An Architecture to Aggregate Heterogeneous and Semantic Sensed Data

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Abstract. We are surrounding by sensor networks such as healthcare, home or environmental monitoring, weather forecasting, etc. All sensor-based applications proposed are domain-specific. We aim to link these heterogeneous sensor networks to propose promising applications. Existing applications add semantics to the sensor networks, more specifically, to the context, rather than to the sensed data. We propose an architecture to merge heterogeneous sensor networks, convert measurements into semantic data and reason on them.

Keywords: Semantic Sensor Networks, Semantic Web technologies, Resource Description Framework (RDF), Linked Open Data, Ontologies, Reasoning, Sensors.

1 Motivation and Research Questions

Sensor networks are used in a great deal of realms such as home monitoring, environmental monitoring (e.g., weather forecasting), health monitoring (e.g., pacemaker, brain waves), vehicular networks, etc. Each application focuses on a specific sensor network. We intent to link these existing heterogeneous sensor networks to provide new applications. For example, by merging the following sensor networks: the smart kitchen, the weather forecasting and the health we could propose a recipe according to ingredients available in the kitchen, the weather and the user's health (diets, diseases, allergies, emotional state). Merging heterogeneous sensor networks is a difficult task due to heterogeneous protocols, heterogeneous data format and the lack of description of measurements. For example, a temperature measurement is related to a body temperature or an outside temperature, with a body temperature we can deduce if the person is sick, this is not the case with the outside temperature.

The main challenges of this motivating scenario are: (1) manage heterogeneous data from sensor networks, (2) convert sensor measurements into semantic data using semantic web technologies and (4) reason on these semantic data.

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2 State of the Art

SensorMasher [1] and the SemsorGrid4env [2] projects both manipulate environmental sensed data. Coyle et al. [3] propose semantic sensor networks for smart homes. Sense2Web [4] is a Linked Data Platform to publish sensor data and to link them to existing resources on the Web. SWAP (Sensor Web Agent Platform) [5] extracts sensor data automatically. The SSN (Semantic Sensor Network) Ontology [6] describes sensors and their measurements. The following sensor ontologies are specific to environmental sensors and do no not focus on the type of the measurement and the unit: Csiro[1] OntoSensor[2], Cesn[3], Sensei[4], SemSOS[5], OOSTethys[6]. SenML [7] and SWE (Sensor Web Enablement) [8] are protocols to retrieve sensor measurements. SenML is a lightweight protocol, SWE is more difficult to deploy but provides interesting services to manage sensors such as be alerted when a specific event occurred by email. Machine-to-Machine (M2M) means that computers can communicate with each other without human intervention. The M2M ETSI architecture [9] is an architecture to manage heterogeneous sensor networks and communication protocols. They propose to add semantics to the context rather than to the measurements.

Existing works focus on a specific sensor network: smart home, smart kitchen, weather forecasting or environmental monitoring. They design a domain ontology without be linked to the existing ones and add semantics to the context (i.e., shut off the light is the room is empty). There are a numerous sensor ontologies and domain ontologies but they are designed without considering the existing ones and propose to add semantics to the context rather than to the measured data. Further, they do not provide semantic-based reasoning (machine learning or recommender systems) on measurements.

3 Approach

We propose an architecture (Fig. 1) to get sensor measurements (sensor gateways), to annotate heterogeneous measurements with semantics (aggregation gateways) and reason on them (semantic-based applications). Our architecture is inspired by the M2M ETSI architecture. We have in mind a distributed architecture, and propose high energy treatments on the cloud computing if necessary. Our sensor gateways retrieve sensor measurements through the SenML protocol. Our aggregation gateways convert sensed data into semantic measurements using semantic web technologies

[1] http://www.w3.org/2005/Incubator/ssn/wiki/SensorOntology2009
[2] http://mmisw.org/ont?form=rdf&uri=http://mmisw.org/ont/univmemphis/sensor
[3] http://www.cesn.org/sensor/cesn.owl
[4] purl.oclc.org/net/unis/ontology/sensordata.owl
[5] http://archive.knoesis.org/research/semsci/application_domain/sem_sensor/ont/sensor-observation.owl
[6] http://mmisw.org/ont?form=rdf&uri=http://mmisw.org/ont/mmi/20090519T125341/general

(RDF, RDFS, OWL and domain ontologies). Semantic-based applications link our semantic measurements to the Linked Open Data[7] and perform reasoning (inference engine, rules, machine learning, recommender systems).

