An EU funded project managed by the
European Union Office in Kosovo

Implemented by:

InWaterSense: Intelligent Wireless Sensor Networks for Monitoring Surface Water Quality

The INWATERSENSE Project: A Semantic Sensor Web to monitor the water quality in rivers in Kosova*

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University of Prishtina & FIEK

- The largest university in the country
  - Some 60 thousand students currently
  - *www.uni-pr.edu*
  - # academic staff: >1000; # academic units: 17
  - 2001: reformation according to Bologna Declaration
- Faculty of Electrical & Computer Engineering
  - Computer Engineering (since 1989), Telecom, Automation, Electronics, Electro-Energetic Systems & Industrial Electro-Energetic
  - Nr of students: >5000; Nr of academic staff: ~100
  - Industry Advisory Board within the faculty

Projects

- **EU IPA** funding scheme, Sept 2012 – July 2015. Project manager (proposal's author):
  - ***InWaterSense: Intelligent Wireless Sensor Networks for Monitoring Surface Water Quality***
- Linnaeus-Palme programme, **Sweden**, June 2012 - Sep 2014. Project coordinator for University of Prishtina:
  - ***Teaching Exchange for Staff and Students***
- HERD funding, **Norway**, Jan 2012 – Dec 2015. Project coordinator for University of Pristina:
  - ***Academic Exchange for Progress (AEP)***
- **EU FP7** programme, Jan 2012 – April 2014. Project coordinator for University of Prishtina:
  - ***ICT-KOSEU: Supporting Dialogue and Cooperation between Europe and Kosovo in Collaborative ICT R&D***
- **National** Research Grants, MEST, Jan 2012 – Dec 2012. Project manager (proposal's author):
  - ***Tourist Tour Planning and Social Network Analysis***

Projects

- **German Foundation for Research (DFG), Germany**, University of Freiburg, 1999-2004:
  - ***Spontaneous integration of heterogeneous information on the Web (ref. nr. LA 598/4-1)***
- **South East European University (SEEU) Research Grant, Macedonia**, Oct 2009 – July 2010. Project manager:
  - ***Linking Public University Data.***
- **EU Tempus Foundation**, 2005-2009. Project coordinator for University of Prishtina:
  - ***Computer Science Master Study Program at University of Prishtina (nr. ref. CD_JEP-19090_2004)***
- **WUS Foundation, Austria**, 2004-2005: *eLearning Task Force of Kosova*
  - ***Design and implementation of an infrastructure for distance learning at University of Prishtina***

Outline

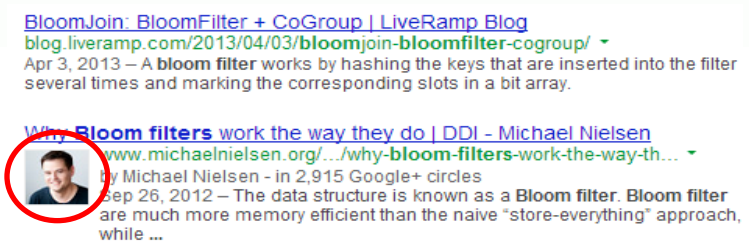
You say `<smart>`, I understand `<semantics>`

- We use them interchangeable, otherwise: !ek&*$@#..ie)m

- Popular Semantic-Rich (Smart) Applications
- Sensor Web Enablement
  - Overview, Standards, Issues
  - How comes Semantic Web?
- Semantic Sensor Web
  - Definition
  - Example
  - Ontologies
- InWaterSense as a Case Study

A little bit of semantics gets you a long way.
(image taken from http://www.doceatdoc.com)

Popular Semantic-Rich Applications



- Semantic Search Engines:
  - SEO, Author Ranking
- Semantic Browsers:
  - Highlight the keywords on a Web page as defined by the semantic description
- Open Government
- Marketing and Advertising
- Healthcare
- Legislation semantics
- P2P Networks:
  - Add semantics to allocate the peers
- Increased investments in the field in industry
  - Oracle, IBM, HP, Siemens
  - Structured data on the Web (BBC with its RSS, data gov, ..)
- A prominent example: Semantic Sensor Web

Semantic Sensor Web

"Sensor data annotated with semantic metadata to increase interoperability as well as provide contextual information essential for situational knowledge" [1]

