Stream Reasoning For Linked Data

M. Balduini, J-P Calbimonte, O. Corcho, D. Dell'Aglio, E. Della Valle, and J.Z. Pan
http://streamreasoning.org/sr4ld2013

ISWC 2013
Sydney, Australia

SPARQLStream: Ontology-based access to data streams

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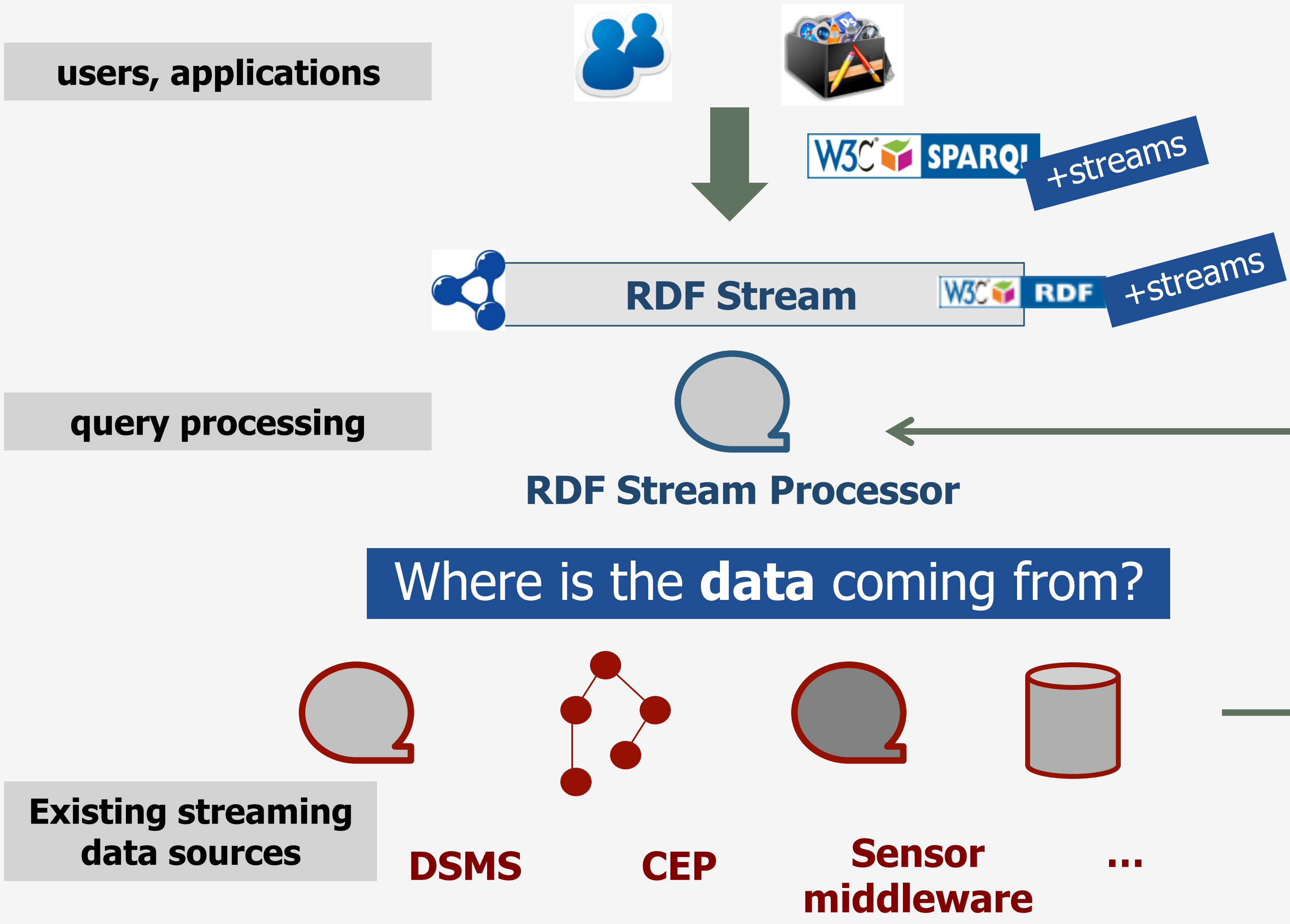
SPARQLStream

- Virtual RDF views over data streams
- Ontology-based access to data streams
  - Examples
  - Architecture
  - Underlying query processors
- SPARQLStream language
- Query rewriting
  - R2RML mappings
- Resources

