Design and Implementation of IoT-Based Automation System for Smart Home

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Design and Implementation of IoT-Based Automation System for Smart Home

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Abstract— **Home Automation System (HAS) gains popularity due to communication technology advancement. Smart home is one of the Internet of Things (IoT) applications that facilitates the control of home appliances over the Internet using automation system. This paper proposes a low-cost Wi-Fi based automation system for Smart Home (SH) in order to monitor and control home appliances remotely using Android-based application. An Arduino Mega microcontroller provided with Wi-Fi module is utilized to build the automation system. In addition, several sensors are used to monitor the temperature, humidity and motion in home. A relay board is exploited to connect the HAS with home under controlled appliances. The proposed automation system, can easily and efficiently control the electrical appliances via Wi-Fi and Virtuino mobile application.**

Keywords— HAS; Smart Home; IoT; Arduino; Virtuino

I. INTRODUCTION

Nowadays, the large diffusion of smart devices with embedded sensors and wireless interfaces have enabled the rapid advancement of Internet of Things (IoT). The IoT plays a remarkable role in improving the quality of life and growing the world's economy. It facilitates global connectivity over the world-wide physical objects (e.g., sensors, RFID, smart-phones, vehicles, appliances) to serve people in a collaborative manner automatically and intelligently. The vision for the IoT states that various "things" are going to be connected and will be controlled across the Internet. Application domains of IoT cover smart home, smart healthcare, smart grid, smart transportation, smart city, industrial automation and surveillance. Among various IoT applications, the design of Smart Home (SH) has drawn great attentions from both academic and industrial because it is more related to people's lives [1-4].

A smart home can be defined in many ways. One definition is a home with an automated system that comprises sensors and device controllers to provide a comfortable, intelligence and secure system to improve the quality of life and control home appliances easily, in particular for elderly and disabled people. The SH automation system as shown in Fig. 1 may provide an interface between smart phone or personal computer and home appliances, via a wireless communication interface Bluetooth and Wi-Fi [5].
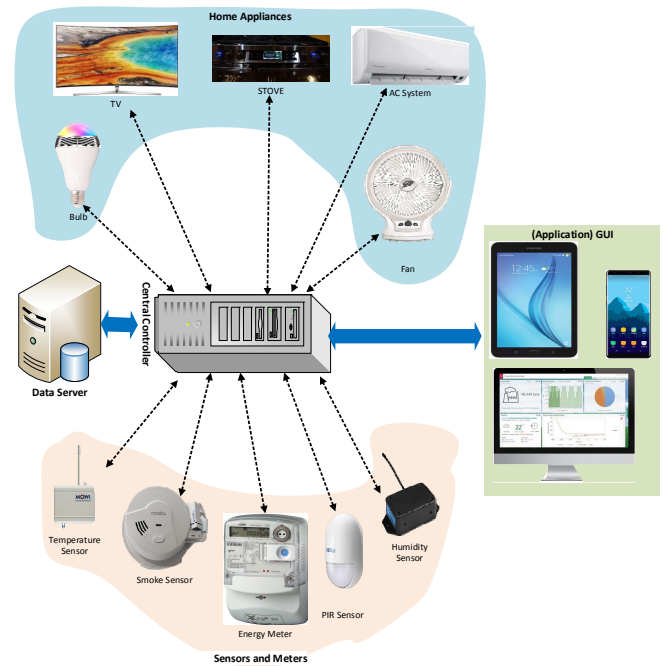

Fig. 1 An example of smart home architecture

There are many of the Home Automation Systems (HAS) that are commercially available and it can be categorized into two main categories: locally controlled and remotely controlled systems [6]. In the first category, users can control their home appliance using an in-home controller with a stationary or wireless communication technology (Bluetooth, Zigbee and GSM) for achieving home automation. In the second category, users can remotely control their homes over Internet connection using their mobile devices or personal computers. However, there are several issues involved when designing such automation system and it should be considered [7].

Home automation system should provide a user- friendly interface to allow setup, monitoring and controlling home appliance easily and efficiently. In addition, the automation system should be fast enough and provide reliable connection with acceptable data rate and communication range to realize the true power of wireless technology [8]. Finally, the system

controller should be cost effective to allow public users to possess and justify its application in home automation.

