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Smart Home Control by using Raspberry Pi & Arduino UNO

Hamid Hussain Hadwan [1], Y. P. Reddy [2]

M.E. Student, Mech. Mechatronics, SCOE, Pune, India[1]

Professor in Mech., SCOE, Pune, India[2]

Abstract: This paper presents a flexible and an inexpensive home control and monitoring system by utilizing network based on Raspberry Pi and using Arduino Microcontroller. The interface between the Access Point and switches with IP connectivity for accessing devices and appliances and controlling it remotely will be made by using Android based Smartphone application or server computer. This switch node connected to electrical devices that can be controlled using sensor and remotely controlled through an access point, the Smart Switch system for Smart Home development consists of two major parts that are smart switch device and the access point. The main hardware for this system contain: Raspberry Pi, Arduino Microcontroller, nRF24L0+ Wireless Transceiver, Relay Modules, Gang Switches, Lamps, Plugs, Sensors and Wire Set. Expected outcomes from this system: programming by using Python that comes built-in with Raspbian, Wireless module adapter to make connections between the Arduino Microcontroller and nRF24L0+ Wireless Transceiver.

Keywords: Smart Home, Raspberry Pi, Arduino UNO R3, wireless sensor network, Android, Home Automation.

I. INTRODUCTION

Home Automation is anything that your home does for you that makes living there more enjoyable or productive. A Smart Home appears to apply intelligence to make that happen. Although being able to email your light switch nodes is delightful. After all, you can control it. By providing information about the real world to your house, it is then able to make decisions by itself. This is the difference between a Smart Home and an automated home.

Home-automation, by way of smart devices which sense physical occurrences then translate them into a stream of information, data, maximizes safety, security, comfort, convenience and energy-savings. The building elements of home automation are sensor nodes and Building Management System (BMS). Sensor Web elements, it's used as a part of it, moving a BMS to global level. Thus, home automation can be defined as a mechanism removing human interaction as much as technically possible and desirable in various domestic processes and replacing them with programmed electronic systems.

This system was used to control HVAC (Heating, Ventilation and Air-Conditioning) as well as fire safety, controlled by a central computer. Home automation includes various features for security, surveillance, lighting, energy management, interfaces and software, entertainment appliances, access control.

The home automation system should be easy to operate, as well as providing for easy expansion, according to users' needs and individual budget. It is important the home automation provides for an alternative solution to the reduction of energy consumption, cost expenditure as well as increased convenience [1].

Wireless sensor network technology has emerged as a viable solution to many innovative applications [2].

This paper describes wireless sensor network systems that have developed using open-source hardware platforms, Arduino UNO R3 and Raspberry Pi model B computer. The system is low-cost and highly scalable both in terms of the number of sensor nodes and the type of sensors, which makes it well suited for many applications related to monitoring systems.

The objectives of our Smart Home system are:
To design smart switches by using a low cost embedded system, develop a program for making the system able to monitor and control lights, room temperature, alarms and other household appliances. Also to offer a Smart Home system designed and created by utilizing network based on Raspberry Pi and using Arduino Microcontroller UNO R3 to interface between the Access Point and switches.

II. RELATED WORK

V. Vujović, M. Maksimović [1] has given an example of system development for monitoring and determining the confidence of fire in a building presented shows the Raspberry Pi's power in home automation. Thus the developed Raspberry Pi prototype Sensor Web node is based on RESTful services and constructed in order to build the infrastructure that supports fast critical event signalling and remote access through the Internet to sensor data (the detection of critical events is performed by using fuzzy logic). Both shown client mean for data processing is just one possible way of application. Use Raspberry Pi as a Sensor Web node with the presented approach makes its applications endless.

Sheikh Ferdoush, Xinrong Li. [2] Developed a wireless sensor network system designed with Raspberry Pi, xBee, Arduino and a number of open-source software packages. The system has many features, including compact, low-

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cost, scalable, easy to customize, and easy to maintain, easy to deploy. The Major advantage of this design comes from the integration of the gateway node of Wireless Sensor Network (WSN), database and web server into single compact, low-power, credit-card-sized computer Raspberry Pi.

It can be easily configured to run headless (i.e., without a keyboard, monitor, and mouse). Such a design is used in many environmental monitoring and data collection applications. The xBee module from Digi encapsulates the 802.15.4 radio transceiver with ZigBee protocol stack; it is capable of forming a complex mesh network structure on its own without interference from user application program running on the microcontroller or microprocessor platform. As a result, it has reduced the complication of wireless sensor network system development.