Querying RDF Streams



Virtual RDF views over data streams

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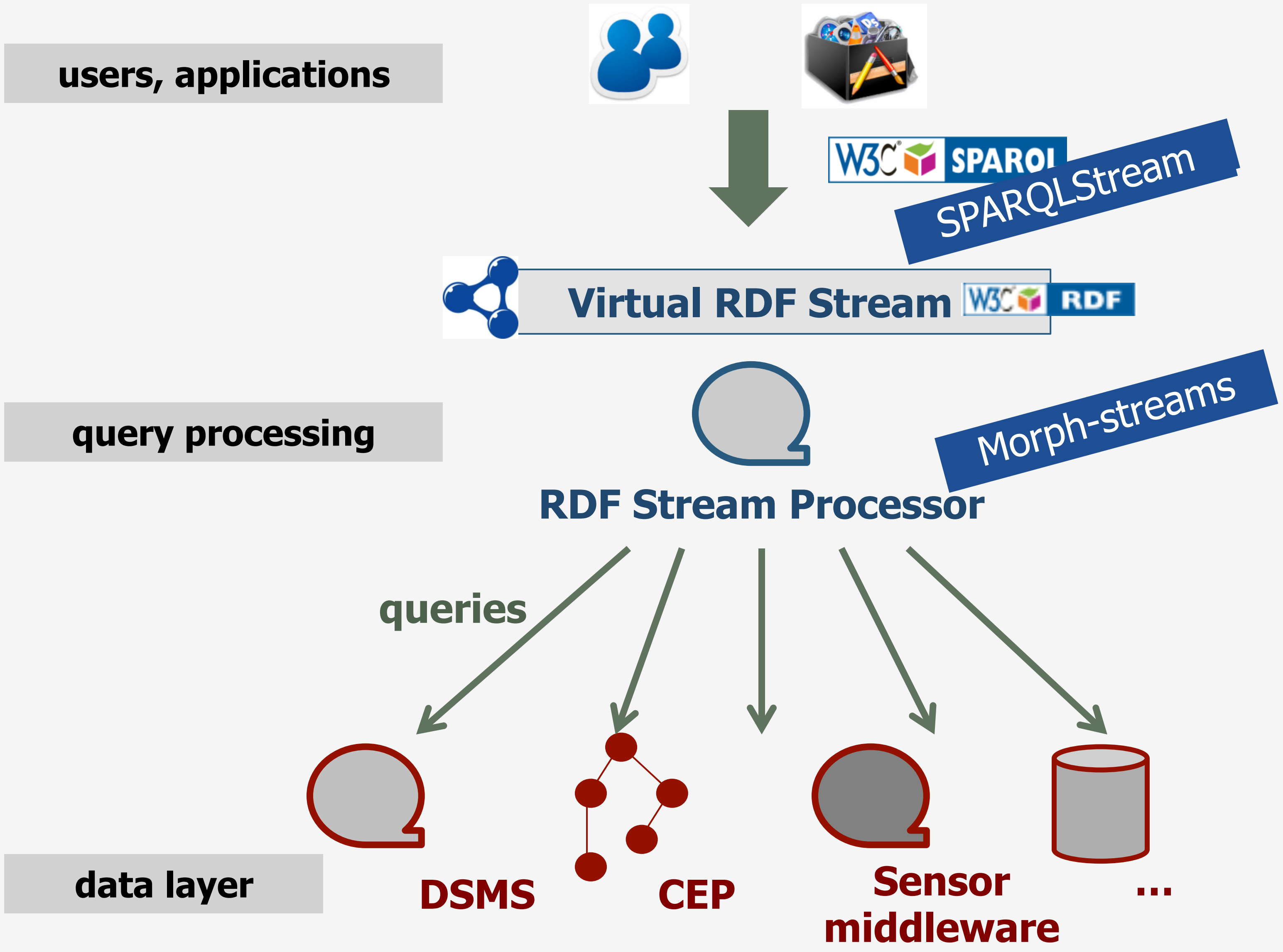
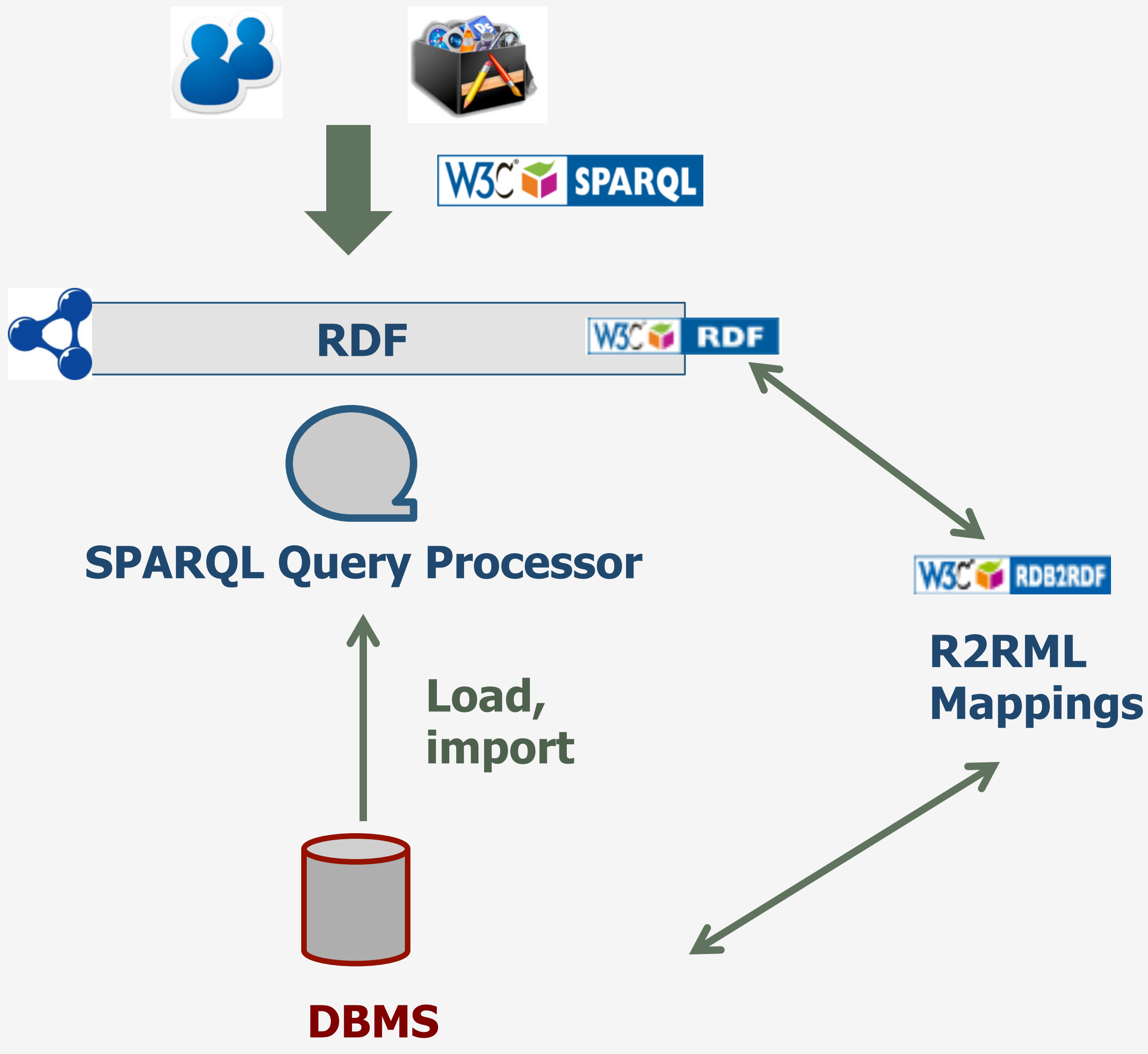


Already seen somewhere…?



Stream Processor Implementations

Data Stream Management Systems (DSMS)

CQL/Stream Borealis
StreamMill NiagaraCQ
TelegraphCQ Esper

Complex Event Processors (CEP)

GEM Rapide Oracle CEP
Cayuga CEDR IBM InfoSphere

Stream Data Middleware

Hourglass Cosm Microsoft StreamInsight
SStreamWare GSN Sybase CEP StreamBase

Diverse **query languages**

Different **query capabilities**

Different **query models**

Morph-streams: Overview

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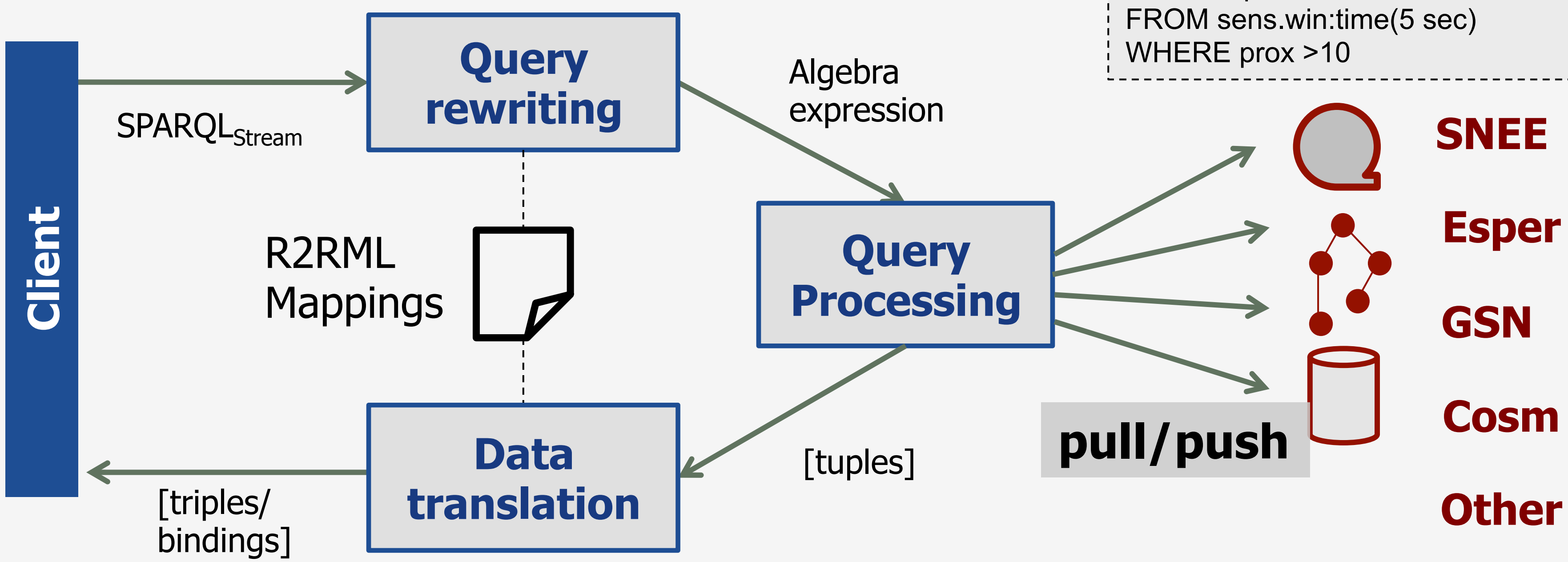
```
SELECT ?proximity
FROM STREAM <http://streamreasoning.org/
SensorReadings.srdf> [NOW–5 S]
WHERE {
  ?obs a ssn:ObservationValue;
       qudt:numericalValue ?proximity;
  FILTER (?proximity>10) }
```

