Integrating Machine-to-Machine Measurement Framework into oneM2M Architecture

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***Abstract*— Recent challenges in Internet of Things (IoT) include - (i) providing interoperability among IoT data, (ii) interpreting data generated by IoT devices, and (iii) assisting developers in accomplishing these tasks. Current standard development organizations such as oneM2M are designing semantic-based IoT architecture to address such challenges. However, the recent release of oneM2M standards does not provide any concrete tool for the semantic treatment of the IoT data. Previously, we proposed the Machine-to-Machine Measurement (M3) Framework which mitigates the challenges and assist developers in building semantic based IoT applications easily. Considering the usefulness and novel aspects of the M3 framework, the paper proposes to integrate it seamlessly into oneM2M architecture. The semantic requirements from oneM2M are pointed out and the M3 components addressing them are identified. A common service function (CSF) dedicated to semantic engine is introduced to the oneM2M architecture which extends the capabilities of common services entity (CSE) in terms of semantic treatment of IoT data. The new CSF also includes a catalog of semantic based IoT templates which are exploited by Application Entities to easily utilize the semantic engine. Two deployment scenarios of the upgraded oneM2M architecture have been discussed. Finally these extensions have been communicated to the oneM2M Management, Abstraction and Semantics (MAS) Group (Working Group 5).**

Keywords—Common service function; Common services entity; Internet of Things; Interoperability; M2M; M3 Framework; oneM2M.

I. INTRODUCTION

The Internet of Things (IoT) is a novel paradigm which is shaping the evolution of the future Internet by extending the connectivity of Internet to physical devices like sensors, actuators and RFID tags. These devices will operate in highly distributed and autonomous fashion and they generate multimodal (temperature, video, light etc.) M2M data. This makes M2M data exchange, management, processing and interoperability a daunting task for developers. But the challenges have to be solved to provide some fundamental requirements in any IoT platform – (i) discovery, naming & addressing of things and (ii) information storage, exchange, representation and unified interpretation of data. The challenges and requirements automatically lead us to consider semantic web technologies for IoT [1] [3]. To explicitly describe sensor measurement and reason on sensor data, we use semantic web technologies, more precisely, ontologies to describe sensor concepts, observations and their properties. But these technologies are not alone sufficient due to the challenges below [2]:

- The domain experts are continuously redefining the domain knowledge including ontologies and rules without considering the existing ones leading into the creation of silos and in turn creating interoperability issues. The experts are also not aware of semantic web best practices.
- The domain knowledge that has been designed by non-semantic web expert is difficult to reuse and combine even with tools such as ontology matching.
- IoT application developers do not use a common vocabulary to express sensor measurements and rules.
- Current standard development organizations (SDO) do not explicitly specify the semantic components in the overall IoT architecture. Even the current release of the oneM2M standards[1] does not have any concrete tools for - (i) the interoperability of sensor data, (ii) an explicit description of sensor measurements, and (iii) a reasoning engine to infer high-level abstractions from sensor data. Swetina et al. explain that industries use proprietary systems that make it difficult to extend applications, integrate new data and interoperate with other solutions [12].

To mitigate the above challenges and bridge the gap between researches and standards, the Machine-to-Machine Measurement (M3) Framework has been designed and developed [2]. Its primary goal is to allow developers building generic cross domain IoT applications which enables horizontal IoT that cuts through several domains or verticals. The overall framework includes the M3 nomenclature and the M3 ontology which provides a common vocabulary for sensors, measurements, units and domains. This is the first step towards interoperability in M2M data processing. To the best of our knowledge, our solution is the first one suggesting an interoperable language to describe data to later interpret it. The contributions of the paper are – (i) mapping the M3 framework components on a generic functional model supporting semantics in oneM2M, (ii) identifying M3 components that meet the oneM2M semantic requirements, (iii) extending the capabilities oneM2M architecture by introducing a semantic engine as common service function (CSF) which also includes

[1] http://www.onem2m.org/technical/published-documents

a catalogue of semantic based IoT application template, (iv) integration of M3 framework into various existing CSFs and oneM2M functional architecture [4] and (v) deployment of the framework at a cloud based system and an Android powered smartphone.

