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Study on Network Management of Smart Home System - Combination of direct and indirect management techniques

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The Internet of Things (IoT) is being hailed as the next Industrial Revolution and it promises billion of IoT devices connected to the Internet in the near future. Due to this, myriads number of IoT devices will be deployed in homes, office buildings, factories, whole cities, and other environments of interest. In smart home environment, emerging networking and back-end support technologies not only have to anticipate this dramatic increase in connected devices, but also the heterogeneity of devices. Heterogeneity is one of the fundamental characteristics of devices as they are based on different hardware platforms and networking technologies. Consequently, the task of management is very challenging because there is no network administrator or technician in every houses.

In smart home environment, many standardization activities have been done for managing and controlling home networks and devices. Such activities include protocols or standards for home device management, home network management, remote device management and they have their own advantages and application profiles. Basically, devices in the home network are indirectly managed by a hierarchical approach with the involving of the Home Gateway. Constrained devices which have limited CPU, memory,

power and resources are able to connect and operate in the home network by the helps of the Home Gateway. By utilizing the Home Gateway, devices that are really constrained or utilize incompatible communication protocols can connect to the network in a secure manner. Therefore, indirect management enables management services for multiple device classes and communication protocols. In large-scale network, the Home Gateway enables management of devices as a group, thus simplifying maintenance and configuration and improving management scalability.

However, in accordance with the development of the hardware and IoT protocols, devices will still remain constrained but become less constrained and are able to connect to the internet in the secure manner without the assistance of the Home Gateway. It enables devices in the smart home to be directly connected and managed. Direct management enables management applications manage devices in the home network directly without any involvement of the Home Gateway. In this approach, the management applications and device's managed agents communicate directly, without the need for intermediate processing of data. Thus simplifying the design of the Home Gateway and achieving better performance.

In this study, a management architecture based on ITU-T Y.2070 recommendation that combines both direct and indirect approach was proposed. We also examined common approaches for designing a Home Gateway to present an intelligent gateway for our architecture. Qualitative and quantitative analysis of the home gateway's implementation patterns has been made. By inheriting advantages of two approaches, our architecture is able to support multiple device classes within a single network, enhances the management scalability, supports both end to end and distributed management, is able to support intelligent management, self monitoring and efficiently exploit device capabilities.

To prove the feasibility of the proposed architecture, a prototype based on this proposed architecture has been implemented. ECHONET Lite has been chosen as the protocol for the Home Gateway to manage devices in the home network (indirect management) and CoAP protocol is a candidate for the remote Management Platform to monitor the Home Gateway and direct manageable devices in the home network also (direct management). Some hints for deciding which devices should be directly managed or indirectly

managed based on device's heterogeneity were described. By observing the experiment's result, we can claim that the proposed architecture has some improvements by reducing number of packets in the home network, reduce the delay time of transmission and efficiently exploit device capabilities.

The future research can be carried out by applying artificial intelligence for management to provide auto configuration, fault detection and self management or exception handling functions. Here is the main contents of this study.

- First, the heterogeneity of devices in the home network was investigated to clarify suitable management approaches that can be applied. Devices are based on different hardware platforms, communication technology and the power budgets. The problem of device heterogeneity concerns a wide range of aspects, but in this research we focus on the heterogeneity in terms of communication models (i.e., device to device, device to gateway, device to cloud, etc.) and device's characteristics (i.e., memory and processing capabilities, strategies for using power to communication).
- Second, the qualitative analysis of indirect management and direct management are made. The characteristics of two management approaches and example of concrete systems are also described. From this analysis, the idea of combining direct and indirect management approaches are considered.
- Third, the qualitative analysis of the Home Gateway implementation patterns are described. These implementation patterns are (i) tunnelling data from the home network to the management platform via the Home Gateway, (ii) translating home network data at the Home Gateway then data is managed by other management protocols, (iii) using application in the Home Gateway to manage the local network then passing the data to the management platform. The proposed pattern based on (iii) is depicted.
- At last, some basic knowledge of the implementation and experiments were introduced. A prototype of the proposed architecture by combining ECHONET Lite for indirect management and CoAP for di-

rect management was implemented. Based on this implementation, the quantitative analysis of the proposed implementation patterns are also made. Future researches can be carried out by investigating more protocol's combinations or applying artificial intelligence for intelligent management.