Home Automation Using Edge Computing and Internet of Things

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***Abstract*—The current smart home ecosystem is fragmented due to competing IoT standards, heterogeneous devices and non-interoperability of home automation solutions. This paper proposes a harmonized and interoperable home automation solutions exploiting the concepts of Edge Computing, Virtual IoT Devices (VID) and the Internet of Things (IoT). We present a smart home architecture, prototype and its application in an use case. Our efforts establish the prototype as a lightweight and secure solution for emerging smart homes.**

***Keywords*-Edge Computing; Home Automation; Internet of Things; Smart Home; Virtual IoT Device; Security.**

I. Introduction

The Internet of Things (IoT) is ushering a set of novel applications and services to many vertical domains. Among them home automation [1] represents an important market segment for Smart Home [2] domain. According to market research company Statista[1], by 2020, value of Smart Home market worldwide will reach $43 Billion which is nearly three times compared to that in 2014. Another US Business Analyst Company IHS[2] estimates that 470 smart appliances will be connected to emerging Smart Homes. Home automation will play a key role in making the modern home smart.

The Smart Home employs IoT technologies to equip home dwellers with increased comfort, energy efficiency, security and interaction with its appliances even when there is no one at home. Such appliances can include connected lighting, thermostat, air condition, television, security camera and much more. Intelligence and communication modules embedded into these devices allow them to (i) exchange data with a data processing and storage unit (e.g. Cloud), (ii) be controlled remotely through the Internet, (iii) report their maintenance needs, (iv) manage themselves automatically and (v) optimize energy and resource usage.

Despite such benefits and enormous business potentials, home automation is challenged by - (i) heterogeneity of smart appliances, (ii) non-interoperability of services, (iii) dependence on cloud, (iv) not considering consumer security and privacy requirements and (v) competing IoT standards. Together they lead to fragmentation into the consumer market of Smart Home and result in inferior consumer experience.

[1]https://www.forbes.com/sites/deborahweinswig/2016/04/19/why-smart-homes-will-be-a-million-times-better-than-the-jetsons
[2]https://goo.gl/7Pa8Bn

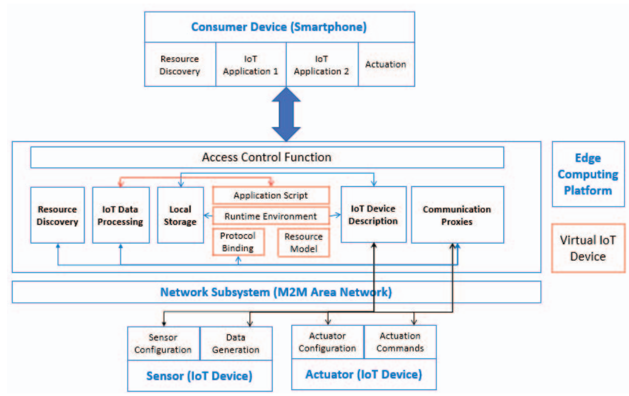

Fig. 1. Edge Computing based IoT architecture for home automation

To address the fragmentation, we propose a novel IoT architecture that utilizes Edge Computing (EC) and Virtual IoT Device (VID) concepts to harmonize home automation applications and services. The architecture follows oneM2M architecture[3] recommendations to preserve interoperability with connected appliances. The building blocks of the architecture follows W3C Web of Things (WoT)[4] specifications to further ease the development and deployment of the architecture. This work is a continuation and application of EC to the IoT architecture proposed in [3].

Rest of the paper is organized as follows. Section II describes our proposed IoT architecture and its components. Section III briefly states our prototyping attempt and results and Section IV concludes the paper.

II. Edge Computing and IoT Architecture for Home Automation

Our IoT architecture exploits Edge Computing philosophy for home automation use cases in a Smart Home. The architecture and its functional components are presented in Figure 1 and are described below.