$$\pi_{timed,prox}$$
$$\sigma_{prox>10}$$
$$\omega_{5\ Seconds}$$
sens

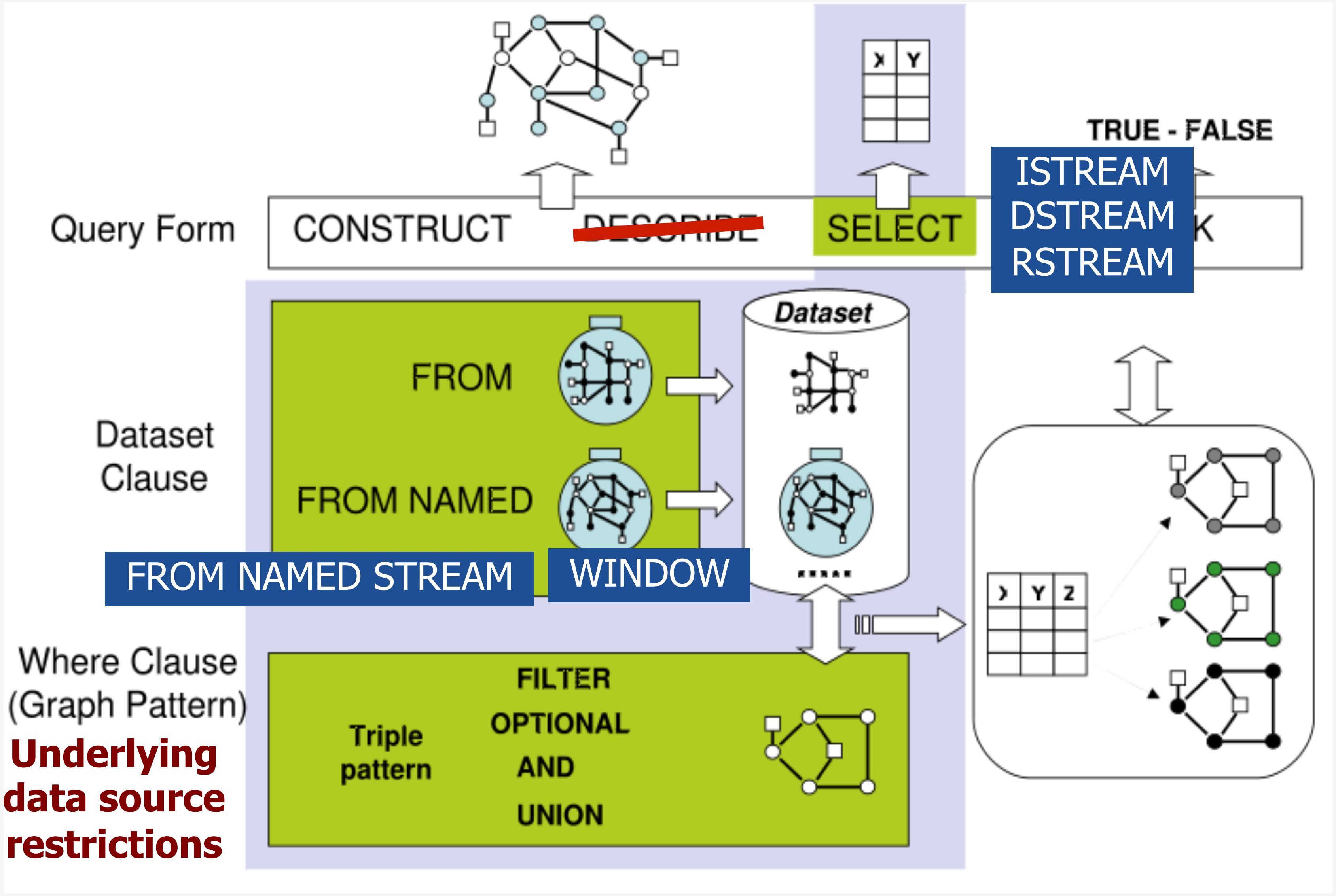
```
SELECT prox
FROM sens.win:time(5 sec)
WHERE prox >10
```



Morph-streams procesing SPARQL$_{Stream}$ queries

https://github.com/jpcik/morph-streams

SPARQLStream Language



Underlying data source restrictions

SPARQLStream: examples

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SPARQL$_{Stream}$

```
PREFIX sr4ld: <http://www.streamreasoning.org/ontologies/socialsensor,owl#>
SELECT ?room
FROM NAMED STREAM <http://www.streamreasoning.org/streams/socialsensor.srdf> [NOW-10 S]
WHERE {
   ?obs sr4ld:observedBy ?sensor.
   ?obs sr4ld:where  ?room.
}
```

All rooms where something was observed in the last 10s

```
PREFIX sr4ld: <http://www.streamreasoning.org/ontologies/socialsensor,owl#>
SELECT (COUNT(?person) AS ?nmb) ?room
FROM NAMED STREAM <http://www.streamreasoning.org/streams/socialsensor.srdf> [NOW-10 S]
WHERE {
   ?obs sr4ld:who ?pers.
   ?obs sr4ld:where  ?room.
}
GROUP BY ?room
```

Number of persons observed in each room in the last 10s

SPARQLStream Language

NamedStream	→ 'FROM' ['NAMED'] 'STREAM' *StreamIRI* '[' *Window* ']'
Window	→ 'NOW-' *Integer TimeUnit* [*UpperBound*] [*Slide*]
UpperBound	→ 'TO NOW-' *Integer TimeUnit*
Slide	→ 'SLIDE' *Integer TimeUnit*
TimeUnit	→ 'MS' | 'S' | 'MINUTES'| 'HOURS' | 'DAY'

```
SELECT ISTREAM ?room
FROM NAMED STREAM <http://www.streamreasoning.org/streams/socialsensor.srdf> [NOW-10 S]
WHERE {…
```

