Semantic Interoperability on the Internet of Things: The Semantic Smart Gateway Framework

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ABSTRACT

Internet of Things should be able to integrate an extremely large amount of distributed and heterogeneous entities. To tackle heterogeneity, these entities will need to be consistently and formally represented and managed (registered, aligned, composed and queried) through suitable abstraction technologies. Two distinct types of these entities are a) sensing/actuating devices that observe some features of interest or act on some other entities (call it 'smart entities'), and b) applications that utilize the data sensed from or sent to the smart entities (call it 'control entities'). The aim of this paper is to present the Semantic Smart Gateway Framework for supporting semantic interoperability between these types of heterogeneous IoT entities. More specifically, the paper describes an ontology as the key technology for the abstraction and semantic registration of these entities, towards supporting their automated deployment. The paper also described the alignment of IoT entities and of their exchanged messages. More important, the paper presents a use case scenario and a proof-of-concept implementation.

Keywords: Internet of Things, Ontology, Ontology Alignment, Semantic Interoperability, Semantic Registry

INTRODUCTION

Internet of Things enables a global connectivity between the real world and a virtual world of millions of distributed entities (observed subjects / objects, sensing / actuating / identity / embedded devices, software applications / services), connects things, not only places or people, and brings real-time machine-published big data to the users of the existing Web.

The ‘things’ on the IoT are various physical entities that are of some interest to humans, e.g. a heater to control, a package to track, an industrial machine to monitor, the air temperature in a room to measure, the motion in a room to detect. Depending on the nature of these ‘things’, different technologies for connecting them to the IoT are used: a) identity devices (e.g. RFID tags or barcodes), b) sensing and actuating devices (e.g. temperature and other sensors, cameras for cars’ register plate recognition, and actuators like remotely-controlled door locks or window blind controls), and c) embedded electronics (e.g. industrial machinery, home electronics,

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smart phones and wearable devices that have embedded parts e.g. processors, data storages, sensors and actuators).

Due to the large diversity of millions of devices, and the consequent distribution of their storage and data analysis resources in order to handle the problem of big data, IoT requires interoperability at multiple levels. On the hardware side, such problems have to be addressed as handling a capability mismatch between traditional Internet hosts and small devices, as well as handling widely differing communication and processing capabilities in different devices. In the interface between the device and network domains, IoT gateways will provide a common interface towards many heterogeneous devices and networks. Some IoT devices, e.g. home electronic appliances will be likely connected directly to the Internet without such middle-boxes. For the communication between heterogeneous IoT devices and applications towards the automated deployment of latter in environments where the former have been already deployed, there is currently a gap of a facilitator technology (interface). Third-party applications that are developed without being aware of devices’ data models (descriptions), but being generic in the sense of being capable of running on various IoT device sets, will not be possible to be automatically deployed. Such inability is caused by the semantic gap between heterogeneous data of both types of entities i.e. devices and applications. Such a gap can be bridged by aligning the meaning of data that both types of entities may ‘carry’ and use these alignments for their semantic matchmaking.

Based on the above ascertainments, distributed and heterogeneous IoT entities need to be consistently, explicitly and formally represented and managed (registered, aligned, composed, and discovered) through suitable abstraction technologies i.e. ontologies. Such a representation and management capability will enable their seamless integration in different application domains of IoT, such as smart home, ambient assisted living, transportation, etc., in a way that deployment of third-party generic applications in non-expert end-users’ IoT settings will be performed automatically, with minimum involvement of both non-experts and experts.

In this paper we focus on the use of semantic technologies, for the automated deployment of heterogeneous and distributed IoT entities, supporting the following three distinct tasks: a) the semantic registration of IoT entities, b) the alignment of IoT entities’ metadata and use of these alignments for their matchmaking, and c) the alignment of the semantics of the data of the messages that are exchanged between these IoT entities during device-to-application communication. We view the deployment of third-party generic applications in such settings as an automated process that hides from end-users the complexity of tasks such as ontology alignment and semantic matchmaking of IoT entities. These complex tasks are not expected to be performed by non-expert end-users but rather they should be supported by an expert third-party service provider e.g. an IoT semantic interoperability as a service (SIaaS) provider that acts as a mediator between IoT application providers and consumers, placing the ontology alignment and semantic matchmaking tasks of the deployment process of IoT entities in a mediation layer of the IoT stack.

In this paper, we consider ontologies as a key technology to solve the problem of automating the deployment of applications in heterogeneous IoT environments, allowing any IoT entity to unambiguously convey the meaning of data/information they ‘carry’. The aim of the presented ontology as an abstraction technology is to hide heterogeneity of IoT entities, acting as a mediator between IoT application providers and consumers, and to support their semantic matchmaking. Acting as a mediator, the ontology objective is to be used by the interested stakeholders independently as a registry for the semantic registration of IoT entities, i.e. by the IoT application providers/developers that will register their software and by the IoT application consumers/users and IoT device owners that will register their sensing/actuating/embedded devices and the associations of these devices with the observed...
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