Common Cognitive Radio language, a CREW-GENI collaboration

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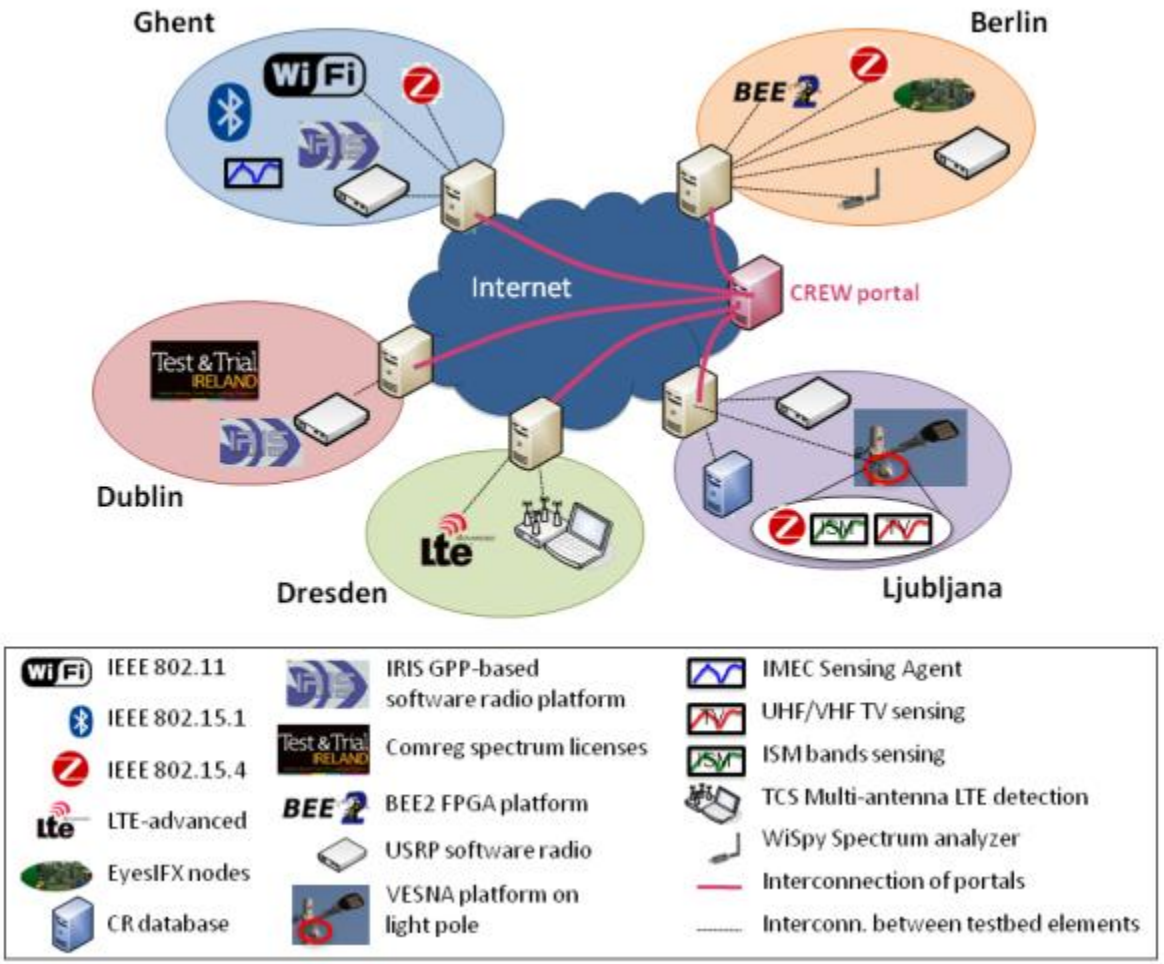
Outline

- Introduction: CREW CDF and TassOR
- About ontologies and CR use cases
- The Spectrum Sensing Ontology
- Modelling and querying cognitive radio devices: selected examples
- Summary