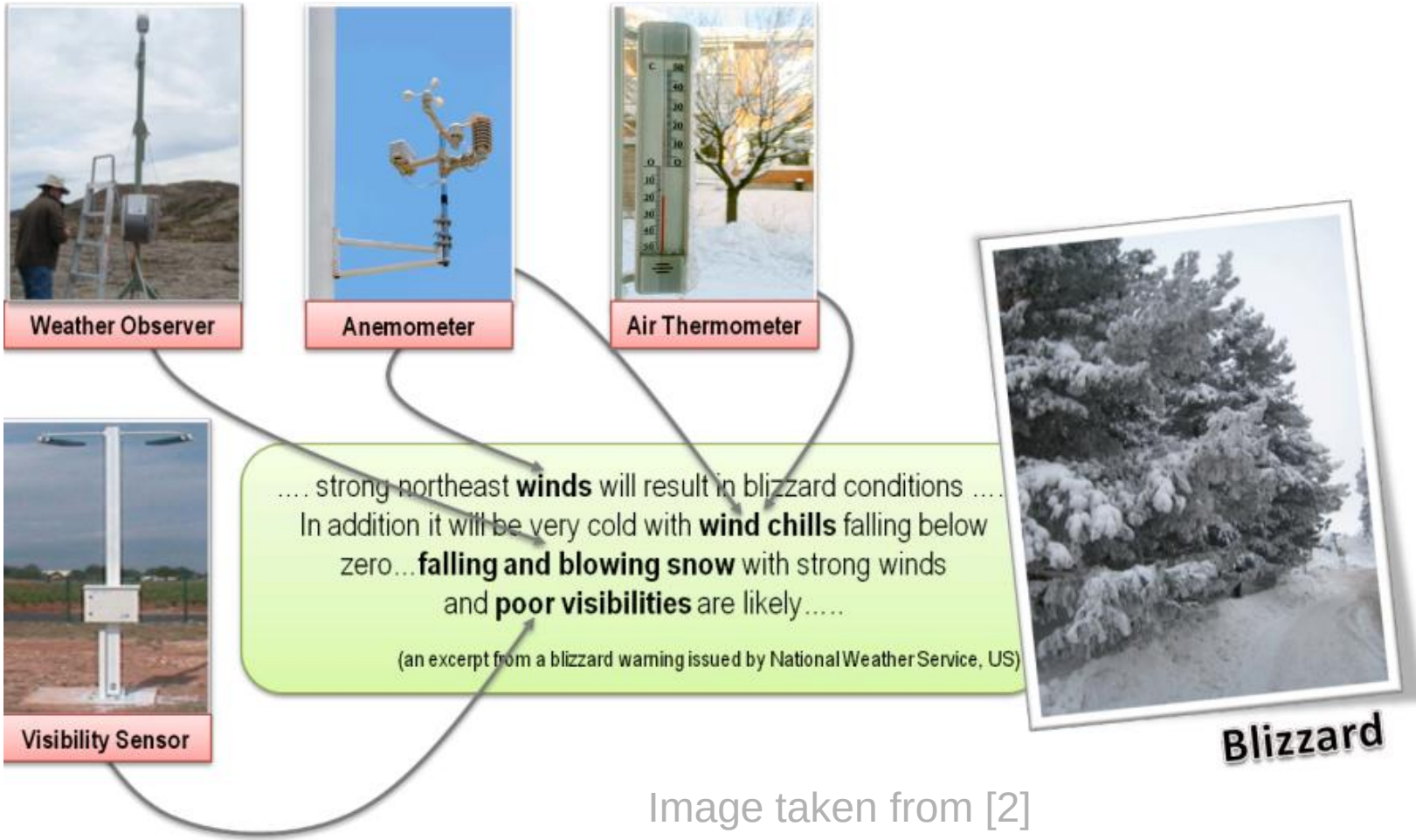
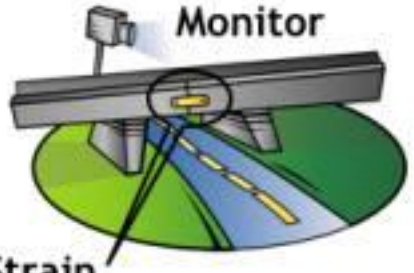


Image taken from [2]

