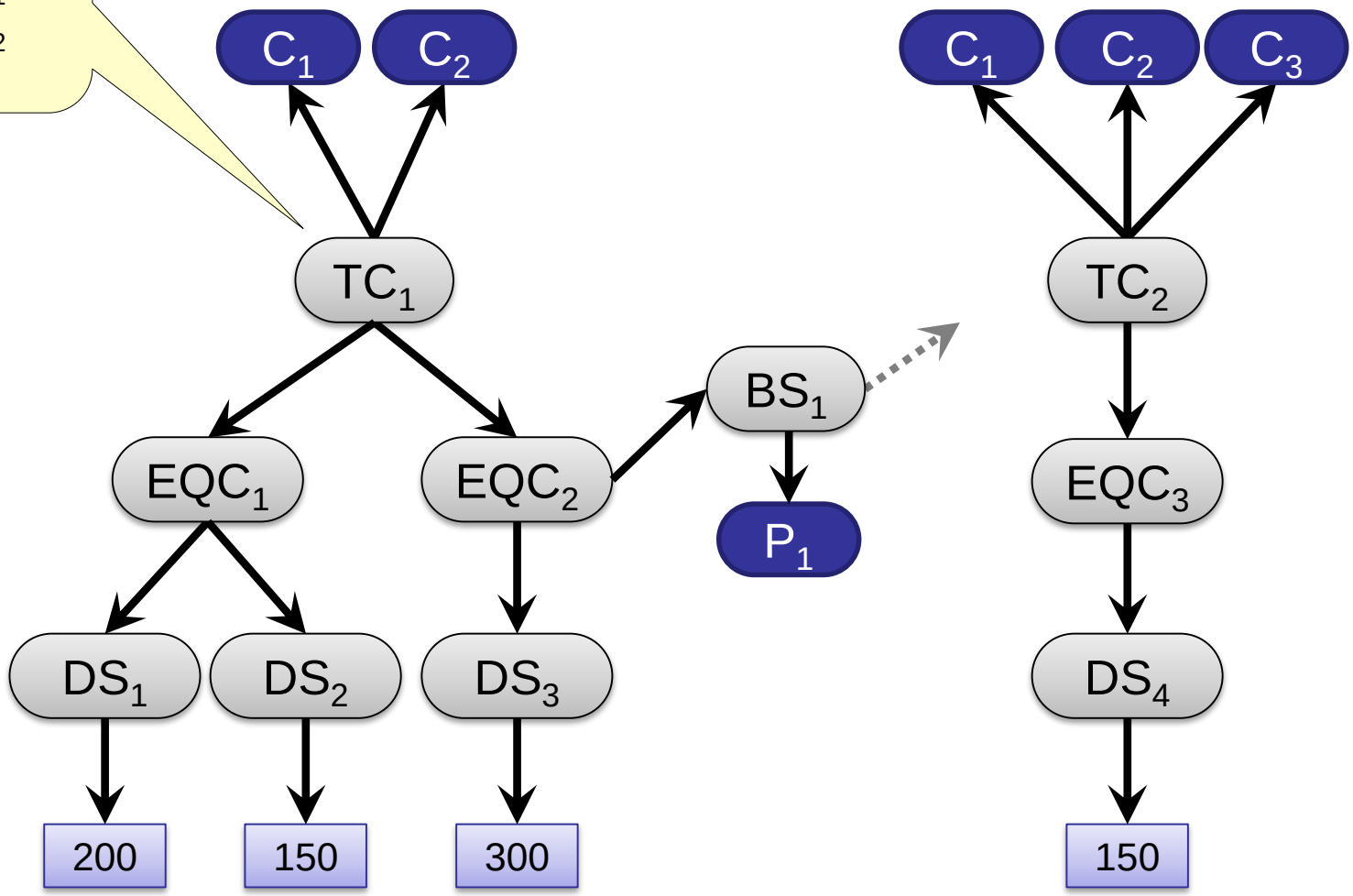


LODatio: Extending the Payload

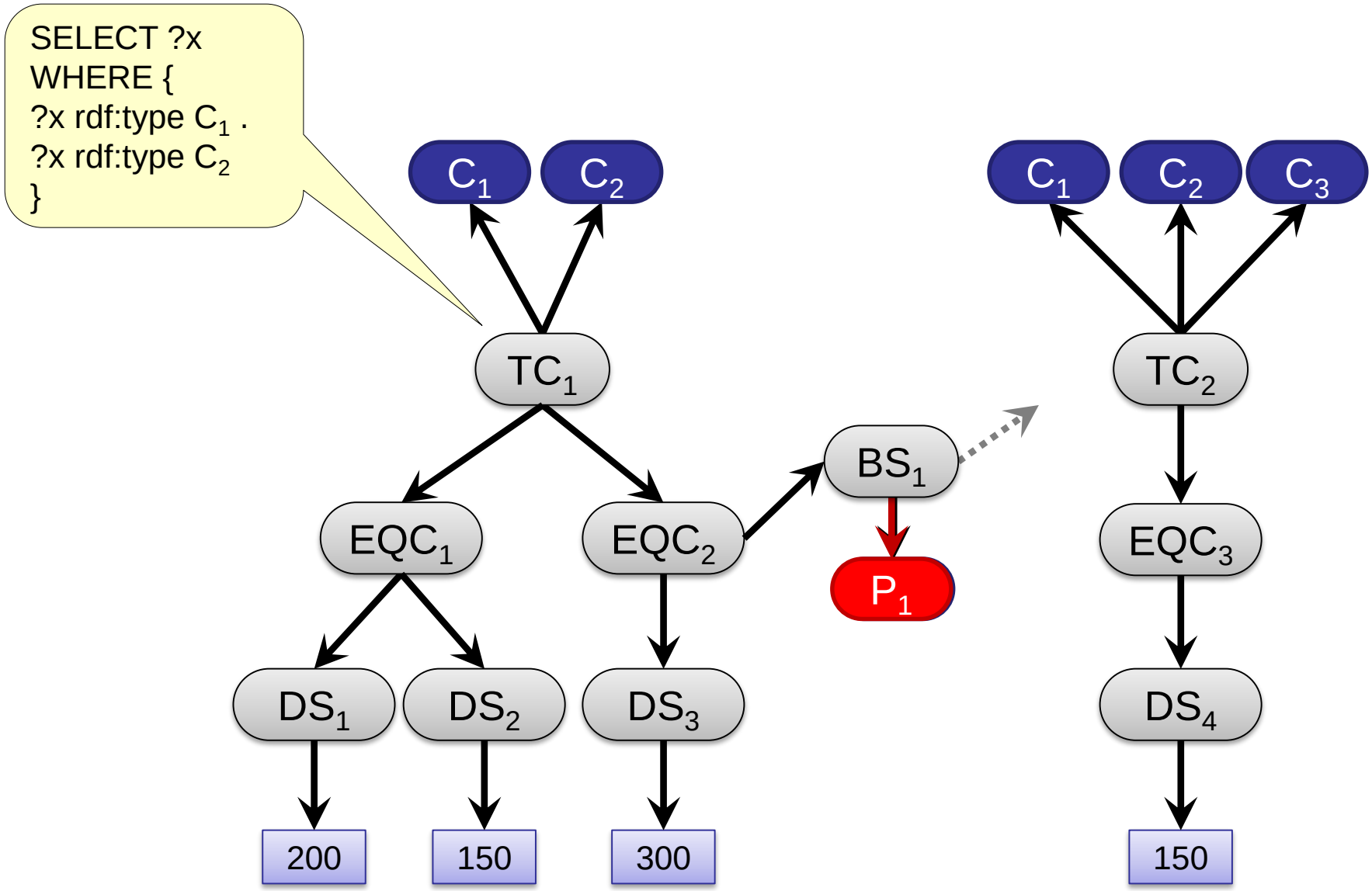


Realizing „Related Queries“

```
SELECT ?x
WHERE {
?x rdf:type C1 .
?x rdf:type C2
}
```