The CREW federation's common data format

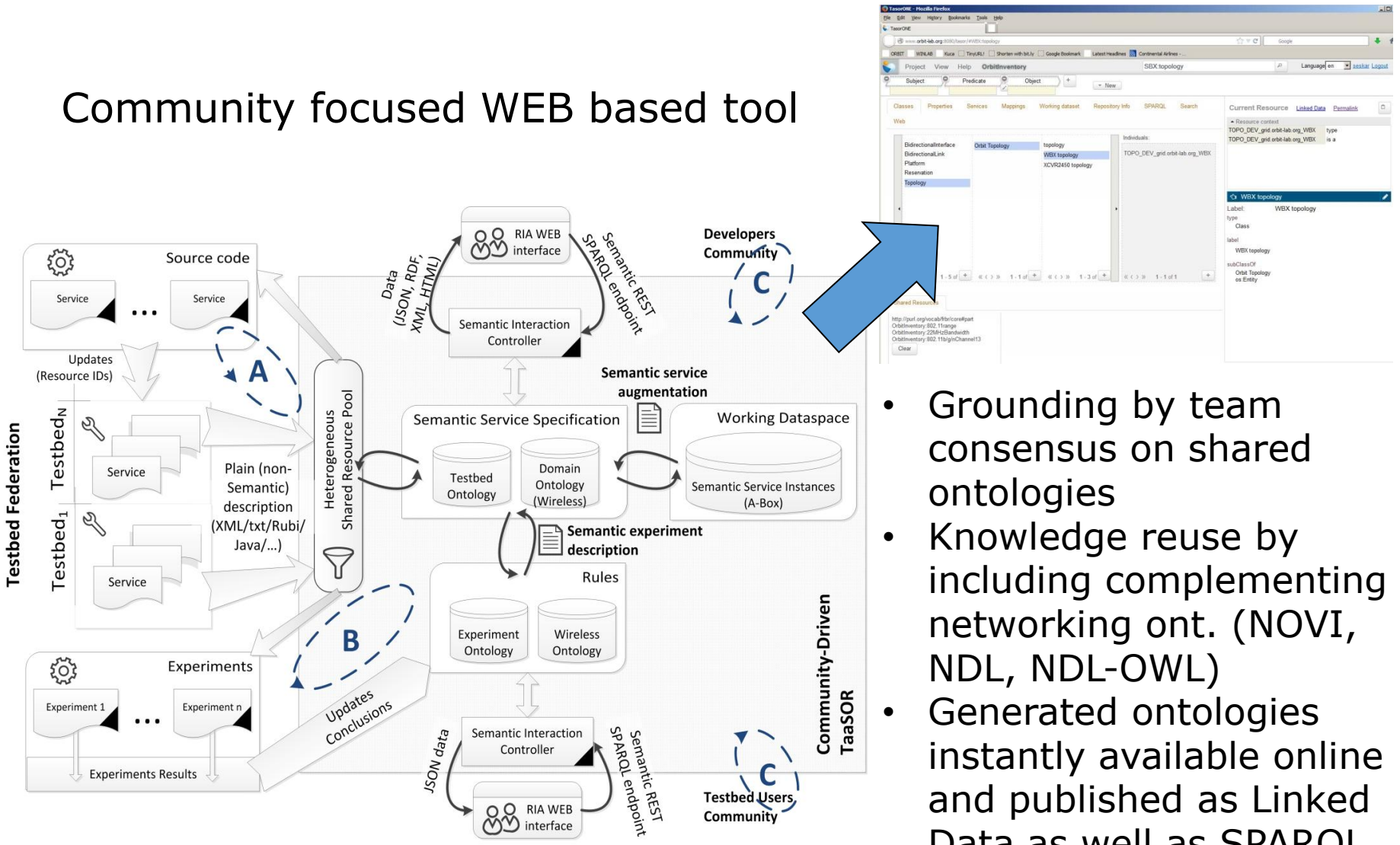
- 5 testbeds
- Need for harmonizing experiment description
- Need for harmonizing the results from the experiment

common data format that includes a vocabulary based on the IEEE P 1900.1 specifications



Testbed as a Service with Ontology Repository (TaaSOR)

Community focused WEB based tool



- Grounding by team consensus on shared ontologies
- Knowledge reuse by including complementing networking ont. (NOVI, NDL, NDL-OWL)
- Generated ontologies instantly available online and published as Linked Data as well as SPARQL endpoint

CREW-GENI efforts

- Starting from
  - existing standard vocabularies provided by ontologies (NOVI, NDL, NDL-OWL)
  - the existing Testbed as a Service with Ontology Repository (TaaSOR)
  - and the CREW common data format

  - create a Spectrum Sensing Ontology capable of describing any device and capability from any cognitive radio testbed

- The final goal is to enable testbed-as-a-service functionality

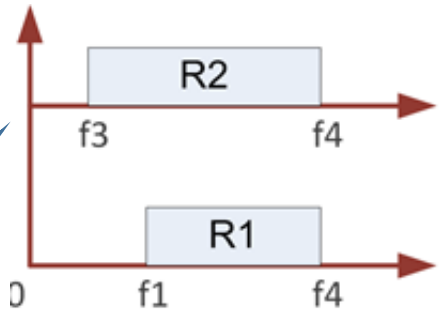
What is an ontology and why semantic web?

