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Semantic IoT System for Indoor Environment Control – A Sparql and SQL based hybrid model

Faiza Tila , Do Hyuen Kim

Computer Engineering Department, Jeju National University,
South Korea.
faizatila7@gmail.com, kimdh@jejunu.ac.kr

Abstract. The realization of Internet of Things (IoT) has gained momentum in the past few years. The main idea is to connect devices with disparate data formats learn, integrate, and communicate to provide intelligent services to humans. These devices generate a large amount of data with various data formats, resulting in some issues i.e. interoperability and data volume. In this paper we have addressed both the problems with a hybrid approach utilizing both semantic and data base technologies. Our research study is based on modelling a context ontology and a database schema to store sensor context data and to control actuators in an environment. An architecture based on IoT system for an indoor environment control is proposed that collects sensor and actuator data as well as its location information and provide it to the external users or applications.

Keywords: Resource Description Framework, Web Ontology Language, Internet of things, Simple Protocol and RDF Query.

1 Introduction

In the recent years the current internet has been given a whole new dimension by interconnecting all the physical objects, devices and their virtual representation. Internet of things (IoT) enables a global connectivity between the real world and a virtual world of entities or things. It requires an overall interoperability due to its vision of the millions of devices connected to each other [1]. The authors in [16] has presented a roadmap for semantic technologies and the internet of things. They have described some of the problems that are faced by the current web e.g. searching an object, and storing the data generated by IoT objects. Further they have identified if the semantic web is beneficial for addressing these problems and if not how they can extended or adapted.

The study [17] covers the importance of semantic technologies for overcoming issues caused by heterogeneity in the internet of things. The study specifically discusses the requirement of various business applications for deployment of IoT systems based on RFID developed by different vendors using different data formats. Integrating these systems becomes complex and challenging. To overcome this issue the authors have proposed an ontology for RFID systems that supports unification of

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concepts thus enabling the interoperability of the same concepts/resources in different domains.

The proposed system is a hybrid system that utilizes both semantic and database technologies to collect, store and provision environmental context information. Ontology schemas of the system modules enable interoperability by annotating context information with semantics, offering efficient querying and reasoning over the context information. The ontology model presented in this study is considered as the key solution for devices to convey their context as useful data. Data relations and data descriptions of the contextual data makes it interoperable for external users and stakeholders using the same ontology.

As we know, ontologies are required to be in memory during program execution in order to be manipulated. This might decrease system performance, specially querying, with the growth of the ontology size. In order to preserve the performance, database techniques might be the best solution [12]. This study presents architecture and models to assess how both the technologies can be used to achieve the best results in a real time system. The sensing data collected in this system might grow with the addition of new devices which will affect the processing performance of ontology.

The rest of the paper is structured as follows; section 2 illustrates the architecture of the semantic IoT indoor system by presenting a detailed figure including the various modules in the system. Section 3 provides the overall structure of all the modular ontologies used in the system. It explains the details of the ontologies by providing a figure, whereas section 4 gives a description about the conclusion and future work.

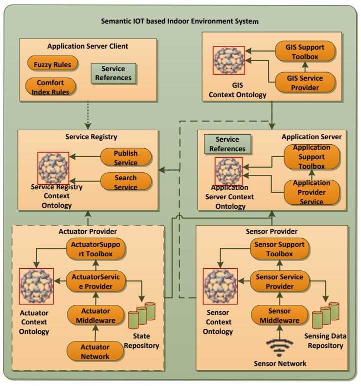

Fig. 1. System Architecture

2 System Architecture

This section provides a comprehensive view of the overall architecture of the system. Fig. 1 shows the architecture of the proposed system including each module, its components and its ontology schemas. Our system consists of five modules i.e. sensor provider, actuator provider, GIS provider, service registry provider, and application (app) server provider. Each of these modules consists of the functional units i.e. a) a middleware unit, b) a service provider unit, c) a support toolbox, related ontology and a database schema.

Functions offered by provider unit's services are implemented using semantic technologies for manipulating the context information collected from the IoT devices. Semantic queries and dotNetRdf APIs [15] are used by the functions to manipulate and process the information. Semantic queries are also executed for storing this context information in the semantic repository or ontology schema maintained within the module.

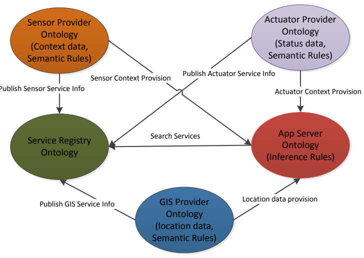

Fig. 1. Overall System Ontology

3 System Ontology Design

An ontology design follows an evolving prototype life cycle rather than a waterfall or an iterative one. This section presents the ontology design phase in detail. It discusses different models describing the ontology from various aspects. Fig. 2 shows a generic semantic model of the system ontology. As shown in the figure the ontologies in our system are: sensor provider ontology, actuator provider ontology, service registry ontology, GIS provider ontology, and app server ontology.

