Search Engine Based Resource Discovery Framework for Internet of Things

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***Abstract*—This paper proposes a search engine based resource discovery framework for Internet of Things (IoT) to discover resources, their capabilities, properties and URIs to access them regardless of communication technology. There is a central registry to store configurations of resources and they are indexed. Based on discovery request parameters, the search engine "looks up" the indices and returns the URI(s) to directly access the resource(s). The functionalities of the proposed framework are exposed to the consumers using RESTful web services. The framework is generic enough to be deployed in cloud platforms, M2M gateways and lightweight mobile application running on smartphones.**

Keywords—Configuration management; Configuration registry; IoT; oneM2M architecture; Resource discovery; Search engine.

I. INTRODUCTION

It is estimated that around 50 Billion of smart objects will be connected to the Internet by 2020[1]. To provide value-added services to the consumers, these devices must interact with the environment and among themselves to exchange metadata, process the information and react automatically. However, the diverse nature of smart objects, their capabilities & properties, communication technologies add to the complexity of effective realization of the IoT platforms. Therefore, to realize the vision of IoT, there must be mechanisms available for automatic discovery of resources [1] [2], their properties and capabilities as well as the means to access them. In this paper, we have proposed a framework for automatic and efficient resource discovery in IoT. The framework incorporates a search engine which provides the "look-up" feature for discovery. The scopes of the discovery mechanism work both locally and remotely. In the local scope, discovery takes place within gateways of an intelligent home environment. The remote scope takes care of discovery from smart city perspective. The framework supports multiple communication technologies through proxies. The main novel aspects of the framework are – (i) integration of a search engine as a part of discovery mechanism, (ii) discovery regardless of the communication technologies and protocols, (iii) search for both smart and legacy objects and (iv) can be deployed at a cloud based system, an M2M gateway or even as a lightweight mobile application. The resource discovery framework presented in this paper is a significant extension of the discovery discussed in [3], [5] and [6].

The rest of the paper is organized as follows. Section II presents the framework along with its requirements and components. Section III outlines how it is incorporated into oneM2M based IoT architecture. Section IV concludes the paper.

[1] http://share.cisco.com/internet-of-things.html

II. RESOURCE DISCOVERY FRAMEWORK

This section presents the requirements of the framework from the consumer perspective. Then a comprehensive description of its components is given while highlighting the novel features.

A. *Consumer centric requirements*

- The discovery framework should allow resource discovery regardless of the communication protocols and technologies used by consumer devices.
- It should support discovery of wide array of consumer M2M devices like constrained devices (characterized by limited capabilities), smart devices (smartphones) and legacy devices.
- The framework must reuse existing networks for IP communication and location to provide a means of discovery to the consumer applications.
- The discovery system should expose the services for consumers through RESTful web services allowing session less interaction with applications.
- The same system should enable discovery of M2M applications running on M2M gateways and M2M devices (e.g. resources).
- Proper access control mechanisms should be applied to stop discovery of resources to which a user does not have any access.
- The discovery module should be flexible in terms of identification schemes (e.g. EPC, URI, IP address, bar code, NFC tag etc.) used by the resources.
- The discovery mechanism should be capable of handling a query for an exact match of a given identifier from the requestor as well as queries possibly containing other qualifying attributes (e.g., location and category) within both the remote and local scopes.
- The discovery framework must use a uniform catalogue to describe resources, their capabilities and properties. This will in turn allow maintaining interoperability among the implementations of resource discovery in various IoT platforms.
- During search process, redundant resources may be found in a network providing the same requested service. The response must be able to intelligently select the optimal service based on input criteria.
- The discovery framework must provide energy efficient guidelines to minimize power consumption in the IoT platforms and resource constrained things.
- The operations of resource discovery framework should be adaptive enough to respond to maintenance, bandwidth change etc.

- The resource discovery service is required to be designed to maintain scalability of the overall system.

B. *Resource discovery framework*

Figure 1 portrays the framework which has been designed following the consumer centric requirements mentioned above.