- “an ontology formally represents knowledge as a set of concepts within a domain, using a shared vocabulary to denote the types, properties and interrelationships of those concepts”
- In a way, an ontology is a taxonomy that also has relationships between the concepts
- Ontologies and semantic web technologies enable machine interpretable representations of data thus increasing interoperability
- In semantic web, everything can be described as a triple:

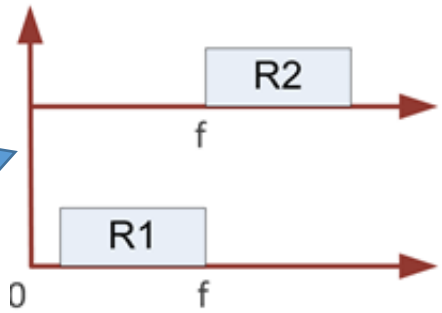
Subject (Resource)	Predicate (Property)	Object (Statement)
sses:RadioDevice	rdf:hasIndividual	sses:SpectrumAnalyzerTest
sses:SpectrumAnalyzerTest	sses:supports	sses:SASettings1

Example use case for CR: model relationships between frequency intervals

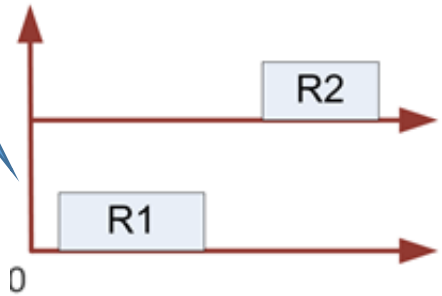
Situations we would like to be able to represent



R1 is a wo:ProperRange
R2 is a wo:ProperRange
R1 wo:hasStartFrequency f1
R2 wo:hasStartFrequency f3
R1 wo:hasEndFrequency f4
R2 wo:hasEndFrequency f4
f3 wo:lower f1
R1 wo:rangeEndMatch R2