The rest of the paper is organized as follows. Section II is focused on mapping of M3 framework components on a generic functional model supporting semantics. Section III discusses the semantic requirements in oneM2M architecture and M3 components addressing them. Section IV details the integration of M3 framework into the oneM2M and Section V describes a prototype implementation. Section VI concludes the paper with contributions and some future directions.

II. MAPPING M3 COMPONENTS ON GENERIC SEMANTIC FUNCTIONAL MODEL

According to [6], the next challenging tasks for Semantic Web of Things are twofold: (i) a uniform description for sensor data and (ii) agreeing on a uniform catalogue of ontologies to annotate sensor data in an interoperable manner. The M3 framework addresses these challenges using the M3 nomenclature and the M3 converter. A generic functional model to support key semantic functionalities is presented in [5]. We have mapped the elements of the model with M3 framework components as shown in Figure 1.

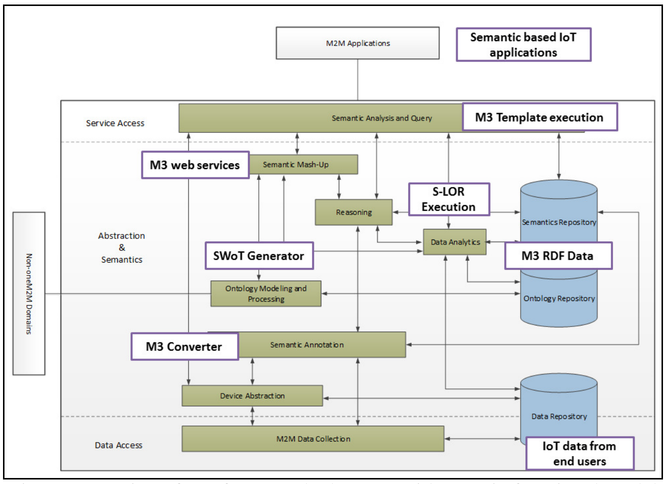

Fig. 1. Mapping of M3 framework elements with generic functional model supporting semantics.

The M2M data collection corresponds to the data generated by the end users and Data Repository houses such data. The Semantic Annotation integrates the M3 Converter component to semantically annotate sensor data in an interoperable manner since the IoT data is come from heterogeneous sources. The Semantic Repository stores semantic sensor data annotated with Resource Description Framework (RDF), more precisely, semantically annotated with the M3 ontology and the M3 converter. The Ontology Modeling and Processing corresponds to the SWoT generator which is based on pre-defined templates and pre-selected ontologies and rules. The Data Analytics executes the M3 template produced by the SWoT generator component by running the reasoning engine to interpret sensor data. It exploits the Sensor-based Linked Open Rules (S-LOR) processing. The Reasoning engine to deduce new knowledge by loading M3 rules produced in the M3 templates. The Semantic Analysis and query execute the SPARQL query produced by the M3 template to get high level abstractions. M3 web services take care of the Semantic Mash-up. The M2M Applications correspond to the semantic-based IoT applications which have been easily designed by exploiting the SWoT generator and the generated M3 template.

III. SEMANTIC REQUIREMENTS IN ONEM2M ARCHITECTURE

This section summarizes the semantic requirements in oneM2M architecture in Table I and identifies how M3 components address them. We have selected oneM2M since it combines the efforts from SDOs around the world and releases a global standard for IoT. The list below is non-exhaustive.

TABLE I. SEMANTIC REQUIREMENTS IN ONEM2M

Category	Requirement	M3 component addressing the requirement
Semantics Annotation	The M2M System shall support a common language for semantic description, e.g. RDF.	M3 nomenclature and M3 ontology[2].
Ontology	The M2M System shall support a common modeling language for ontologies (e.g. OWL).	M3 interoperable domain knowledge.
Ontology	The M2M System should be able to provide translation capabilities from different modeling languages for ontologies to the language adopted by oneM2M if the expressiveness of the imported ontology allows.	M3 converter which is based on M3 nomenclature and M3 ontology.
Ontology	The M2M System shall provide the capability to retrieve semantic descriptions and ontologies stored outside of the M2M System.	This is taken care by the catalogue of domain ontologies relevant for IoT, called Linked Open Vocabularies for Internet of Things (LOV4IoT)[3].
Semantics Annotation	The M2M System shall support semantic annotation based on related ontologies.	M3 converter
Ontology	The M2M System shall be able to use ontologies that contain concepts representing aspects (e.g. a room) that are not represented by resources of the M2M System.	M3 interoperable domain knowledge or ontologies referenced in the LOV4IoT dataset.
Semantics Reasoning	The M2M System shall be able to support semantic reasoning e.g. ontology reasoning or semantic rule-based reasoning.	Sensor-based Linked Open Rules[4] (SLOR).
Semantics Annotation	The M2M system shall enable applications to retrieve an ontology representation related to semantic information used in the M2M system.	SWoT Generator

