An Introduction to "Beyond Semantic Sensor Network Ontologies (SSNO)“

Ontology Summit 2015 Track B
Internet of Things: Toward Smart Networked Systems and Societies

Session 1 Jan. 29, 2015

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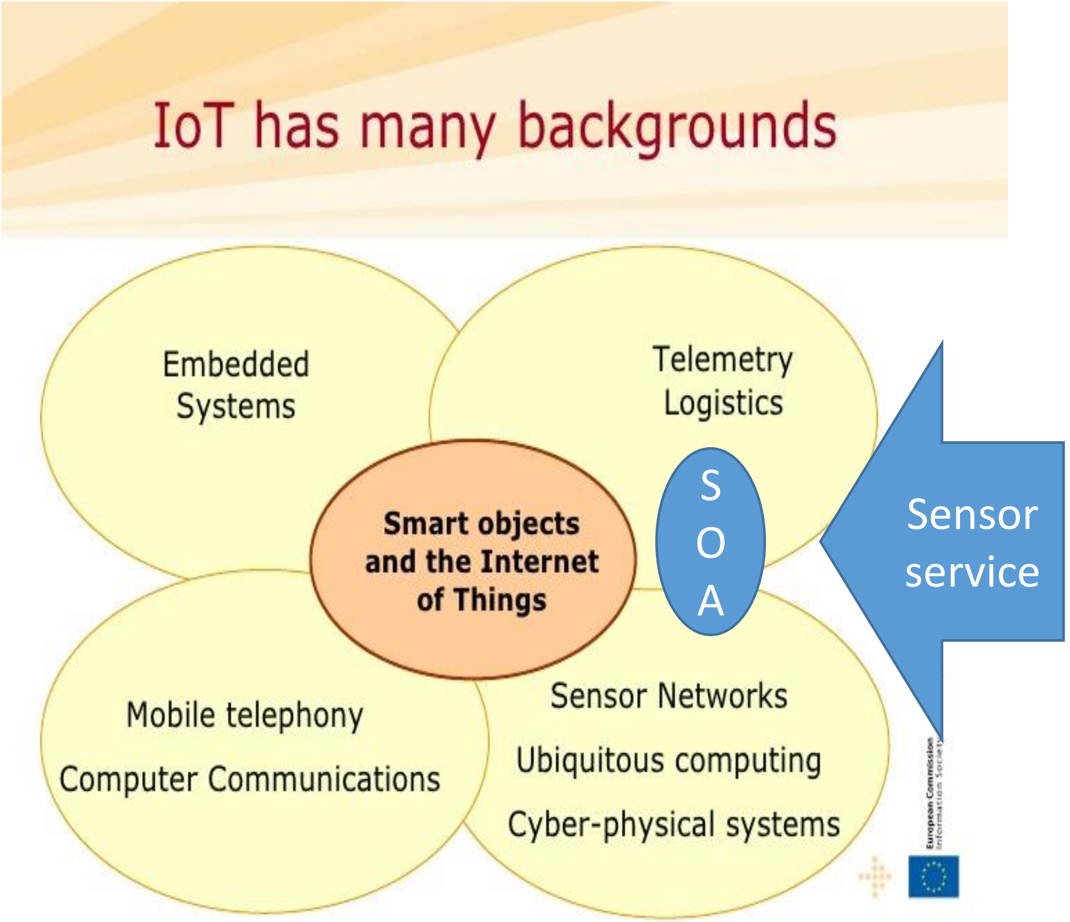
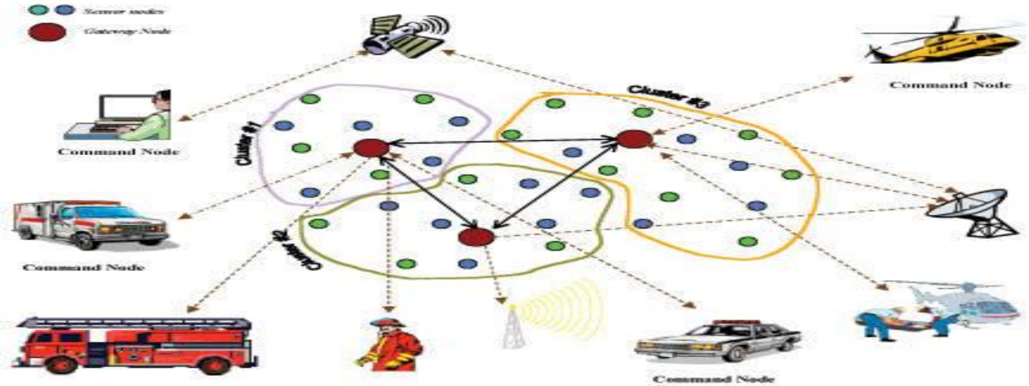
