The Development of Control and Energy Usage Information Modules for Smart Homes

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Abstract—**In this highly information-oriented era, people enjoy the comfort and convenience life brought by technology, even homes simply provide residential purposes also get benefit and become smart ones. Smart homes provide comfortable, security and safety, energy saving and sustainability, and home care to people live in. Even in the absence of smart element, the human living space more or less is able to meet several or all of the above goals since ancient times. However, through modern technology, the result may be more concrete. Collective and independent residential lifestyle has a little different, as also in the construction of the smart home. It is about one hundred thousand of new residential houses built each year in Taiwan. In addition, there are about 8 million exist houses. The difference between exist and new house should be taken into consideration when developing a smart home system. In this paper an integrated module called hybrid smart home module for building a new smart home or renewing a traditional home into smart one is introduced. It consists of processing unit, power acquisition unit, communication unit, bypass unit, web server, and application software. This module provides almost all needed service within a single unit, although it is small but perfectly formed.**

Keywords: Tibbo, hybrid smart home,

I. INTRODUCTION

Smart home was first official introduced by American Association of House Builders in 1984 [1]. The free dictionary defines smart house is a highly automation house in which not only audio/video entertainment facilities are networked, but also air conditioner and lighting control are networked as well. Network service can be accessed everywhere in house, such that home appliances at any place may be interconnected with other devices [2]. Aldrich [1] defined a smart home is a place that equipped with computing and information technology, and can accept as well as reply resident's request. The purpose is to provide resident a comfort, convenient, safety, and joyful life through managing various technologies at home and outside world.

The Japanese government defines smart home is an information house. Currently, special attention is paid on energy saving and carbon emission reducing. It is expected to control energy usage efficiency through connecting electrical appliances and related devices in house with information network. The Korean government initiates short, medium, and long term milestones as digital home (~2009), smart home (~2012), and convergence home (~2015) respectively. Ministry of Economic Affairs of Taiwan established Smart Living Technology Promotion Office and proposed i236 project in 2009. The goal of this project is to develop 20 kinds of technologies for applying to smart living, and actually used in smart town and smart commerce and Trade Park within five years.

The number of houses is approximately 8 million in Taiwan, therefore I should take all style of houses such as new, old, townhouse, or collective residential building into consideration when design devices used in smart homes. In addition, a certain proportion of houses are not entirely need all the appliances automation, especially a certain age detached independent building. Besides, in response to the increasing depletion of fossil energy, the solution comes from both energy saving and alternative energy development. The alternative energy approach is to proceed through the research and development of renewable alternative energy such as solar, wind, and so on. The energy saving approach is through the change of habits, and the use of more energy-efficient home appliances. To change users' habits to conserve energy, if they know the consumption situation of the home appliances, will have better result.

Based upon previous conclusion and discussion, in this paper a module is introduced which can be used to make existing or newly built house becomes a smart one. This module has both control and monitoring function and energy usage information for home appliances. In addition, it has feature of easy to install. A prototype was developed to verify the proposed module; the preliminary experiment result meets the requirement of smart homes.

II. BACKGROUND AND RELATED WORKS

A. Residential types

The facilities and lifestyle have slightly different within different type of residential. According to the information in the residential e-network of the Ministry of the Interior Construction and Planning Agency of Taiwan, residential according to the type of use can be divided into: 1) townhouse, single family detached house or villas, 2) apartment, suite, or condominium. According to information provided by the Ministry of the Interior Construction and Planning Agency the number of existing residential houses is about eight hundred million in Taiwan, in which the percentage of townhouse is slightly more than 20. In addition, the number of new houses obtained use license is about one hundred thousand in 2011; it is about 1.25% of total houses in Taiwan. If a house built within five year is called a new one, then the

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percentage of old houses is over 90, so about two millions of townhouses are built over five years.

