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Enablement of IoT Based Context-Aware Smart Home with Fog Computing

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ABSTRACT

The recent advent of Internet of Things (IoT), has given rise to a plethora of smart verticals- smart homes being one of them. Smart Home is a classic example of IoT, wherein smart appliances connected via home gateways constitute a local home network to assist people in activities of daily life. Smart Home involves IoT-based automation (such as smart lighting, heating, surveillance etc.), remote monitoring and control of smart appliances. Besides automation, human-in-the-loop is a unique characteristic of Smart home to offer personalized services. Understanding the human behavior requires context processing. Thus, enablement of Smart home involves two prominent technologies IoT and context-aware computing. Further, local devices lying in the smart home have the implicit location and situational information, hence fog computing can offer real-time smart home services. In this paper, the authors propose ICON (IoT-based CONtext-aware) framework for context-aware IoT applications such as smart home, further ICON leverages fog-based IoT middleware to perform context-aware processing.

KEYWORDS

Context-Aware Computing, Fog Computing, Internet of Things, IoT, Smart Home

1. INTRODUCTION

The concept of Smart home aptly justifies the popular thought by (Weiser, 1999) about technology becoming an integral and indistinguishable part of everyday life. Making everyday life easier with the help of technology dates back with notable works in embedded electronics e.g. washing machines, ovens, dishwashers etc., followed by innovations in wireless sensor networks (WSN) e.g. senor based things- taps, doors etc., which in present time is being endowed by the upcoming technology Internet of Things (IoT). In IoT, sensor based everyday devices communicate with the computing platforms (Fog computing, Cloud Computing platforms) for processing the raw sensor data to take wise and smart actions Atzori (2010) and Gubbi (2013). The distinct feature of IoT which differentiates it from its precursor technologies, is the use of a middleware to support processing and long-term analysis of sensor big data stream to take wise actions.

The IoT middleware (computing infrastructure to enable IoT data storage, processing and analysis) can be cloud based Gubbi et al. (2013) or fog computing based Bonomi et al. (2012), Dastjerdi et al. (2016). Per the cloud based IoT middleware, the Cloud platform offers its IaaS, PaaS and SaaS

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services to perform data storage, processing and analysis for IoT applications, and after the analysis meaningful results or actions are carried back to the user or actuator, in this way the cloud act as middleware for IoT wherein, the IoT data flow occurs in the loop as: user-cloud-user to realize sense-process-actuate sequence for IoT applications. Alike cloud computing, fog computing also offers storage and compute capacity, though bounded by limited resource capacity of fog nodes, but at a nearer distance (in terms of number of network hops) resulting in significant reduction in latency and communication cost. In contrast to the centralized resource pool in cloud computing, the resources in fog computing are distributed in nature and include all sort of potential storage and compute devices encountered across the network between end-user and the cloud and such fog nodes may include nearby idle PCs, servers, access points, routers, and also end-user devices etc. Bonomi et al. (2012). In simpler words, fog computing is the distributed computing paradigm, which provisions data storage, compute and networking on resources occurring between end-device and the cloud server, preferably choosing the resources nearer to the end-devices lying within the local edge network. Hence, it can be concluded that cloud is the centralized on-demand computing infrastructure, while fog is distributed opportunistic computing infrastructure. In fog computing, the management of IoT data within edge network helps to reduce latency, saves cloud communication bandwidth and enables capturing of context information by implicit location and situation awareness. Hence, this paper suggests using fog computing-based IoT middleware to perform IoT data storage and processing on devices such as home gateways, routers, desktop and other computing devices which exist near to the end devices. With sensing-processing-actuating loop, IoT enables enormous applications like smart home, smart healthcare, smart grid etc. However, IoT based smart home is the focus of this paper.

In addition to IoT, smart home has been discussed widely in literature in the field of ubiquitous computing, particularly in the field of context-aware computing. Researchers applied context-aware computing approaches to realize smart home scenario in order to understand the user context and learn user habits for providing personalized smart home services. Models, architectures for context-aware smart home has been discussed in Wang (2005), Zhang (2005), and Klimek (2015). Various works Si (2005), Baralis (2011), Al-Muhtadi (2003), Ellenberg (2011), Vlachostergiou (2016), and Gu (2004) have performed context-aware computing in smart home scenario. Context-aware processing, when applied to smart home enables- modeling user's current context, incorporating user-defined policies, understanding user preferences, and providing context services, thereby providing ambient intelligence to enjoy a comfortable life inside home.

Smart home enablement has been addressed by both the technologies- IoT and context-aware computing. It is quite interesting to note that the two technologies are complementary to each other as, IoT deals with tangible hardware aspect involving the inter-networking of sensors, computation middleware, actuators, smart devices etc. to enable the sensing-processing-actuating control loop while, context-aware computing deals with the intangible software aspect involving various approaches and methods to process and understand the context for taking high-level decisions. With this view, this paper take initiative to propel this upcoming context-aware IoT paradigm. A recent survey on context-aware IoT can be found in Perera et al. (2014), however the authors did not propose any framework or layered architecture for context-aware IoT, which the authors attempt to address here. In this paper, the authors propose ICON (IoT-based Context-aware) framework for context-aware IoT applications such as smart home, which leverages fog computing as the IoT middleware to perform context-aware processing.

The rest of this paper is organized into six sections. Section 2 discuss the literature work related to smart homes. Further, Section 3 gives a description of considered smart home scenario and the undertaken use cases. Then in Section 4, the proposed framework-ICON for context-aware IoT applications has been discussed. In Section 5, the context-processing for the considered scenarios has been described. Finally, the paper is concluded with discussion on implementation in Section 6.