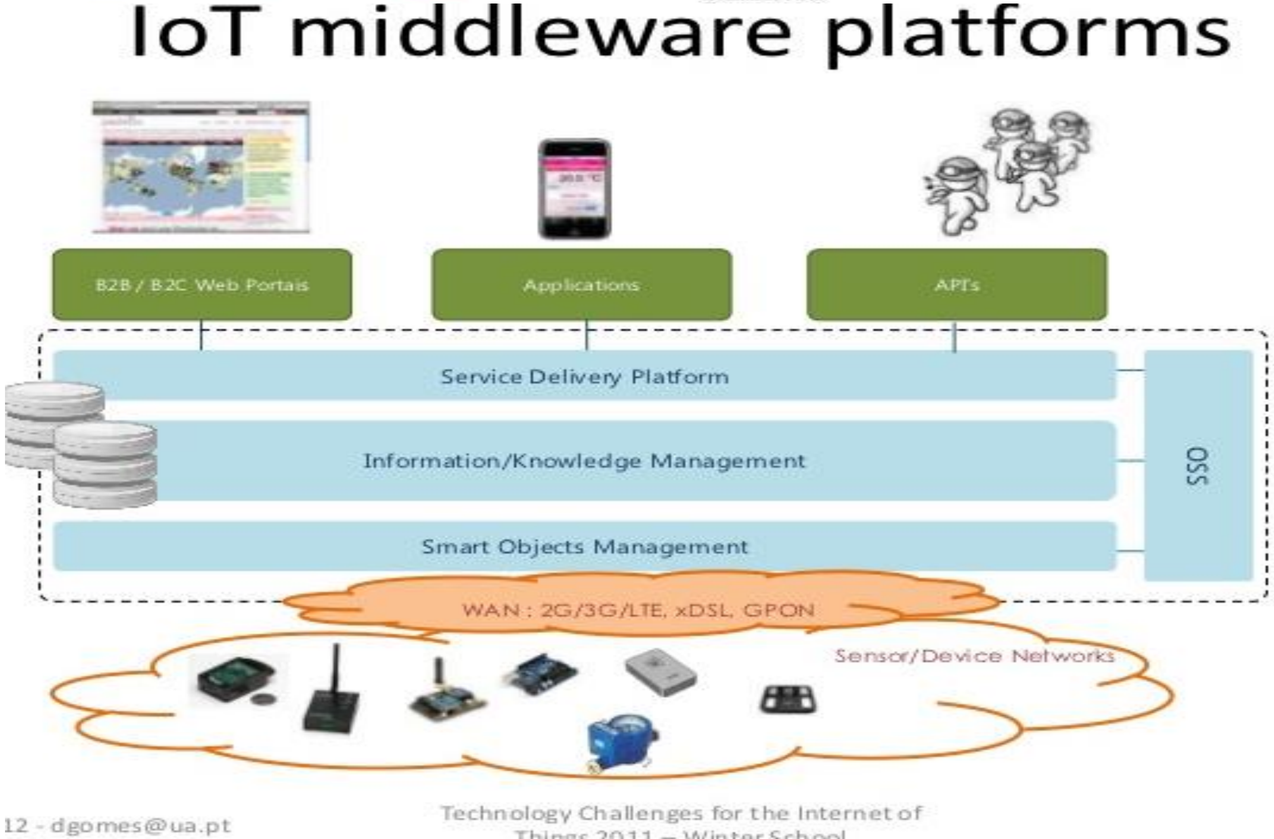
Outline

1. IoT and Sensor (and Actuator) Networks
2. How can we make use of Semantics to help?
3. Base SSNO
4. Extension Examples
5. Topics from Past Ontology Summits
   - Big Data Variety Problem
   - Ontology Engineering Bottlenecks
   - Standards