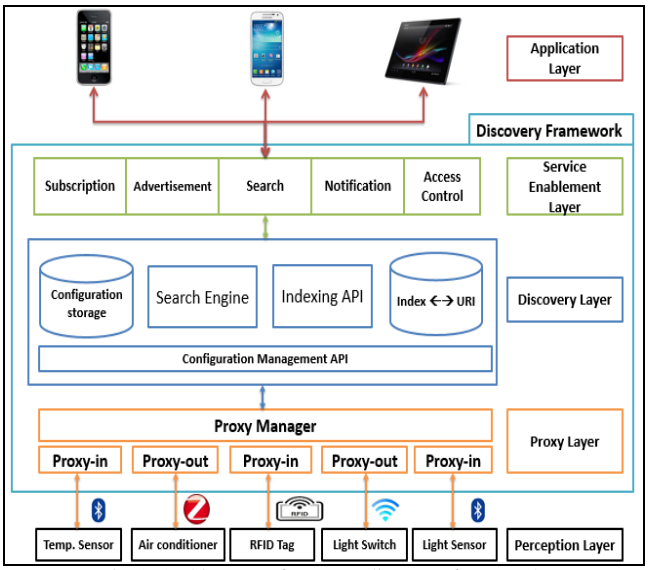

Fig. 1. Architecture of resource discovery framework.

The framework is composed of three layers namely proxy layer, discovery layer and service enablement layer. The layers are developed using RESTful web services which eases the interaction among the layers.

- **Proxy Layer**: There are two types of proxies [3], namely proxy-in (in charge of sensors) and proxy-out (in charge of actuators). Each proxy has a URI and uses one communication technology to interface with the physical objects at the perception layer. This allows the framework to search and access devices regardless of the communication technologies used. From a consumer standpoint, this feature allows adoption of any heterogeneous objects and communication technologies further realizing the ubiquitous vision of IoT. The physical objects also communicate their configurations to the framework through the proxies. For a smart object, it can generate CoRE Link based configuration description itself. A legacy device is assisted by a proxy for this [4].

- **Discovery Layer:** This layer houses multiple functionalities of the proposed framework. The configurations of the physical objects are received at the configuration management API. It converts the CoRE Link payload into appropriate format suitable for configuration storage. Then the "Index API" creates a unique index for each of the object. That index and the URI to access the object configurations are stored in a separate storage. This together with the configuration storage forms a central registry for objects. The "search engine" basically extracts key parameters from the discovery request and internally provides a "look up" facility. This intelligently matches the discovery request with the stored configuration indices. If suitable matches are found, then the properties and capabilities of those objects are communicated along with the URI for accessing directly. The novel aspect of this layer is to integrate the search engine as a part of the framework.

- **Service Enablement Layer:** The core functionalities of the discovery framework are exposed to the consumers through RESTful web services. The access control service restricts the discovery procedure to the objects to which the consumer has access to. The discovery request originates from mobile devices of the consumer and is communicated to the search service. It relays the request to the search engine of discovery layer and provides the list of discovered objects back to requestor. Finally, the subscription and notification are used to subscribe to periodic discovery notifications.

The discovery functionalities are also necessary to develop consumer centric IoT applications for mobile phones. An approach is outlined in [7] which considers the discovery as the forefront of the entire operational phases. Since discovery is a fundamental requirement, oneM2M standards [2] have proposed discovery as a common service function (CSF) residing into common service entities (CSE). The following section highlights integrating the resource discovery framework into oneM2M architecture.

III. INTEGRATION IN ONEM2M ARCHITECTURE

oneM2M is a global standard development organization dedicated to create a scalable and interoperable standard for consumer devices and services used in M2M and IoT applications. The organization combines the efforts and partners with ARIB, ATIS, CCSA, ETSI, TIA, TTA and TTC. The released specifications provide guidelines to design and develop an IoT framework to support wide range of applications in smart grid, connected vehicle, home automation, eHealth and more domains.

The portrayed resource discovery framework can be deployed to a cloud system (smart city applications), M2M gateway (smart home scenarios) or a mobile application [7] depending on the context and scope of deployment. This is enabled by integrating the framework into oneM2M architecture as depicted in Figure 2. The field domain comprises of (i) physical objects, (ii) middle node which is the M2M gateway and (iii) application service node which is analogous to the consumer mobile application. The infrastructure node is comprised of the cloud system which provides discovery services for smart city based applications.