[2] http://www.sensormeasurement.appspot.com/?p=m3
[3] http://www.sensormeasurement.appspot.com/?p=ontologies
[4] http://www.sensormeasurement.appspot.com/?p=swot_template

Ontology	The M2M System shall enable functions for data conversion based on ontologies.	M3 converter web services
Data Analytics	The M2M System shall be able to support capabilities (e.g. processing function) for performing M2M data analytics based on semantic descriptions from M2M Applications and /or from the M2M System.	Sensor-based Linked Open Rules.
Semantics Reasoning	The M2M System shall be able to support adding and updating semantic information based on semantic reasoning.	The processing of S-LOR will add new triples comprised of high-level abstractions in the Triple store.

IV. INTEGRATING M3 FRAMEWORK INTO ONEM2M ARCHITECTURE

At this juncture it is established that the M3 framework is addressing several requirements of oneM2M as well as bridging the gap between researches and standards. Thus the natural next step is to integrate the framework into oneM2M architecture. The first issue towards such integration is that there is no semantic engine present in the architecture [4]. We propose to introduce the engine as a CSF into the common services entity and this CSF will expose the semantic functionalities to application entities (AE) at different nodes. This provides the unique advantage of utilizing the semantic engine at various nodes like infrastructure node (IN), application service node (ASN) and middle node (MN). In turn it allows distributed semantic treatment of IoT data at various nodes. Extending the capabilities of the CSE by including the engine is a major contribution of this paper. Along with the semantic engine, the M3 framework components are embedded into other CSFs as described below.

A. *Semantic Engine*

The semantic engine [9] is also called S-LOR in the M3 framework. The engine is responsible for – (i) semantically annotating IoT data, (ii) semantic reasoning to enrich IoT data and (iii) combining domains to generate cross-domain applications which are unique to M3 framework. The proposed CSF will be dedicated to perform the above mentioned functionalities and interact with the following CSFs as necessary.

B. *Data Management and Repository (DMR)*

This CSF provides data storage and mediation functions. DSR collects raw and/or processed data from M2M devices, converts that into a specified format and stores it for further analysis and semantic processing. From the point of view of M3 framework, it stores (i) the M3 ontology and the M3 interoperable domain knowledge, (ii) M3 semantic sensor data (raw or processed), (iii) M3 interoperable rules designed in S-LOR and (iv) M3 SPARQL queries designed in M3 templates. DMR also enables the execution of the M3 templates generated by the SWoT generator.

C. *Security*

The focuses on identity management, access control and security association establishment. We extend this to include the Security Toolbox: Attacks & Countermeasures (STAC)[5] application which is a cross-domain security knowledge base and helps IoT application developers to find security mechanisms & attacks specific to technologies [7] [8]. STAC has been designed using the same approach described to build the M3 interoperable domain knowledge. The application classifies numerous technologies and their attacks, the existing security mechanisms, security properties, features, etc. used in various domains including sensor networks, cellular networks, wireless networks and web applications. As a future work, we will look into how semantic information can be relevant to enable security policies automatically.

D. *Subscription and Notification (SUB)*

The SUB CSF sends notification to a subscriber (end user or an IoT application) that monitors event changes on a resource. The result(s) obtained after SPARQL query execution (as a part of M3 template execution) can be sent as a notification service to the end user. For example, in personal healthcare, if it is inferred that the person has fever from body temperature sensor data, that knowledge could be notified to the person.

E. *Communication Management and Delivery Handling*

This provides a way of communication with a specific target (CSE/AE) and is used to communicate the semantically inferred data to other nodes. This is integrated along with the M3 web services which allow the end users to request services too.