[3]http://onem2m.org
[4]https://www.w3.org/WoT/

A. IoT Devices

Connected appliances like lights, door locks, air conditioner, security camera are treated as the IoT devices (e.g. sensors and actuators). They have the capability to (i) reply to a query for IoT data and (ii) accept a command for actuation. Each of the IoT devices contains an IoT device description that represents the capabilities of the devices using events, properties and actions. This is analogous to the Thing Description concept used in W3C WoT specifications [4]. When such an appliance is connected to the Smart Home system, it must communicate its description to the Edge Computing platform. The description is a basic requirement for resource discovery and automatic IoT device management at a later stage.

Use of standard web technologies for IoT device descriptions and RESTful web services for data exchange are the primary steps to preserve interoperability in our proposed architecture.

B. Edge Computing Platform

This is at the heart of the home automation system and houses many common service functions of the IoT. They are developed using RESTful web services.

Communication Proxies. Due to the heterogeneous nature of Smart Home appliances, they produce different type data (e.g. audio, video, binary), use different radios (e.g. BLE, Wi-Fi) and utilize different data exchange protocols (e.g. HTTP, CoAP). They give rise to the fragmentation problem in Smart Home. To address this challenge, we include this layer which contains software drivers for different communication technologies and protocols. It allows a wide range connected appliance to be a part of the proposed Smart Home system. This is one of the novel aspects of the IoT architecture.

IoT Device Description. This serves as a repository of Thing descriptions which stores the local configuration of the IoT devices. We follow the W3C WoT ongoing work and describe the devices using event, properties and actions [4].

Resource Discovery. This component allow the IoT applications to search for a required device. The complete resource discovery framework is described and implemented in [5]. IoT applications running on consumer devices search for appropriate connected appliance in this software module. Imagine a consumer scenario when there is no one in a Smart Home and the home owner wants to remotely turn off the lights - the IoT application will first search for all lights utilizing resource discovery. More detailed consumer device and service discovery methods are described in [6].

Local Storage. This is a NoSQL database that stores the raw IoT data locally. For long term data storage, a Cloud system is necessary.

IoT Data Processing. This is the most important part of the EC platform. The data generated by the sensors are treated here in three steps. The first step is to validate the data which is done by checking if the data belongs to the output range of a sensor. If not, the data is discarded. The second step is metadata annotation which creates a Sensor Measurement Lists (SenML)[5] compliant metadata. This is another step to interoperability. The final step is to secure the metadata using AES-256 encryption. This is used to secure the data payload between consumer devices (e.g. smartphone, tablet) and the EC platform.

Virtual IoT Device. A VID can be associated with one or more physical devices and can be configured as a virtual sensor or a virtual actuator. The VID is composed of an application script, runtime environment, protocol binding and resource model. The main purpose of incorporating the VID is to assist IoT developers in easily - (i) determining IoT application requirements for intelligent control of Smart Home appliances and (ii) developing the applications and services. The application logic is described in the application script which in turn uses the IoT data processing, resource discovery and local storage. Integrating the VID also helps in countering the fragmentation in Smart Home ecosystem.

C. Consumer Device

This is the interface of home dwellers with their home automation IoT system and smart appliances. The consumer devices are fitted with a mobile application that exposes the IoT devices, their data and functionalities to home dwellers.

III. Prototype and Results

We have developed a prototype of the entire system. An Android powered smartphone is used as the consumer device. The EC platform is developed and deployed in a Raspberry Pi. Three sensors and an actuator is used. The EC platform is developed using NodeJS and the memory footprint is around 130KB. During the operation of home automation services, the CPU load on the Raspberry Pi is 14-20%. The Android application's memory footprint is 2.89MB and average CPU load is less than 5%. So overall implementation is feasible and lightweight.

IV. Conclusion

In a nutshell, we present an Edge Computing based IoT architecture for home automation services. The functional components of the architecture are explained and prototype evaluation results are outlined. The entire experiment shows that our method is feasible, secure and address the current problems in the Smart Home domain.

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