Virtualization of Wireless Sensor Network: Smart House perspective

Md. Motaharul Islam, Eui-Nam Huh
Department of Computer Engineering
College of Electronics and Information
Kyung Hee University
Yongin-Si, Gyeonggi-do
Republic of Korea
{motahar, johnhuh}@khu.ac.kr

Abstract. Wireless Sensor Networks (WSNs) are gaining tremendous importance thanks to their broad range of commercial applications. Out of the fields of research in WSN, virtualization of wireless sensor network is a brand new research approach. In this age of economic recession, this state-of-the art technology can provide the opportunity to build economic business model for smart house. In this paper we propose a business model of cost effective way for implementing smart house for the rapidly growing elderly populations of the world. The evaluation method shows that virtualization of sensor network technology dramatically reduces the overall cost and complexity for implementing smart house.

Keywords: VSN, smart house, Virtual Sensor Network, ALU, SInP, SVNSP.

1 Introduction

Advances in wireless communications and electronics have enabled the development of low-cost, low-power, multifunctional sensor nodes that are small in size and communicate untethered over short distances. A sensor network consists of a large number of sensor nodes that are densely deployed either inside the phenomenon of interest or very close to it [1] [2]. Due to the rapid advancement of electronics, tiny sensor nodes are capable of supporting IP protocol stack. 6LoWPAN facilitates the IPv6 communication over low power and low cost sensor nodes [3] [4].

In the past, applications of sensor networks were thought to be very specific. The communication protocols of sensor networks were also very simple and straightforward. Some researchers were even against the use of the internetworking concept in WSNs for different reasons such as the resource constraints for layered architecture, the problems of configuring large numbers of devices, the essence of sensor nodes’ distinct identity, etc., but with the advent of the Internet of Things and federated IP-WSNs, this demand is going to be blurred. The huge numbers of IPv6 addresses, the necessity for end to end communication and advances in micro-
electronics have changed the concepts of the research community. Now a tiny sensor node can hold a compatible TCP/IP protocol stack, so we can now think of using the concept of internetworking protocols in IP-WSNs.

IP-enabled sensor nodes have opened the door for further research into advanced and distributed applications in sensor networks [3]. Recently, network virtualization has created a resonance among the network based research community. The concept of sensor virtualization has also attracted a great deal of attention from industry and academia [5]. Virtualization on sensor networks (VSN) can be defined as the separation of the function for the traditional wireless sensor network (WSN) service provider into two parts: sensor infrastructure provider (SInP) that manages the physical sensor infrastructure, and sensor virtualization network service provider (SVNSP) that develops the VSN by aggregating resources from multiple SInPs and offer services to the application level users (ALU).

The WSN virtualization renaissance has been caused mainly from the realization that most of the sensor nodes in a WSN remain idle for most of the time. Sensor network virtualization is one of the best ways to utilize the physical sensor node. Virtualization of sensor networks can provide a platform upon which novel sensor network architectures can be built, experimented and evaluated [5]. In addition, virtualization in WSNs is expected to provide a clean separation of services and infrastructure and facilitate new ways of doing business by allowing the trading of sensor network resources among multiple service providers and application level users.

This type of virtual sensor environment can be ensured from the coexisting heterogeneous WSN architectures that are free from the limitations of existing multi-vendor sensor networks. The importance of sensor virtualization is manifold in this age of worldwide economic recession. VSN can provide cost effective and green technology solutions to design smart houses and cities [5] [6]. In this paper we demonstrate a brief overview of the virtualization of wireless sensor network, its business model, architecture and discuss the challenges and opportunities. Finally we justify the application of VSN in monitoring smart houses.

The main contributions of this paper are as follows:

(a) We have proposed a novel business model of virtualization of sensor networks with concentration to the design of smart houses.
(b) We have demonstrated the sensor node architecture for VSN.
(c) We have evaluated the VSN in smart house application designing
(d) Finally we have depicted future research scopes and summarized the contemporary sensor network virtualization projects.

The remainder of the paper is organized as follows: Section 2 reviews the background related to virtual sensor network, VSN and its business models. In Section 3 we discuss VSN system architecture. Section 4 describes the evaluation. Section 5 discusses future research scope and a few contemporary sensor network virtualization projects. And finally section 6 concludes the paper.
2 Backgrounds

Virtualization of Sensor Network (VSN) is a brand new research approach in the field of Wireless Sensor Network (WSN). Before proceeding further, we need to clarify a few basic concepts and the difference between traditional WSN, conventional Virtual Sensor Network. In brief, a traditional wireless sensor network consists of a large number of sensor nodes that are densely deployed either inside the phenomenon of interest or very close to it [1]. In this paper VSN means virtualization of WSN as defined in the introduction and in section 2.2. The term VSN in this paper is synonymously used for the process of virtualization of sensor network and for the network that support virtualization.