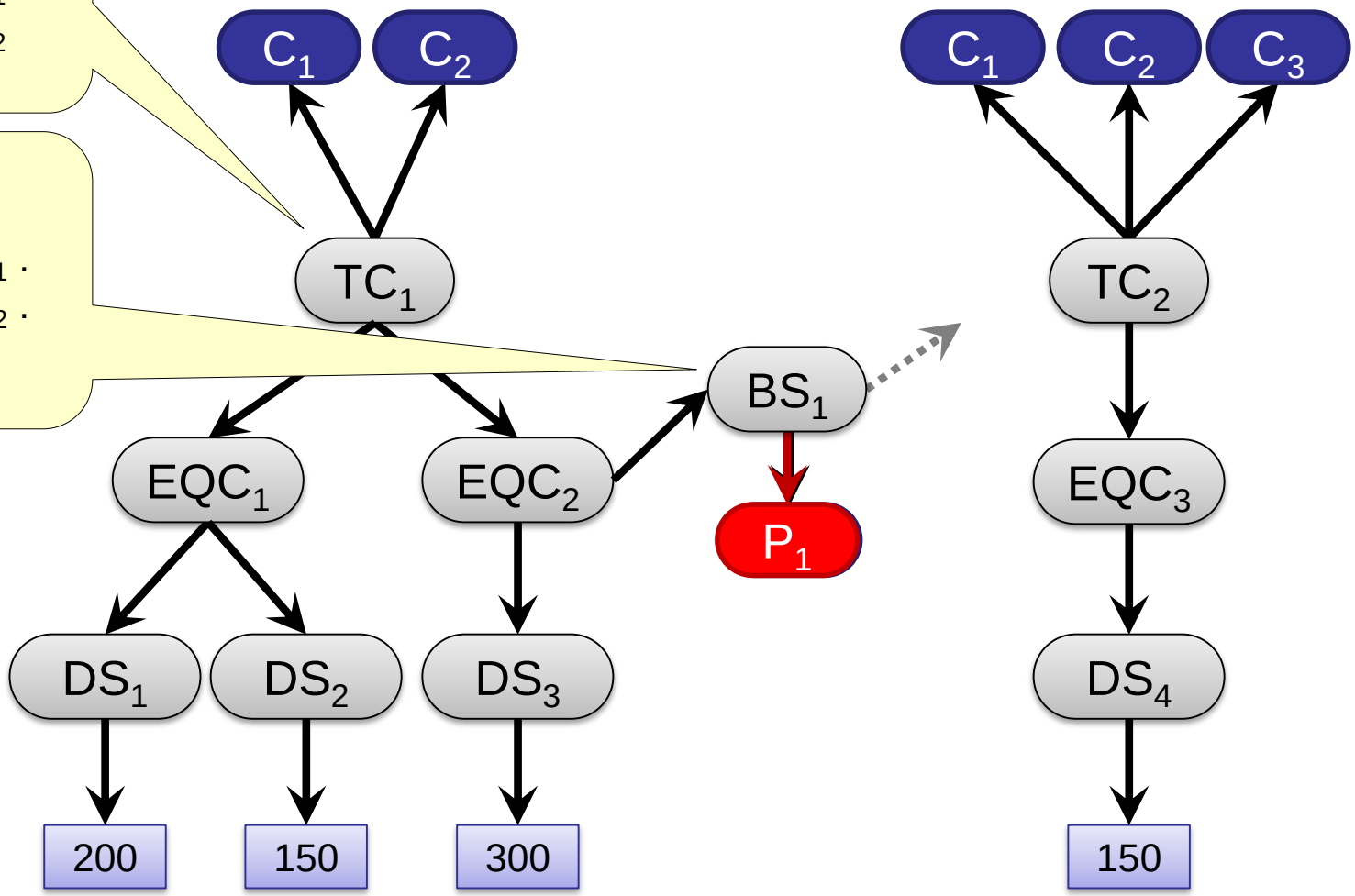
Realizing „Related Queries“



Realizing „Related Queries“

```
SELECT ?x
WHERE {
?x rdf:type C1 .
?x rdf:type C2
}
```