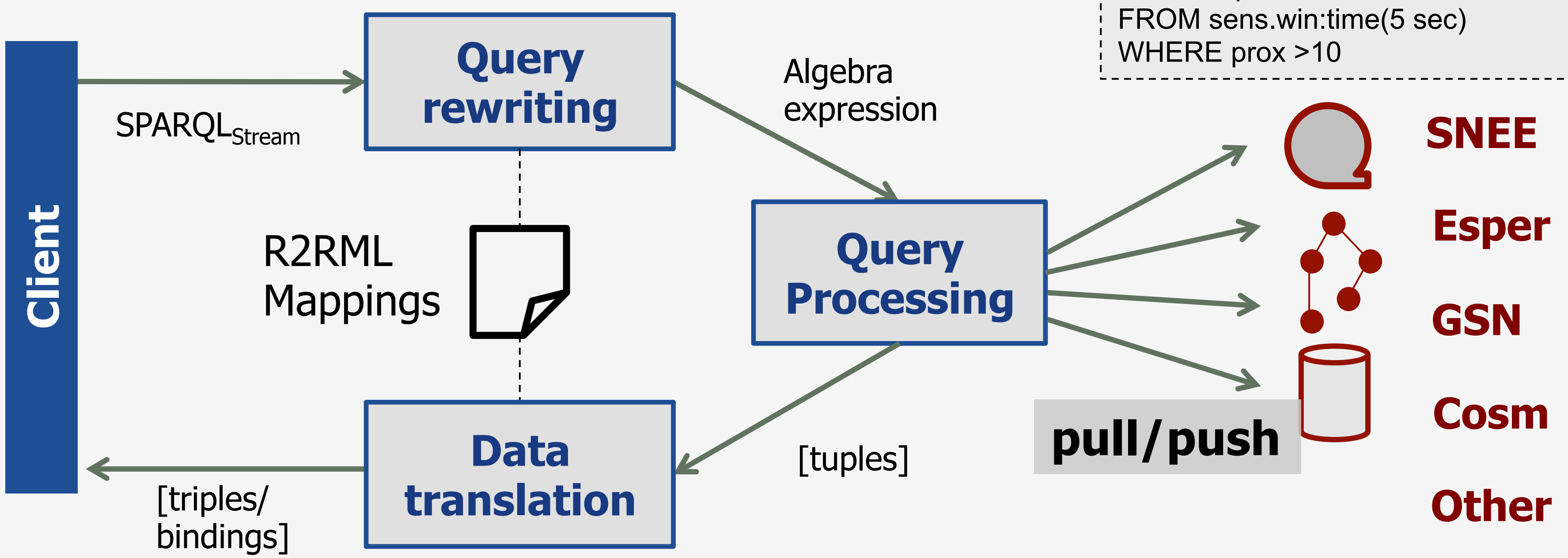
Select	→ 'SELECT' [*Xstream*] [*Distinct* | *Reduced*] …
Xstream	→ 'RSTREAM' | 'ISTREAM' | 'DSTREAM'

Morph-streams: Overview

```
SELECT ?proximity
FROM STREAM <http://streamreasoning.org/
SensorReadings.srdf> [NOW–5 S]
WHERE {
  ?obs a ssn:ObservationValue;
      qudt:numericalValue ?proximity;
  FILTER (?proximity>10) }
```

$$\pi_{timed,prox} \; | \; \sigma_{prox>10} \; | \; \omega_{5\ Seconds} \; | \; sens$$

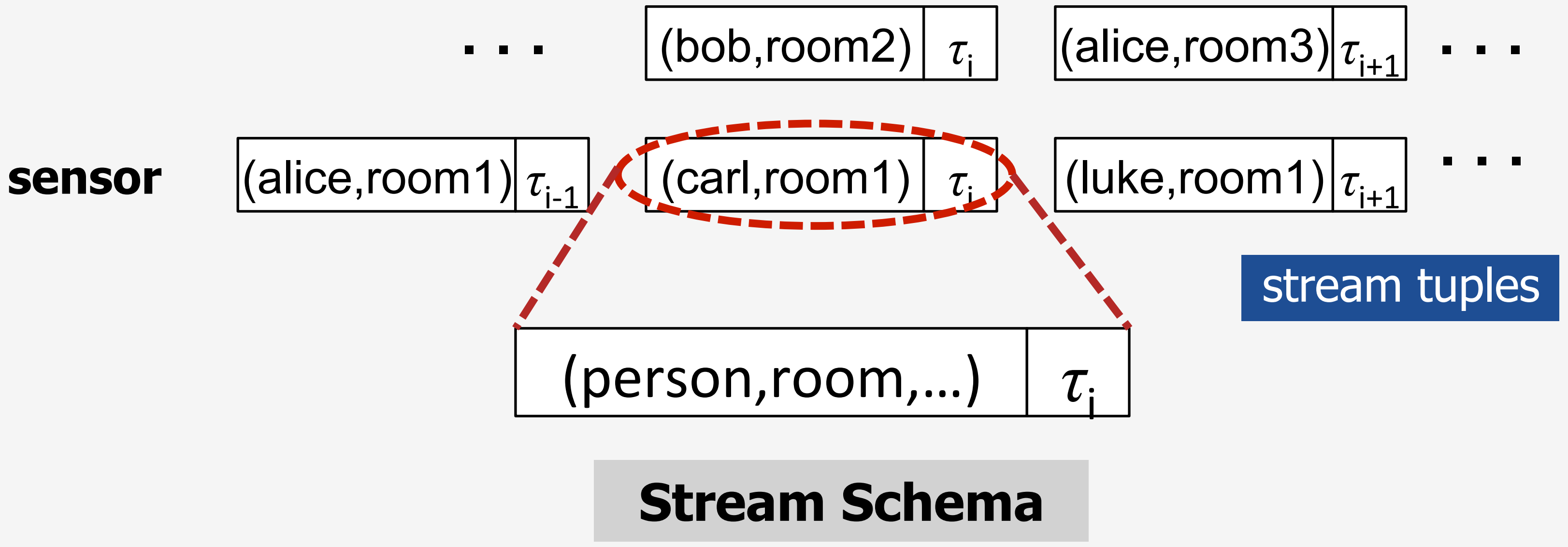
```
SELECT prox
FROM sens.win:time(5 sec)
WHERE prox >10
```



Morph-streams procesing SPARQL$_{Stream}$ queries

https://github.com/jpcik/morph-streams

Now, where is the data?


. . .
(bob,room2) τ_i
(alice,room3) τ_{i+1}
. . .
sensor
(alice,room1) τ_{i-1}
(carl,room1) τ_i
(luke,room1) τ_{i+1}
. . .
stream tuples
(person,room,...) τ_i
Stream Schema

DSMS, CEP, middleware can evaluate queries over this model

Underlying Query Processors

Esper
- CEP/DSMS
- EPL language

```
SELECT prox FROM sensors.win:time(5 minute)
WHERE prox >10
```

SNEE
- DSMS/Sensor Network Query Evaluator
- Compile queries to sensor code

```
SELECT prox FROM sensors [FROM NOW-5
MINUTES TO NOW]
WHERE prox >10
```

GSN
- Sensor middleware
- REST API

```
http://montblanc.slf.ch:22001/multidata?
vs[0]=sensors&
field[0]=proximity_field&c_min[0]=10&
from=15/05/2012+05:00:00&to=15/05/2012+10:00:
00
```

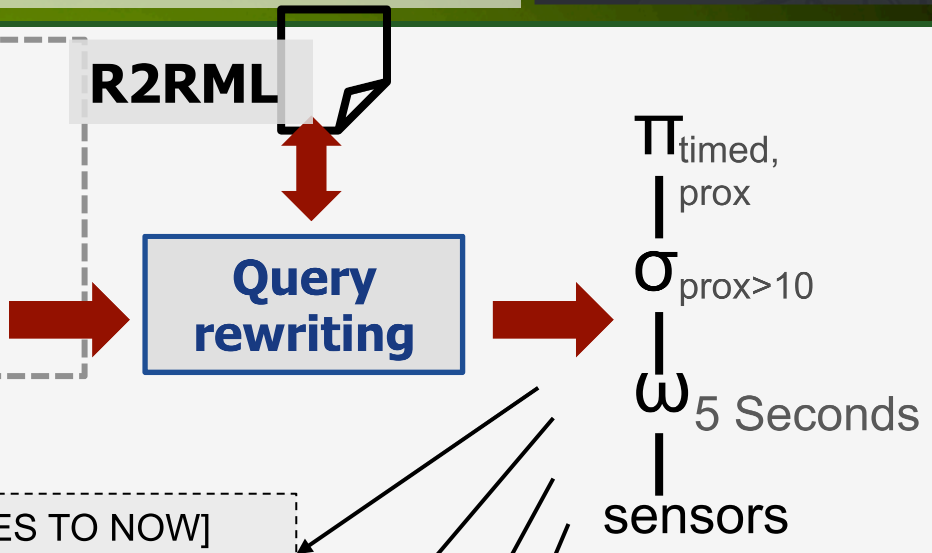
Cosm/Xively
- Sensor middleware
- Open platform
- REST API

```
http://api.cosm.com/v2/feeds/14321/datastreams/
4?
start=2012-05-15T05:00:00Z&end=2012-05-15T1
0:00:00Z
```

