UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF AN EMBEDDED SMART HOME SYSTEM

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By

THINAGARAN PERUMAL

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirement for the Degree of Master of Science

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Dedicated to,

My Family

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

DEVELOPMENT OF AN EMBEDDED SMART HOME SYSTEM

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THINAGARAN PERUMAL

July 2006

Chairman: **Associate Professor Abdul Rahman Ramli, PhD**

Institute: **Advanced Technology**

Smart home systems are expected to become key research area for ubiquitous and embedded system computing in coming years. In this thesis, a new scheme in smart home systems technology using embedded system for providing intelligent control of home appliances is proposed. An embedded system act as protocol glue that incorporates wired and wireless option such as Short Message Service (SMS) router with wireless local area network (WI-FI) for intelligent automation and higher speed of home appliances connectivity. The system is implemented in 2 tier models. First-tier model consist of incorporated design of SMS Router and Wireless Access Point. Wireless local area network (WI-FI) is selected as mechanism due to its transmission range within 100m which suits the smart home requirement for automation and control, justifies the Personal Area Network (PAN) for mobile device connectivity. Second tier model consist of remote application server systems, which cater a conceptual model between embedded hardware and software integration of appliances in smart home. This interface model will be between in house networks and external communication environment,

whereas embedded system acts as storage media and server for information interchange between systems especially with mobile devices within a smart home. Embedded system sits at the core of the home network, acts as residential gateway and enables bi-directional communication and data transfer channel among networked appliances in the home and across the Internet. On the other hand, client-side application provides a user-friendly Graphic User Interface (GUI) to enhance the usability of the system. The proposed embedded system has been implemented and verified that the system can be a core device for smart home environment functionality.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN MODUL TERBENAM UNTUK RUMAH BESTARI

Oleh

THINAGARAN PERUMAL

Julai 2006

Pengerusi: Profesor Madya Abdul Rahman Ramli, PhD

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Sistem rumah bestari di jangka menjadi topik penyelidikan utama dalam bidang pengkomputeran merata dan sistem terbenam dalam tahun yang akan datang. Dalam tesis ini, satu skema baru dalam teknologi sistem rumah bestari menggunakan sistem terbenam untuk kawalan cerdik peralatan rumah dicadangkan. Sistem terbenam berfungsi sebagai penggabung protokol antara wayar dan tanpa wayar dengan menggunakan perkhidmatan pesanan ringkas (SMS) and WiFi untuk automasi dan rangkaian pantas alatan rumah. Sistem ini diimplementasikan dalam 2 aras. Aras pertama merujuk kepada gabungan perkhidmatan pesanan ringkas (SMS) dan titik capaian tanpa wayar. Wi-Fi dipilih kerana penghantaran normal 100m yang memenuhi keperluan sistem rumah bestari untuk kawalan dan automasi, sekali gus menepati kehendak rangkaian kawasan persendirian (PAN). Aras kedua merujuk kepada aplikasi pelayan jauh yang mewakili konsep antara sistem terbenam dan integrasi perisian

peralatan rumah. Sistem tersebut berpusat di antara rangkaian rumah dan luaran di mana modul terbenam bertindak sebagai storan media dan pelayan untuk pertukaran maklumat di antara peranti bergerak dan sistem rumah bestari. Sistem terbenam akan menjadi penghubung utama rangkaian rumah, sebagai ruang akses, membolehkan komunikasi dua hala dan saluran pemindahan data di antara peralatan rumah dan Internet. Selain itu, aplikasi antara muka grafik pengguna (GUI) yang mudah diguna telah menambah keberkesanan terhadap sistem operasi. Sistem terbenam yang di uji telah menunjukkan bahawa sistem ini boleh menjadi teras untuk persekitaran rumah bestari.

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I certify that an Examination Committee has met on 4th July 2006 to conduct the final examination of Thinagaran Perumal on his Master of Science thesis entitled "Development of An Embedded Smart Home System" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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THINAGARAN PERUMAL

Date:

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LIST OF ABBREVIATIONS

API	Application Programming Interface
DNS	Domain Name System
DSL	Digital Subscriber Line
GUI	Graphical User Interface
GSM	Global System for Mobile Communication
IP	Internet Protocol
ISP	Internet Service Provider
LAN	Local Area Network
OS	Operating System
PAN	Personal Area Network
PPP	Point-to-Point Protocol
SMS	Short Message Service
TCP	Transmission Control Protocol
TSP	Telecommunication Service Provider

CHAPTER 1

INTRODUCTION

1.1 Smart Home

Internet has revolutionized many new emerging technologies. Rapid spread of Internet use at home inspires a new convenient way for controlling appliances at home thus conceptualised a smarter home. The smart home, the talk of the decade, has been predicted to be the next gigantic leap in the field of remote monitoring, becoming an important research topic in recent years. Research on smart homes has been moving towards applying the principles of ubiquitous computing [1]. The smart home is defined as one that is able to acquire and apply knowledge about its inhabitants and their surroundings in order to adapt to the inhabitants and meet the goals of comfort and efficiency [2]. The smart home may adjusts its functions to the home owner's needs according to the information it collects from inhabitants, the computational system, and the context.