2.1. Virtual Sensor Network

In traditional sensor network, all the nodes in the network perform more or less as equal partners to achieve the goal of deploying sensor nodes [1]. Virtual Sensor Network consists of collaborative wireless sensor network. It is formed by a subset of sensor nodes of a wireless sensor network, with the subset being dedicated to a certain task or an application at a given time [7]. In contrast, the subset of nodes belonging to the virtual sensor network collaborates to carry out a given application at a specific time. A virtual sensor network can be formed by providing logical connectivity among collaborative sensor nodes. Nodes can be grouped into different virtual sensor networks based on the phenomenon they track or the task they perform. The virtual sensor network protocol should provide the functionality for network formation, usage, adaptation, and maintenance of subset of sensors collaborating on a specific task. Even the nodes that do not sense the particular event could be part of it as long as they are allowing sensing nodes to communicate through them.

2.2. Virtualization of Sensor Network and its Business Model for Smart Home

Unlike wireless sensor networks, the VSN environment has a collection of multiple heterogeneous sensor network resources that coexist in the same physical space. In Figure 1, there are different types of physical sensor networks existing in the same domain. There are many Sensor Infrastructure Providers (SInPs), indicated by different circles in the lower layer of Figure 1. There are two Sensor Virtualization Network Service Providers (SVNSPs) in the model. Each SVNSP hires resources from one or more SInPs to form VSNs, and deploys customized protocol and services.

In traditional wireless sensor networks the infrastructure provider and service provider are same entity, but increasingly diversified applications of sensor networks in different fields such as building smart homes, make it necessary to differentiate between the WSN infrastructure providers’ and service providers’ perspective. The objective behind this is to minimize the cost of establishment and to reduce the manageability cost. The main difference between the participants in the sensor
network virtualization model and the traditional model is the presence of two different roles, SInP and SVNSP, as opposed to the WSN provider as a whole.

**SInP:** It deploys and manages the substrate physical sensor network resources. They offer their resources through programmable interfaces to different SVNSPs. SInPs distinguish themselves through the type of services they provide and the sensor node of which vendor and communication protocol they used. Different Vendor Companies can deploy sensor nodes and make their individual infrastructure which can be used by the company or can be leased to different virtual service providing companies to run their individual applications. It helps the effective utilization of the physical sensor node on a broader scale.

**SVNSP:** It leases resources from multiple SInPs to create and deploy VSNs by sharing allocated virtualized network resources to offer end to end application user services. A SVNSP can achieve network services from multiple InPs. The resources used by the SVNSP can be reused by the other SVNSPs in a recursive fashion.

**ALU:** Application level users (ALUs) in the VSN model are similar to those of the existing WSNs, except that the existence of multiple SVNSPs from competing SInPs provides a wide range of choice. Any end user can connect to multiple SVNSPs from different SInPs for using multiple applications.

---

**Figure 1.** Business model of sensor network virtualization in Smart Home.
3 System Architecture

The major objective of this work is to provide an alternative and cost effective business model for implementing state-of-the-art technology based smart house. Through the virtualization of sensor network technology, a fully functional sensor node can support multiple applications. To facilitate the environment of a smart house we consider two types of sensor node, the fully functional device (FFD) and reduced functional device (RFD) sensor node. FFD support the sensor virtualization environment. And RFD only performs sensing activities. Figure 2 represents the sensor virtualization of a single FFD sensor node.

![Figure 2: Virtualization of the FFD Sensor Node](image)

Figure 2 shows the layered approach of the virtualization of the FFD sensor node. It includes the lower layer that consists of the physical sensor resources such as clock, USB, RF, Temperature sensing and storage. The sensor operating system layer consists of a typical multitasking sensor network operating system. In this model we use Tiny OS. VSNware is the proposed Mate based virtual machine that supports concurrent applications. VSNware layer includes network management module, input/output module and application management module. We use the Mate and Melete systems as the background work of VSNware [8] [9]. Finally the application layer runs multiple applications on the VSN based FFD sensor node such as temperature sensing application, humidity sensing application, sound and video sensing application as discussed in the [10].

