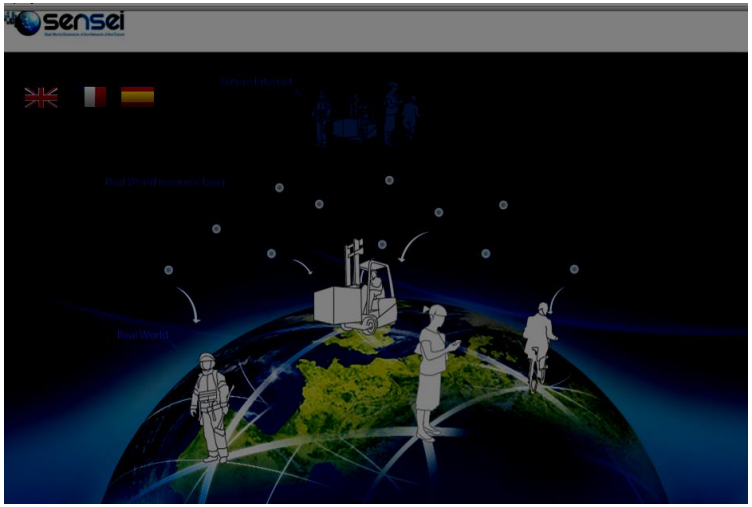
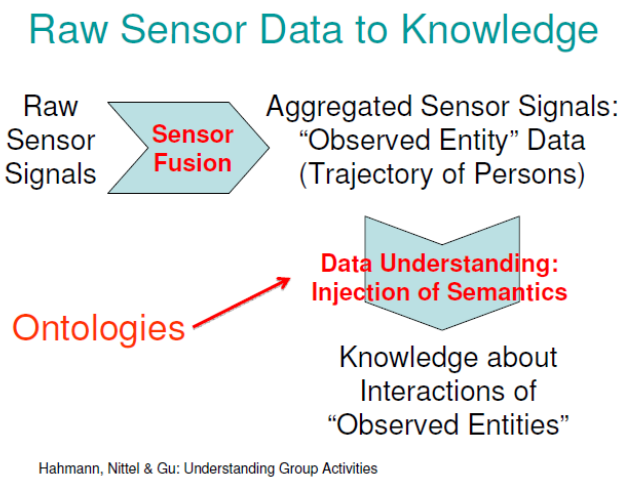
Synthesis "Beyond Semantic Sensor Network Ontologies“

Ontology Summit 2015 Track B

Internet of Things: Toward Smart Networked Systems and Societies

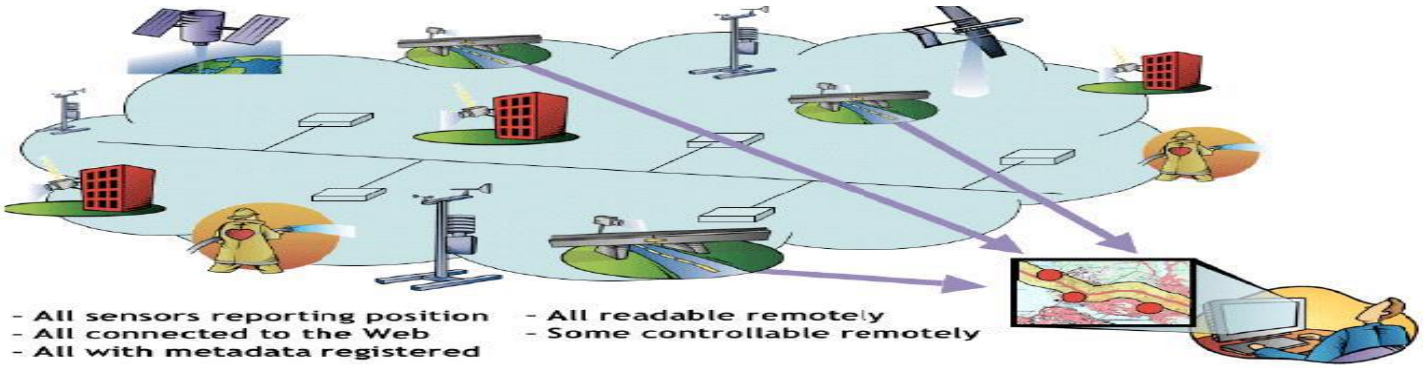




- March26, 2015
- Gary Berg-Cross (SOCoP) & Torsten Hahmann (U of Maine)