Its SemanticLESS Prehistory – Sensor Web

- Today ~ 4 billion mobile devices that may act as sensors, plus even larger number of fixed sensors in the globe
- Sensors increasingly connected with the Web to provide services & knowledge
  - Open Geospatial Consortium (OGC) www.opengeospatial.org
  - OGC developed a packet of Sensor Web Enablement (SWE) standards around sensors for their modeling & access/control of them through Web services

Sensor Web Enablement: Overview



- All sensors reporting position
- All connected to the web
- All with metadata registered
- All readable remotely
- Some controllable remotely

Sensor Web Enablement: Example

```
<?xml version="1.0" encoding="UTF-8"?>
<GetObservation xmlns="http://www.opengis.net/sos/1.0”..>
<offering>GAUGE_HEIGHT</offering>
<eventTime>
   <ogc:TM_During>
   <ogc:PropertyName>urn:ogc:data:time:iso8601</ogc:PropertyName>
        <gml:TimePeriod>
              <gml:beginPosition>2008-12-05
   10:00:00+01</gml:beginPosition>
              <gml:endPosition>2008-12-06
   12:15:00+01</gml:endPosition>
        </gml:TimePeriod>
   </ogc:TM_During>
</eventTime>
<observedProperty>urn:ogc:def:phenomenon:OGC:1.0.30:waterlevel</o
   bservedProperty>
<responseFormat>text/xml;subtype="om/1.0.0"</responseFormat>
</GetObservation>
```

Sensor Web Enablement: Issues

- Are the objectives achieved? Recall the SWE objectives.

Its SemanticLESS Prehistory – Sensor Web

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Sensor Web Enablement: Issues

- Are the objectives achieved? Recall the SWE objectives
  - Services? YES
  - Knowledge? At a restricted level due to:
    - Limitations in expressing existing knowledge (thematic, spatial, temporal)
    - No support to infer new knowledge:
      - prediction of floods, blizzards, earthquakes, and similar

=> Your computer serves you simply “in black and white”!

Sensor Web Enablement: Issues Example

1. SWE system tells us:

water level is increased at a dangerous limit in the river WaterFull

2. We wish the system is able to infer new knowledge of kind:

IF *the river WaterFull flows across the city NewCity*”
AND the river WaterFull flows across the city NewCity

THEN given IF is true, and knowing 1:

NewCity is among cities in danger due to the risk from the flood

Semantic Sensor Web: Definition

- OGC SWE + Semantic Web = Semantic Sensor Web
  - OGC SWE with its simple time, space and thematic constructs
  - Semantic Web with its rich expressivity & reasoning capabilities for sophisticated time, space, and thematic knowledge

Semantic Sensor Web: An Example

- A weather ontology with definitions for winter storms and their observable properties
- Annotating sensor data with concepts from this ontology enables the reasoning over such concepts
  - Each property is semantically annotated with a link to its definition within an ontology
  - From observations generated by this weather station, a blizzard may be inferred

Semantic Sensor Web: An Example (cont)

```
<sos:Contents>              // http://purl.oclc.org/NET/ssnx/ abbreviated with onto:
  <sos:ObservationOfferingList>
    <sos:ObservationOffering gml:id="urn:ogc:def:procedure:JPEO-
   CBD::WeatherStation_1">
      <gml:name>urn:ogc:def:procedure:JPEO-CBD::WeatherStation_1</gml:name>
      <gml:boundedBy>
        <gml:Envelope srsName="urn:ogc:def:crs:EPSG:4326">
          <gml:lowerCorner>18.556825 -72.297935</gml:lowerCorner>
          <gml:upperCorner>18.556825 -72.297935</gml:upperCorner>
        </gml:Envelope></gml:boundedBy>
      <sos:time>
        <gml:TimeInstant xsi:type="gml:TimeInstantType">
          <gml:timePosition indeterminate="now"/></gml:TimeInstant>
      </sos:time>
      <sos:procedure xlink:href="onto:ssn-dev#WeatherStation_1"/>
      <sos:observedProperty xlink:href="onto:cf/cf-property#snow-precipitation"/>
      <sos:observedProperty xlink:href="onto:cf/cf-property#temperature"/>
      <sos:observedProperty xlink:href="onto:cf/cf-property#windspeed"/>
      <sos:featureOfInterest xlink:href="http://sws.geonames.org/5248611/"/>
      <b><i><sos:featureOfInterest xlink:href="onto:ssn-dev#Blizzard_1"/></i></b>
      ..
    </sos:ObservationOffering></sos:ObservationOfferingList></sos:Contents>
```