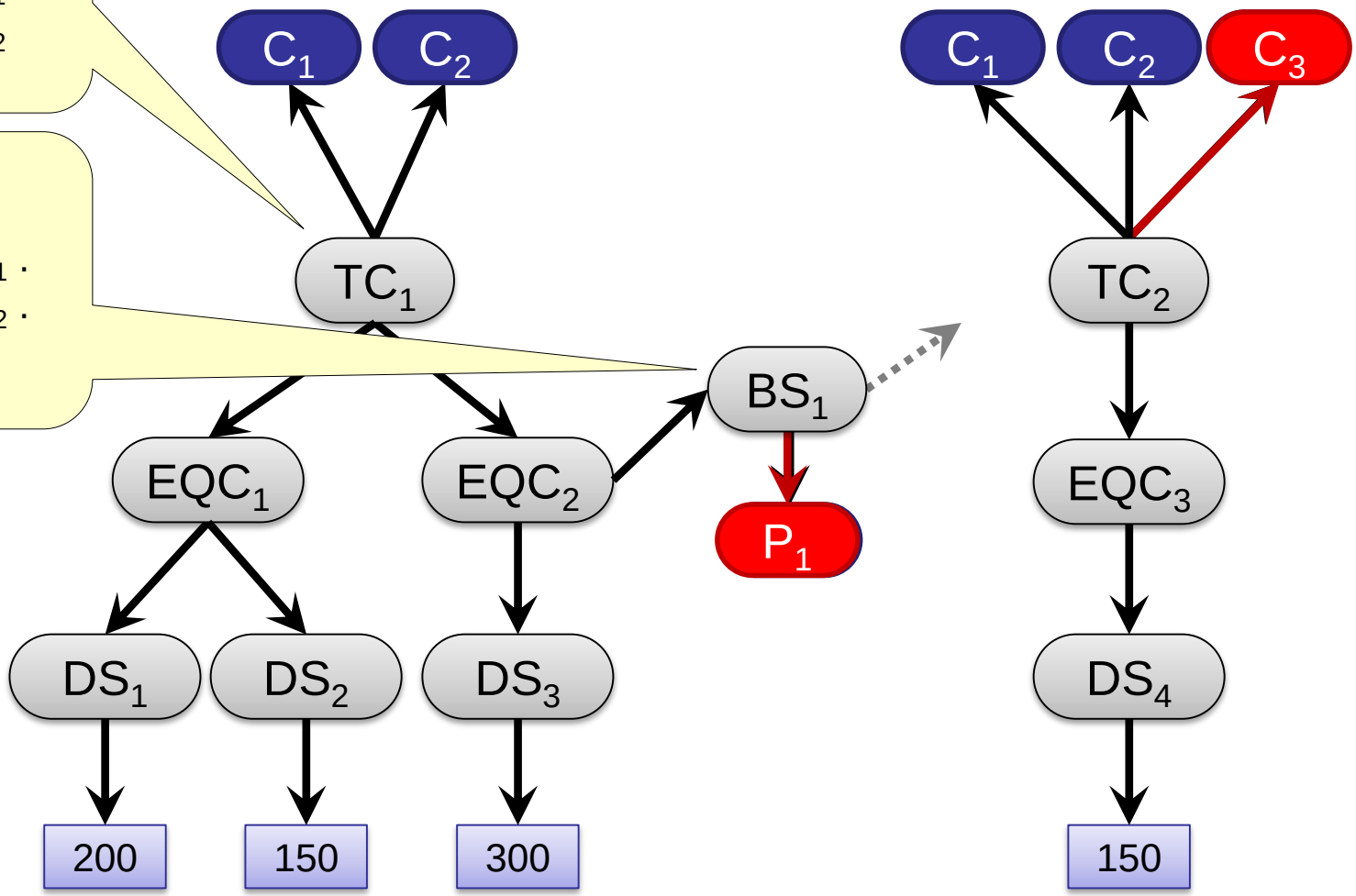
```
SELECT ?x
WHERE {
?x rdf:type C1 .
?x rdf:type C2 .
?x P1 ?y
}
```



Realizing „Related Queries“

```
SELECT ?x
WHERE {
?x rdf:type C1 .
?x rdf:type C2
}
```

```
SELECT ?x
WHERE {
?x rdf:type C1 .
?x rdf:type C2 .
?x P1 ?y
}
```