On the other hand, Taiwan is a highly information-oriented countries, not only the export amount of information technology (IT) products accounts for a considerable proportion of the national GDP, IT is almost in every corner especially in business, industry and government departments. Information-related equipments are also very popular at home. According to the statistics information of Taiwan in 2010, the mobile phone penetration rate in 2010 reached 90.6 percent, the cable TV equipment penetration rate is about 83.0%, other advanced information technology appliances or home PC penetration rate of more is over 71.3%, and network facilities is about 68%. Since the information related equipment has been highly popular at home, it is ready to deploy information technology-based smart home services into family.

B. Hybrid Smart Home

Currently, hybrid smart home does not have a consistent definition. Regardless of topic, it mixes two or more things or technologies. However, the general concept of hybrid refers to energy, especially on electricity. Such as Allan Nicholson defines a hybrid smart home is powered by a combination of solar panels, LPG gas, a back-up diesel generator and a battery bank which allow the house to generate its own power [3]. In this paper hybrid refers to mix up of traditional and modern technology. In general, a contemporary smart home uses central control approach such as using iPad or iPhone as user interface. In such manner, user controls electrical appliances such as air conditioner, lamps, or fans with iPad or iPhone. In contrast, electrical appliances are controlled by individual switches which are embedded onto wall. In hybrid smart home, traditional and contemporary approaches are coexisting. For digital native generation, they can use iPad to access appliances, while the older generation access appliances with traditional switches.

C. Information system at smart homes

The common configuration of information system for smart homes is shown in figure 1. It consists of user interface (UI) and distributed control unit (DCU), these two units are connected with communication channel (CC). UI is a necessary one, it sometimes equips with touch screen. It was usually custom-made device prior to tablet computers get popular, nowadays, it is being replaced with tablet computers such as iPad. CC can be Ethernet, RS485, or wireless network. UI is usually installed at a location easy to access while DCU is placed on distributed or control panel which is invisible to usual people.

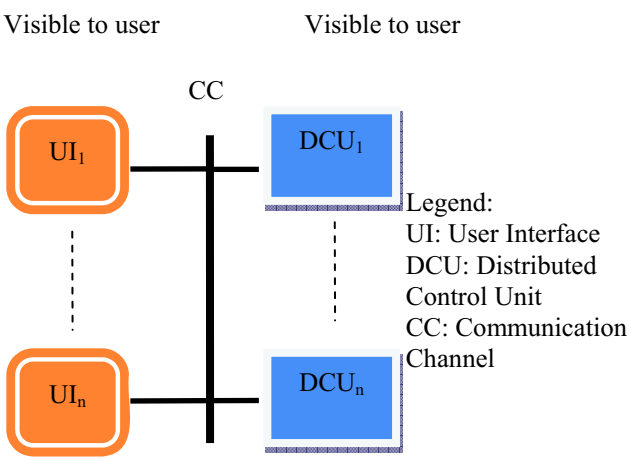

Fig. 1 common configuration of information system

The major information system for smart homes is in integrated form, such as products of Creston[1], touchlife[2] in Taiwan, and Advantech[3], and demo sites at Living 3.0[4]. The default UI of these products or systems is centralized operation panel, and does not take the usual operation habitat at traditional living environment such as house into consideration.

Paradigm shift takes time, transferring from traditional to intelligent home not only should consider living experience of inhabitants but also working experience of other participants such as building constructors, electrical circuit designer, and installer. During transition period, related personnel must have sufficient time to get familiar with new technology. Currently, any electrical wiring of a home installed by an electrician, other electrician can easily understand due to they are at the same technology basis. In contrast, a dedicated smart home system installed by a company, another company may need to pay a lot of time to understand it. In addition, lightings and home appliances do not need to totally be smart. Occasionally, people put a lot of efforts and resource to perform an intelligent task which can be done instantly in traditional way.