Semantic Sensor Web: Ontologies

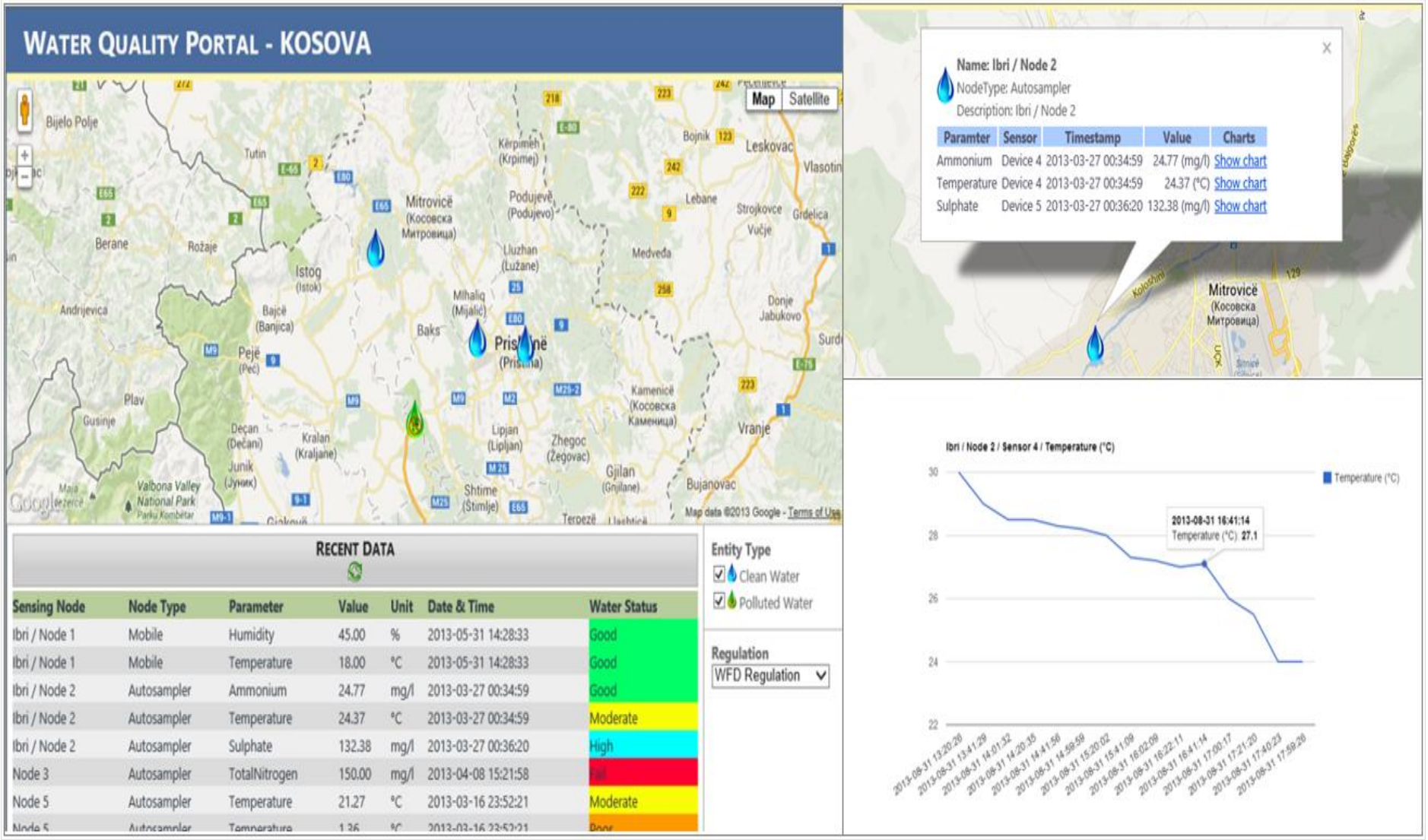
- SemSOS - a semantically enabled SOS
- OWLTime ontology (www.w3.org/TR/owl-time/)
- SSN ontology of the W3C Semantic Sensor Network Incubator Group
- **InWaterSense ontology extends SSN ontology to waters domain**