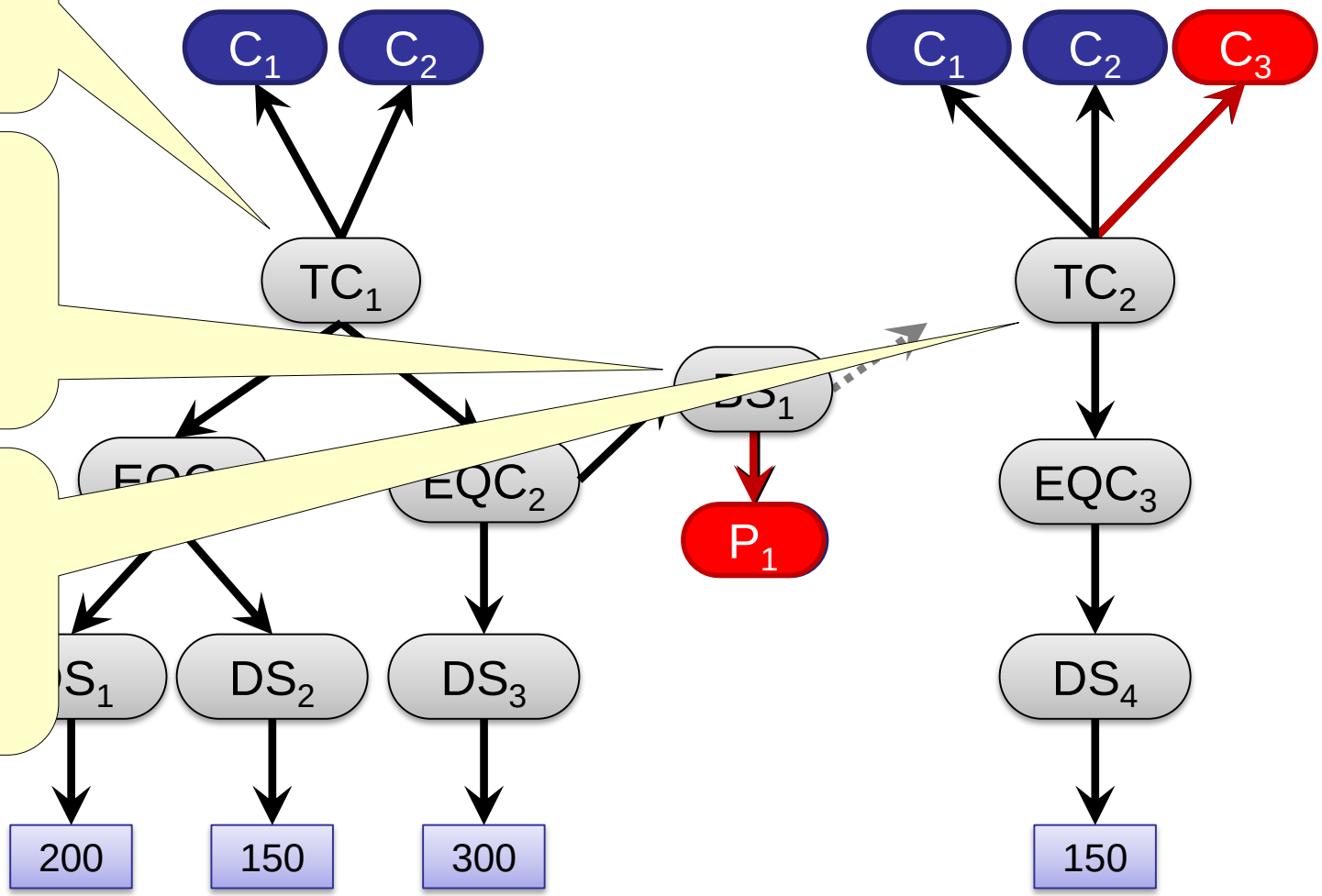


Realizing „Related Queries“

```
SELECT ?x
WHERE {
?x rdf:type C1 .
?x rdf:type C2
}
```

```
SELECT ?x
WHERE {
?x rdf:type C1 .
?x rdf:type C2 .
?x P1 ?y
}
```

```
SELECT ?x
WHERE {
?x rdf:type C1 .
?x rdf:type C2 .
?x P1 ?y .
?y rdf:type C3 .
}
```



Conclusions

- Programming the Semantic Web requires new concepts
- Linked Open Data
  - High volume, Varied data, Varying schemata
- Schema-level indices
  - Efficient approximative computation
  - High accuracy
- Applications
  - Search
  - Analysis
  - ... (many more)

Thank you!

WeST
People and Knowledge Networks

References

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