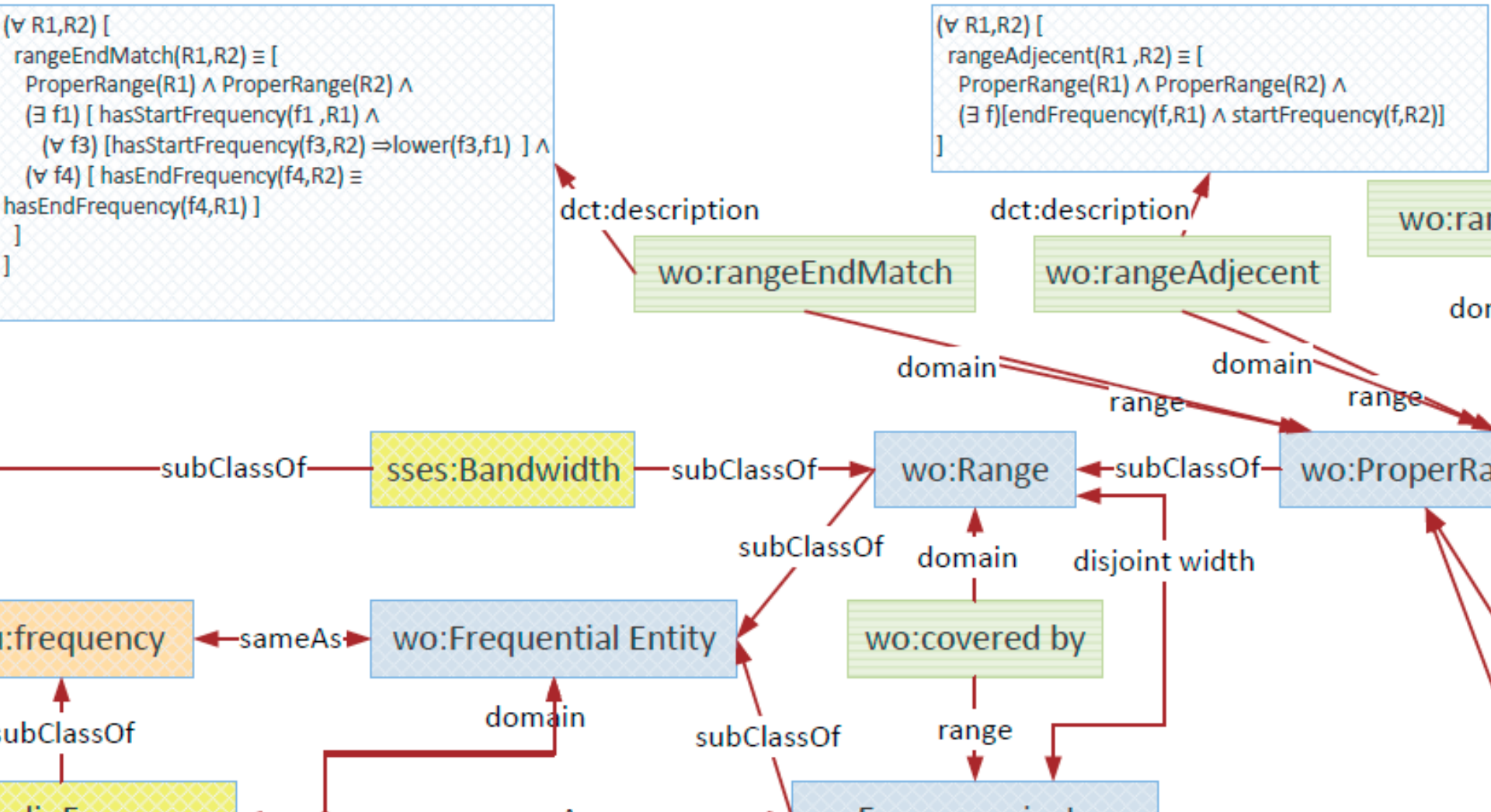


R1 is a wo:ProperRange
R2 is a wo:ProperRange
R1 wo:endFrequency f
R2 wo:startFrequency f
R1 wo:rangeAdjecent R2



R1 is a wo:ProperRange
R2 is a wo:ProperRange
R1 wo:lower R2
R1 wo:rangeLower R2

Possible semantic rules for expressing the relationships about frequency ranges



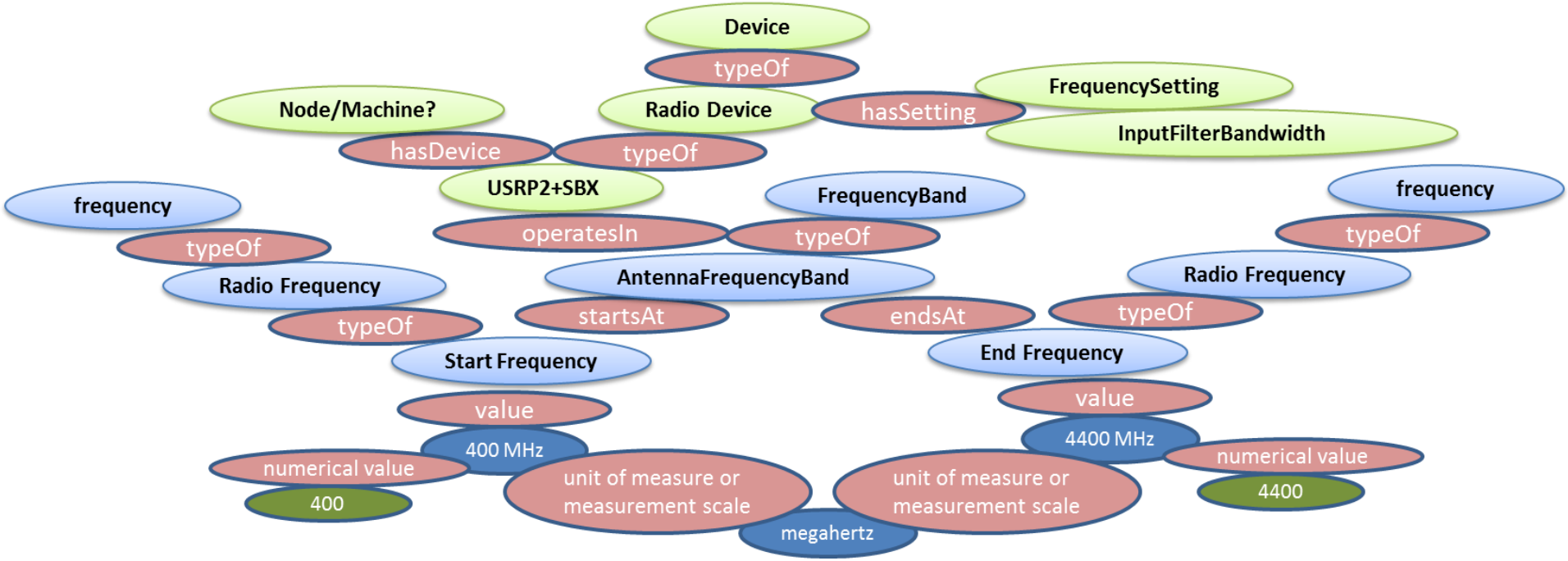
The Spectrum Sensing Ontology (1/2)

- The ontology has three orthogonal parts are that allow the description of:
  - spectrum related theoretical aspects,
  - device spectrum sensing capabilities and
  - ranges of values for each

