Smart Power Switch for Smart Homes

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***Abstract*— The main focus of this paper is to analyze and design a Proof-Of-Concept (POC) Smart Power Switch (SPS) that will give users the ability to conveniently turn their home into a Smart Home. This Smart Power Switch allows the user to control any of the home appliances from anywhere. A standard switch/power outlet in a home can be replaced with a SPS that can be controlled remotely with any smartphone or Personal Computer (PC). Smart Homes can also reduce energy usage by up to 30% for typical residential users. Our research can be considered as an application of Internet of Things (IoT) for Smart Homes. A common definition of Smart Home is an "electronic networking technology to integrate devices, appliances and security so that the entire home can be monitored and controlled centrally as a single machine.**

Keywords- Proof-Of-Concept (POC), Smart Home, Internet of Things (IoT), Information Technology (IT).

I. INTRODUCTION

Since its beginnings, the Internet has evolved significantly, and, in recent years, it has influenced every aspect of our lives. In line with this Internet explosion, it appears we are about to connect everything in our physical world to the Internet. One of the areas that will be affected by this change is our homes, the place where we spend most of our time. Although some electronic devices are already connected to the Internet, in the future, all the objects in our home may get connected to the Internet, thus transforming our homes into Smart Homes. The idea of a Smart Home has existed for a long time, but actual Smart Homes were not designed and built until the early 2000s [12]. However, since this idea is relatively new and the related technology is still under development, it has been referred to by many names such as Smart Homes, Home Automation, Digital Home, etc. A common definition of Smart Home is an "electronic networking technology to integrate devices, appliances and security so that the entire home can be monitored and controlled centrally as a single machine" [2]. Any device in our home that uses electricity can be put on our home network and on a single command. Whether the command is given by voice, remote control, tablet or smartphone, the home reacts. Most applications of Smart Home ideas are related to lighting, home security, home theater and entertainment, and thermostat regulation. Today's smart homes are also focusing on living green, and thus, trying to conserve energy, in addition to controlling homes remotely using smartphones, automating home lights and thermostats, and scheduling appliances [2]. What we expect to see in the near future is the real evolution of Smart Homes; we may be living in such homes.

The technology used in a Smart Home may employ all of the following elements: intelligent control, home automation and internal networks [1]. Following are some of the main aspects of Smart Home:

- The intelligent control is a control system that is composed of two parts: sensors, which will monitor and report the status, and a controller (human or software based) which will process the information given by the sensors, and complete the requested operation.
- The home automation function is achieved by electrical or electronic devices that will make changes to the existing environment by completing the required tasks.
- The required home automation commands are often sent over a cloud system or smartphone application.
- The home network will be the medium for all other parts of the system to communicate and send information.

The system may get multiple repetitive tasks over time, such as turning the light on after the sunset, and may require the whole cycle to repeat itself every day.

In section II we will present the state of the art on Smart Homes; section III covers market research about Smart Switch; section IV talks about securing Smart Home; section V outlines the development of the Smart Power Switch; section VI details the testing results; and finally we conclude in section VII.

II. STATE OF THE ART

Authors in [5] report that lot of research is being done by Information Technology (IT) developers on Smart Homes, in the context of in-home services. Research articles on Smart Homes and their users are on the rise; authors in [6] present a methodical analysis of research themes as well as the linkages and disconnects among them. However, clarity on the use of Smart Home technologies is still missing. Information Technology designers and inventers are always striving for better energy management and improved

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functionality to meet the needs and requirements of homes called Smart Homes. A state-of-the-art Decision Support and Energy Management System (DSEMS) for residential energy users is proposed in [7]. The DSEMS is represented as a finite state machine and consists of a series of situations that are chosen based on user preferences. The paper also presents various designing and testing approaches and their results to show savings in energy usage and continuity of electricity supply. A new decision support tool for residential consumers is proposed in [8]. The tool can be used to optimize electrical energy services thus exploiting benefits to scheduling of energy services. A load promise framework that automatically changes electrical loads in order to minimize household use of energy resources and payment is proposed in [9].

III. SMART POWER SWITCH

Trends in the development of communication and electronic industry indicate that hundreds of smart communicating devices in future may stretch the functionalities of current devices. This may lead to creating the potential to change the way we work, learn, entertain, live, and innovate. Some researchers stated that by the year 2032 we could individually be in contact with 3000 to 5000 smart devices in our everyday life, and that would be truly transformative. In the following sections we will provide market research about smart switches and will attempt to give a comparison between a few similar products currently in the market.

A. WeMo® Light Switch

WeMo Light Switch [10] replaces a standard light switch in your home and can be controlled remotely with an Android Smartphone or Tablet, iPhone, iPad, or iPod touch. It can work with any existing Wi-Fi® network and anywhere your smartphone or tablet has an Internet connection (3G or 4G LTE). Table 1 lists Pros and Cons of WeMo Light Switch.