Outline

- Sessions, Speakers & Topics
- IoT Visions, Mission & Objectives
- Synthesis of “Beyond Semantic Sensor Network Ontologies”
  - Evolving SSN in order to a place it into the larger IoT context, including interfacing it with other ontologies etc.
  - Using 2 directions to add more semantics in sensor networks,
- Tools & Notes



Sensor Web View From Cory Henson talk

Our 10 Speakers & Their Talks

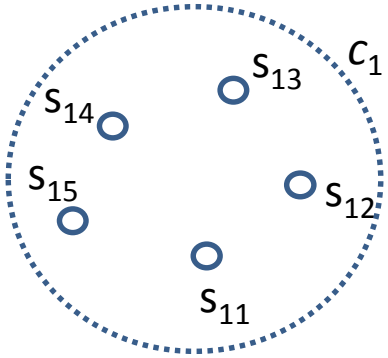
Session 1 (January)

1. Gary Berg-Cross Overview of the SSNO+ topic
   - What does the ontology problem and solution space look like ? Possible Approaches & Issues
2. Jeff Voas (NIST) – Sensors Model for IoT
3. Cory Henson: SSNO – Past, Present & Future Perspectives

Session 2 (March)

1. Charles Vardeman, II: Computational Observations Hackathon idea
2. Ingo Simonis: OGC Sensor Web & Semantics
3. Konstantinos Kotis: Managing unknown IoT entities by uncovering and aligning their semantics
4. Jean-Paul Calbimonte: Ontology-based Access to Sensor Data Stream
5. Torsten Hahmann, Silvia Nittel: Understanding Group Activities from Movement Sensor Data
6. Barry Smith: Ontology of Sensors: Some Examples from Biology

Introduction, Mission and Scope of Track B within an Adaptive IoT Vision



- Sensors & their clusters are a big, embedded, "primitive" part of IoT & its sensing-processing infrastructure
  - result in Big Data challenges (heterogeneity etc.)
- The Semantic Sensor Network ontology (SSN) ontology, associated ontologies & reasoning, play a major role in the IoT & future visions
  - Currently applied to help process and understand sensor information.
  - A source of good work useful for starting work with some lessons learned relevant to IoT which has generated work going forward.
- A Sensor network focus allows discussion of some the major challenges in utilizing semantic technologies for a more adaptive IoT

  E.g. sensor "Things" are part of the inherent IoT **heterogeneity** with:

  - Multiple Techs, Standards, Information Sources and a variety of data

  - Sensing "things" now also have some other processing capabilities

Approach to Synthesis of "Beyond Semantic Sensor Network Ontologies"

The range of work springing from or leveraging SSNO is broad.

- We have leveraged insight from our 10 speakers and the community discussion of approaches, issues and problems.
  - We have attempted to distilled the virtual meeting topics to a useful summary for the face-to-face Symposium.
- Our Synthesis is organized into several parts:

1. Evolving SSN in order to a place it into the larger IoT context, including interfacing it with other ontologies etc.
    1. Sensor-network interactions, services etc.
2. Two directions for using more semantics in sensor networks
    1. Semantics in the cloud, including sensor registries
    2. More local semantics on the edge, including smart sensors

Evolving SSN

SSNO was Developed by W3C SSN-XG (2011)

- Introduces a minimal set of classes and relations centered around the notions of *stimuli, sensor, and observations*.
- Allows discovery, understanding, real-time access to & querying of sensor data
- In the process of standardized by OGC/W3C Spatial Data on the Web WG (~2016)
- Integrating SSNO with web standards & other ontologies
  - Extend SSN to Computational Observations
  - SSNO + PROV-O
  - SSNO + CoAP (Constrained Application Protocol)
  - SSNO + RDF Data Cube Vocab
  - Bio-Medical Ontologies
    - Ontology for Biomedical Investigations (OBI)
      - Pain reports & sensor failure
    - Ontology for General Medical Science

Evolving SSN (contd)