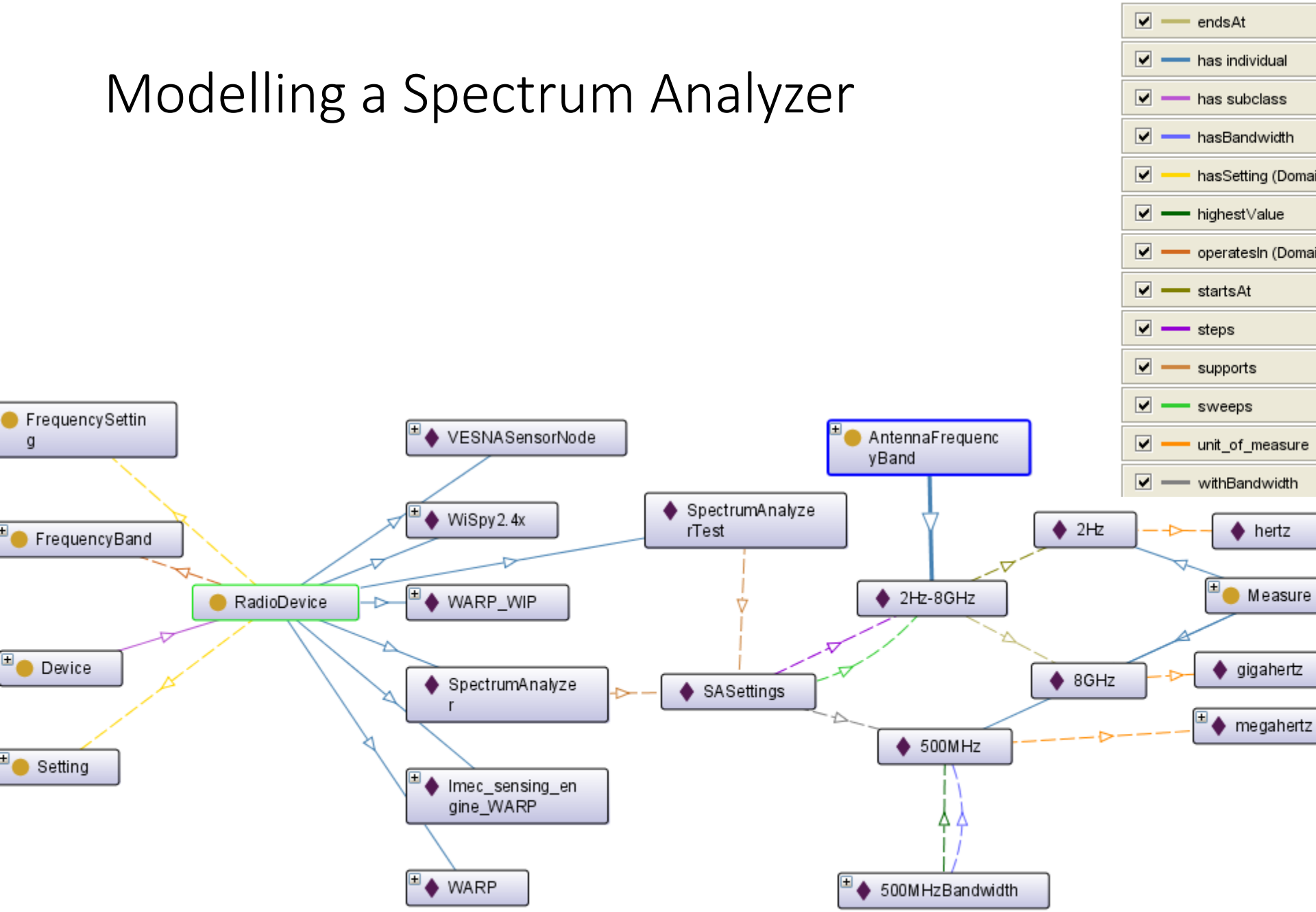
- Basic device capability description: base band and RF capabilities described
- Description of the processing for base

- Current version: http://sensorlab.ijs.si/2013/v0/SpectrumSensingExperimentSpecification.owl

The Spectrum Sensing Ontology (2/2)



Modelling a Spectrum Analyzer



Example query: Devices and their sweeping bands

- A set of devices have been added as individuals of the concepts in the ontology
- Their properties were also modelled
- A SPARQL query retrieves all the devices and the frequency ranges they are able to sweep

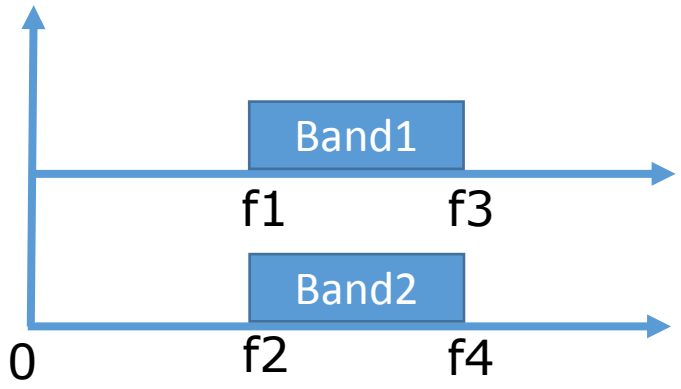
SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX sses: <http://sensorlab.ijs.si/2013/v0/SpectrumSensingExperimentSpecification.owl#>
PREFIX om: <http://www.wurvoc.org/vocabularies/om-1.8/>
PREFIX swrlb: <http://www.w3.org/2003/11/swrlb>