Underlying Query Processors

SPARQLStream

```
SELECT ?proximity
FROM STREAM <http://streamreasoning.org/SensorReadings.srdf>
[NOW–5 S]
WHERE {
  ?obs a ssn:ObservationValue;
       qudt:numericalValue ?proximity;
  FILTER (?proximity>10) }
```



```
SELECT prox FROM sensors [FROM NOW-5 MINUTES TO NOW]
WHERE prox >10
```

SNEE (DSMS)

```
SELECT prox FROM sensors.win:time(5 minute)
WHERE prox >10
```

Esper (CEP)

```
http://montblanc.slf.ch:22001/multidata?
vs[0]=sensors&field[0]=proximity_field&c_min[0]=10&
from=15/05/2012+05:00:00&to=15/05/2012+10:00:00
```

GSN (middlwr)

```
http://api.cosm.com/v2/feeds/14321/datastreams/4?
start=2012-05-15T05:00:00Z&end=2012-05-15T10:00:00Z
```

Cosm Xively

Underlying query processors

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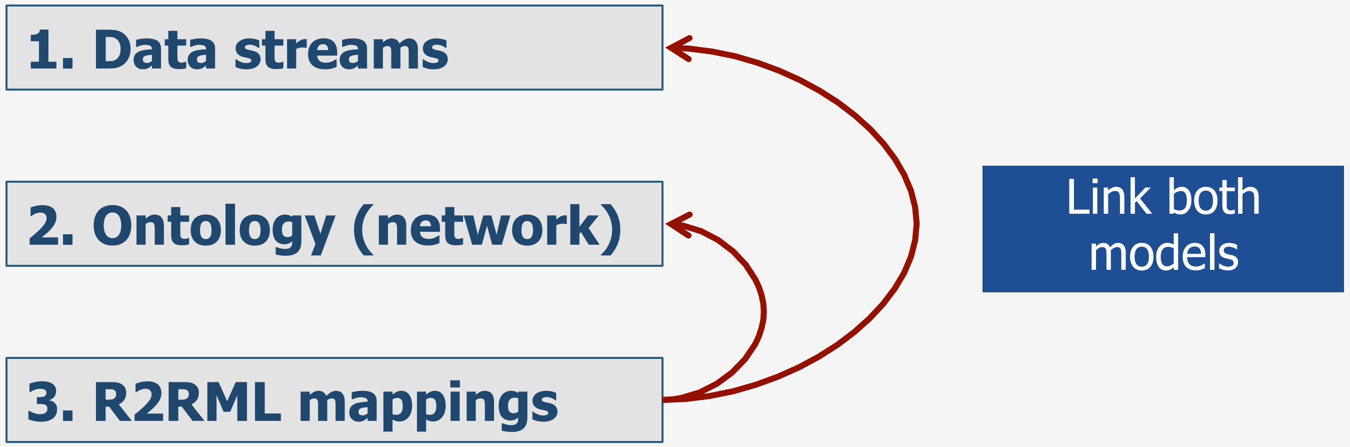
Features	Esper	SNEE	GSN	Cosm/Xively
Projection	✔	✔	✔	Fixed
Proj expression	✔	✔	✖	✖
Joins	✔	✔✖ only window	✖	✖
Union	✖	✔✖ not windows	✔	✖
Selection	✔	✔	✔	✖✔ limited
Aggregates	✔	✔	✔✖	✖
Time window	✔	✔	✔	✔
Tuple window	✔	✔	✔	✖
R2S	✔	✔	✖	✖
Conjunction, Disj	✔	✖	✖	✖
Repetition pattern	✔	✖	✖	✖
Sequence	✔	✖	✖	✖

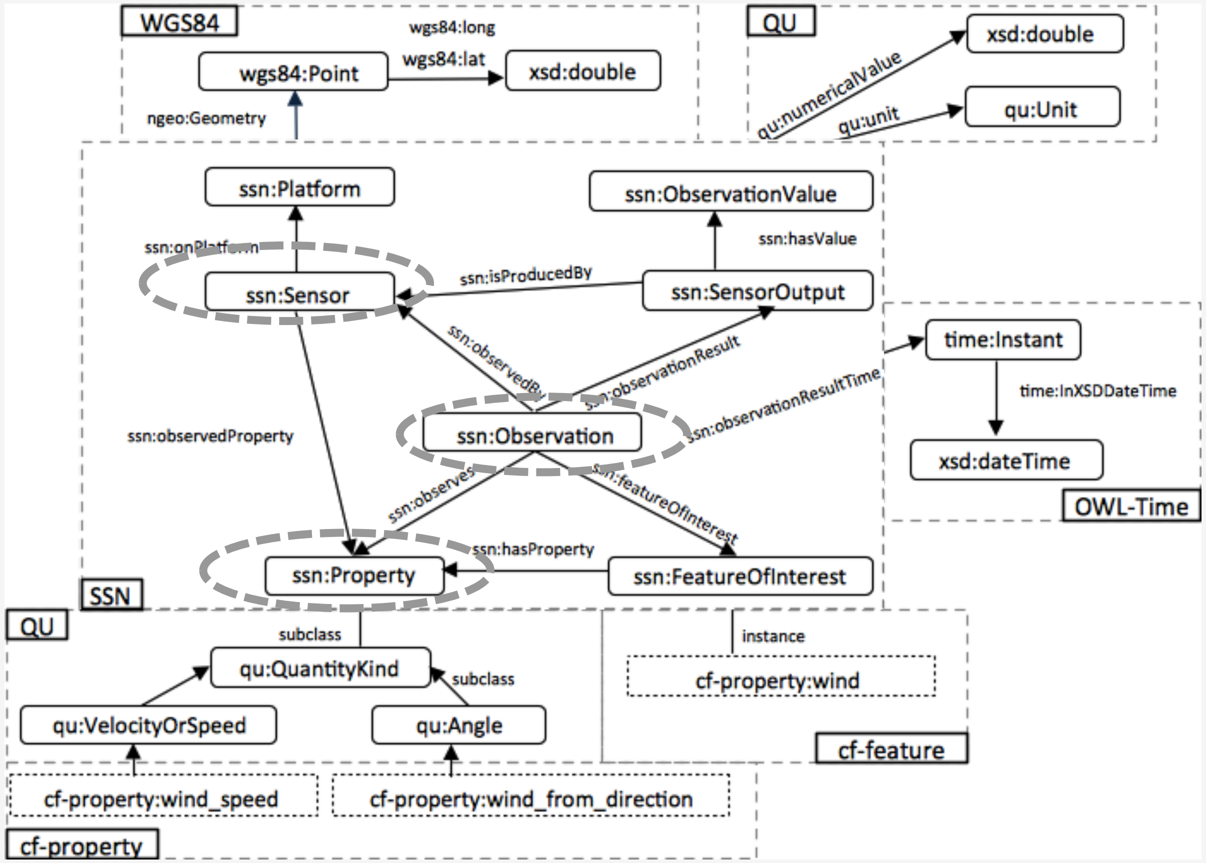
Configuring Morph-streams

- Main ingredients:



SSN Ontology with other ontologies

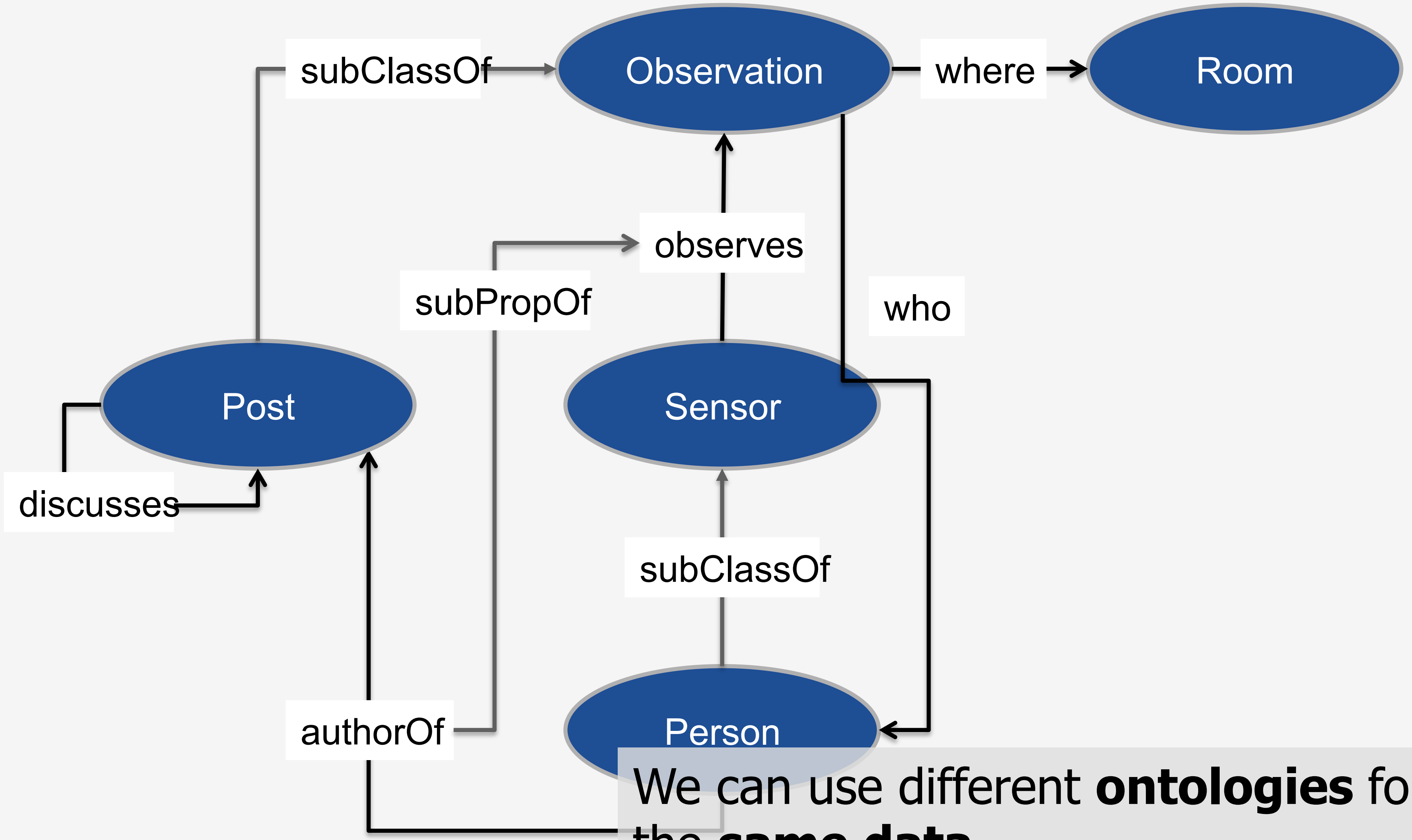
W3C SSN Ontology



modeling our streaming data

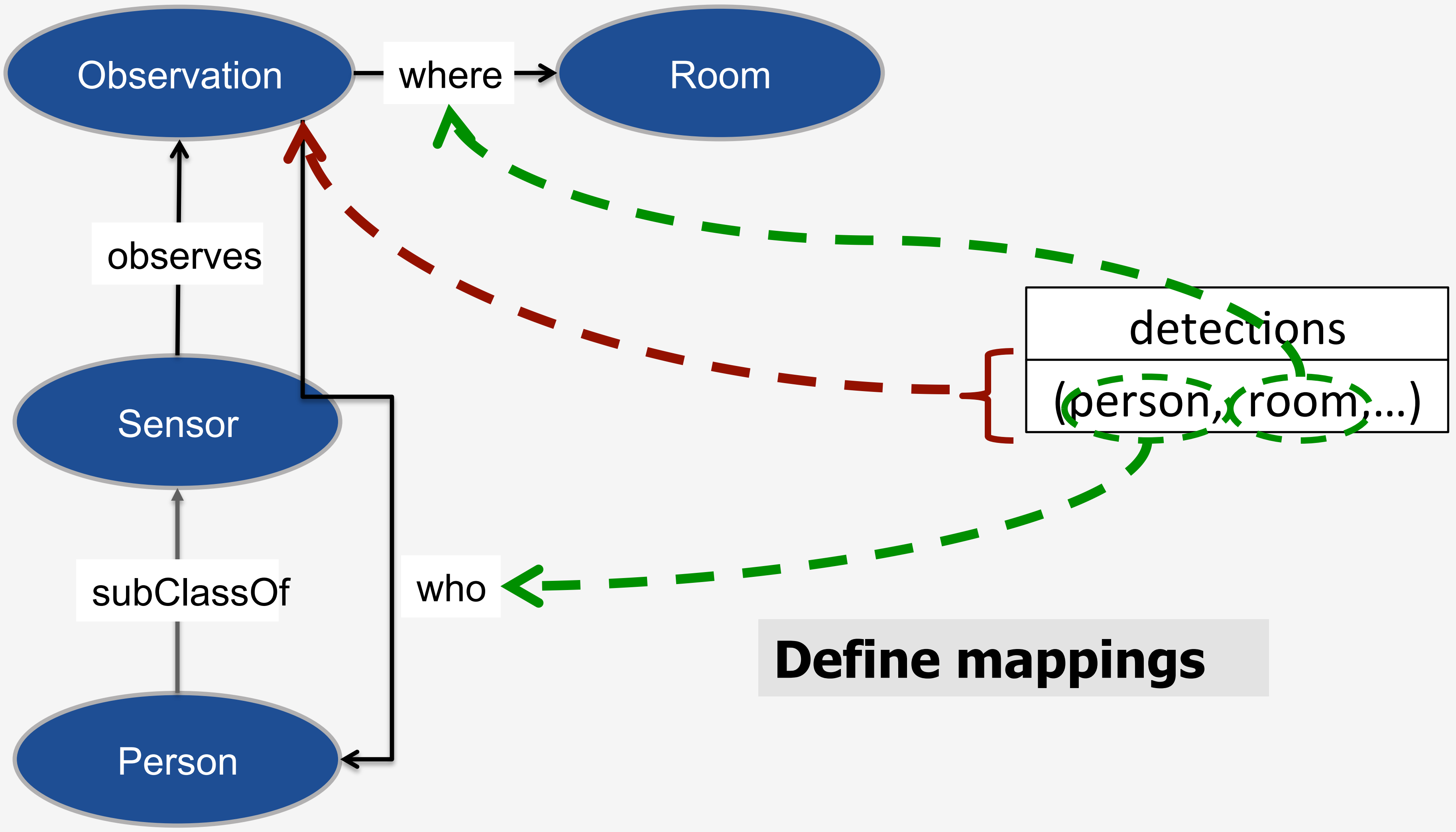
combine with **domain ontologies**

Our simpler ontology…



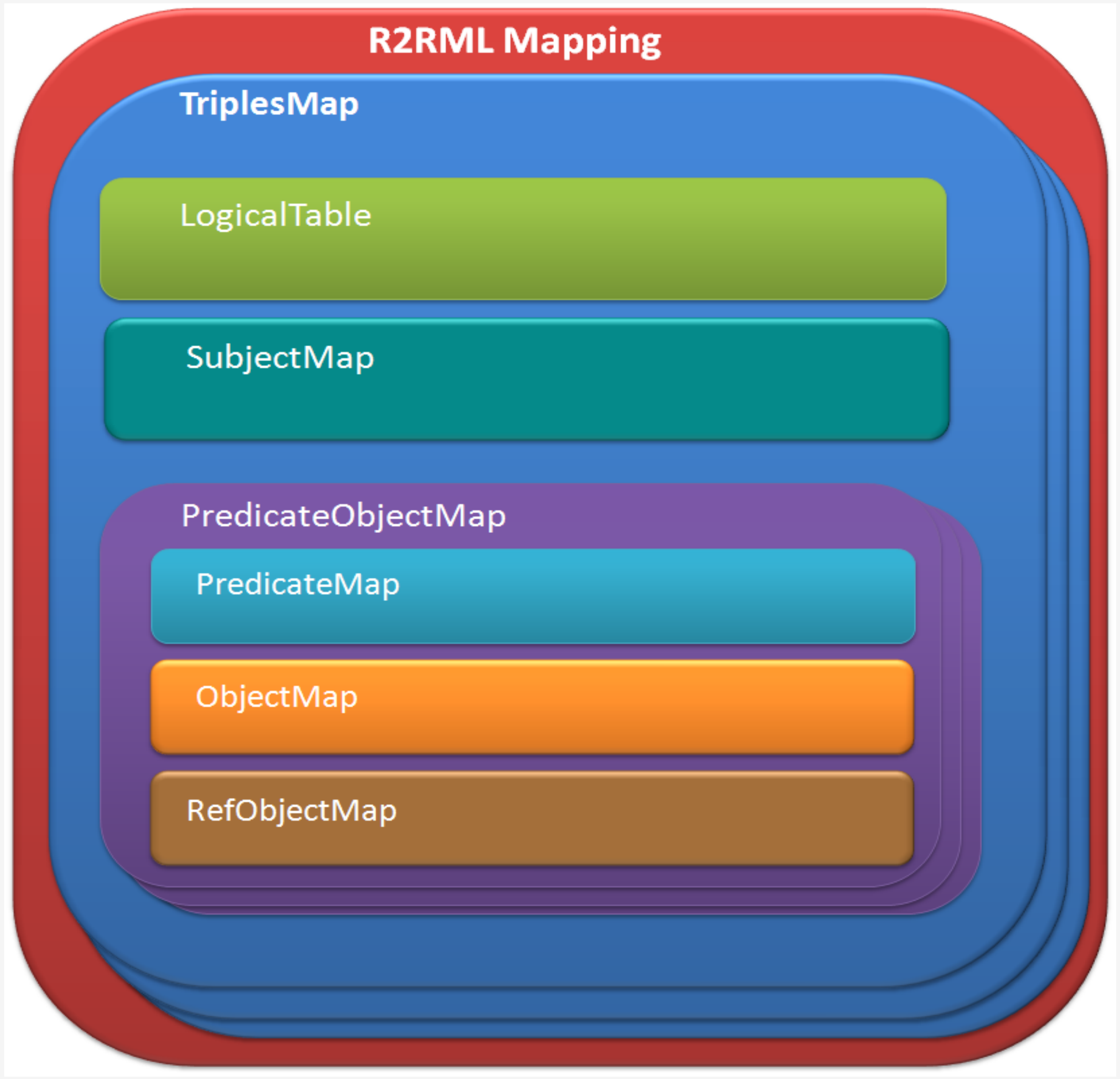
We can use different **ontologies** for the **same data**

Our simpler ontology…

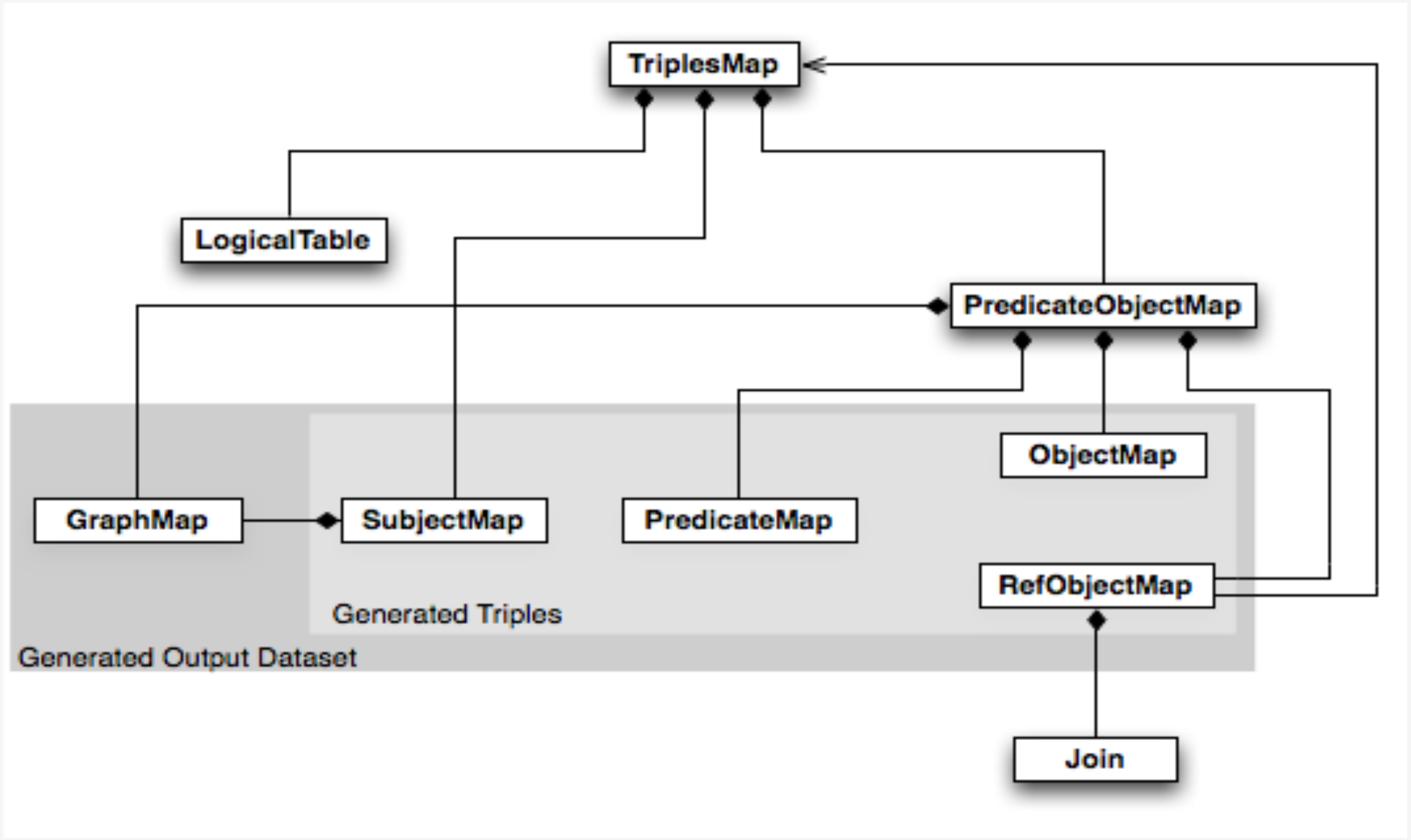


Define mappings

R2RML - Overview



R2RML - Overview



Encoding in R2RML

W3C RDB2RDF

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Mapping definition

the stream name

stream attributes

subject URI

triple predicate + object

```
:triplesMap a rr:TriplesMap;
  rr:logicalTable [  rr:tableName ”sensors"; ]

  rr:subjectMap [
    rr:template  "http://streamreasoning.org/data/Observation/{person}{timed}";
    rr:class sr4ld:Observation; rr:graph sr4ld:socialstream.srdf ];

    rr:predicateObjectMap [
      rr:predicate sr4ld:who ;
      rr:objectMap [ rr:template “http://streamreasoning.org/data/Person/{person}” ]];.
```

the object (a URI in this case)