- Integration with evolving service "standards"
  - Example: IoT Interoperability Service (IoT-IaaS) to enable the interoperation of all the different types of IoT entities in a **Plug-n-Play** fashion
- Enhancing SSNO: Most of the existing IoT or sensor-related ontologies represent IoT devices only partially,
  - e.g. only sensing devices in SSNO. Current work extends this to include other entities including tight links to actuator devices, aggregators, etc.
- Extending SSNO with other ontologies and a future vision for IoT requires some improved semantics:
  - E.g. Intellego provides a framework for interpreting sensor data, loosely based on cognitive models of perception.
  - IoT Semantic Smart Gateway Framework (**IoT-SSGF**):
    - **IoT ontology** as a semantic registry for IoT entities (Kotis – more on this later)
  - A reference model of IofT based on 10 primitives has been developed at NIST that incorporates security and reliability issues (Voas)

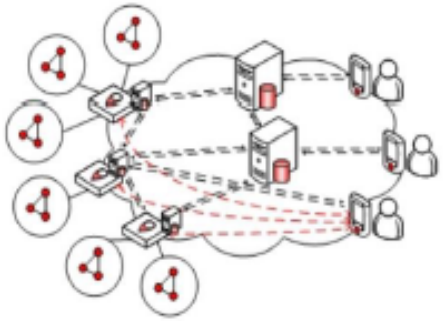
More Semantics in Sensor Networks

Two fundamentally different approaches as illustrated by this diagram (Cory Henson's talk)

Approach 1: Semantics in the Cloud

Send all sensor observations to the cloud for semantic annotation and processing.

Centralized processing approach of spatially distributed and heterogeneous sensor data vs.



Approach 2: Semantics at the Edge

Downscale semantic representation and reasoning for local processing.

Intelligent (geo-) sensor networks with Distributed/In-place computation

http://www.knoesis.org/library/resource.php?id=1772

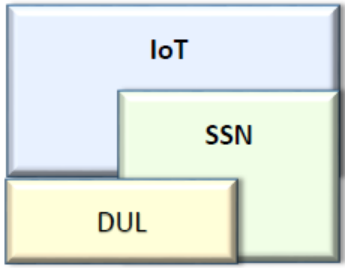
More Semantics in Sensor Networks

Sensor data discovery and integration	In-network data stream processing
"Offline": happens after the fact	"Online": happens when/where 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

More Semantics in Sensor Networks: Semantics in the Cloud

K. Kotis:

- A Semantic Registry for IoT entities is needed on top of DUL and SSN: IoT Semantic Smart Gateway Framework (**IoT-SSGF**)
- Besides the registration of IoT things we need abstractions of technological heterogeneity (vast amount of heterogeneous IoT entities)
  - Need to use heterogeneous domain ontologies to semantically annotate data of IoT entities



More Semantics in Sensor Networks: Semantics at the Edge

K. Kotis:

For automated alignment, matchmaking, and deployment of them in heterogeneous IoT environment we need **Smart Entities and Control Entities** and **communication** between them

- The notion of a smart entity (**SE**) corresponds to an abstract representation of the association of:
  1. sensing/actuating/embedded/identity devices,
  2. features of interest that they are 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

(see K. Kotis and A. Katasonov. "An ontology for the automated deployment of applications in heterogeneous IoT environments." Semantic WEB J.)

J.-P. Calbimonte:

Need to develop semantic query languages to access data streams just like we access centralized RDF data: RDF Streams

More Semantics in Sensor Networks: Semantics at the Edge

T. Hahmann & S. Nittel:

Challenge: How to extract knowledge from the raw sensor data?

- understand “big picture” of what is happing
- understand complex processes and events and their interactions that cannot be captured by a single signal alone

But there are Several *layers* of signals to understand

- Layer 1: Raw sensor signals (e.g. light)
- Layer 2: “Observed entity signals” (indoor trajectory)
- Layer 3: Activities of observed entities (e.g. meetings)
  - Higher-level concepts such as “meetings” will require defining:
    - necessary conditions
    - What different kinds of meetings are there?
    - How to distinguish types of meetings?

Tooling

Need many tool improvements to insert semantic technology into IoT work and test its scalability.

- Tools for ontology creation and visualization
- Tools supporting integration of LOD with IoT
- Support close-to-full automation in terms of discovering and aligning the semantics of IoT entities

Notes

- We referenced past Ontology Summits (for example, the Big Data and Ontology Reuse discussions)
- Proposed a potential Hackathon for an ODP development relevant to IoT (Vardeman).
  - People cam comments on the daft pattern itself
  - We want to develop the pattern and examples from IoT to which the pattern could be applied?