Sensors and Networks are Merging: It’s about making Connected Things “Smarter”





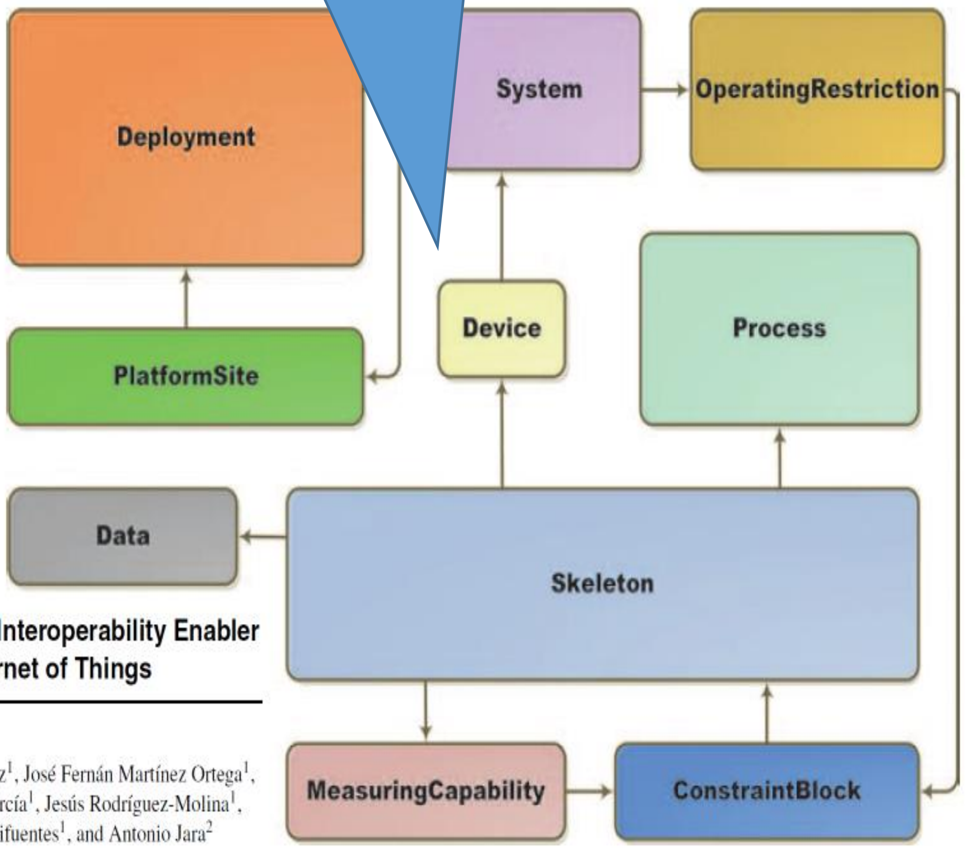
1. Sensors (& people) are a key component of the IoT most closely in touch with the outside world.
2. Sensors observations produce data content in context: environment, technical limits, spatio-temporal setting, …
3. “Software sensor agents” managing the sensors can represent the original content in a logical/digital form that can be broadcast through a networked system.
4. Increasingly these sensor agents can be expected to work smarter as cooperative agents in network.

What can ontologies do to help? (from Big Data Variety session of Ontology Summit 2014)

- Sure scale, dynamism, trust, security etc. are issues, but so is meaning and meaningful interactions for
  - interoperability, discoverability, stability, evolvability, maintainability etc.
- Semantics/ontologies are needed as meta-data to describe the IoT resources/data and as knowledge for reasoning about inferred things:
  - Background knowledge of the domain
  - The structure of the data
  - Annotation of data and metadata
  - Provenance of the data (Transformations, Analyses, Interpretations)
  - Data processing workflows
  - Privacy concerns
  - Hypothesis generation and their workflows

The Ontology Sensor Network Ontology

– **models** the sensor from device, process and system point of views.