F. *Application and Service Layer Management (ASM)*

The ASM provides management functionalities like configuration, troubleshooting and upgrading the functions of CSEs and AEs. The management functions are of two types, namely configuration function (CF) and software management function (SMF). In this case, SMF is of particular importance as it provides the capability of manage software components of M3 framework mentioned above. It is also capable of managing the lifecycle of the software packages.

Currently we are working to enhance the M3 framework further by utilizing two more CSFs namely discovery and location. The discovery module searches for applications and services depending on a combination of keywords, identifiers, location information as well as semantic information. Semantic based discovery is treated as an important criterion in IoT platforms. On the other hand the location information is inherently semantic information and may be further modelled semantically. The semantic location information is already a part of the IoT framework proposed by IPSO Alliance[6].

V. PROTOTYPE AND DEPLOYMENT SCENARIOS

We have adapted a simplified version of the oneM2M functional architecture for the prototype implementation as

[5] http://www.sensormeasurement.appspot.com/?p=stac
[6] http://www.ipso-alliance.org/wp-content/media/draft-ipso-app-framework-04.pdf

shown in Figure 2. Along with that, we also describe two scenarios of deploying the framework for semantic treatment of IoT data.

The prototype architecture consists of physical things as application dedicated nodes (ADN) which are interacting with a smart M2M gateway [13] over M2M area network. The gateway acts as MN and the MN-CSE comprises of device discovery, management and proxy-in and proxy-out [10]. The M3 framework and its components are implemented and deployed both in the infrastructure node (cloud system) and in an Android powered smartphone (ASN). For the cloud based system, the respective CSFs are developed utilizing Apache Jena framework and the prototype is operational[7]. The sensor metadata is represented in Sensor Markup Language format [10] [11] and is sent to the IN-CSE via the MN-CSE. Then the previously mentioned CSFs systematically operate on the sensor data and produce high level abstraction as a result.

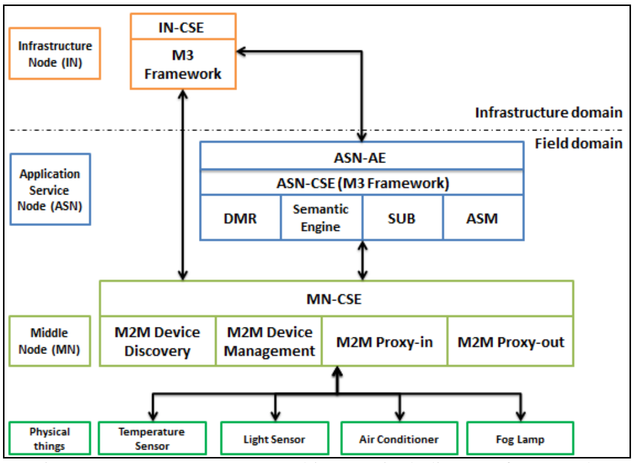

Fig. 2. Prototype oneM2M architecture including M3 framework.

The major challenge is to integrate the framework and the CSFs into Android powered smartphone. The motivation behind this are manifold – (i) allowing local treatment of raw M2M data and sharing the inferred data which protects privacy, (ii) creating an user centric model for semantic data processing and more. The Apache Jena framework is highly complex to be included in a smartphone. A comparatively lightweight library called AndroJena is used for the semantic engine implementation.

VI. Conclusion

In a nutshell, the paper advocates for embedding M3 framework and its components into oneM2M architecture. Our gap analysis has identified the limitations in current M2M and IoT standards in terms of semantic treatment of data. The M3 framework allows bridging the gaps. To the best of our knowledge, this is the first approach for proposing an entire automatic process which can semantically annotate IoT data, enrich it with the S-LOR semantic engine to provided high-level abstractions or even suggestions. Considering the overall usefulness of the framework, the integration of M3 components into oneM2M is investigated in details. The semantic requirements from oneM2M are pointed out and the M3 components addressing those requirements are identified. For seamless integration of M3 framework into oneM2M architecture, a new CSF i.e. the semantic engine (S-LOR) is introduced into CSE. The other necessary CSFs for the integration are also discussed. Finally two deployment scenarios are presented. As for future work, we are working towards enabling semantic based discovery as a part of the overall M3 framework.

[7] http://www.sensormeasurement.appspot.com/

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