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A Lightweight Semantic Web-based Approach for Data Annotation on IoT Gateways

Mahmud Al-Osta*, Bali Ahmed, Gherbi Abdelouahed

Department of Software and IT Engineering, École de technologie supérieure, Montreal, H3C 1K3, Canada

Abstract

Internet of Things (IoT) applications rely on networks composed of set of heterogeneous sensors and smart devices, which have the capability to constantly, observe the surroundings and gather data. This heterogeneity is reflected on raw data gathered by such type of systems. Consequently, the task of high-level IoT applications to interpret such data and detect events in the real world is more complex. Moreover, data heterogeneity leads to the lack of interoperability between IoT applications. Semantic Web (SW) technologies have been widely adopted to model and integrate data from different sources on the web; extending them to the IoT domain can be used to mitigate the aforementioned challenges. Semantically annotating IoT data is a fundamental step toward developing smarter and interoperable IoT applications. However, this type of process requires a large amount of computing resources, especially in scenarios where a large number of sensors is expected to be involved such as smart city. To address these challenges, we propose a lightweight semantic annotation approach that can be implemented on resource-constrained IoT gateways connected to a limited number of sensors. To evaluate the feasibility of the proposed approach, we have carried out a set of experimentations using a middleware prototype implementation. Several benchmarks are considered such as: Data size, response time, and resource utilization.

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Keywords: Semantic Web; Internet of Things; Ontology; Data Heterogeneity; Data Annotation;

1. Introduction

IoT is a novel paradigm that is foreseen to change the landscape of Information and communication technology (ICT). This conversion is promoted by the unprecedented proliferation of Internet connected devices in our contemporary life. Recent study by cisco anticipates that by 2020, 50 billion devices will be connected to the Internet [1]. These devices are expected to be deployed in different fields of applications to continually observe the environment. This deployment is primarily targeting collecting situational data, that can be further used to develop application human can use to monitor events in the real world and react accordingly. Thus, generate a massive amount of data, which further can be transferred through gateways to the Internet cloud platforms. These platforms have the capability to further process and analyze the collected data and harness them to develop innovative IoT applications that can potentially contribute in improving several areas of our daily life such as health care, transport logistics, and traffic monitoring [1 2].

* Corresponding author. Tel.: +1-514-266-8581 ; fax: +1-514-840-5514.
E-mail address: mahmud.al-osta.1@ens.etsmtl.ca

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Typically, IoT systems are composed of a varied set of sensors and devices that monitor different aspects of the environment and collect data. This heterogeneity characteristic of IoT system components is reflected on the generated data, which in turn encumbers the task of IoT application to interpret data and effectively utilizing it. Moreover, data integration process is hardly maintained in such environment, which leads to the lack of interoperability among different IoT systems. Thus, limiting the development of applications that can benefit from data generated from diverse domains of IoT[3,4]. In nutshell, in order to develop interoperable IoT applications that can detect events in the real world and response accordingly, deducing knowledge from gathered raw data is prerequisite.

In addition to the heterogeneity aspect of IoT data, these data are continuously streaming. Consequently, huge amounts of data are regularly generated and sent to cloud platforms for further processing and analyzing. Although these platforms have the capabilities to manipulate such amount of data, this process consumes a considerable amount of resources, where in some cases users would have to expand their storage facility to meet the increasing amount of data. Further more, blindly sending data forth and back between the cloud and IoT gateways has led to network traffic overloading and latency issues that might influence time-sensitive services[4].Also, applying semantic annotation algorithms on such amount of data at the gateway device level will result in extensively consuming its resources, which likely to impact its performance.

Semantic Web (SW) technologies have been extensively utilized to interpret and integrate data coming from a diversity of resources on the Web. Recently, they have been extended to the IoT domain to enhance the quality of data and to promote interoperability[5]. This is achieved by modeling IoT data based on shared vocabularies that can be interpreted by different software agents. This process is called semantic annotation, which implicates employing several SW standards such as: OWL, RDFs, and RDF to build conceptual models (i.e. Ontology) to describe application domain concepts and the relationships that exist between them[6]. Moreover, SW technology stack provides SPARQL protocol and RDF query language, which can be employed to query and reason over RDF databases to infer knew knowledge form them[6].

To alleviate the burden of transmitting data to the cloud through IoT networks, and to minimize processing cost at the cloud level, a recent trend of emploing IoT gateway devices as hub for data aggregation and processing has been widely adopted. Recently, these devices have seen a significant improvement in terms of computing resources, which empower them to implement filtering and annotation algorithms.Moreover, these devices could achieve faster response times since they work closely to sensor nodes. This way can be helpful in reducing the amount of data volumes transferred to the cloud, which lighten the network traffic and lower latency.

In this work, we propose to develop a lightweight semantic based annotation approach. The proposed approach is intended to be implemented on resource-limited devices. Thus, we seek to meet the following requirements. First, minimizing resources required for the annotation process; to achieve this, we have designed data aggregation and filtering mechanisms to filter-out unnecessary data based on a rule engine; thus reduce the amount of data to be annotated and further sent to the cloud. Second, lighten the annotation process by concentrating on annotating the data that mostly queried and used by end applications.

The reminder of this paper is organized as follows: We discuss some background details and related work in Section 2. Section 3 presents details about our proposed approach followed by prototype implementation and evaluation in Section 4. While Section 5 concludes the paper and highlights some points for future directions.

2. Background and Related Work

Due to their capabilities of annotating data, so they can be machine interpretable, several semantic web technologies have been recently adopted to promote data integration and interoperability in the IoT filed.

RDF is a standard language for representing information about Web resources as XML format. It provides a unified framework for exchanging information between applications without loss of meaning. Data in RDF are stored in the form of triples; each triple is consisted of (subject, property, and object). In typical IoT application consisted of set of devices generating set of data, devices are semantically represented by the subject; while the property represents the measured quantity, and the object represents the measured value. RDF Schema (RDFS) is an extension of RDF vocabulary, which enables more detailed description taxonomies of classes and properties. In another word, RDFs can be perceived as an expressive meta-model used to describe the vocabulary used in an RDF document.OWL represents more expressive way to model data on the semantic web. It was essentially developed to overcome some RDF and RDFs limitations such as the lack of a clear way for domain or range constraints description, and the lack of the

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