  [L. Ahmedi, E. Jajaga, F. Ahmedi. Semantic Sensor Networks@ISWC, Sydney, Australia, Oct 2013]

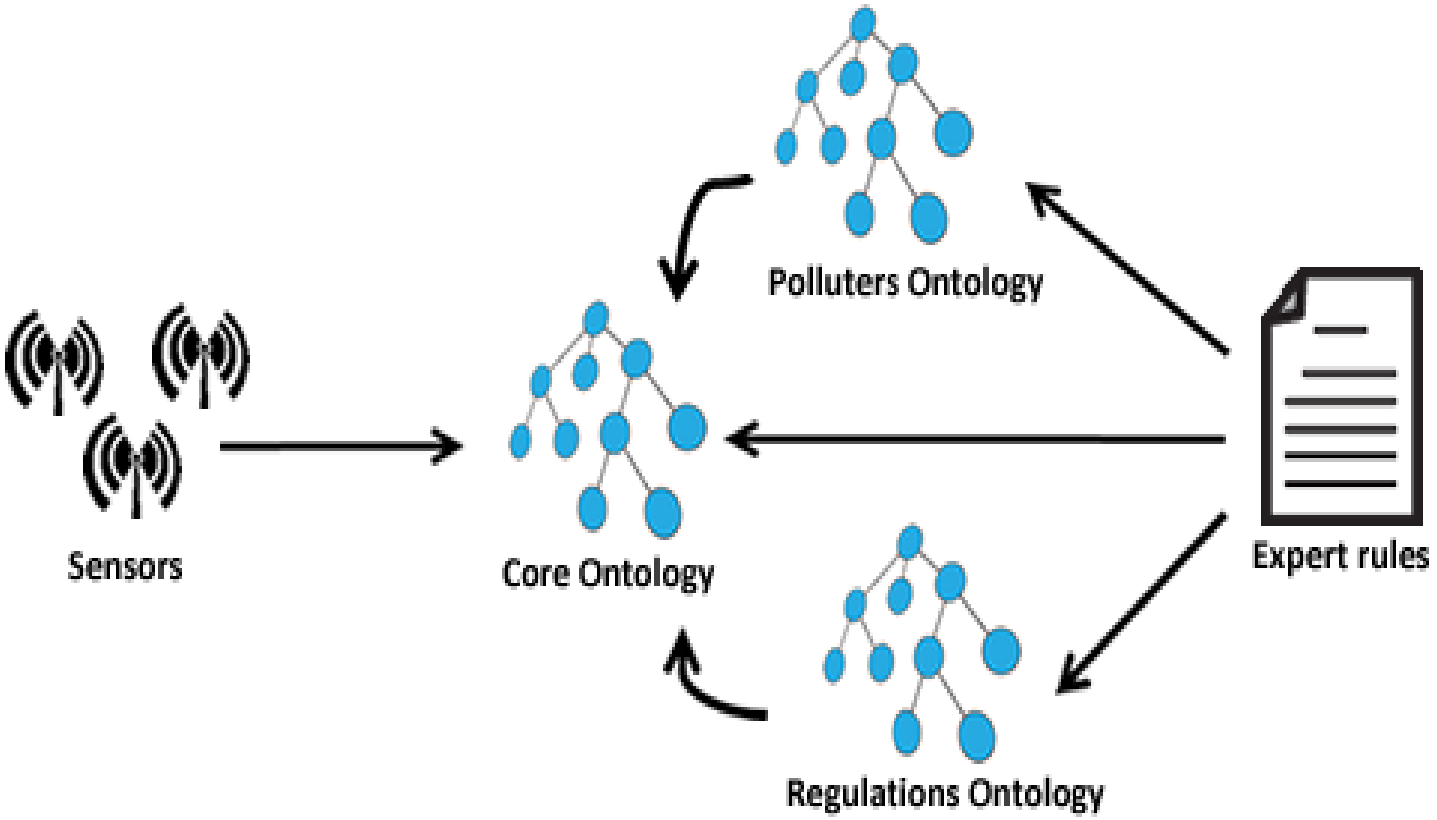
SSW Case Study: InWaterSense

- InWaterSense: Intelligent Wireless Sensor Networks for Monitoring Surface Water Quality
  - A running EU funded project at University of Prishtina
    - Computer Engineering Department, UP
    - Hydro-Technical Department, UP
    - Hydro-Meteorological Institute of Kosova
    - Tyndall Institute
    - Linnaeus University
    - Vienna Institute of Water Resources Management
    - Duisburg-Essen University

