IoT Device Management Framework for Smart Home Scenarios

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***Abstract*—**The paradigm of the Internet of Things (IoT) requires pervasive connectivity to billions of heterogeneous devices. In recent time, rapid growth of IoT devices in smart home environment envisioned a wide range of novel services and applications. However, due to the inherent heterogeneity, home environment is becoming complex making device management extremely difficult. This paper proposes a lightweight IoT device management framework for smart home services. The framework can be deployed at home gateways and consumer smart devices. A prototype implementation and performance evaluation results are also presented.

Keywords—Device management; IoT; Smart home.

I. INTRODUCTION

Recent advancement in consumer appliances as well as communication technologies enabled the IoT paradigm to be deployed in smart home environment. Cisco predicts that around 7 billion of IoT devices are already connected to the Internet providing services to end users and enterprises [6]. Rapid introduction of small scale devices and actuators have also contributed towards deploying prototypes and services in smart home environment. Internet of Things (IoT) paradigm in smart home environment covers the heterogeneous endpoints including consumer appliances, sensors, tags and custom devices that caters user's requirements [1] [5]. Heterogeneity has always been an issue in managing IoT devices due to their lack of unifying approach in sustaining data-intensive capabilities IoT device management. Smart home scenarios are normally governed by data diversity, self-configuration management, managing legacy devices as well as access control mechanism for home dwellers. These factors increase the challenges for deploying IoT ecosystem in smart home environment. In this work, we have outlined the requirements for IoT device management in smart home scenarios and provide a bespoke framework to manage them in a federated manner.

The rest of the paper is organized as follows. Section II describes the proposed IoT device management framework along with its components, deployment and a prototype evaluation. Finally we conclude the paper in Section III.

II. IOT DEVICE MANAGEMENT FRAMEWORK

In this section, the framework is shown in Figure 1 and its functionalities for smart home environment are highlighted. The framework is composed of three layers described below.

A. *Proxy Layer*

The proxy layer includes the drivers for different communication technologies and protocols. This is necessary since the consumer IoT devices can communicate using BLE, NFC, Zigbee, low power Wi-Fi etc. The proxy layer therefore makes the framework interact and manage devices regardless of communication protocols and technologies. Another aspect of the proxy layer is that it assists the framework in managing legacy devices. The proxy-in and proxy-out are described in [2] [3]. These also allow creating the CoRE Link Format based configurations of the legacy devices. This is a unique aspect of the framework considering that smart homes will contain both smart and legacy IoT devices.

B. *Device Management Layer*

This layer houses several functionalities like configuration management, device discovery and services for processing and analytics. These functionalities are developed and exposed using web services at service enablement layer.

- **Service processing**: It consists of web service modules that allow home user to configure their IoT device configuration and also enabling IoT device discovery. Apart from device discovery, access control mechanism and feedback notification for IoT devices are also part of the layer functionalities. The service discovery later plays a pivotal role in ensuring IoT device dependencies in smart home environment are sustained throughout the usage period.

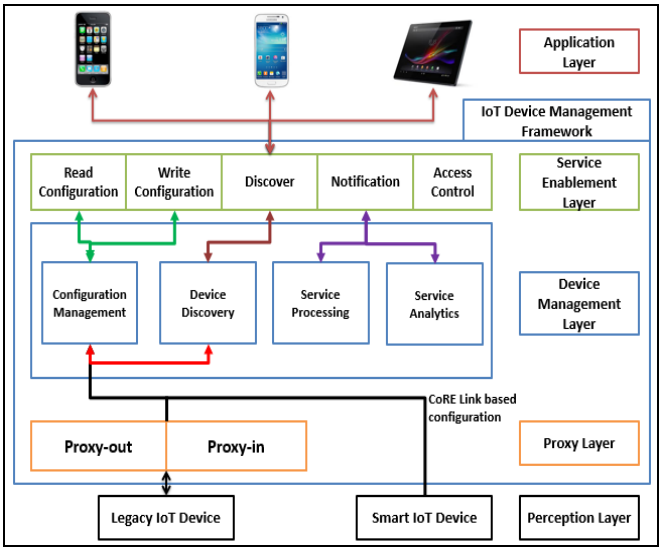

Fig. 1. Lightweight IoT device management framework for smart home scenarios.

- **Configuration management**: It ensures that the configuration resources [3] of IoT devices are

available for all entities in smart home environment. It includes an API that enables extractions of resource descriptions of IoT devices registered in the smart home environment. The descriptions are such as endpoint, device ID, and configuration resources are stored in a database configured within the component. It also enables integration of legacy devices in smart home environment and ensures joint execution of tasks in a federated manner. Such integration of legacy devices will sustain dependencies among heterogeneous IoT devices in smart home environment. Details of such integration and IoT device registration, un-registration phases are described in [4].

- **Service analytics**: It collects data from IoT devices automatically using Sensor Markup Language (SenML). This provides a uniform mechanism to encode sensor measurement and other IoT device parameters as a payload of HTTP or CoAP. This component subsequently simplifies analytical tasks among heterogeneous IoT devices for joint execution of tasks. An Event Manager module is integrated within this layer that provides bespoke rules for ensuring interoperation among IoT devices in smart home environment. The module consists of an inference engine, with pre-defined rules that corresponds to registered IoT devices in home network. The engine is capable of generating actionable intelligence from raw measurement. The derived intelligence allows the framework to function automatically and providing self-management facilities to the connected IoT devices.

- **Device discovery:** It is a fundamental aspect of the proposed framework. This allows the consumers discover the managed IoT devices, their properties, capabilities and URIs. This module also makes use of the configuration management module.

C. *Service Enablement Layer*

The core functionalities mentioned above are exposed to the consumers using RESTful web services. This further promotes interoperability with wide range of IoT services for smart home scenarios. This layer also implements access control policies which limit the access of users to their authorized devices only. The consumer smartphones could connect to this layer to access various functionalities of the IoT device management framework.

D. *Smart Home Deployment Scenarios*

The proposed framework is lightweight in nature which allows easy integration of IoT devices within a mobile application, subject to user requirements or use cases. Smart home, being a complex augmented entity in nature needs a unified framework that performs joint execution of tasks of IoT devices in interoperable manner. The proposed framework will offer a scalable approach in managing heterogeneous IoT devices in smart homes. The framework will be implemented inside a mobile solution that interacts with IoT devices using home networks. For every smart home related activity, the IoT devices would need to register themselves to the framework. The registration mechanism is as follow:

E. *Prototype Implementations and evaluation*

The prototype is implemented and deployed in both smartphone and M2M gateway. The smartphone application requires 6.25MB memory while the memory requirement for the overall framework deployed in the M2M gateway is found to be less than 20 MB. These establish the lightweight nature of the framework. Each IoT device description takes less than 1KB memory. It is due to the fact that CoRE Link Format offers a serialized implementation using JSON. The time takes to access the core functionalities are found to be in milliseconds. Thus the prototype allows real time interaction with consumer smartphones and IoT devices.

III. CONCLUSION

The paper presents an architecture for IoT device management framework which is targeted for smart home scenarios. The internal components of the architecture are highlighted along. Deployment scenario along with prototype implementation and evaluation are presented. The overall prototype is found to be lightweight and allows real time interaction. Such prototypes could also pave way for developing user centric IoT services for smart home using other M2M functions like discovery, semantic data processing [7].

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