Describing Things in the Internet of Things

From CoRE Link Format to Semantic Based Descriptions

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***Abstract*—Efficient mechanism for describing the physical things is necessary for automatic configuration and management in the Internet of Things (IoT) ecosystem. This paper highlights an evolution in Thing Description (TD) from CoRE Link Format to semantic based descriptions. Adding semantics enable sensors and actuators to be represented in terms of events, properties and actions. This provides further granularity in TD which allows higher layer IoT applications and consumers to easily configure and manage the connected things. A thing management framework is developed based on semantic TD. JSON for Linking Data (JSON-LD) provides a serialized representation of such TD model and is a lightweight Linked Data format. This paves way for seamless thing to thing interaction in IoT spaces. Integration of the proposed framework into oneM2M architecture and prototyping aspects are also highlighted.**

***Keywords*— CoRE Link Format; IoT; JSON-LD; oneM2M; Semantics; Thing Description.**

I. INTRODUCTION

The Internet of Things (IoT) envisions an ecosystem that seamlessly connects physical things to the Internet with the target of providing consumer centric applications and services. To provide the value added services, the ecosystem must (i) allow the participating things to interact with their environment and (ii) enable thing to thing interaction. This paves the way for efficient exchange and analysis of metadata, creation of high level intelligence and results into actuation according to the need. However, the participating things are heterogeneous in terms of capabilities, properties, nature and support for communication technologies and protocols. As a result, the mechanisms for thing and metadata discovery, automatic thing management, uniform data analysis and thing to thing interaction become difficult. These can be solved by (i) describing the things in a uniform fashion using CoRE Link Format [1] and (ii) utilizing a lightweight framework for M2M device management [2]. The TD of [1] and framework mentioned in [2] can be utilized in smart home domain [4] as well as in cross domain IoT application development [3].

In this paper, we present an evolution of the thing description where semantic based descriptions are considered. The main advantages are – (i) uniform nomenclature to describe the things, (ii) representing things in terms of event, properties and action add further granularity in TD, (iii) allows interoperability at the treatment of thing metadata, (iv) enables automatic configuration and management of things and (v) TD can be represented using JSON-LD which is extremely lightweight and beneficial for constrained devices. The added granularity also promotes semantic treatment of thing metadata resulting in generation of actionable intelligence and enabling thing to thing interaction. The main contributions of the paper are twofold – (i) a lightweight thing management framework that utilizes semantic based TD as well as simplifies the framework described in [2] and (ii) integrating the proposed framework into an oneM2M standard architecture. The work also mitigates the following issues – (i) settle heterogeneity of for thing description, (ii) enable self-configuration management, (iii) ease of adding and deleting things to the IoT frameworks and (iv) support mobility of the things and (v) describe the legacy things with support from proxies. Rest of the paper is organized as follows. Section II describes the proposed framework with an example of semantic description of a light switch. Section III focuses on the oneM2M architecture and prototyping of the framework. Section IV concludes the work.

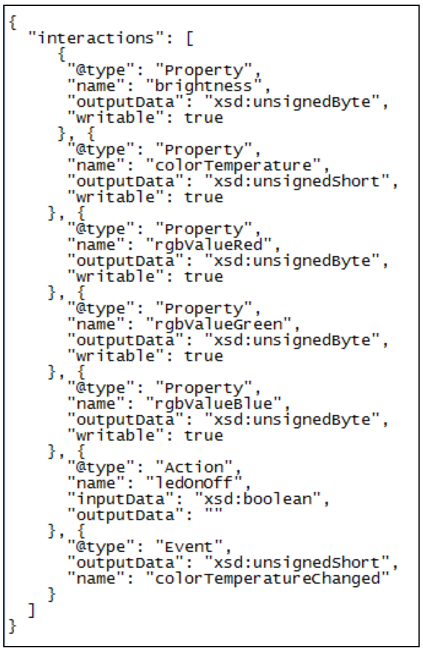
II. LIGHTWEIGHT THING MANAGEMENT FRAMEWORK

A. Semantic based thing description

This section initially presents how a semantic based thing description can be represented using JSON-LD. The serialization of the syntax assumes a JSON-LD context. It maps short names to RDF URLs, e.g. to the RDF core datatypes that RDF imports from XML Schema. The context is used by the TD to refer to the domain context. Since the same sensor can be used different domains across its lifetime, the context information allows the higher layer applications to determine the domain in which the sensor belongs. This field could be ignored if the sensor belongs to a highly resource constrained device. As mentioned, the things are represented in terms of events, properties and actions. Such semantic based TD model is actually protocol independent. One example of a LED is shown in Figure 1. The brightness, color temperature, RGB values are encoded as properties of the LED while on/off function is an action and color temperature change is an event. Semantic treatment of the TD reveals that the LED is attached to a light switch (on/off action), its color temperature can be configured (event) and RGB values are also accessible. Such intelligence cannot be derived easily from the previous mechanisms mentioned in [1] and [2].