SELECT ?Device1 ?f1 ?f2
        WHERE {
        ?Device1 rdf:type sses:RadioDevice.
        ?Device1 sses:supports ?Settings1.
        ?Settings1 sses:sweeps ?Band1.
        ?Band1 sses:startsAt ?f1.
        ?Band1 sses:endsAt ?f2.
        }
```

Device1	f1	f2
VESNASensorNode	470MHz	862MHz
SpectrumAnalyzerTest	2Hz	8GHz
SpectrumAnalyzer	2Hz	8GHz
Imec_sensing_engine_WARP	2412MHz	2472MHz
WARP_WIP	2400MHz	2500MHz
Imec_sensing_engine_WARP	2484MHz	2484MHz
VESNASensorNode	470MHz	862MHz
WiSpy2.4x	2400MHz	2495MHz
Imec_sensing_engine_WARP	5500MHz	5700MHz
Imec_sensing_engine_WARP	2402MHz	2480MHz
Imec_sensing_engine_WARP	5180MHz	5320MHz
Imec_sensing_engine_WARP	5745MHz	5805MHz
WARP_WIP	4900MHz	5350MHz
WARP	2412MHz	2482MHz

Example query: Devices with same sweeping bands



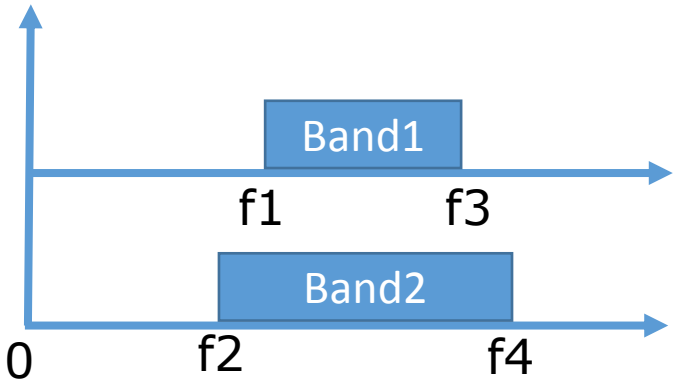
SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX sses: <http://sensorlab.ijs.si/2013/v0/SpectrumSensingExperimentSpecification.owl#>
PREFIX om: <http://www.wurvoc.org/vocabularies/om-1.8/>
PREFIX swrlb: <http://www.w3.org/2003/11/swrlb>

SELECT ?Device1 ?Device2 ?Band1 ?Band2
                WHERE {
                ?Device1 rdf:type sses:RadioDevice.
                ?Device2 rdf:type sses:RadioDevice.
                ?Device1 sses:supports ?Settings1.
                ?Device2 sses:supports ?Settings2.
                ?Settings1 sses:sweeps ?Band1.
                ?Settings2 sses:sweeps ?Band2.
                ?Band1 sses:startsAt ?f1.
                ?Band2 sses:startsAt ?f2.
                ?Band1 sses:endsAt ?f3.
                ?Band2 sses:endsAt ?f4.
                ?f1 sses:numericalValue ?x.
                ?f2 sses:numericalValue ?y.
                ?f3 sses:numericalValue ?z.
                ?f4 sses:numericalValue ?t.
                FILTER(xsd:integer(?x) = xsd:integer(?y)).
                FILTER(xsd:integer(?z) = xsd:integer(?t)).
                }
```

Device1	Device2	Band1	Band2
VESNASensorNode	VESNASensorNode	470-862MHz	470-862MHz
VESNASensorNode	VESNASensorNode	470-862MHz	470-862MHz
SpectrumAnalyzerTest	SpectrumAnalyzerTest	2Hz-8GHz	2Hz-8GHz
SpectrumAnalyzerTest	SpectrumAnalyzer	2Hz-8GHz	2Hz-8GHz
SpectrumAnalyzer	SpectrumAnalyzerTest	2Hz-8GHz	2Hz-8GHz
SpectrumAnalyzer	SpectrumAnalyzer	2Hz-8GHz	2Hz-8GHz
Imec_sensing_engine_WARP	Imec_sensing_engine_WARP	2412-2472MHz	2412-2472MHz
WARP_WIP	WARP_WIP	2400-2500MHz	2400-2500MHz
Imec_sensing_engine_WARP	Imec_sensing_engine_WARP	2484-2484MHz	2484-2484MHz
VESNASensorNode	VESNASensorNode	470-862MHz	470-862MHz
VESNASensorNode	VESNASensorNode	470-862MHz	470-862MHz
WiSpy2.4x	WiSpy2.4x	2400-2495MHz	2400-2495MHz