TABLE 1: PROS AND CONS OF WEMO LIGHT SWITCH

Pros	Cons
Remote Control	Doesn't Support 2/4 way Switches
Wall Wired Light Control	Only Compatible with 120vAC
Android/IOS Applications	Bad Performance Applications
Sunrise/Sunset Rules	No Power Monitoring
Compatible with IFTTT	No Web Application
	No Lights Dimming

B. ZULI

The Zuli Smartplug [11] communicates with a smartphone using Bluetooth Low Energy, giving users unmatched control, monitoring and automation at an affordable price. Table 2 summerizes Pros and Cons of Zuli Smartplug.

Table 2: PROS AND CONS OF ZULI SMARTPLUG

Pros	Cons
Location Based Automation using BLE	Cannot Control Wall Wired Lights/Appliances
Energy Monitoring	Cannot Control it Form Outside the House
Lights Dimming	IOS only app
Scheduling	Require Phone that support Bluetooth 4.0
Reusability	Compatible with USA plugs
	Only Compatible with 120vAC

IV. SECURING OUR SMART HOME

One of the main components for creating and managing a Smart Home is the control system that can be an embedded device. Embedded devices and systems have wide-ranging applications in residential consumer, commercial, industrial, automotive, health-care, and many other industries. Generally, embedded device are designed for a specific application; thus it has operating system or firmware for only designed applications. These devices are very small with low power consumption and little computing power. For example, a heart rate monitor embedded within a wristwatch can be connected to a smart phone for displaying the heart's status in real time; Point of Sale (POS) and Automatic Teller Machines (ATM) are also examples of embedded devices or systems. Many factors impact the process of choosing the best control system including cost and complexity of installation in addition to the best technologies available [2].

Cyber Security is one of the serious concerns in reference to Smart Homes, since information and control is wireless and over the internet. Our proposed system will be using wireless communication protocols to give devices and users the ability to send and receive information between each other as well as control home appliances. This may make the whole system very vulnerable to hackers' attacks. Thus the devices should be installed in the home in a secure way, ensuring that these are not visible to any intruder. Therefore, we implemented the Near Field Communication (NFC) protocol that allows these devices to establish peer-to-peer communication, thus enabling them to transfer data among each other by either touching them or placing them in very close proximity to each other. The device will not reveal

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its id and pair with any smartphone until the user gets their phone and passes it on the switch; then the switch will reveal its id address and pair with the user's phone. Access to this device through any phone is not possible if the device is not registered by the owner of the device, thus preventing intruders from communicating with the device. However, as soon as the user establishes communication with the system, the device id of the user is exposed to the hackers or intruders thus raising security concerns. This problem is tackled by encrypting data at the sender device and then decrypting it at the destination device and vice versa. The encrypting technique we use depends on the machine-to-machine communication protocol (M2M).

V. SMART POWER SWITCH SYSTEM

This section outlines the development of the Smart Power Switch system, one of the important components of the smart system. We attempt to identify the user profile and requirements, for the Smart Power Switch system, by considering the findings outlined in a survey reported in [4]. In general, a typical family household may have children, are technologically savvy, as well as have a smartphone or computer and an Internet connection. These stated user profiles are not a must for every household; these are the more likely users that may be interested in living in a Smart Home. While this system is generally meant to be used in family households, it can also be used in various other environments. For example, companies, schools, and any other facility may want to turn their buildings into smart buildings. The stakeholders will be the same, but may be under different names, as there will be administrators, and users who will likely be using some parts of the system. The aim of this paper is to present a Proof of Concept (POC) Smart Power Switch system that gives users the ability to turn their home into a smart, internet-connected home by replacing the standard home switches and outlets with the smart ones. Moreover, by using the system we can control home lights/appliances remotely, schedule tasks for devices, and monitor the power consumption.

The Smart Power Switch system is divided into three main parts, The Application, The Cloud, and The Smart Switch, as shown in Fig. 1 [12]. There are two ways to communicate between the application and the switch. The application layer will be able to communicate with the smart switch through internet. In the case of controlling the switch remotely, a request submitted by the application over the internet to the cloud; the cloud in turn will send the command to the switch. The second scenario is the exact opposite: the energy consumption sensor located inside the smart switch will calculate the consumed energy and submit data to the cloud; that data will be processed in the cloud; and the analysis of the data collected will be sent back to the application when the user requests it [12]. In the second case, the user must be in the same local area network to which the smart switch is connected, and then the user will be able to control the switch locally without the need of the internet connection. The controlling events will be saved locally in the smart device, and later when there is an internet connection it will be sent to the cloud for processing.