The configuration proposed in this paper is shown at Fig. 2; it has BPU and CU two more units with comparing to common configuration shown at Fig. 1. BPU is a bypass unit, which is usually consisted of traditional lamp switches which allow users to operate home appliances with traditional approach during system malfunction. Since it is rarely used, it is usually installed at inside of distributed panel. Another conventional unit (CU) is consisted of conventional wall mounted lamp switches and/or power sockets. It is especially convenient for building partial smart home or renewing traditional home into smart one. CU is main operation interface at this proposed configuration while UI is optional. For many people, although UI with touch screen provides more information,

[1] http://www.crestron.com/
[2] http://www.touchlife.com.tw/topic.asp?TPID=467
[3] http://www.advantech.com/
[4] http://www.living3.org.tw/ils-museum/

traditional switches or component may be more natural operation interface.

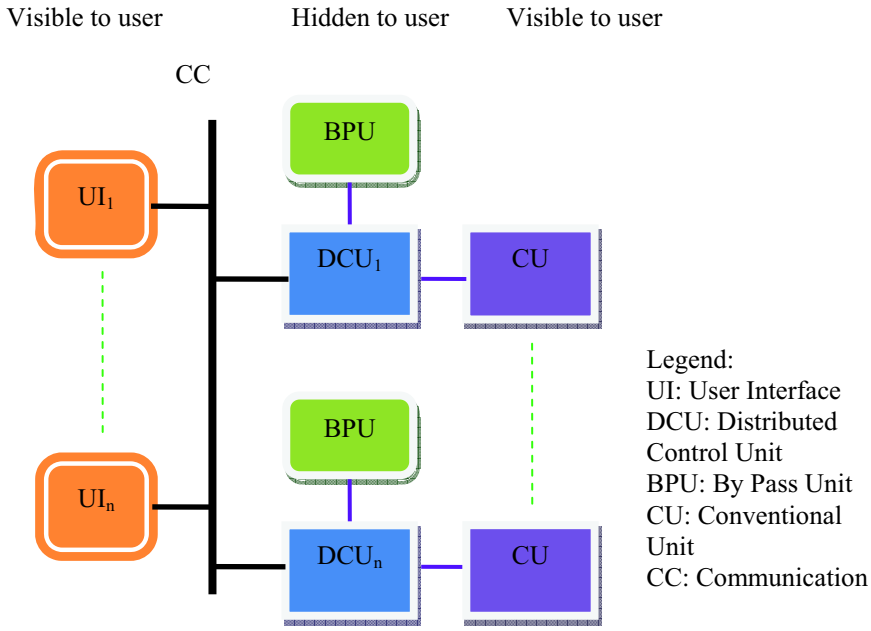

Fig. 2 The proposed configuration of information system application software.

D. *Smart meter*

Lin developed a power consumption information unit which is similar to Google's recent retired service called PowerMeter [4]. This unit introduced persuasive technology in which users can have instant power consumption information, and may change their behavior on home appliances usage with comparing and analyzing approaches. In such manner, the goal of energy saving is achieved.

III. Module Design

Based on previous consideration, the proposed hybrid smart home module is as shown in Fig. 3. As stated before, the term of hybrid is defined as blending traditional and smart element which is different from usual smart home systems. It is not absolutely necessary to make everything in home smart, especially in case of renew traditional house into smart ones. In addition, this module also contains power acquisition unit which is not exist in usual smart home systems.

Many countries include Taiwan are building smart grid infrastructure. Smart meter is part of this infrastructure. With smart meters, users can always know their instant power usage, and also have many other services that are not available in traditional power meters. Although the power meters of some high voltage users have being replaced with smart meters in Taiwan, but the schedule for home users is still unclear. In order to realize the energy saving objective of smart homes, a power acquisition unit is included. The hardware portion of this module consists of 1) processor unit, 2) power unit, 3)relay unit, 4)communication unit, 5) by pass unit. The software portion of this module consists of 1) web server, 2) web pages and server side script program, 3)

A. *Processor unit*

The web server unit, communication unit and processor unit can be located in the same unit. The processor unit can receive control signals from the outside, based on the design of control logic computing and the results of operations, set the status of each output point. Through these module functions it can easily reach the goal of the smart home: safety, comfort and convenience, energy saving and sustainability, and home care.

