IoT Semantic Data Integration through Ontologies

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***Abstract*—In this position statement we advocate how the use of ontologies may provide a proper solution for IoT semantic data integration. With this, we will improve IoT interoperability and will facilitate the development of software applications that allow providing management and monitoring of different IoT installations in a generic and homogeneous way.**

***Index Terms*—IoT, semantic data integration, ontology**

I. Introduction

The fragmentation of the Internet of Things (IoT) and the lack of interoperability prevent the emergence of broadly accepted IoT ecosystems [1]. The main reason behind this fragmentation lies on the huge amount of available IoT devices, each one with its particular format for providing the data. That makes very difficult to develop software applications able to provide solutions for a particular domain independently of the devices used to get the information from that domain.

For instance, assume we want to develop an app to identify parking availability. It may likely be the case that a parking in Barcelona uses cameras to identify whether a certain slot is occupied, while another parking in Wolfsburg uses sensors. Clearly, if our app deals directly with the data format provided by the cameras in Barcelona, it will not be able to handle parking availability in Wolfsburg, unless we completely reprogram it to be able to understand the data format provided by the sensors. Moreover, if the parking in Barcelona decides to substitute cameras by sensors our app will stop working.

Semantic data integration is the process of combining data from disparate sources and consolidating it into meaningful and valuable information, i.e. knowledge. In this way, we could abstract from the particular format used by an IoT device to provide a certain data and rely only on the knowledge underlying this data. In our parking example, we could develop an app that understands whether a parking slot is occupied or not independently on whether this is determined by a camera or by a sensor.

An ontology is a way of showing the properties of a subject area and how they are related, by defining a set of concepts and categories that represent the subject [2]. We may create ontologies in every domain to limit complexity and organize data into information and knowledge in order to improve problem solving within that domain.

Creating ontologies for the IoT domain allows us to abstract from the particular syntax and data formats of the different devices and to provide common semantics to all the data managed. In this way we will properly contribute to IoT semantic data integration, and this will allow us to better achieve IoT interoperability and to develop applications that allow providing management and monitoring of different IoT installations in a generic and homogeneous way.

II. An Ontology for Connectivity Management

To illustrate the advantages provided by ontologies to IoT semantic data integration we have taken as an example one out of the several ontologies that have already been proposed for the IoT domain. In particular, we have chosen the CMTS ontology (Connectivity Management Tool Semantics ontology) [3] because of our previous experience on it.

This ontology has been created as a result of our joint industrial research at the inLab FIB (https://inlab.fib.upc.edu/en), the innovation and research laboratory of the Faculty of Computer Science of Barcelona, with Worldsensing (https://www.worldsensing.com), a company focused on providing services through the monitoring of industrial environments from IoT devices. The development of a platform able to control and act on its own and third-party industrial IoT devices has become a critical goal for the success of the company, and the need to consider different types of devices can only be successfully addressed through this common vocabulary.

The CMTS ontology is shown in Figure 1. It is specified by means of a UML Class Diagram that states the concepts of the IoT domain that have to be considered to provide the aimed connectivity management in IoT sensing across different devices and settings of the sites being monitored.

The main concept in the ontology is the IoT device. A physical IoT infrastructure contains three common types of IoT devices: gateways, nodes and sensors, as stated by the subclasses of the *Device* concept.

A device is hosted in an IoT site (also called platform), and we have also information of the connection status of the device in that site.

Gateways, *nodes* and *sensors* are physically installed as provided by the associations stated by the ontology among these concepts.

Sensors are aimed at identifying data for their *ObservableProperties*, such as the temperature of a sensor in an environment or the inclination of a surface. When a sensor captures the value of an observable property at a given time it generates an *Observation*.

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We refer the reader to [3] for more details about the ontology.

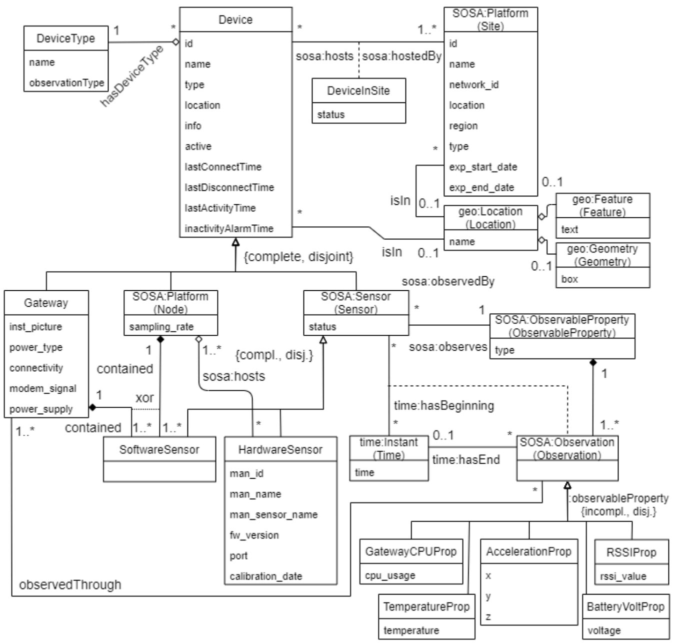

Fig. 1. The CMTS Ontology

The CMTS ontology summarizes and makes explicitly the knowledge required to manage and to monitor a physical IoT infrastructure. This is done at an abstract level and independently of the particular IoT devices and data formats used in the infrastructure. Moreover, an infrastructure can be either located in a building or in a car and nothing changes as far as the knowledge that can be managed from it.

In our parking example, no matter whether we observe parking lot occupancy through a camera or a sensor, our app will be able to work in both situations since it will monitor observations at an abstract level thus being able to assess whether a parking lot is occupied independently on the way this is technically determined.

Now, a software application able to deal with all the concepts in the ontology as first class citizens, i.e. making an explicit use of them in its implementation, will be able to manage all physical IoT infrastructures that conform to this ontology.

The only thing that needs to be done to make all of these work in this way is to develop programs for each particular physical IoT infrastructure that convert the format of the data captured by its devices into instances (i.e. objects) of the concepts in the ontology. Then, we can add and remove new infrastructures without having to modify any single line of code of our application running on the ontology.

The CMTS ontology is complete in the sense that it incorporates all concepts and properties required by the IoT domain under consideration. Moreover, it can be easily extended since new concepts and properties can be added to the ontology without having to modify the programs running on the current ontology.

III. CONCLUSIONS

In this position paper we have argued that we see the creation of IoT ontologies as an appropriate solution to provide IoT semantic data integration.

Ontologies allow to abstract from the particular syntax and data formats of the different devices and provide common semantics to all the data managed. Therefore, they contribute to: (1) share a common understanding of the structure of information among software agents; (2) enable the reuse of domain knowledge; (3) domain assumptions are made explicit; (4) domain and operational knowledge are kept separated.

Then, a software application able to deal with all the concepts in the ontology will be able to manage all physical IoT infrastructures that conform to this ontology without having to modify any single line of code. Moreover, adding new concepts into the ontology will not affect the behaviour of the running application.

With this, we improve IoT interoperability and facilitate the development of software applications that allow providing management and monitoring of different IoT installations in a generic and homogeneous way.

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