

Implementing Smart Homes with Open Source Solutions

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Abstract

A Smart home provides living environment with comfortable, convenient, energy saving, safety and health care place to people live in. From technology viewpoint, its core is information system with physical manipulation capability which is referred as cyber physical system. Most of such systems available currently are proprietary products which put end users in risk of some issues such as long term support, system compatibility and cost. To address such issues, an approach with emerging open source solutions was discussed. The core of the proposed open source system is Arduino platform. A module for performing functions to implement smart homes also proposed in this paper. It is a typical cyber physical system and consists of input, output and energy monitoring functions. The detail of this module is presented and discussed.

Keywords: *Open source systems, Smart homes*

1. Introduction

People enjoy comfortable, convenient, energy saving, safety and health care life in smart homes. To provide such residential place some automatic interactions with the parameters in that environment should be performed. Having temperature, humidity and/or brightness information and conducting start or stop operation on some lamps or switches are examples. The abovementioned operations can be performed with various ways, such as manual, electronic or computerized. Computerized approach is superior to other ones. A computerized system can perform interactions with objects in the physical world is called cyber physical systems (CPS) which are integrations of computation and physical processes [1]. No matter what approach is used to constructing smart homes; the key point is human –centric that is serving human live in. Therefore, a smart home is an application of human-centric sensing because some sensors are deployed in. The human-centric sensing can be classified into one of following category in terms of the extent and human participation: 1) human as target of sensing, 2) human as sensor operators, 3) human as data sources [2].

To implement a smart home some issues should be taken into consideration. The life expectancy of a house is at least several decades, or even centuries, in contrast life expectancy of CPS is much shorter. The future maintenance and development of the CPS is the first issue. If cost is not the problem, most people prefer to live in a smart home. The major cost of constructing a smart home is CPS systems. If a smart home can be built with less expensive CPS systems, more people can afford to have it. Therefore cost is another issue. Cloud computing offers users many kind of services. Integrating with cloud computing is third issue. Open source solution is one of feasible approaches to address these issues. An approach to build smart homes with emerging open source solutions was proposed in this paper. The core of the proposed open source system is Arduino platform. A module based on the proposed approach is also presented.

2. Backgrounds and Related Works

2.1. Arduino and Google ADK

Open source is a concept that the detail information of a product, such as software and hardware, is disclosure to the public under certain conditions. To help students develop interactive projects with lower cost, staff of a university in Italy developed a system called Arduino which is based on Atmel AVR micro controller. Arduino is not a standalone device but a platform which includes Arduino board and IDE development environment. In addition, Arduino itself was not a brand new design but based and derived from various early systems. Following the same trend, a number of systems exist are also from Arduino. Arduino board itself is open source hardware. The hardware information is open to public with open source license. These sources include Bill of Material (BOM), schematics, layout, device drivers, and application program interface (API), and development platform.

Google released the Android Accessory Development Kit (ADK) 2012 for implementation of an Android Open Accessory device. The ADK 2012 (<http://developer.android.com/tools/adk/adk2.html>) is based on the Arduino with some hardware and software extensions that allow it to communicate with Android devices. There are two main physical hardware components in ADK 2012: 1) Main processing board which is basically an Arduino board and contains the microprocessor, USB connections, power connector and input/output pins, and 2) Shield board which may contain sensors, LEDs, input controls and audio amplifier. It shows Google's ambition to obtain a leading position in the field smart homes with integrating Android and Arduino platforms.

2.2. Smart Homes

American Association of House Builders official introduced Smart home in 1984 [3]. 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 [4]. Aldrich [3] 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 safety, convenient, comfort and joyful life through managing various technologies at home and outside world.

2.3. Cloud Services and IoT

Amazon proposed an Elastic Compute Cloud, EC2 service in 2006 which opened the cloud service era [4]. The concept of cloud computing was made public first by Eric Schmidt on SES San Jose Meeting in 2006. Since then cloud computing rises rapidly and become popular because of arise of diverse computing devices, such as smart phone, tablet computer and other handheld devices.

Unlike most of cloud services available currently, Pachube, founded in 2008 as its pronounce implies ' patch bay' like patch bay (or telephone switchboard) that allowing many-to-many connection of real objects is a web service available that enables users to store, share & discover real time sensor, energy and environment data from objects, devices & buildings around the world [5]. In general it is an Internet of Thing (IoT) Platform. Ashton claimed that IoT has the potential to change the world just as Internet. He stated that most of the data available on the Internet nowadays were first created or captured by human beings, but people have time, attention and physical limitation which make them not very good on data

capturing. Instead, computers do not have such limitations which make them are good data capturers. Therefore people need to empower computers so that they can see, hear and smell the things in the world. The approach enables computers to observe, identify and understand the world is by sensor technology. In other words, IoT has certain autonomy and the key elements of IoT are sensors [6]. Pachube was acquired by a leading provider of cloud-based connectivity solutions called LogMeIn [7] in July 2011, and in turn renamed to Cosm in May 2012. It can pull periodically or accept automatically real time information of physical objects such as sensors, energy meters or switches fed by connected device such as Arduino. Its major advantages are data storage and connecting physical world. It also displays long term historical trend of connected objects graphically. In addition, message can share with others which is one of major advantages of cloud service.