Semantic as an Interoperability Enabler in Internet of Things

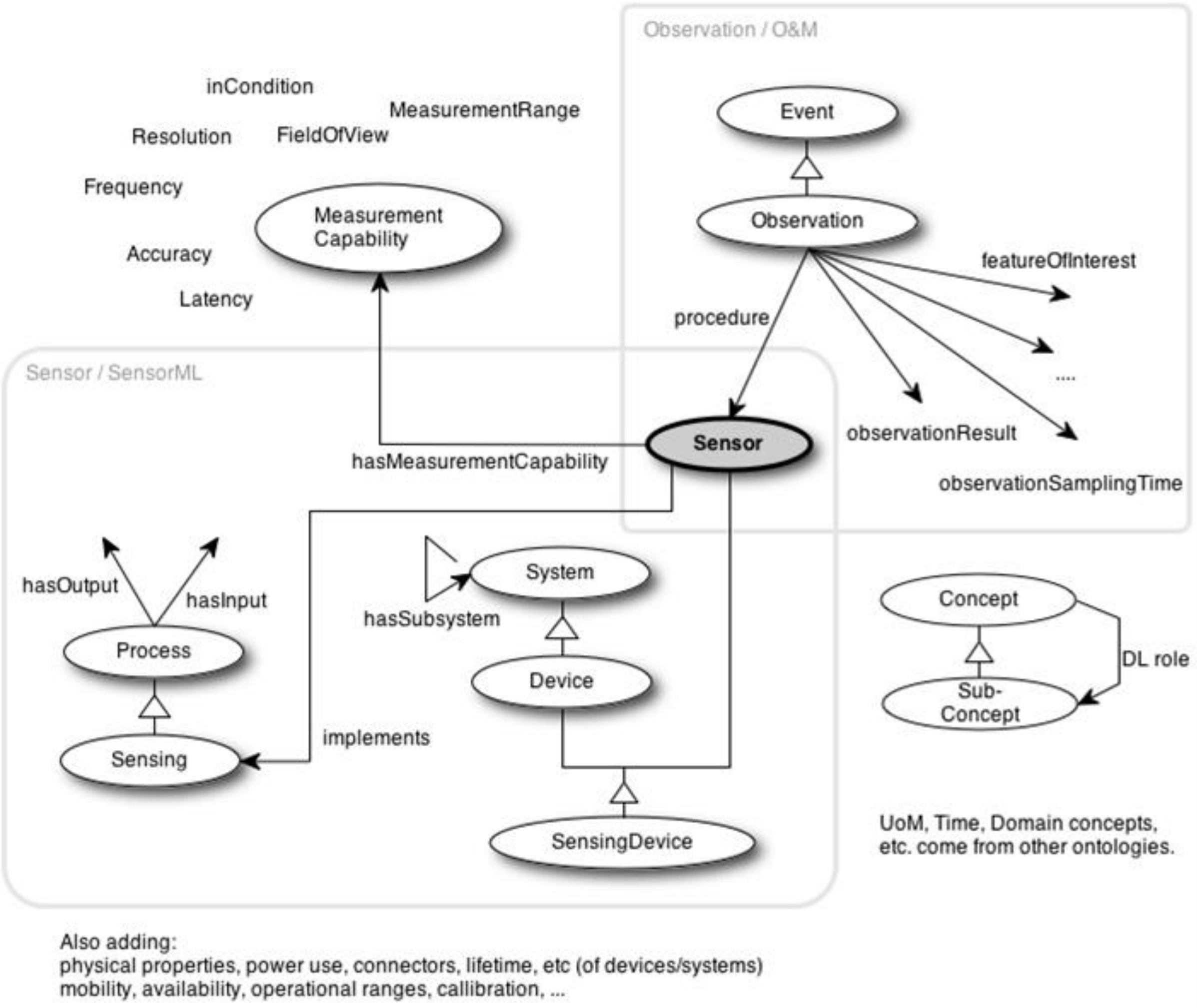
Vicente Hernández Díaz[1], José Fernán Martínez Ortega[1], Alexandra Cuerva García[1], Jesús Rodríguez-Molina[1], Gregorio Rubio Cifuentes[1], and Antonio Jara[2]