Many researchers presented Smart Home automation by using Arduino microcontroller boards. For example: K. Baraka, M. Ghobril, S. Malek, R. Kanj, A. Kayssi [3] demonstrated the use of Home Automation techniques to design and implement a remotely controlled, highly scalable and energy efficient Smart Home with basic features that safeguard the residents' comfort and security. Their system consists of a house network (sensors and appliance actuators to respectively get information from a house environment and control it). They used an Arduino microcontroller as a central controller that communicates with an Android program, the user interface. They house network brings together both wireless ZigBee and wired X10 technologies, thus making it a cost-efficient hybrid system.

III. SYSTEM DESIGN

The design of this system by using suitable size components, then this leads to make modification in the system by making devices smaller and can fit into the existing switches casting. Hence the price of the components will become less. The figure 2 shows All System architectures.

The System architecture which consists of the main parts:

A. An access point or Base station

It controls all smart switches by using nRF24L0+1 Wireless Transceiver. The Base station consists of Raspberry Pi as shown in figure 2 that can communicate with the internet and transfer data to hosting server or Smartphone. The hosting server can transfer and received the data, then store it in a database. The data from database transfer to web page, on the hosting server to show the data. The web page on hosting server can read and update the database.

The Base station consists of:

Raspberry Pi: For the base station used a credit card sized single board computer Raspberry Pi 1. Figure 1 shows Raspberry Pi 2 B architecture with GPIO connectors. The CPU on the board is an ARM processor, 900 MHz clock speed. CPU performance can be compared to a Pentium II 300 MHz processor.

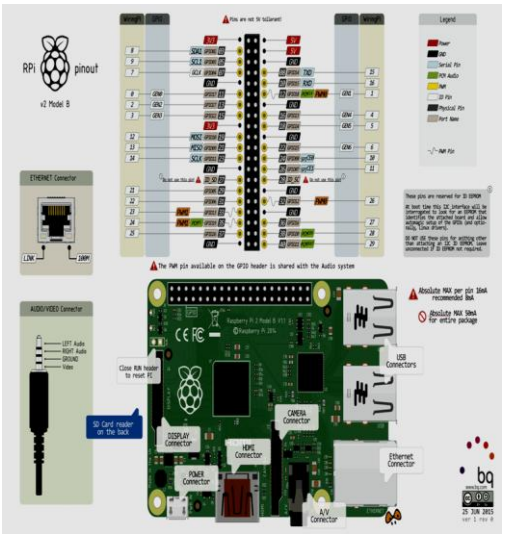

Fig.1. Raspberry Pi 2 B [7].

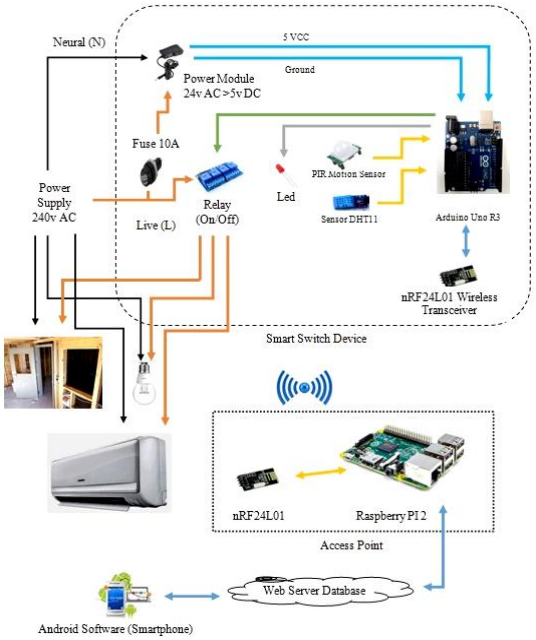

Fig. 2. System architecture

It has a variety of interfacing peripherals, including HDMI port, USB port, 1 GB RAM, SD card storage and 40 pin GPIO port for expansion. Monitor, keyboard, and mouse can be connected to the Raspberry Pi 2 through HDMI and USB connectors and it can be used like a desktop computer. It supports many of operating systems like a Debian based Linux distro, Raspbian which is used in this design. Raspberry Pi 2 can be connected to a local area network by using an Ethernet cable or USB Wi-Fi adapter, and then it can be accessed through remote login. Functional building blocks of the base station, including gateway application, database, and web application [2].

The specification of Raspberry Pi 2 Model B is shown in TABLE I . It runs 6X faster than the B+ with 1GB of RAM that's double the amount of RAM of the previous model. It's equipped with a new ARMv7 quad core processor that's very quick, runs an updated OS, and is compatible with all B+ accessories.

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TABLE II: RASPBERRY PI 2 MODEL B SPECIFICATIONS [8].