4 Evaluation

For evaluation, we first consider typical 2 applications based scenario which is depicted in figure 3. Next we consider the whole smart home designing [11] scenario which is depicted in figure 4. Based on the above two scenario we perform cost...
analysis. We consider one hundred square meter area for simulation environment. There are around 10 motes per square meter. So for 100X100 meter space we need to deploy 10X100= 1000 motes. The experiments were conducted on a computer with AMD Athlon TM 2.5 GHz CPU and 2 GB primary memory. The cost of each mote for typical two applications scenario is around 10,000 won. Figure 3 shows the number of motes versus cost scenario. Figure 3 also depicts that in terms of costs, VSN approach outperform the traditional approach which consist of individual mote deployment for application 1 and application 2.

![Figure 3: Cost model of Smart house application in VSN environment](image)

For the whole smart home implementation scenario (figure 4), we consider different types of motes. Cost of the mote for sound detection is 3000 won, for temperature detection is 2000 won, for humidity detection is 2500 won, for image detection is 5000 won, for VSN detection is 8000 won. The currency is South Korean won.

![Figure 4: VSN vs. traditional approach for Smart home implementation.](image)
5  Future Research Scope

Virtualization has opened a new dimension in different research fields especially in WSN. The whole world is facing economic recession. So virtualization in sensor network can be a promising research issue in large scale sensor network deployed in smart house. Among the future research scopes few of them may be developing convenient operating system which can support virtualization in sensor network. Managing resources, scheduling the sensing activities, minimizing energy consumption are few of the future research area in sensor network virtualization. Large scale federated sensor network framework with multiple applications sharing the same physical resources has already attracted the researchers. Table 1 summarizes sensor network virtualization research related projects.

Table 1: Sensor network virtualization research related projects.

<table>
<thead>
<tr>
<th>Project</th>
<th>Research Area</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRESnel</td>
<td>To build a large scale federated sensor network framework with multiple applications sharing the same resources.</td>
<td><a href="http://www.cl.cam.ac.uk/research/srg/netos/fresnel/index.html">http://www.cl.cam.ac.uk/research/srg/netos/fresnel/index.html</a></td>
</tr>
<tr>
<td>VSNs</td>
<td>Random routing, virtual coordinates, and VSN support functions</td>
<td><a href="http://www.cnrl.colostate.edu/Project/VSNs/vsns.html">http://www.cnrl.colostate.edu/Project/VSNs/vsns.html</a></td>
</tr>
<tr>
<td>Sensor Planet</td>
<td>SensorPlanet is a Nokia-initiated cooperation, a global research framework, on mobile device-centric large-scale Wireless Sensor Networks.</td>
<td><a href="http://www.sensorplanet.org/">http://www.sensorplanet.org/</a></td>
</tr>
<tr>
<td>ViSE</td>
<td>Virtualization of sensor/actuator system, creating customized virtual sensor network test beds</td>
<td><a href="http://groups.geni.net/geni/wiki/ViSE">http://groups.geni.net/geni/wiki/ViSE</a></td>
</tr>
<tr>
<td>STONE</td>
<td>Energy-efficient Storage for sensors</td>
<td><a href="http://sensors.cs.umass.edu/projects/esse">http://sensors.cs.umass.edu/projects/esse</a> nse/</td>
</tr>
<tr>
<td>DVM</td>
<td>To build a system that supports software reconfiguration in embedded sensor networks at multiple levels</td>
<td><a href="http://nesl.ee.ucla.edu/project/show/51">http://nesl.ee.ucla.edu/project/show/51</a></td>
</tr>
<tr>
<td>PRESTO</td>
<td>Takes a fresh look at the design of tiered large-scale sensor networks</td>
<td><a href="http://presto.cs.umass.edu/">http://presto.cs.umass.edu/</a></td>
</tr>
<tr>
<td>SenQ</td>
<td>Complex virtual sensors and user-created streams can be dynamically controlled as a single, unified, virtual sensor network.</td>
<td><a href="http://www.cs.virginia.edu/wsn/medical/projects/senq">http://www.cs.virginia.edu/wsn/medical/projects/senq</a></td>
</tr>
<tr>
<td>WebDust</td>
<td>Multiple, heterogeneous, wireless sensor networks can be controlled as a single, unified, virtual sensor network.</td>
<td><a href="http://ru1.cti.gr/projects/webdust/wiki/JWebDust_application_environment">http://ru1.cti.gr/projects/webdust/wiki/JWebDust_application_environment</a></td>
</tr>
</tbody>
</table>
implementation. Our future interest is to emphasize on building a large scale federated sensor network framework with multiple applications sharing the same physical resources that will facilitate the rapid deployment of the emerging smart home.

Acknowledgment

This research was supported by the MKE (The Ministry of Knowledge Economy), Korea, under the ITRC (Information Technology Research Center) support program supervised by the NIPA (National IT Industry Promotion Agency)” (NIPA-2012-H0301-12-1004)

References