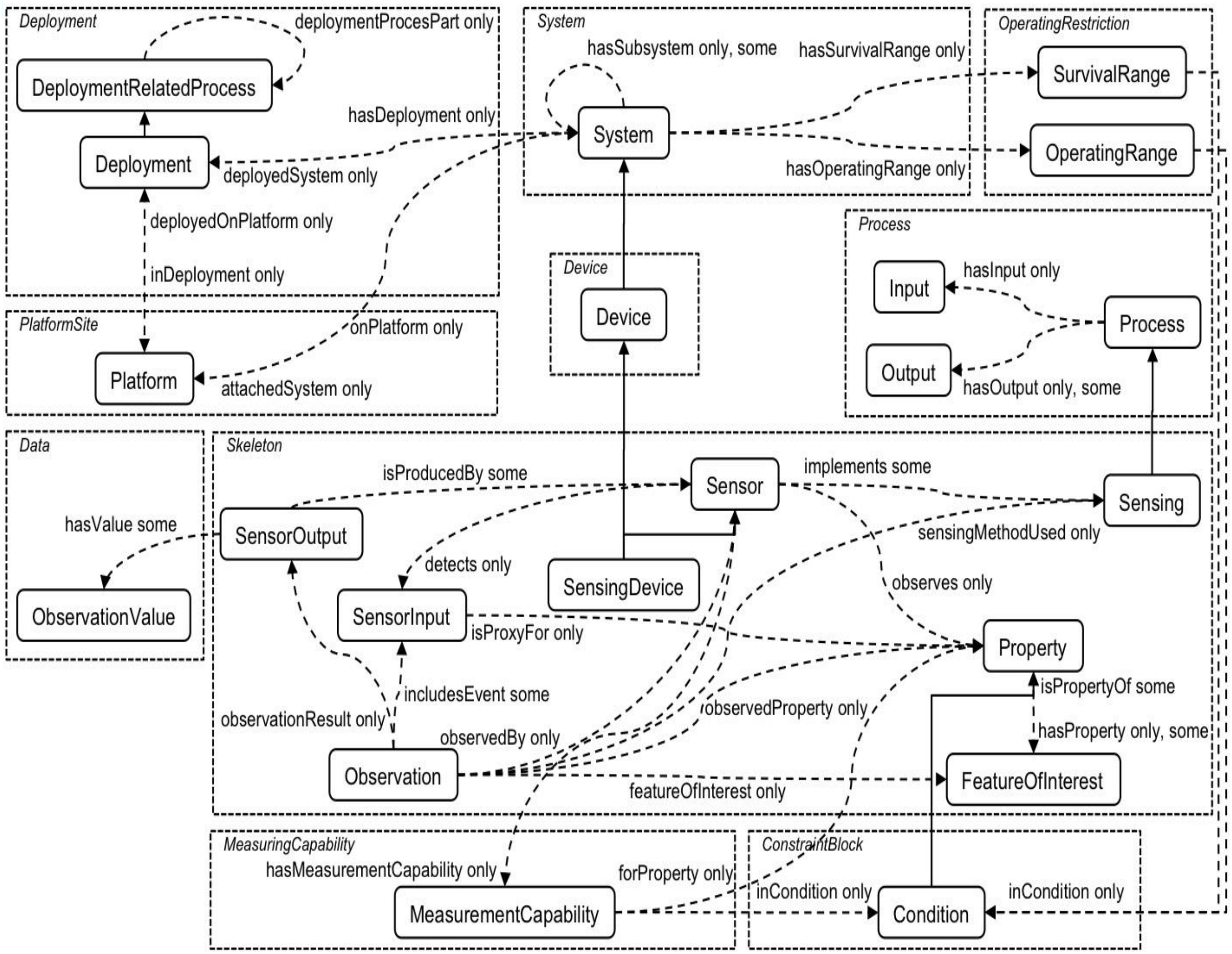
Fig. 9.4 Overview of the Semantic Sensor Network ontology classes and properties.

SSN is an ontology for describing sensors.

– It includes different operational, device related and quality of information attributes that are related to sensing devices.
– describes the operational range, battery and power and environmental ranges that are specified for sensor devices.