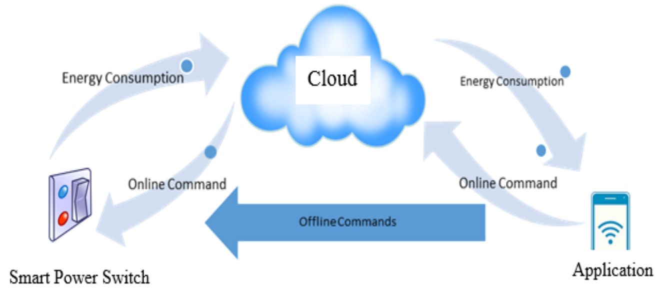

Figure 1: Components of Smart Power Switch System

VI. TESTING

In this section, we are going to report the testing carried out with the Smart Power Switch system. It provides details of the test plan, running the system and a summary of the results and the outcomes of the test. Testing plans for the system include: operating it around the clock, controlling it by a mobile app, and then connecting one TV to a standard power outlet, while the TV under test is connected to a smart sensor. The system will switch off the device once it is in standby mode, and the system reports all data to the cloud. After programming the cloud side of the system, an account is created on IBM Bluemix Platform, and services such as Node-RED Service, Cloudant Service, Internet of Things Foundation Service, or Node.js Application Service are set up. For testing with only one device, the processing power required is not great: The requirement for a system under consideration is 512MB per Instance per day, up to 20GB data storage and up to 500,000 API calls per month.

Programming the android application was accomplished with Android Studio, which allows a memory monitoring thread to run that keeps monitoring the memory and, in turn, reporting the results in a separate window. There are three possible authentication protocols to verify the communications between the app and the server: authenticating requests using Cloudant account credential, authenticating requests using auto-generated API keys, and authenticating requests from a users database. Authentication using users' database is the best security, because there are different access authorizations for different users. However, this has security which is a high priority requirement for our system.

Through the testing process, there were a few problems. One problem was that the fuse inside the smart switch was capable of handling currents under 5 Amps whereas our system was able to handle current up to 10 Amps. In one of

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the testing processes, the fuse blew because the current was greater than 5 Amps. Therefore the fuse was replaced with a 10 Amp fuse. In Tables 3 and 4, we have provided the summary of the testing process, each with its rating out of 3, PASS/FAIL, and some notes.

TABLE 3: DEVICE SUMMARY

P/F	Rating	Notes
P	1	The devices was power by the current coming from the AC/DC converter successfully
P	1	The devices was controllable form the mobile app
P	2	The device calculated the current with 80% accuracy
P	1	The device published data to event topic successfully
P	3	The scheduled commands runs but with some delays

TABLE 4: CLOUD SUMMARY

Name	P/F	Rating	Notes
Running the System	P	1	The cloud system runs perfectly during the testing process period
Provisioning the Devices	F	-	Provisioning devices require more complex communication between the app and the device. So we hardcoded the device data in the cloud system.
Handling Requests	P	1	The system received all request via the MQTT broker.
Fast Data Querying	P	1	The Mapreduce function works efficiently and responded with the correct data.
Security	P	3	The cloud rejects requests coming from unauthorized users and securely transmits data in and out.

The testing process proved that the system is reliable and works efficiently. The results show, in Fig. 2, how implementing the smart power saving feature reduced the power consumed up to 20% per Wh.

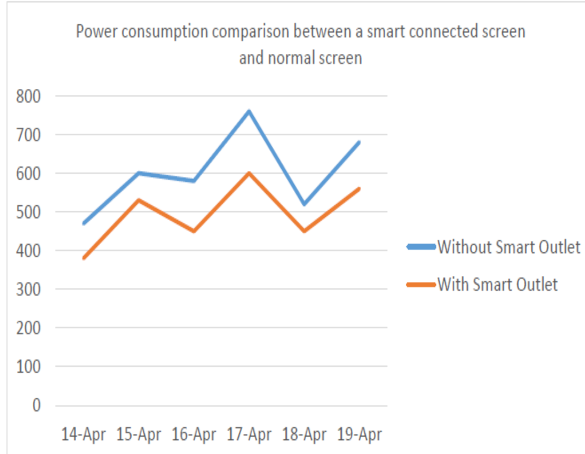

Figure 2: Comparison between a smart connected screen and a normal screen

VII. CONCLUSION AND FUTURE WORK

In this research, we defined the main proposes and objectives of our work and provided research about Smart Homes, we realize that the number of devices used in a household is increasing, and in the next few years we may have hundreds of devices accessible per person. We discussed how hard it is today to transform our life into a smart, internet-connected life. After implementing and testing the system for a few days in real life situations and comparing the devices to other Smart Homes systems, the most important finding is that it is possible to transform a normal home into a Smart Home by only changing the house power plugs and switches, as compared to complicated approaches presented by other researchers. Using our system to create Smart Homes provides a much lower cost solution than implementing traditional Smart Homes systems that may require in-wall wiring, and changing appliances to smart appliances. Transforming a home into Smart Home can benefit us in many different ways. Smart Homes can reduce energy usage up to 30% percent for normal users and can be a nice and comfortable place for elderly and disabled people. The system can also be scaled for huge buildings without compromising the same fast performance. This system worked as required for the proof-of-concept stage, however, for mass production the system requires more research in many areas including AI. In our project, we implemented a small set of AI code into the system, which resulted in a large benefit and reduced energy consumption. Additional work needs to be done to further improve the smartness of the system, and to enable it to make smart decisions securely and correctly. The hardware part of the prototype device also needs additional work leading to Design for Manufacturing (DFM).

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