The smart home systems industry is gaining significant attention from manufacturers ranging from consumer electronics to computers and communication networks. The potential business value of smart home systems products rivals some of the largest industries in the world, such as automotive. Basically, a smart home systems is a complete enabling system that provides common resources needed for home automation in a multi-product, multi-vendor environment, a system controller, a house wide wiring

network, communications protocols, standard interfaces for connecting other digital consumer products, and basic user controls. Providing complete smart home functionality depends on the addition of other products, such as more complex user controls, home appliances, and application-specific controllers. Designing and implementing smart homes requires a unique breadth of knowledge and not limited to a single discipline, but integrates aspects of machine learning, decision making, human-machine interfaces, wireless networking, mobile communications, databases, sensor networks, and pervasive computing. With these capabilities, the home can control many aspects of the environment such as climate, lighting, maintenance, and entertainment. In this kind of intelligent environment, information processing and networking technology is hidden away, and interaction between the home and its devices takes place via advanced natural user interaction techniques. As the size of computers become smaller and their speeds become faster, they will be embedded in every device, appliance, or even clothing. Embedding intelligence in automation, security and communication systems has become a dominant theme in smart home environment and state-recognition systems for ubiquitous computing. These systems aims to provide more holistic approach to the smart home, directed by centralized controller, and designed to interpret the user's needs in an efficient and well-defined way. Various intelligent appliances such as cellular phones, air conditioners, home security devices, home theatres are set to realize the concept of smart home. Smart home systems can contribute to better comfort levels and at the same time increase safety and security, detecting and signalling emergency and intrusion situations. It can be very helpful to elderly people with disabilities who may have difficulties in moving or executing tasks. While there are as many as 50 standards for smart home systems, only a handful is considered important

[3]. Some standards are open and many are proprietary. X-10, EIB, Cebus and LonWorks to name a few, act as open standard. These technologies are incompatible with each other. Another rising problem with current technologies is that they do not offer standard approaches to the problem of system design and adaptation to specific home and users. In most cases, the technology introduced meant to be used by technical personnel and not by common or even savvy users. Therefore, and for some technologies, a user cannot change his / her system or upgrade it without contacting a specialized company. The main constraint will be the lack of generic applications for monitoring and controlling a smart home that can accommodate change and allow the user to modify the system behaviour and adapt it to new needs and preferences. The demand for smart home systems is stimulated by invention of affordable products and services. Simply interconnecting existing appliances or control systems is not sufficient. Effective products must make any internal complexity invisible to the user with simple operating procedures and minimal training. As such the design and development of centralized embedded based system with multimedia support are critical for system reliability in smart home environment.

1.2 Embedded System in Smart Home

Embedded system is a customized computer system with both hardware and software, housed with programs embedded and has digital interfaces for several communication modules using mobile devices for appliances connectivity and control. It is the control centre that functions as a bridge and links consumer devices and manages the flow of data, voice and video between the outside world and devices on the network. With the maturing of wireless technology and communication middleware, smart home designers and inhabitants have been able to raise their standards and expectations. The system need to address interoperability requirements, interconnectivity requirements and plug-compatibility requirements of devices and appliances in smart home environment.

Home appliances or information appliances are consumer devices, which offer Internet or network access without using traditional operating system interface [4]. In particular, these devices use a gateway to communicate with each other, sharing data to build a more informed model of the state of the environment and the inhabitants, and retrieving information from outside sources over the Internet or wireless communication infrastructure to respond better in current state and needs. The devices can access information from the Internet such as menus, operational manuals, or software upgrades utilizing a central embedded based system as task distributor. The system sits at the core of the home network, acts as residential gateway and enables bi-directional communication and data transfer channel among networked appliances in the home and across the Internet. Many research findings suggested that these types of module and

residential gateway are expected to become key integrated service enabler in smart home environments.

1.3 Problem Statements

While there are many standards and organization involved in providing smart home backbone, only a small number had wider acceptance. The most common feature of smart home environment, X-10 technology refers to the electrical wiring that exists in the home to provide power for appliances using the existing power outlets available throughout a home [5]. Currently X-10 is used for applications with low data rate requirements such as lighting and appliances networks, and some security applications. Observing current systems and trends, both in research and practice, the following weaknesses emerge: -

a) Low bandwidth provides low data rate and incompatibility for new consumer electronics devices whereas X-10 transmission rate limited only 60b/s; it is also unsuitable for handling traffic.
b) No system feedback to check or monitor connectivity, unreliable and no guarantee of reception
c) Due to many standards available, there is no multi-connectivity support for smart home systems, therefore difficulties and no interoperability between devices
d) Lack of user interface support in existing modules

An embedded system is needed to act as ‘protocol glue’ that incorporates other wireless options such as Short Message Service (SMS) router and wireless local area network (Wi-Fi) for intelligent automation and higher speed of appliances connectivity. With this system, the system will solve the problem mentioned by providing a single user interface for home dwellers with multi-connectivity support. The system also will solve the X-10 drawback by providing feedback on control event of home appliances and to indicate whether it is successful or not. With this type of system, home appliances control in smart home environment can be enhances and produce efficiency in total management of appliances.

1.4 Research Scope And Contribution

The goal of this research is to show the capability of the embedded system in smart home technology, and to explore the factors in this technology that expands the interoperability. The design and implementation of the system is examined to find ways to provide a reliable interface using wireless infrastructure, improving the connectivity and control of smart home appliances and devices which will likely be required in the future using high-speed and high-precision data communication link. The contributions of this research are illustrated as follows:

- New hybrid module that incorporates wireless technology (Wi-Fi and SMS)
- Provides a single mobile user interface for appliance control in smart home environment