Overview of the ontology (skeleton): before & after its modularization and alignment to DUL

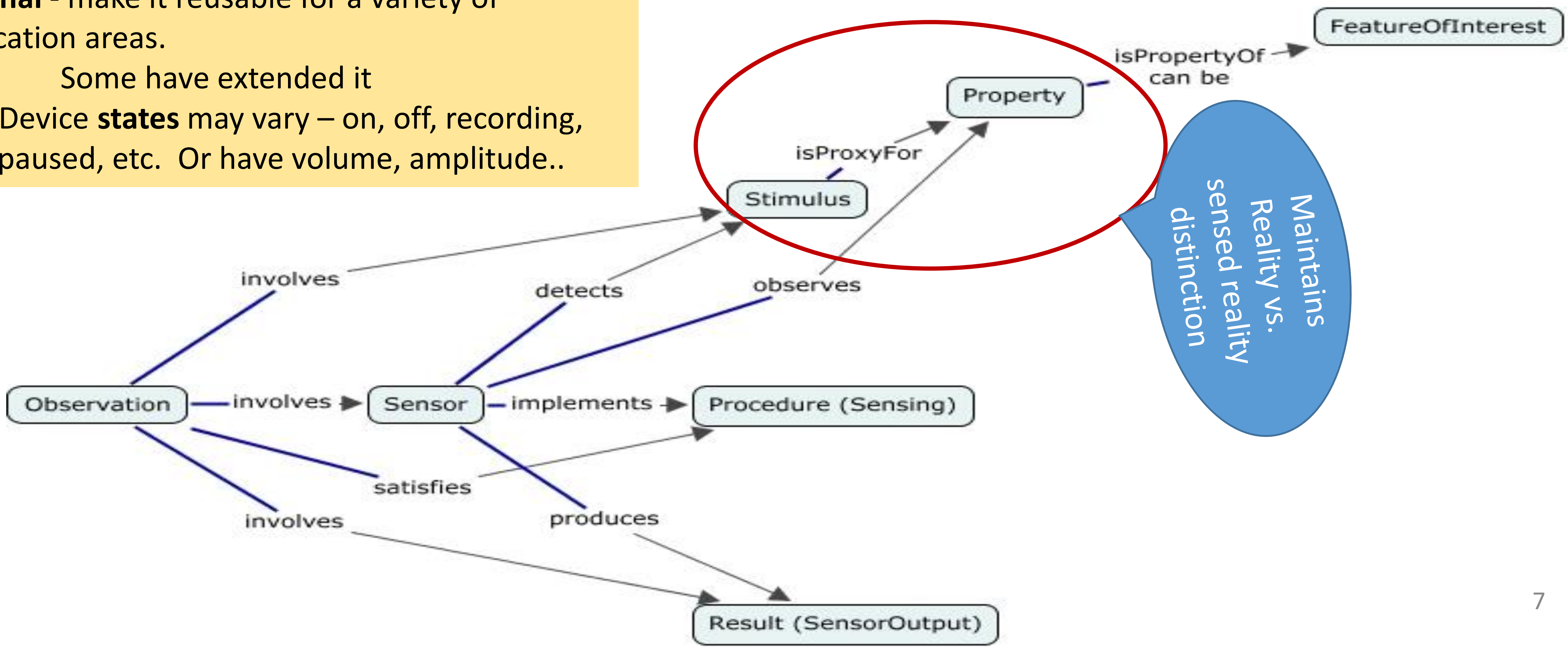




From http://www.w3.org/2005/Incubator/ssn/XGR-ssn-20110628/#The_Skeleton_of_the_Semantic_Sensor_Network_Ontology

The *Stimulus-Sensor-Observation* Ontology Design Pattern (used to build SSN)

Illustrates the principle of **minimal ontological commitments**
Rational - make it reusable for a variety of application areas.
Some have extended it
E.g. Device **states** may vary – on, off, recording, free, paused, etc. Or have volume, amplitude..