Consider the smart home module is an information equipment, so is has chance of failure. It generally has no safety backup equipment in smart homes due to cost consideration; and the malfunctioned system may need certain time to be repaired. To avoid causing households inconvenient at this period, this module provides link to connect an external bypass switch, so that they can still operate home appliances.

B. *Power unit*

The research results showed that people do not understand their own power consumption information but anticipate knowing. Some countries including Taiwan have begun to replace power meters to smart ones. As stated previously, it takes time to complete and the purpose is slightly different from smart home viewpoint. Therefore, a complete smart home building blocks need to take into account. In general, smart home control modules focus on realization of smart functions, and less concerned on the function of the energy consumption monitoring. The power acquisition module of the proposed module has two objectives:

1. To get electricity consumption information in all kinds of household appliances

2. Most of control functions of smart home systems are open-loop control, when users switch on home appliances, they cannot be sure if the home appliance is actually turned on/off unless they are at site. The actual status of home appliances can be inferred with power consumption information.

C. *Bypass unit*

In addition, traditional and smart lighting control has following different considerations. A traditional lighting control switch is a robust element which has lifespan as long as building itself unless certain circumstance occurred (such as short circuit). In contrast, the robustness of smart controller is weaker than traditional one. Unless industrial grade controller is adopted; occasionally malfunction will occur. It takes certain time to fix it by a specific domain expert duo to smart living space is not a common style currently. Therefore, it should add a bypass switch from practical viewpoint. This bypass switch can switch on/off lighting as traditional switch does. A bypass switch is used to control lighting while smart controller is being malfunction. Its installation location is less constraint such as inside of distribution panel due to avoiding confusion with traditional one and rarely using. A bypass switch is not necessary part. The main objective of the bypass switch is to temporarily switch lights or other control device when the module is in malfunction. User may not install it if they think it is unnecessary. Almost none of the existing smart home control systems take this problem into consideration; the proposed module introduces this simple but important concept, which adds practicality and affinity to the module itself.