Example query: Devices with included sweeping bands



SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-n
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX sses: <http://sensorlab.ijs.si/2013/v0/SpectrumSer
PREFIX om: <http://www.wurvoc.org/vocabularies/om-1.8
PREFIX swrlb: <http://www.w3.org/2003/11/swrlb>

SELECT ?Device1 ?Device2 ?f1 ?f2 ?f3 ?f4
        WHERE {
        ?Device1 rdf:type sses:RadioDevice.
        ?Device2 rdf:type sses:RadioDevice.
        ?Device1 sses:supports ?Settings1.
        ?Device2 sses:supports ?Settings2.
        ?Settings1 sses:sweeps ?Band1.
        ?Settings2 sses:sweeps ?Band2.
        ?Band1 sses:startsAt ?f1.
        ?Band2 sses:startsAt ?f3.
        ?Band1 sses:endsAt ?f2.
        ?Band2 sses:endsAt ?f4.
        ?f1 sses:numericalValue ?x.
        ?f2 sses:numericalValue ?y.
        ?f3 sses:numericalValue ?z.
        ?f4 sses:numericalValue ?t.
        FILTER(xsd:integer(?x) < xsd:integer(?z)).
        FILTER(xsd:integer(?t) < xsd:integer(?y)).
}
```

Device1	Device2	Band1	
WARP_WIP	Imec_sensing_engine_WARP	2400-2500MHz	2412-2472MHz
WARP_WIP	Imec_sensing_engine_WARP	2400-2500MHz	2484-2484MHz
WARP_WIP	Imec_sensing_engine_WARP	2400-2500MHz	2402-2480MHz
WARP_WIP	WARP	2400-2500MHz	2412-2482MHz
WiSpy2.4x	Imec_sensing_engine_WARP	2400-2495MHz	2412-2472MHz
WiSpy2.4x	Imec_sensing_engine_WARP	2400-2495MHz	2484-2484MHz
WiSpy2.4x	Imec_sensing_engine_WARP	2400-2495MHz	2402-2480MHz
WiSpy2.4x	WARP	2400-2495MHz	2412-2482MHz
Imec_sensing_engine_WARP	Imec_sensing_engine_WARP	2402-2480MHz	2412-2472MHz
WARP_WIP	Imec_sensing_engine_WARP	4900-5350MHz	5180-5320MHz
Imec_sensing_engine_WARP	Imec_sensing_engine_WARP	2400-2485MHz	2412-2472MHz
Imec_sensing_engine_WARP	Imec_sensing_engine_WARP	2400-2485MHz	2484-2484MHz
Imec_sensing_engine_WARP	Imec_sensing_engine_WARP	2400-2485MHz	2402-2480MHz
Imec_sensing_engine_WARP	WARP	2400-2485MHz	2412-2482MHz

Rules to simplify the SPARQL queries and abstract the underlying complexity

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX sses: <http://sensorlab.ijs.si/2013/v0/SpectrumSensingExperimentSpecification.owl#>
PREFIX om: <http://www.wurvoc.org/vocabularies/om-1.8/>
PREFIX swrlb: <http://www.w3.org/2003/11/swrlb>

SELECT ?Device1 ?Device2 ?Band1 ?Band2
        WHERE {
        ?Device1 rdf:type sses:RadioDevice.
        ?Device2 rdf:type sses:RadioDevice.
        ?Device1 sses:supports ?Settings1.
        ?Device2 sses:supports ?Settings2.
        ?Settings1 sses:sweeps ?Band1.
        ?Settings2 sses:sweeps ?Band2.
        ?Band1 sses:startsAt ?f1.
        ?Band2 sses:startsAt ?f2.
        ?Band1 sses:endsAt ?f3.
        ?Band2 sses:endsAt ?f4.
        ?f1 sses:numericalValue ?x.
        ?f2 sses:numericalValue ?y.
        ?f3 sses:numericalValue ?z.
        ?f4 sses:numericalValue ?t.
        FILTER(xsd:integer(?x) = xsd:integer(?y)).
        FILTER(xsd:integer(?z) = xsd:integer(?t)).
        }
```

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX sses: <http://sensorlab.ijs.si/2013/v0/SpectrumSensingExperimentSpecification.owl#>
PREFIX om: <http://www.wurvoc.org/vocabularies/om-1.8/>
PREFIX swrlb: <http://www.w3.org/2003/11/swrlb>