Competing paradigms for utilizing ontologies/semantics in sensor networks

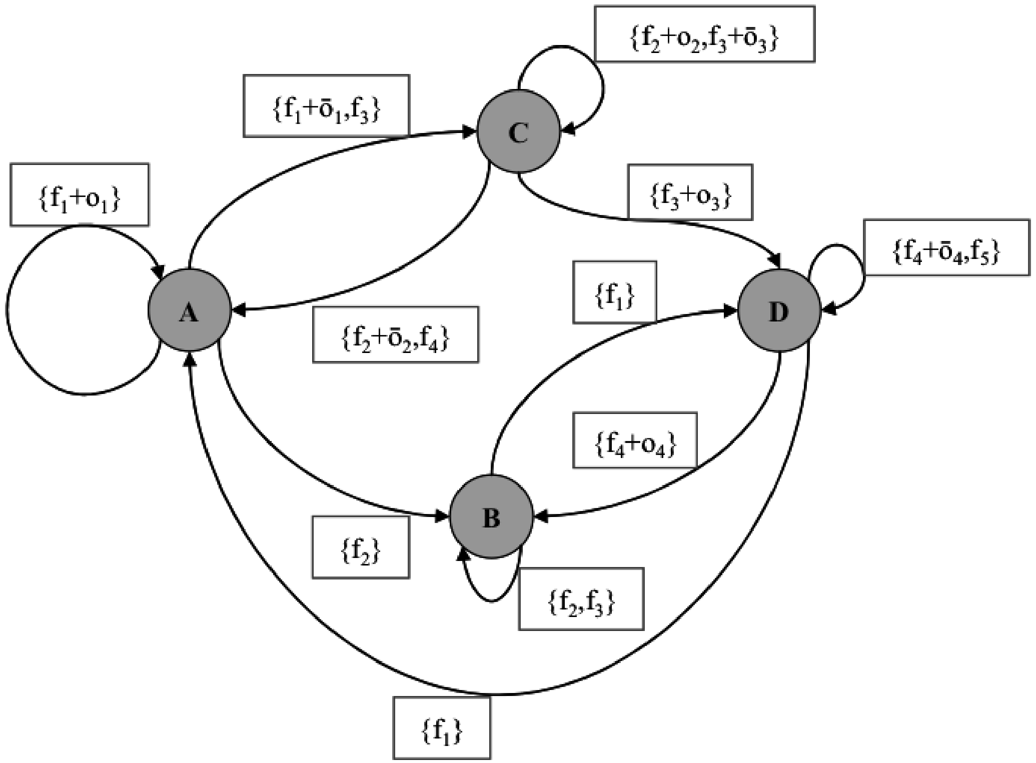
Sensor data discovery and integration	In-network data stream processing
"Offline": happens after the fact	"Online": happens when the data is collected
Somewhat centralized: only need to integrate data from different data collection servers	• Completely decentralized: Each device is both sensor and data processor • Sensors make individual or collaborative (with neighbors) decisions
Full datasets (with broad spatial and temporal scope) are available	Only small "window" (spatially and temporally) of data accessible
Can utilize full available computational power	Limited in processing power (sensor device limitations incl. bandwidth, energy consumption)
Can employ complex ontologies	Limited to small, tailored ontologies
Typical semantic problems: • Integration problems arising from variety • Context of data and sensors play a role • Provenance	Typical semantic problems: • Ontologies that can be deployed on sensors • Integrating/maintaining ontologies across sensors • Interaction between ontologies and data

Examples of Relate/Extended/Beyond

Two distinct approaches for applying ontologies to sensor networks:

- Offline integration of heterogeneous data
  - NSF Earth Science application (EarthCube)
  - EU-Project "Planet Data“ (http://www.planet-data.eu)
  - **SENSEI**
  - **SemSorGrid4Env**
  - Smart City projects
- In-network processing
  - Account for device state
  - *More next week …*

Device State & Dependencies of Sensors



- Modeling the finite state machine of a connected object through a graph.
  - 4 states and 5 functionalities.
- Change of state depends on both functionality involved and as context content generated.
  - After *Semantic profiles to model the "Web of Things"* Benoit Christophe & Alcatel-Lucent

Modeling Smart and Control Entities

Most of the existing IoT or sensor-related ontologies represent IoT devices only partially e.g. sensing devices in SSN ontology.

For automated alignment and matchmaking and the automated deployment of them in heterogeneous IoT environment we need: **Smart Entities and Control Entities:**

- The notion of a smart entity (**SE**) corresponds to an abstract representation of the association of:

1. sensing/actuating/embedded/identity device (Adds variety)
2. “features of interest” that they observe, and
3. software agents that are responsible for the entity’s conceptualization (domain ontology) and for entity’s functionality (provided as a service).