3. System Design

As mention previously, maintainability, future development and cost are some key issues of constructing smart homes. The development of Information systems is toward open architecture such as open computing project (<http://www.opencompute.org/>) and open handset alliance (<http://www.openhandsetalliance.com/>). It provides another approach to implement smart homes. The advantages of open source platform for constructing smart homes are:

- ✚ In general, technical progress of open source system is faster than close system
- ✚ Main stream companies such as Google and Facebook are supporting open source
- ✚ The total cost of ownership of open source solution is less than other approach.

Based upon previous discussion, a proposed CPS with open source solutions for smart home is shown in Figure 1. It consists of 1) processor unit, 2) power unit, 3) by pass switch connector and relay unit. There are some open source platforms available [8]. Among these platforms, Arduino may be the most suitable one for constructing smart homes due to its ecosystem. Many of technologies used to form Arduino were from MIT media Lab, and there are many variations derived from Arduino platform exist. The main body is within red dashed rectangle.

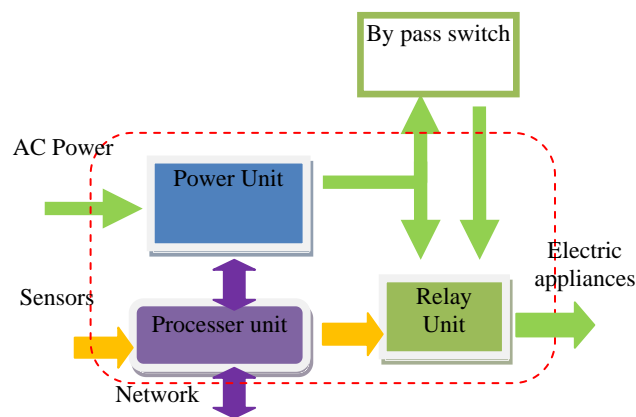


Figure 1. The Proposed Architecture

There are some previous works on applying open source platform to construct smart homes [9, 10]. Most of these implementations deal with ordinary sensing environmental conditions

and manipulating actuators to perform the serve people live in. From more realistic viewpoint some others issues should taken into consideration. First is about energy consumption information. The previous research showed that people do not have clear picture of their actual power consumption in real time but eager to know. In general modules for implementing a smart home usually do not provide information of power usage. Although traditional residential power meters have being gradually replaced with digital (or smart) ones; but it takes a certain time to complete and its main purpose is apparently different from objective of smart homes. Therefore power consumption information should be provided in smart home module. This function does not intend to measure individual power consumption of connected devices but sum of them. In addition, its main objective is to have an overall picture of real time power consumption so that users may have chance to take proper actions say turning unnecessary lighting to reduce power consumption but no to make comparison with bill issued by power company. It has two objectives:

- ✚ To get electricity consumption information in all kinds of appliances
- ✚ To understand actual status of each appliance

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. As stated it does not measure power consumption of individual device, a common approach called non-intrusive is adopted [11].

Voltage and current are two basic parameters to calculate information of power usage, but it needs to intrude into wiring circuit to measure them especially for current. In order to simplify the measurement process of individual electric load, a non-intrusive approach based on the voltage and current measured at the interface to the power source was developed [10]. Its major advantage is simplification of measurement process while the major challenge is how to find features such as harmonic to uniquely identify an electric appliance with analytical and statistic approach. The proposed architecture does not exactly same as the normal non-intrusive approach with statistical method but a simple heuristic. It is assumed that when an electrical appliance such as lamp or electric fan is turned on and the current measured is increased in about rating of this appliance; it may infer this appliance is actually turned on.

Second issue is about reliability and continuity of smart home system. In general, traditional lighting control switch and socket are robust with lifespan as long as building unless certain circumstance occurred (such as short circuit); in contrast, the robustness of information system is weaker. It makes people in inconvenient state when system malfunction occurs. In order to without causing inconvenience; it needs a simple yet inexpensive solution. Almost none of the existing smart home modules take this issue into consideration. The solution proposed is with a bypass switch. It switches lamp on/off as traditional switch does. It is used to control lighting while smart home module is being malfunction. Its installation location is less constraint such as inside of distribution panel. User may not install it if they think it is unnecessary.

Third issue is linkage within a clan. In general, after children grew up and get married, they may move out and build their family. This forms a clan. Cloud services such as Youtube, Facebook, or Flickr offer people great opportunity to share bits of life. Instead of popular human-centric cloud services, there is existing IoT cloud service such as Cosm for physical objects. If smart home systems can communicate with other ones within same clan just as sharing life with families it will give people much more services than ever.