Now some code

Morph-streams:

- Coded in **Scala**
- JAR bundle, use it from Scala or **Java** code
- Maven, Sbt
- **Examples**
  - **One off query**
  - **Register continuous query**
  - **Pull data**
  - **Push**
  - **Basic REST**
- **https://github.com/jpcik/morph-streams**

Code examples

- Parse SPARQLStream

```
val query= "PREFIX sr4ld: <…>. SELECT ?a …"
val syntax= StreamQueryFactory.create(query);
```

- Execute One-off query

Mapping

```
val query= "PREFIX sr4ld: <…>. SELECT ?a …"
mapping=Mapping(new URI(mappings/social.ttl))
val adapter:QueryEvaluator=Application.adapter(system)
val results= adapter.executeQuery(query,mapping)
```

Bindings

Code examples

- Register and Pull

```
val queryid= adapter.registerQuery(query,mapping)
val results1=adapter.pull(queryid)
val results2=adapter.pull(queryid)
```

Query identifier

- Register and Push

Implement receiver

```
class ExampleReceiver extends StreamReceiver{
  override def receiveData(s:SparqlResults):Unit=
     Logger.debug("got: "+res)
 }
val receiver=new ExampleReceiver
val queryid= adapter.listenToQuery(query,mapping,receiver)
```

SPARQLStream from command line

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- encoded_value=$(python -c "import urllib; print urllib.quote('''SELECT DISTINCT ?timeto ?obs FROM NAMED STREAM <http://emt.linkeddata.es/data#busstops.srdf> [NOW - 30 S] WHERE { ?obs a <http://emt.linkeddata.es/data#BusObservation>. ?obs <http://purl.oclc.org/NET/ssnx/ssn#observedBy><http://transporte.linkeddata.es/emt/busstop/id/2018>. ?obs <http://purl.oclc.org/NET/ssnx/ssn#observationResult> ?output. ?output <http://emt.linkeddata.es/data#timeToBusValue> ?av. ?av <http://data.nasa.gov/qudt/owl/qudt#numericValue> ?timeto. }''')")

Just encoding query

- curl "http://streams.linkeddata.es/emt/sparqlstream?query=$encoded_value”

Disclaimer: Simplistic, not implementing all of the SPARQL protocol

Sample result

Bindings in JSON

```
{
  "head": {
    "vars": [ "timeto" , "obs" ]
  } ,
  "results": {
    "bindings": [
      {
        "timeto": { "datatype": "http://www.w3.org/2001/XMLSchema#string" , "type": "typed-
literal" , "value": "0" } ,
        "obs": { "type": "uri" , "value": "http://transporte.linkeddata.es/emt/busstop/id/2018/
busline/9/observation/20/09/2013%2010:28:19%20%2B0200" }
      }
    ]
  }
}
```

Resources

- Morph-Streams
  - https://github.com/jpcik/morph-streams
- See demos
  - http://transporte.linkeddata.es/ (SPARQL-Stream tab)
  - Check our Madrid buses demo at SSN2013 workshop tomorrow
- Read out more
  - Enabling Query Technologies for the Semantic Sensor Web.
    J.-P. Calbimonte, H. Jeung, O. Corcho and K. Aberer.
    International Journal on Semantic Web and Information Systems
    IJSWIS, Volume 8(1)., 2012
- Contact point
  - jp.calbimonte@upm.es
  - ocorcho@fi.upm.es

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RDF Streams

$\langle s,p,o \rangle$

<aemet:observation1, ssn:observedBy, aemet:Sensor3>

<aemet:observation1, qudt:hasNumericValue, “15.5”>

For streams?

$(\langle s,p,o \rangle, \tau)$

(<aemet:observation1, qudt:hasNumericValue, “15.5”>,34532)

timestamped triples

- Gutierrez et al. (2007) Introducing time into RDF. IEEE TKDE
- Rodríguez et al. (2009) Semantic management of streaming data. SSN

Streaming SPARQL execution approaches

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Extend RDF for streaming data

Extend SPARQL for streaming RDF

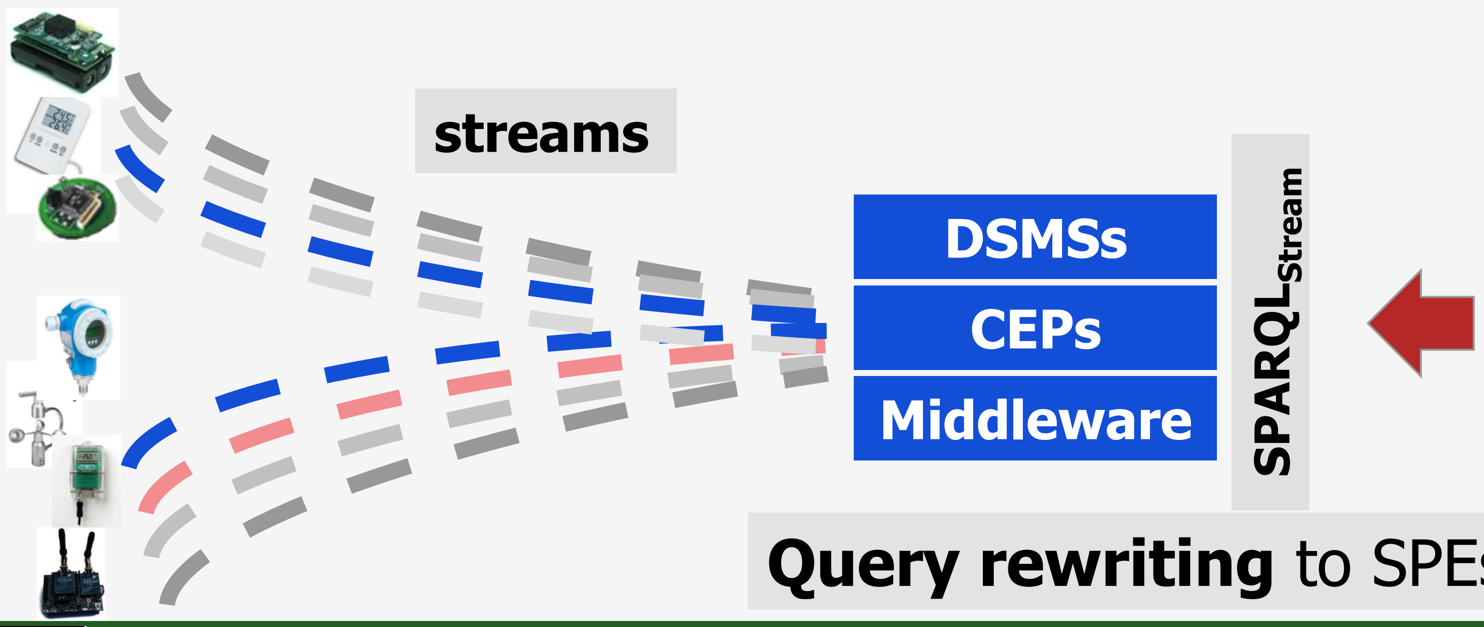
~Similarities

Use a **SPE internally** for evaluation

Logic-programming based query evaluation

RDF Streaming engine **from scratch**

Divergence



Query rewriting to SPEs