- Control entities (**CE**) represent applications as IoT entities

Reference: Kotis, Konstantinos, and Artem Katasonov. "An ontology for the automated deployment of applications in heterogeneous IoT environments.“ Semantic WEB J.

SENSI: sensor data discovery

- **SENSEI** a European research project about bringing sensors and actuators to the Web (an offline example).
  - resources are addressable entities, empowered by “semantic metadata” to allow fine grained discovery (via semantic query).
  - SENSEI defines integrating mechanisms such as “rendezvous”, allowing the creation of applications build upon several resources.
    - M. Presser, P. Barnaghi, M. Eurich, and C. Villalonga, “*The real world internet: Integrating the physical world with the digital world of the network of the future,*” Global IEEE Communications Magazine Newsletter Section, vol. 47, no. 4, pp. 1–4, Apr. 2009

European FP7 SSW project **SemSorGrid4Env**

SemSorGrid4Env project - a 3 year European project as part of an integrated information space where **new sensor network data sources can be discovered** using web tech & **semantic descriptions.**

- Ontologies used include, a sensor network and observation ontology, a domain-specific ontology describing the concept of flood and an ontology describing the content of a dataset exposed by a service (e.g., the dataset's spatial coverage, its structure, etc) .
- It has a semantic **registry** in which resource metadata is modeled using *stRDF*, a constraint-based extension of RDF, that can be used to represent *thematic*, *spatial* and *temporal* metadata.
- Resource metadata are queried using stSPARQL, an extension to SPARQL for querying stRDF data developed.
- Rapid development of decision support systems are being developed within the context of ocean monitoring for flood and fire warnings.

Reference: Semantic Sensor Grids for Rapid Application Development for Environmental Mana (SemsorGrid4Env). http://www.semsorgrid4env.eu

http://mayor2.dia.fi.upm.es/oeg-upm/index.php/en/activeprojects/56-semsorgrid

Worth Nothing: Issues for Use of Ontologies in IoT *is Similar to Big Data*

- Building vs mining vs induce vs direct queries to large data stores
- Do even light-weight sensor ontologies scale?
- What is realistic for ontological commitments for big heterogeneous data sets?
- How will ontologies make the biggest impact?
  - Annotate or represent IoT data?
  - Can we use ontologies to process data streams on the fly?
    - aggregate, filter, understand, access data streams

Ontology Summit 2014: Big Data
Ontology Engineering Bottlenecks
Report from Track C Sessions (2014/02/06)

- **Knowledge acquisition** -from SMEs, and explaining the model to developers.
- **Ontological Complexity** Modeling axioms or K-Rep language fragments can increase reasoning complexity but reducing the reusability of ontologies, a tooling issue
- K**nowledge representation languages** such as OWL do **not** necessarily replace the need for a **knowledge modeling language** (see Werner Kuhn's talk)

Potential solutions:

- Suites of **reusable patterns** to ease ontology development and alignment
- Need for improved data-driven techniques to scale the development of patterns and ontologies without loosing **reference frames**(Aldo Gangemi)
- **Fit for purpose semantics** with **purpose-driven modeling granularities** that provide **sufficient semantics** without over-engineering
- **Behavioral abstraction** (e.g., duck typing) may be one approach to support the development of more robust ontologies (Also Kuhn)

Ontology Summit 2009: Toward Ontology-based Standards

- Ontologies have the potential to facilitate both the creation and exploitation of standards.
- There are tens of thousands of existing traditional standards which effectively define the characteristics of products and their permitted values, tolerances and relationships (e.g. what can the sensors sense?)
- Even without ontologies, there is a challenge to represent such standards in a form where the established agreements can be exploited in an electronic environment, either singly or integrated into a consistent body of knowledge.
- There are standards which define simple lists of permitted values for properties, such as country codes and currency codes. Information models have been created for physical products, buildings, factories and geographical entities.
- These standards provide an existing body of knowledge that provides a rich source of material which could potentially be exploited using ontological tools to capture all or selected parts of the content and the related implicit knowledge.


The World is getting smarter:
Cities are at the core of this trend
Smarter Transportation
Smarter Education
Smarter Food Systems
Smarter Healthcare
Smarter Energy
Smarter Retail
Smarter Countries
Smarter Government Services
Smarter Water
Smarter Public Safety
Smarter Regions
Smarter Cities

Thank You