InWaterSense: The Project Portal



InWaterSense Ontology: Modules



InWaterSense Ontology: Modules (cont)

- **Core ontology:** real-time observational water quality data coming from data sources (sensors or lab measurements)
- **Regulations ontology:** permitted water parameter thresholds regulated by different authorities, like is the Water Framework Directive
- **Polluters ontology:** pollution entities & their attributes, like is facilities discharging wastes in water bodies
- **Water expert rules:** if-then water expert rules, e.g.:
  - if a particular water quality thresholds passed, then the water body should be classified in a specified status

InWaterSense Ontology: An Example

Example observation stream data (ABox) of a river quality here:

- the observation instance oo11724, which is a water temperature measurement:

```
oo11724 ssn:observedProperty Temperature
```

- which is in turn a river feature: `Temperature ssn:isPropertyOf RiversWaterFeature`
- it is produced by a device named `d1:` `oo11724 ssn:observedBy d1`
- it is sampled on `2013-02-13` at `09:32:22`, which is same as the entry system time since there is no latencies, i.e., data are already in machine:

```
oo11724 ssn:observationSamplingTime v11724
oo11724 hasObservationTime "2013-02-13T09:32:22.133"^^<xsd: date>
```

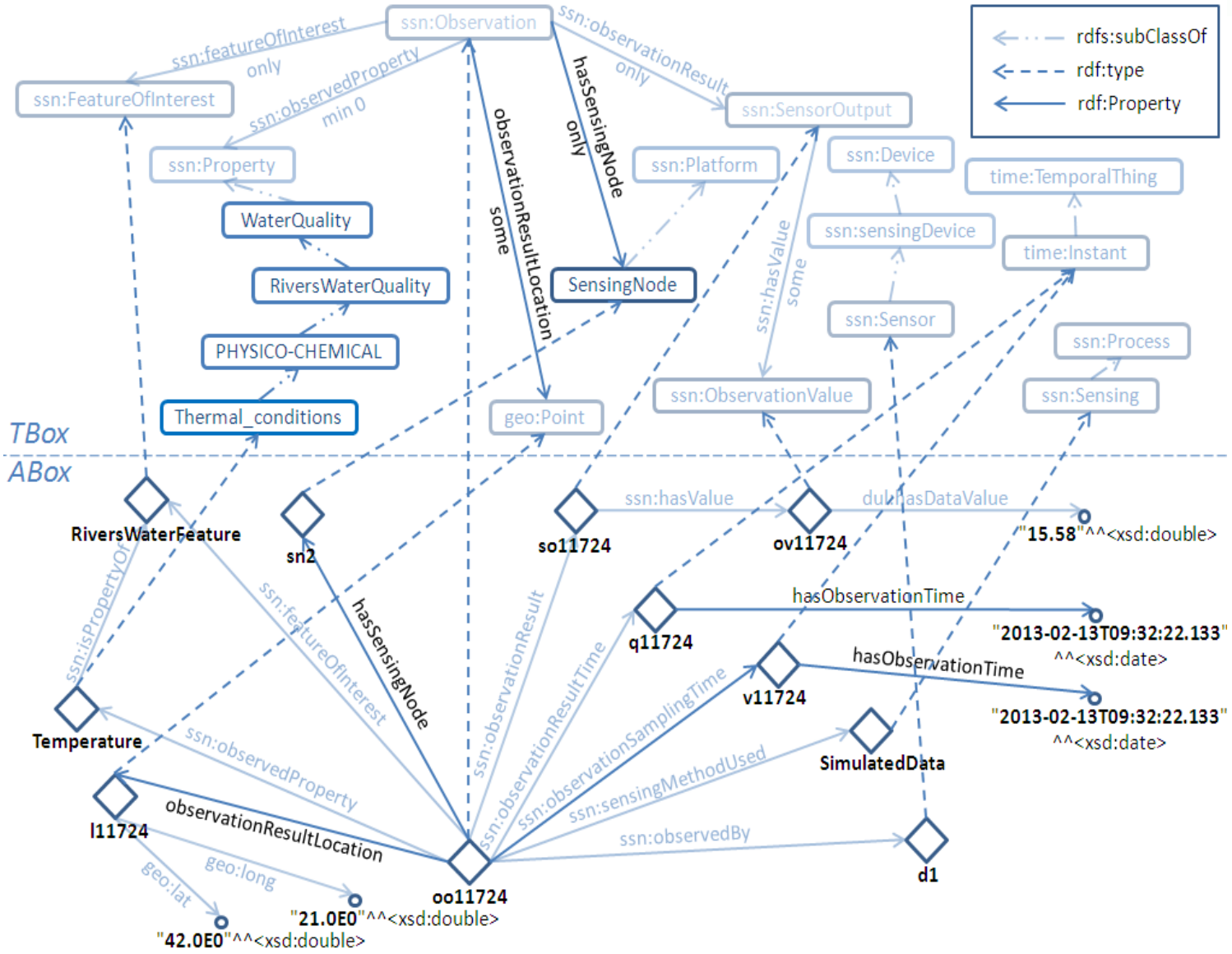
- it's measured value is `15.58`:

```
oo11724 ssn:observationResult so11724
so11724 ssn:hasValue  ov11724
ov11724 dul:hasDataValue "15.58"^^<xsd:double
```