[2] http://www.onem2m.org/technical/candidate-release-august-2014

A. *Prototype of discovery framework for smart home*

A prototype of a lightweight M2M gateway with the framework is developed for discovery of home automation objects. The prototype is running as a web server on a constrained device. Each object configuration description takes less than 1KB storage in the server making the storage requirement minimal. Also, time taken by the search service is 450-600 milliseconds making the system ideal to be used in smart home scenarios. Extensions to the framework could also be used in other domains like eHealth and smart city.

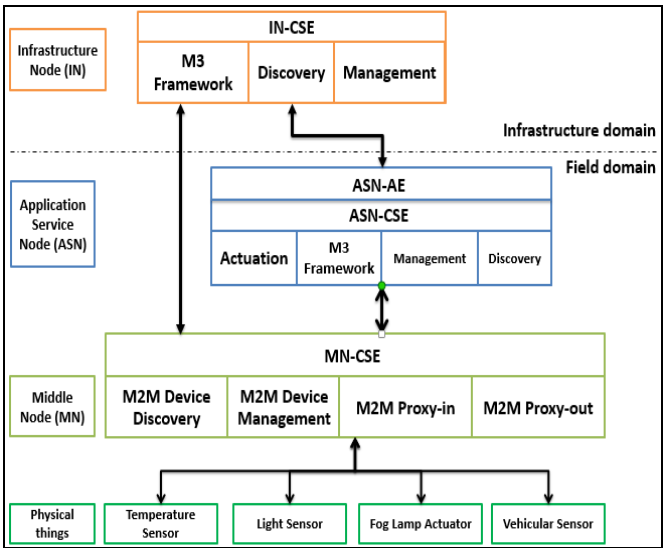

Fig. 2. Integration of resource discovery framework into oneM2M architecture.

IV. CONCLUSION

In a nutshell, the paper outlines the consumer centric requirements of resource discovery framework. Then the architecture is depicted with the components and novel aspects are mentioned. Finally the integration of the framework in oneM2M architecture is shown which portrays deployments at cloud system, M2M gateway and a mobile application. We are working towards including the proposed framework into the discovery phase presented in [7].

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REFERENCES

[1] Meirong Liu; Leppanen, T.; Harjula, E.; Zhonghong Ou; Ylianttila, M.; Ojala, T., "Distributed Resource Discovery in the Machine-to-Machine Applications," Mobile Ad-Hoc and Sensor Systems (MASS), 2013 IEEE 10th International Conference on, pp.411,412, 14-16 Oct. 2013.

[2] Cirani, S.; Davoli, L.; Ferrari, G.; Leone, R.; Medagliani, P.; Picone, M.; Veltri, L., "A Scalable and Self-Configuring Architecture for Service Discovery in the Internet of Things," Internet of Things Journal, IEEE, vol.1, no.5, pp.508,521, Oct. 2014.

[3] Datta, S.K.; Bonnet, C.; Nikaein, N., "An IoT gateway centric architecture to provide novel M2M services," Internet of Things (WF-IoT), 2014 IEEE World Forum on, pp.514,519, 6-8 March 2014.

[4] Datta, S.K.; Bonnet, C., "A lightweight framework for efficient M2M device management in oneM2M architecture," Recent Advances in Internet of Things (RIoT), 2015 International Conference on, pp.1,6, 7-9 April 2015.

[5] Datta, S.K.; Bonnet, C.; Nikaein, N., "CCT: Connect and Control Things: A novel mobile application to manage M2M devices and endpoints," Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), 2014 IEEE Ninth International Conference on, pp.1,6, 21-24 April 2014.

[6] Datta, S.K.; Bonnet, C., "Smart M2M Gateway Based Architecture for M2M Device and Endpoint Management," Internet of Things (iThings), 2014 IEEE International Conference on, and Green Computing and Communications (GreenCom), IEEE and Cyber, Physical and Social Computing(CPSCom), IEEE , vol., no., pp.61,68, 1-3 Sept. 2014.

[7] Datta, S.K.; Gyrard, A.; Bonnet, C., Boudaoud, K., "oneM2M architecture based user centric IoT application development," in 3rd International Conference on Future Internet of Things and Cloud (FiCloud-2015), 24-26 August 2015.

[3] http://www.agence-nationale-recherche.fr/?Projet=ANR-13-INFR-0008