4. Implementation of Sample Module

A smart home module was built to demonstrate and verify the concept of open source solution. This module is a typical CPS module and consists of:

- ✚ Arduino platform
- ✚ Input for sensors and switches
- ✚ Output for control electric appliances
- ✚ Power consumption monitoring
- ✚ Connecting to Cosm

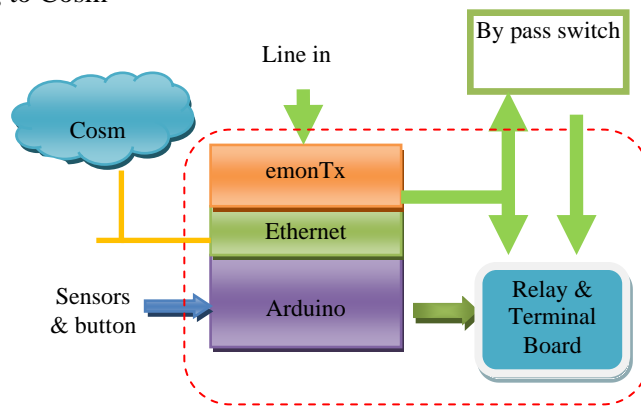


Figure 2. Configuration of Sample Implementation

The configuration of this implementation is shown on Figure 2. The open source platform used is Arduino Mega ADK board (<http://arduino.cc/en/Main/ArduinoBoardADK>) with Ethernet shield to provide computing and interfacing functions. Information of power consumption is provided by emonTx (<http://openenergymonitor.org/emon/emontxshield>) which is an Arduino compatible shield and can be directly plug into Arduino board. The data generated such as event of status change on inputs and output as well as power consumption are stored on to a 4G MicroSD storage which is on the Ethernet shield. This stored information may be viewed in form of historical trend or downloaded latter. In addition, this implementation also feed some information onto Cosm. Although putting sensitive information onto public cloud platform is not a good idea from safety viewpoint, but in some circumstance it indeed provides certain benefits. An example of sharing message on living space (*i.e.*, smart home) is a product called Good night lamp (<http://vimeo.com/goodnightlamp/kickstarter>) which is an approach to keep in touch with someone you care in distance, for example parents care about children who stay at school dormitory. The lamp installed at the location to be monitored is connected to cloud such as Cosm. Another one who wants to have real-time status of the lamp has a Good night lamp indicator which is also hooked to Cosm and reflects actual status of the monitored lamp. The ON or OFF state of a Good night lamp follows statue of the physical lamp.

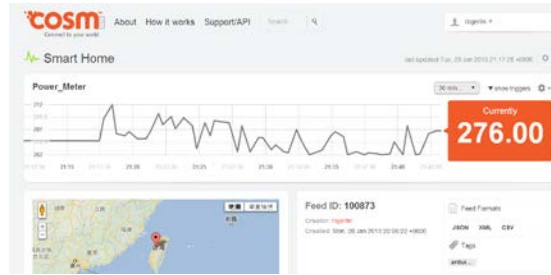


Figure 3. Snapshot of Sample Screen on Cosm

Since Arduino ADK board can communicate with Android devices such as smart phone or tablet, the default user interface applications are on these devices. Due to this implementation has Ethernet connection, a simple web server was built on this module. There are four functions users can operate:

Status

It shows status of devices connected to this module, such as operation status of connected lamps and electrical appliances and status of all connected sensing elements. Users may also manually manipulate connected devices. A sample screen snapshot is shown in Figure 4.

Power

It displays power usage status of connected devices such as voltage, current, active power and power factor. It also has setting function on here.

Historical

This is function will log any event occurs such as status change of a connected device for further reference.

Setting

Parameters other than power related parameters are set with this function.

Users can access these functions with web browsers either on desktop computer or smart mobile devices.

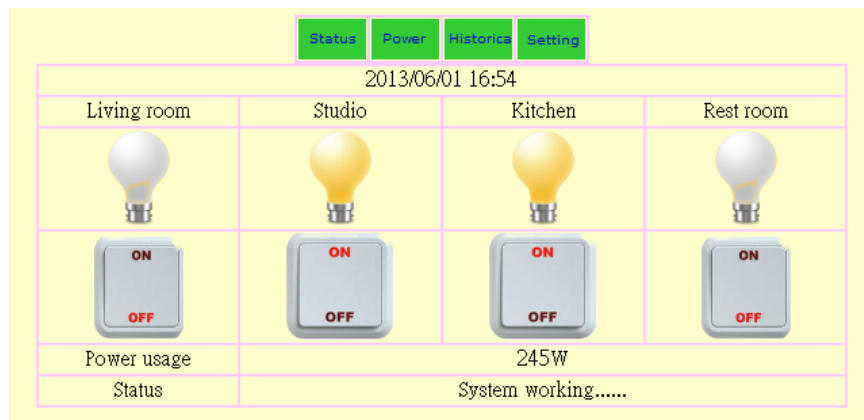


Figure 4. Snapshot of Sample Screen

5. Conclusions

Smart TV is going to become popular and information centre of smart homes; the major suppliers are developing wide range of functions to strength their products. On this issue, Google took a further step to ADK which makes a tighter connection with Arduino platform. To take an insight on this issue, open source solutions were proposed to construct smart homes and a module based upon Arduino platform for smart home was also introduced in this paper. The trend in information system is toward to opening. The service such as Cosm, components such as storage or modules such as power module used in the proposed smart home module can be easily integrated with Arduino platform. It provides flexible, sustainable, maintainable approach with reasonable cost to build smart homes.

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