- it is measured by the `sn2` sensing node: `hasSensingNode sn2`
- at the sample position of `21.0E0` for longitude, and `42.0E0` for latitude:

```
oo11724 observationResultLocation  l11724
l11724 geo:lat "42.0E0"^^<xsd:double>
l11724 geo:long "21.0E0"^^<xsd:double>
```

InWaterSense Ontology: An Example (cont)



InWaterSense Ontology: An Example (cont)

- "If total ammonia is less than 0.04 (mean), than river belongs to the high status of nutrient conditions" assuming that we are querying the observations after date 2013-02-13 on 09:11, may be expressed through the following SWRL rule:

```
ssn:Observation(?x) ∧ ssn:observedProperty(?x,inws:Ammonium) ∧
ssn:observationResultTime(?x,?y) ∧ inws:hasObservationTime(?y,?z)
∧ temporal:after(?z,"2013-02-13T09:11:00") ∧
ssn:observationResult(?x,?r) ∧ ssn:hasValue(?r, ?v) ∧
dul:hasDataValue(?v, ?val) ˚ sqwrl:makeSet(?sv, ?val) ˚
sqwrl:avg(?avg, ?sv) ∧ swrlb:greaterThan(?avg, 0.04) →
                        HighNutrientConditions(?x)
```

?x
oo11937
oo11948
oo11959
oo11970
oo11981

Semantic Sensing Vision

- The existing citizens-related services
  - The **smart vs. not-smart border**?
    - Reminds on the Web 2.0 vs. Web 3.0 borer. Hard to strictly define it
  - Be service-oriented is not sufficient
    - Turn services into smart knowledge-aware services
    - **Semantic-enabled services** are a way to drive them

Semantic Sensing Vision (cont)

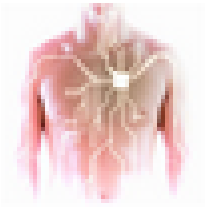
- **Open government portal case study**:
  - Monitor the policy-making in line with the actual jurisdiction
  - Monitor the citizens, say if not paying real-estate taxes, and react in real-time, say disable issuing a new ID card online
  - Monitor the industry, say if not paying revenue taxes, and react in real-time, say preventing to further do business (conditioned by mandatory online services)
- Further semantic-enabled apps towards smart cities:
  - **Bridge sensors** to monitor the they are in vital condition
  - BAN (**Body Area Networks**) to monitor the health of an individual, or a group of patients in case of epidermis
  - Traffic management, like **traffic lights switch periods**

Semantic Sensing Vision: What Next?

- Interest to extend the research on other Smart components of the **Internet of Think** (IoT)
  - A meeting in Dec2014 in Norway with GUC for a potential joint project on this
  - http://www.internet-of-things.no/iot.html

Smart Cities

Connected Communities



Smart Health

Healthcare System

Smart Industry

Industrial Environments

Smart Energy

Electric Grid