Sensor Provider ontology is maintained in the sensor service provider module. Fig. 3 shows the ontology model for sensor provider. It stores context information of sensors available in the network in RDF format. Sensor provider module has the following units: a middleware, a service provider, and a support toolbox. The sensor provider ontology reuses the SSN ontology, which is one of the most significant information model for sensory data [21].

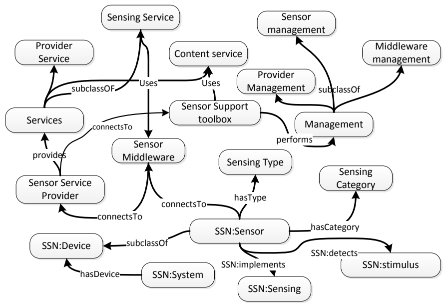

Fig. 2. Sensor Service Provider Ontology

Actuator Provider module stores information in its knowledge base called Actuator Provider ontology. The actuator provider module consist of the following functional units i.e. actuating device, actuator middleware, actuator service provider, actuator support toolbox and service control. The actuator functionality can be controlled by sending control and command messages between these functional units. Fig. 4 shows the ontology model of actuator provider module.

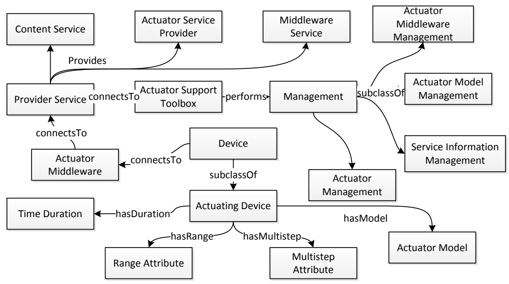

Fig.4. Actuator Provider Ontology

```
ActuatingDevice rdfs:subClassOf Device
Actuator01 rdf:type ActuatingDevice
<owl:NamedIndividual
              rdf:about=Actuator1">
     <rdf:type rdf:resource=Actuating_Device"/>
     <ActuatorName
rdf:datatype="&xsd;string;</ActuatorName>
```

The Sparql code given shows that Actuator01 is an instance of device class. It shows that actuator01 is a type of actuating device, and that actuator01 has a data type property actuator name. It also shows that actuator name has data type string.

Similarly data properties and object properties are defined for other classes in the ontology. Semantic IoT indoor system requires storing the location information of the devices it is monitoring. It uses the GIS provider module for this task. The location information of the resources is stored in the GIS ontology shown in Fig. 5.

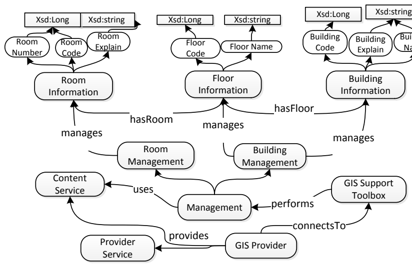

Fig.5. GIS Provider Ontology

The application server module is the top module in the semantic IoT indoor system. It consists of application service provider and application support toolbox functional units.

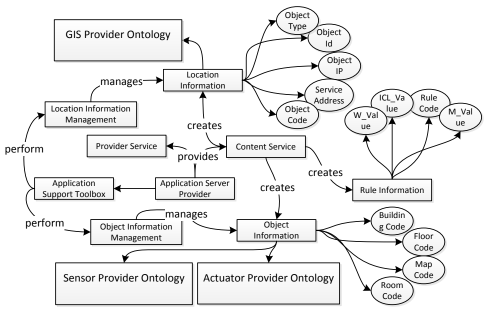

Fig.6. Application Server Ontology

Application server ontology shown in Fig.6 acts as a repository for application server module. The application server module offers sensor provider, GIS provider and actuator provider API to client. The client can search for application server address in service registry ontology and by connecting to specific application server ontology it can access sensor and actuator provider's ontologies via the application server ontology. The rule information table provides a scale for the system to determine the thermal comfort of the indoor environment.

4 Conclusion

In this paper we have discussed the advantages of applying semantic technologies to internet of things. We have presented architecture for the semantic IoT indoor system as well as the different ontology models used by the system. The application of semantic technologies enables interoperability between various IoT devices. The hybrid nature of the presented architecture enables the system to isolate the context and device information in various modular ontologies while storing the real-time sensed data into SQL based databases. The presented hybrid approach is intended to facilitate the system's performance in terms of query time and reasoning by restricting the growth of the ontologies in question. Future work includes the implementation of the system and carrying out a detailed comparison analysis with traditional ontology based approaches.

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