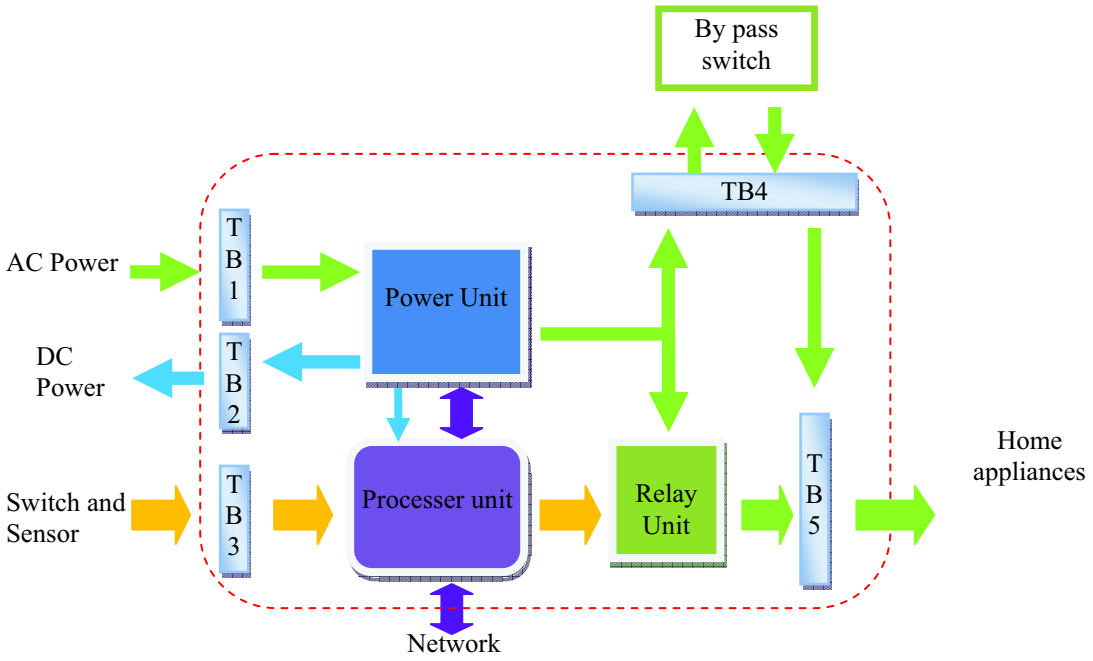

Fig. 3 Hybrid smart home module

D. *Web server*

In addition to a few LED lights used to display the state of this module, there is no default hardware man-machine interface, such as LED or LCD display device. Because currently computers and handheld devices are very popular in Taiwan, and Taiwan has very high proportion of Internet connection, home computer, as well as mobile phone, while these devices is the most appropriate man-machine interface. And it also assumes that households obtain and install the module, should have at least Internet connection device, therefore, the proposed human-machine interface of this module is information technology equipment with the browser and the Internet capacity, such as smart phones or computers.

The web server allows users control and supervise home appliances or set the parameters of the module in smart home.

E. *Application software*

The internal programs of the module (see Figure 4) consists of application programs and web pages. Application programs process signals from hardware switch or sensor and set control outputs according control algorithm.

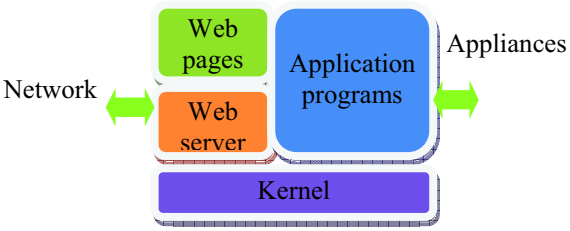

Fig. 4 Software stack

IV. MODULE IMPLEMENTATION AND EVALUATION

In order to verify the feasibility of the proposed module, a

prototype was built with components on the shelf in which processor unit is Tibbo EM1206[5] and power unit is Joseph Tech MI-P3[6].

In general, Tibbo does not provide user interface such as console I/O commands, in other word, it does not have screen based user interface. Its default UI is a mini LCD like simple display with keypads. Another UI form at Tibbo is web browser. The intended application of Tibbo is control module, therefore it is a real time system, and provides even driven and interrupt type programming to make sure events can be handled on time.

Tibbo is a single task system, only one event can be handled at a time, but other unprocessed events will queue for processing later. Web pages and application programs run on Tibbo are programmed with Tibbo Basic which is BASIC programming language likes language dedicate for Tibbo system.

The default user interface of prototype module is traditional switches and power socket, it also users access module with web browser. There are four functions: status, power, historical, and setting.

A. Status

The status of home appliances such as status of lamp, electric appliances, and sensors is shown on status screen. Users also can manipulate the connected appliances manually at this screen.

B. Power usage

This function display power usage status of all connected appliances including voltage, current, power factor, and instant power. In addition, it also allows users set parameters related to power usage. For each output point of module, users can set name of appliance and power consumption rating, such as output point 1 is electric fan and power consumption is 60W. If users without measurement tool to measure power consumption of appliance, they can only have this information from product specification. This module provides a convenient approach to allow users record actual power consumption of a specific appliance.

C. Historical

This module logs status change of all connected appliances. Users can query these event logs with this function later.

D. Setting

This function allows users set module related parameters except power parameters are set at power function.

The prototype module has been tested at lab of a university in northern Taiwan.

V. CONCLUSIONS

A module for building hybrid smart home is proposed in this paper. It is different from other smart home module on taking smart and traditional aspect into consideration. It is particular suitable for blending traditional and smart component into a smart home. A prototype module has been built with commercial components; the result showed that met predefined function.

ACKNOWLEDGMENT

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