To overcome these design issues and minimize the shortcomings of home automation systems, this paper proposes an integration for locally and remotely controlled home automation systems. The proposed system will provide a locally controlled home automation system via a Wi-Fi interface and the low cost Arduino microcontroller in addition to the use of the IoT concepts for remotely control. This allows the system to be independent of both user location and mobile provider. It also allows the developed automation system to be used locally with various Android-based smart phones via Wi-Fi or to operate remotely via an IoT platform which allows individuals to manage, monitor, and control their appliance and devices through the Internet.

The remaining part of this paper is structured as follows: The next section discusses the background of home automation systems and their benefits. Section III introduces an overview of the adopted methodology and materials. The implementation of the proposed system is discussed in in Section IV. The results and discussion are introduced in Section V. Finally, a conclusion is drawn up and the future work is highlighted in Section VI.

II. BACKGROUND

A. Home Automation Systems

Home automation or Smart Home is a key component of the "Internet of Things," in which everything has an assigned IP address, and can be monitored and accessed remotely from anywhere at any time. It is the way where the home appliances and other devices are networked to control over all aspects of smart home. For many decades, home automation systems have been in term of lighting and simple appliance control. Recently, technology is enabling full control of our smart appearances at home from anywhere for the idea of the interconnected world to become a reality [9]. Home automation can dictate how a device should react, why and when it should react. It brings convenience, fully-control and money savings. Furthermore, home automation system can alert the user to events that might occur when they are gone such as water leaks, gas leaks, fire and unexpected access to their home. At any time, the user has the ability to make any changes in the settings of automation system based on his requirements and desire by using android application or other control device.

B. Why Smart Home?

One of the benefits of SH is the advanced lighting control system. The user does not have to manually switch on or off the electrical appliances anymore. For example, when user enters the bedroom, there are two options; either the light will automatically on and off after the person leave the room, or the user can control the switching from the application using his smart phone. The brightness of the light also can be controlled so that the power consumed will be reduced. Besides that, the user has the choice to adapt the room conditions based on the sensor readings (temperature, humidity, etc.) like control the speed of the fan from the mobile application or the speed will be automatically adjusted based on the room temperature. By this way, the energy efficiency can be improved because when the electrical appliances are automatically or easily turned off when not used, this will save more energy and decrease electrical bill cost.

Additionally, the user can control the electrical appliances and monitor the house conditions from anywhere by using smartphone, tablet or laptop. As example, if the user has forgotten to switch of the fan and he already arrived at his office, he can switch off using his smart device. The smoke, carbon monoxide and flood sensors also can be installed so that the user will know if their house is in flood or the air surrounding is dangerous, they just can stay at home.

For the security system, if there is any incident happened, the user will receive alert at their phone. They do not have to worry if there is an intruder try to sneak into their house since they can monitor from their phone by implement the motion sensor and if any motion is detected, the alarm will be on. The security system is the most important part to keep our house safe from the intruders. By having a security system installed, we can prevent the burglar from entering the house with the installation of wired surveillance cameras. All the smart home components such as ventilation, heating, air conditioning, centralized lighting system, automated appliances and security system can give comfort in daily lives and also security.

C. Limitations of the Existing HAS

Based on the researches that have been done, one of the main issues in most existing HAS is their implementation and maintenance cost which is not affordable for most users. Furthermore, some current systems provide a view of the house from a web application which is inconvenience for users, who must access the Web each time they wish to control or view the status of their houses [10]. In addition, some HAS lack of user friendly interfaces for monitoring and controlling appliances. Besides, there are some limitations in the communication technologies that have been used in the existing automation systems. For example, the communication range of Bluetooth is limited to 10 meters. If more than 10 meters, the connection will be lost and the user not able to control home's appliances. Furthermore, ZigBee is designed for low rate wireless personal area networks with data rate 250Kb/s which is insufficient data rate. Another communication technology is GSM which can be access anywhere in the world but it is costly and it has low data rate of transmission and limitations in coverage for rural areas [11].

Therefore, in this paper, we propose a new system to overcome the limitations of the existing home automation systems. This can be achieved by design and fabricate a low cost Wi-Fi-based Automation System for Smart Home prototype using Arduino microcontroller and Android-Based smartphone. The system is developed to control all the electrical appliances at home easily and efficiently and enable the remote control by supporting the IoT concept.

III. METHODOLOGY AND MATERIALS

A. Conceptual Framework

This section describes the conceptual framework and the methodology adopted for this work including the systematically organized different stages of the research in conjunction with the detailed implementation features of the proposed system. In addition, it clarifies the structural components of the proposed system and their integration to achieve the research aim. The flowchart in Fig. 2 illustrates the research stages followed in the present study.