SELECT ?Device1 ?Device2
        WHERE {
        ?Device1 rdf:type sses:RadioDevice.
        ?Device2 rdf:type sses:RadioDevice.
        ?Device1 sses:supports ?Settings1.
        ?Device2 sses:supports ?Settings2.
        ?Settings1 sses:sweeps ?Band1.
        ?Settings2 sses:sweeps ?Band2.
        ?Band1 sses:sameBand ?Band2.
        }
```

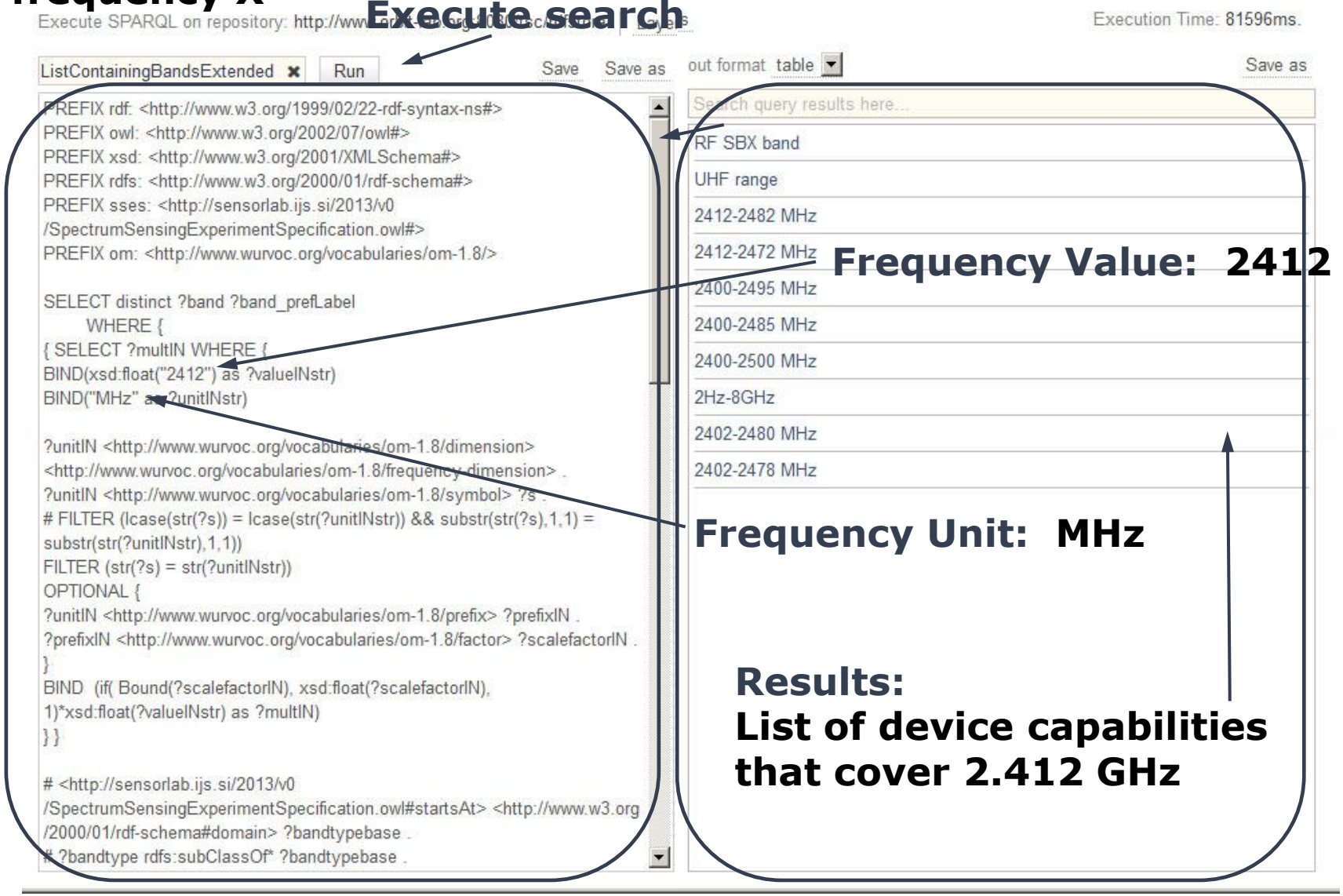
Rules:

Rules

```
AntennaFrequencyBand(?B1),
AntennaFrequencyBand(?B2),
endsAt(?B1, ?f2), endsAt(?B2,
?f4), startsAt(?B1, ?f1),
startsAt(?B2, ?f3),
numericalValue(?f1, ?x),
numericalValue(?f2, ?y),
numericalValue(?f3, ?z),
numericalValue(?f4, ?t),
equal(?x, ?z), equal(?y, ?t) ->
sameBand(?B1, ?B2)
```

Complex SPARQL Query:
Find all spectrum sensing devices capable of sensing frequency X

Search in Tasor



Summary

- We have defined and developed a working Spectrum Sensing Ontology that is openly available
- We have modelled several devices and exemplified on use cases how it can be use
- There are several other aspects related to the spectrum sensing device and experiment specification that we have identified but are not yet solved in the current version

- Questions?
- I am happy to provide further explanations and show the running demos locally in Protégé or remotely in TaasOR (today and next days here at FIA)
- Thank you!
- http://sensorlab.ijs.si/2013/v0/SpectrumSensingExperimentSpecification.owl