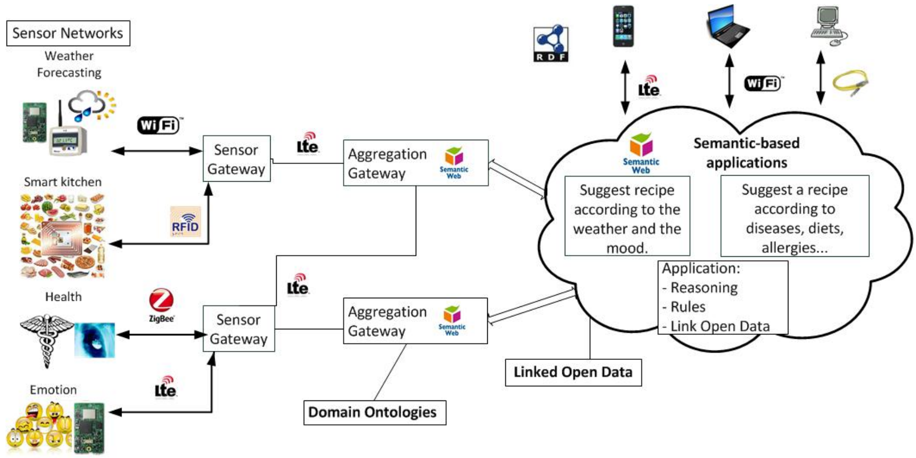

Fig. 1. The proposed architecture

In our scenario, we have two aggregation gateways, the former stores semantic data related to the weather, ingredients and health, the second manages semantic data related to the health and the brain waves. Semantic-based applications merge and query aggregation gateways to provide new services such as suggest the menu for dinner adapted to the weather, the season, available ingredients in the kitchen and the user's health (diseases, diets, allergies, emotional state).

We design the SenMESO (sensor Measurements Ontology)[8] to convert automatically heterogeneous sensor measurements into semantic data. This ontology acts as a hub to merge heterogeneous measurements and domain ontologies. Our ontology describes the measurement concept: a measurement has a name, a value, a unit and a type. SenMESO is linked to numerous domain ontologies to obtain additional information: health (ontoreachir[9]), sensor (SSN[10]), meteo (AWS[11]), smart home (dogont[12]), emotion[13], etc. We aim at constructing a tool to update automatically this ontology with other domain ontologies. Semantic measurements are linked to the linked Open Data to obtain additional information. An example is to link our food measurements to the SmartProduct[14] datasets defining a great deal of ingredients and recipes.

[7] `http://linkeddata.org/`
[8] `http://sensormeasurement.appspot.com/`
[9] Search on google (filetype:owl Ontoreachir).
[10] `http://www.w3.org/2005/Incubator/ssn/ssnx/ssn`
[11] `http://www.w3.org/2005/Incubator/ssn/ssnx/meteo/aws.owl`
[12] `http://elite.polito.it/ontologies/dogont.owl`
[13] `http://emotion-ontology.googlecode.com/svn/trunk/ontology/`
[14] `http://projects.kmi.open.ac.uk/smartproducts/ontology.html`

We want to create a generic algorithm to reason on the heterogeneous semantic data using machine learning, recommender system and semantic tools.

4 Research Methodology

We designed the architecture at the beginning of the thesis and an ontology to convert heterogeneous measurements into semantic data. We evaluate our ontology by using it in the prototype implementation.

Current steps are to work on the refinement of this architecture and the ontology. We are working on updating automatically this ontology with new domain ontologies. We are implementing a prototype to evaluate the components of our architecture (sensor gateway, aggregation gateway) and the M2M applications.

Future steps are to integrate a semantic-based recommender system on semantic measurements to propose applications as presented in the first section. Our prototype will be integrated to the Com4Innov[15] platform deploying a real architecture with heterogeneous sensors and communication protocols (4G). Finally, we will evaluate the performance of the prototype and the real architecture, more precisely, algorithms implemented to aggregate, convert sensed data and reason on them.

5 Results

We have implemented a first prototype to validate the proposed architecture. The sensor gateways[16] retrieve raw measurements and return them according to the SenML protocol. We obtain simple measurements: the name, the value, the unit, and the date (i.e., the temperature is 5°C, 250 grams of butter). The aggregation gateways convert XML data into RDF data. We have implemented the SenMESO ontology to annotate measurements with semantics. The M2M applications reason on semantic measurements to propose an application as the one presented in the first section. The architecture has been implemented with the following technologies: the Java language, Google Application Engine (GAE), the Jena framework, HTML5 and JavaScript. Both the prototype and the ontology are available online[17]. The final version of the prototype will be integrated to the Com4Innov project, to test it in a real environment with heterogeneous sensors and protocols.

6 Conclusion and Future Works

We proposed to merge heterogeneous semantic sensor networks. We annotate measurements with semantics rather than add semantics to the context. Currently, we are

[15] http://www.com4innov.com/platforms_presentation.en.htm

[16] http://emulator-box-servi ces.appspot.com/senmladmin/ahdzfmVtdWxhdG9yLWJveC1zZXJ2aWNlc3IbCxIJWm9uZUFkbWluIgxBbWVsaWVDb3JuZXIM/edit

[17] http://sensormeasurement.appspot.com/

working on the refinement of the architecture, the distributed aspect and the implementation. Future works are to integrate semantic-based machine learning algorithms and recommender systems to reason on heterogeneous semantic measurements. We are also interesting in the security aspects. We are designing a semantic-based security application[18] to help a non-expert in security to secure his/her application, by suggesting the best security mechanism to use.

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[18] http://securitytoolbox.appspot.com/