Fig. 2 Flowchart of research activities

The layout design of home prototype is displayed in Fig. 3 which is followed by modelling phase, where all the necessary equipment and materials are used for building a smart home prototype.

Fig. 3 Plant layout

The prototype of smart home is built using plywood as presented in Fig. 4. After that, the wiring and hardware implementation is carried out. Then the programming phase of Arduino Software is accomplished. For design enhancement and optimization, any problem that occurs during building the project, is identified and solved during testing phase. Some improvement is also done to avoid the same error. Finally, the complete design of the project is evaluated.

Fig. 4 Top view of the house prototype

B. Main Components of Home Automation System

1) Arduino: Arduino Mega as shown in Fig. 5 (a) is used as the main controller in this project because it is inexpensive, cross-platform, simple, clear programming environment, opensource and extensible software. The electrical appliances and the sensors are connected to the pin of Arduino Mega. The function of Arduino board is to read the input and turn it to output, receive and transmit serial data, trigger an interrupt on a low value, provide 8-bit PWM output and more.

2) WI-FI MODULE ESP8266: Wi-Fi Module ESP8266 has 8 pins which is depicted as in the Fig. 5 (b) is connected to the Arduino Mega. This module is compatible to 3.3V logic level only. ESP8266 is chosen because it is low cost and high features and that makes it an ideal module for IoT applications.

(a)   (b)

Fig. 5 (a) Arduino Mega 2560   (b) Wi-Fi Module ESP8266

3) RELAY BOARD: In this project, the relay module as illustrated in Fig. 6 is also used to provide connection between two or more points in response with the input signal. It is connected to the fan and bulbs that acts as output. Relay are used in many applications because of their relative simplicity, long life and proven high reliability. The function is to protect, regulate and control the power.
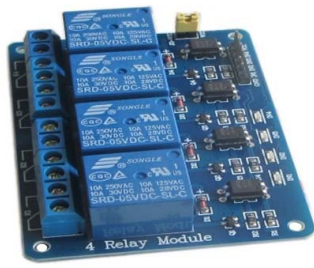
Fig. 6 Relay board

In addition to these three main components, several sensors and equipments are used either to monitor or control the Smart Home such as voltage regulator, temperature sensor, humidity sensor, PIR motion sensor, buzzer and samples for home appliances like bulbs and fans.

IV. SYSTEM ARCHITECTURE AND IMPLEMENTATION

This paper focus on the usage of Arduino Mega microcontroller along with WI-FI module ESP8266 in HAS for controlling the home appliances. A local control system over Wi-Fi and a remote control is established based on IoT. A suitable Wi-Fi-based android application which is Virtuino is utilized because it has a user-friendly interface and it can work efficiently with Arduino Mega to control and monitor via smart phone. Arduino controller is programmed to interact with the Virtuino application. The Wi-Fi module, buzzer, temperature and humidity sensor will be connected directly to Arduino Mega microcontroller. The sensors are represented the inputs of the microcontroller. The relay board receive its input signals from Arduino Mega, while the bulbs and fan which are only samples for real home appliances are connected to the relay outputs. The sample architecture looks for the proposed system is shown in Fig. 7.

The detailed connection of the devices is displayed in Fig.8. The steps on how to control the electrical appliances using Virtuino are depicted in Fig. 9. Through this procedure, the considered electrical appliances and home conditions can be controlled and monitored via mobile phone.
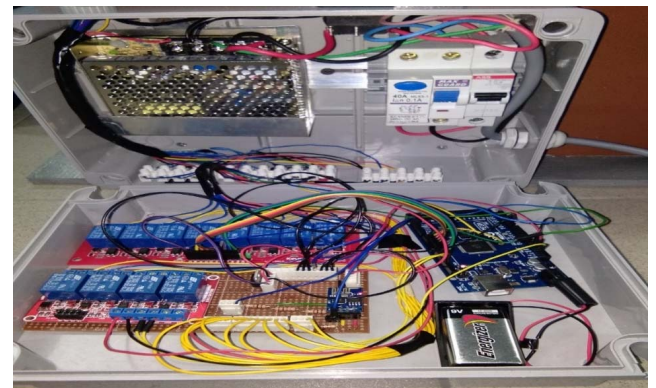