B. Thing Management Framework

To take advantage of the JSON-LD based TD, we updated the framework introduced in [2]. The evolved framework is depicted in Figure 2. The perception layer contains both the smart and legacy endpoints or things. The smart things contain the tools to provision them with necessary information to generate the JSON-LD based TD. The thing can communicate its TD to the description storage layer of the management framework using CoAP PUT or HTTP POST message. The thing description storage API extracts the TD payload received and stores it into the local storage. In comparison to [2], the storage also becomes lightweight. For the legacy things, the semantic based TD is generated by the proxy layer to which the legacy things are attached to. The detail functionalities of the proxy-in and proxy-out are described in [1]. Finally, the service enablement layer consists of RESTful web services which allows the higher layer applications or consumer devices to read, write, update thing description, enable discovery based on TD and more functionalities.



```
{
  "interactions": [
     {
      "@type": "Property",
      "name": "brightness",
      "outputData": "xsd:unsignedByte",
      "writable": true
     }, {
      "@type": "Property",
      "name": "colorTemperature",
      "outputData": "xsd:unsignedShort",
      "writable": true
    }, {
      "@type": "Property",
      "name": "rgbValueRed",
      "outputData": "xsd:unsignedByte",
      "writable": true
    }, {
      "@type": "Property",
      "name": "rgbValueGreen",
      "outputData": "xsd:unsignedByte",
      "writable": true
    }, {
      "@type": "Property",
      "name": "rgbValueBlue",
      "outputData": "xsd:unsignedByte",
      "writable": true
    }, {
      "@type": "Action",
      "name": "ledOnOff",
      "inputData": "xsd:boolean",
      "outputData": ""
    }, {
      "@type": "Event",
      "outputData": "xsd:unsignedShort",
      "name": "colorTemperatureChanged"
    }
  ]
}
```

Fig. 1. JSON-LD based thing description for a LED.

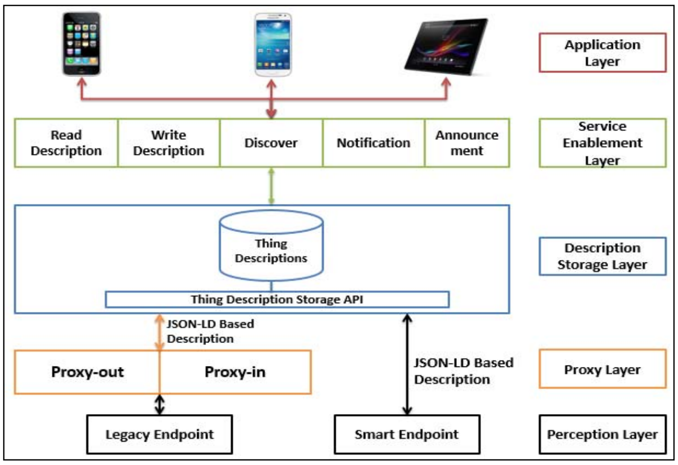


Fig. 2. Semantic based thing management framework.

III. Integration into oneM2M Architecture

Standards play an important role for interoperability among consumer devices, applications and services. To ensure that the proposed framework interoperates with similar frameworks, we integrated it into oneM2M architecture shown in Figure 3. Following the conventions of oneM2M, the thing management framework is embedded as a common service function into the common service entities (CSE). The proposed framework can be a deployed at (i) an M2M gateway (middle node) for managing things in a smart home and (ii) a cloud system (infrastructure node) to configure and manage thing belonging to a smart city for example.

A prototype of the framework is implemented using available open source Java and python libraries. The python based implementation is running on an M2M gateway deployed at a Raspberry Pi. The consumer devices (application specific node in Figure 3) are equipped with an Android application called Connect and Control Things. This allows the consumers to read, write and update the thing descriptions. The testbed used for the prototyping and performance evaluation is relatively robust from scalability point of view. The thing description file itself takes a few Kilo Bytes in memory. This lightweight aspect allows high volume of sensors to be a part of the system.

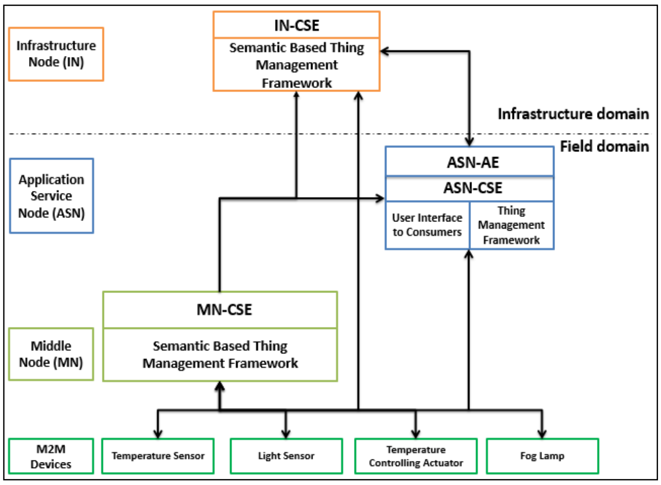

Infrastructure Node (IN)
IN-CSE
Semantic Based Thing Management Framework
Infrastructure domain
Field domain
Application Service Node (ASN)
ASN-AE
ASN-CSE
User Interface to Consumers
Thing Management Framework
Middle Node (MN)
MN-CSE
Semantic Based Thing Management Framework
M2M Devices
Temperature Sensor
Light Sensor
Temperature Controlling Actuator
Fog Lamp

Fig. 3. oneM2M architecture with semantic thing management framework.

IV. Conclusion

In a nutshell, this paper describes an evolutionary approach for thing description used in IoT ecosystems. Semantic based approach is described in this work where things are described using events, properties and actions. The benefits of the approach are outlined. A framework is presented that utilizes the JSON-LD based thing description. It's integration into an oneM2M architecture is highlighter. For future work, we are extending the same for connected vehicles.

Acknowledgment

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References

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