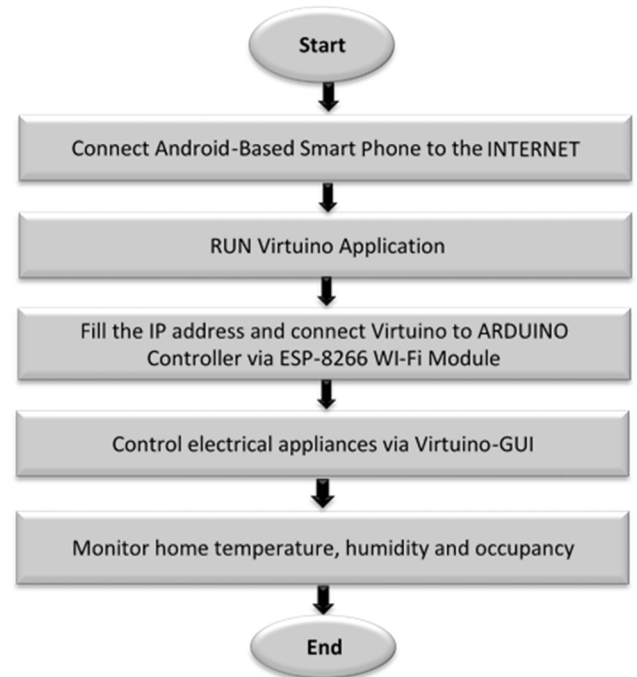Fig.8 Distribution box with hardware connection
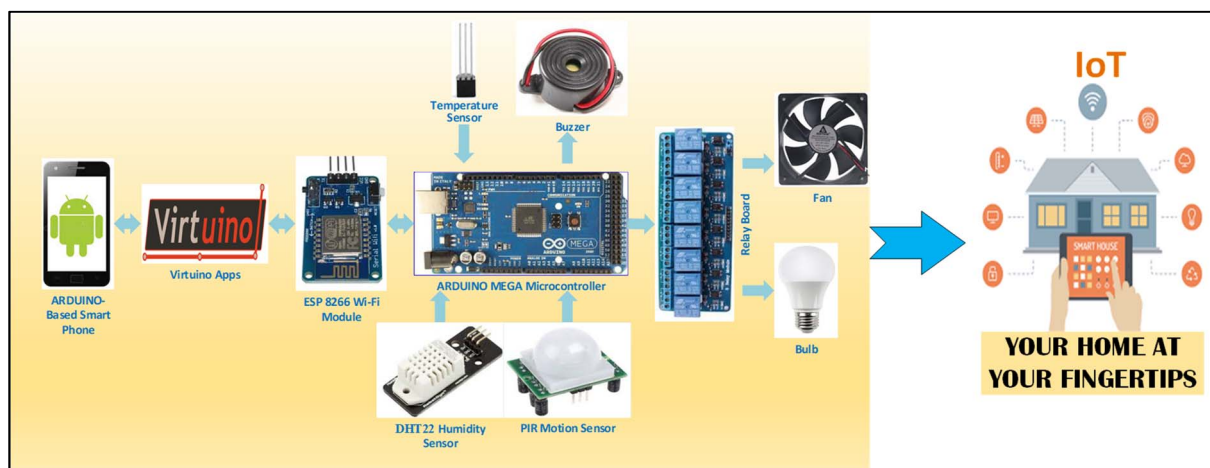

Fig. 9 Flowchart of project setup

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Fig. 7 The proposed system architecture

This section presents an example to verify and validate the implementation of the proposed HAS. The preliminary results that we obtained in this paper will be used for further extension and enhancement This paper was managing to successfully develop a Wi-Fi-Based Automation System for Smart Home Using Android Mobile Phone.

Firstly, we need to connect our Android-Based smart phone with the available Wi-Fi. Then open Virtuino application in our mobile and fill in the IP address before connect. The IP address can be found in commend prompt in PC. Connect Virtuino application to Wi-Fi. Now we can control all the electrical appliances and able to monitor the motion, temperature and humidity of the house.

The electrical appliances such as bulb and fan can be controlled and monitored using Android app which is Virtuino as demonstrated in Fig. 10. Further, the sensor DHT22 can measure and monitor the temperature and humidity in the house from the android-based mobile phone and these parameters can be used in the next step to fully automated the AC system and fans. The motion sensor also can detect if there is any motion in a certain area and give alarm via buzzer, which can be used later on in the security system or in automated the operation of lights.
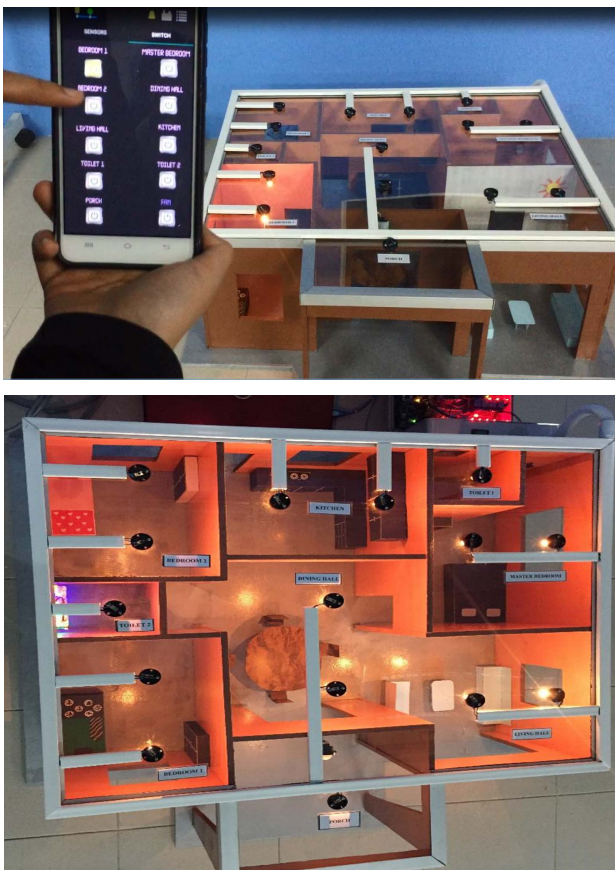

Fig. 10. House prototype with electrical appliances controlled via Android

At the end of this stage of our project, all the electrical appliances can be controlled by using Virtuino application as shown in Fig. 11. Moreover, the humidity and temperature as well as the motion in a house can be monitored from the Android-Based Smart phone.

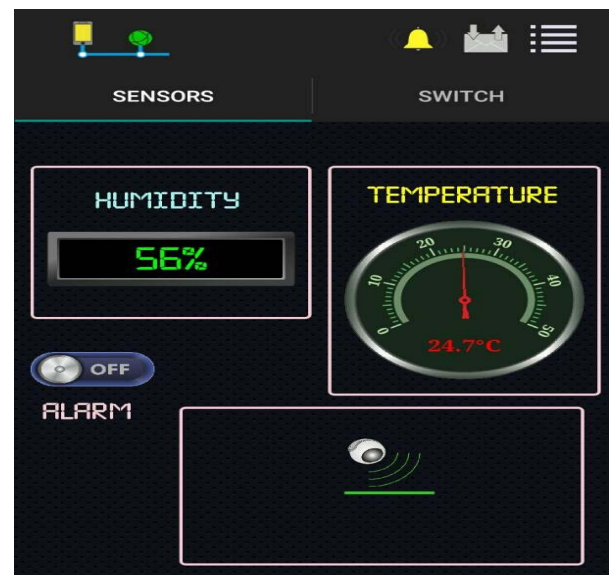Fig. 11. Developed user interface for switching using Virtuino

Fig. 12. Condition of humidity, temperature and motion at home

VI. CONCLUSIONS

This research project has proposed, designed and fabricated a low cost Wi-Fi based Automation System for Smart Home prototype using Arduino and Android smartphone. It enables the control all the electrical appliances such as the bulb and fan at home easily and efficiently via Wi-Fi. The sensor can monitor the motion, humidity and temperature of the house. Buzzer will be ON when there is a motion detected in the house. The Smart Home Automation System provide a comfortable, intelligence, good security and improve the quality of life. By using this smart home system, electric bill can be reduced because the user can control the electrical appliances anytime without using human energy.

The next step of our research will be enabling the remote control of the developed system based on IoT concept so that the user can control it using webserver even when they are not around their house. We are going to increase the number and variety of sensors for more safety and security in addition to provide option for the fully-automated of home appliances. We will implement a gateway to connect all sensors to an IoT platform and we may replace some sensors with a wireless sensor to overcome some wiring problems. Our final product should be a compact box which is easy to be integrated to an existing switching board of real houses appliances via relay board and provide safer control.

ACKNOWLEDGMENT

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