Characteristic	Raspberry Pi 2
Processor Chipset	900 MHz Broadcom ARMv7 Quad Core Processor powered Single Board
RAM	1GB SDRAM at 450 MHz
Storage	Micro SD
USB 2.0	4* USB Ports
Ethernet Port	Yes
GPIO	40 pins
Power Draw/ Voltage	1.8A at 5V

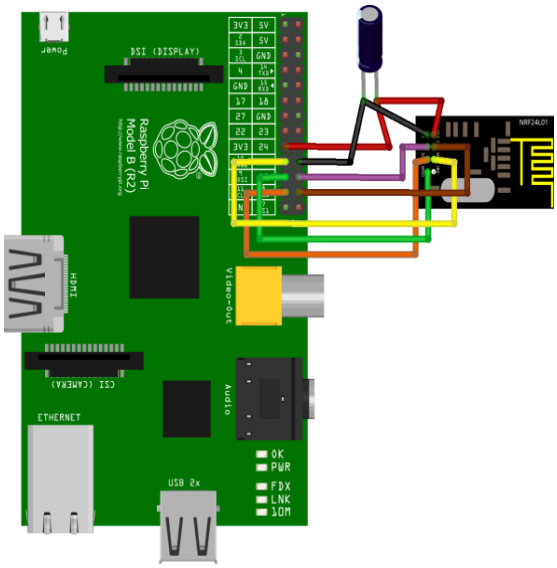

Fig. 3. nRF24L0+1 Wireless Transceiver connects to Raspberry Pi 2

The new Raspberry Pi is backward compatible with almost all your existing Raspberry Pi accessories. Figure 3 shows Raspberry Pi 2 connection to nRF24L0+1 Wireless Transceiver. The table.1 gives a more complete comparison of how the new Pi 2 measures up.

B. The nRF24L0+1 Wireless Transceiver

It is used to transmit and receive data between access point node and appliance node. The nRF24L0+1 is a 2.4 GHz Wireless Transceiver that appropriate for low cost wireless and low power applications. It is operated at 3.3V-5V. The Arduino UNO R3 doesn't have an output pin for 3.3V. A voltage Adapter is used to convert from 5V Arduino UNO R3 output pin to 3.3V that suitable for nRF24L0+1 to operate. This wireless transceiver operates by using ISM frequency at 2.40 GHz – 2.48 GHz. It can be configured and controlled for transfer a data through Serial Peripheral Interface (SPI). The nF24L01 used broadcast to send the packet data. The communication range of this nF24L01 transceiver is 100 meters in open area. The figure 4 shows nF24L01 Wireless Transceiver.

Fig. 4. The nRF24L0+1 Wireless Transceiver

C. The smart switch device

The smart switch device connects the existing wiring of the electrical appliances in a house to transfer power supply for example a lamp and ceiling fan. These devices will get power from the live and neutral wire from house supply. It will convert 240V AC current to 5 DC (Direct Current) by using adapter to give a proper power supply to Arduino UNO R3. The live wire connects to a lamp through a relay. The function of the relay module is like a normal switch that turn "ON" or "OFF" a switch node. A detection system consists of sensors as input while light emitting diode and relay as output of Arduino UNO R3 a smart switch device can be connected to four infrared detection systems that can control four electrical devices in a house. That means one infrared detection system can control only one electrical device.

D. The Arduino UNO R3

The Arduino UNO R3 is kind of a microcontroller board based on the ATmega328 as shown in figures 5 and 6. The ability of the Arduino UNO R3 to communicate with the Raspberry Pi gives us flexibility in the types of devices that we can add. It has 14 digital input/output pins which 6 of them can be used as PWM outputs, 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, an ICSP header, a power jack and a reset button. It contains almost everything we need to support the microcontroller. Simply connect the Arduino UNO to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Arduino UNO R3 is different from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 has been programmed as a USB to serial converter. Figure 5 shows the Arduino UNO R3 connection to NF24L01 Wireless Transceiver [4].

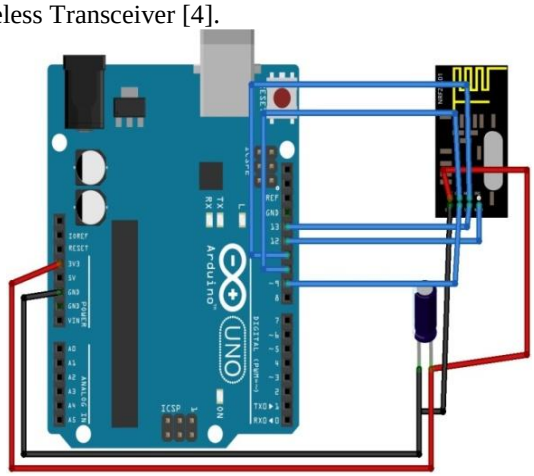

Fig. 5. nRF24L0+1 Wireless Transceiver connects to Arduino UNO R3

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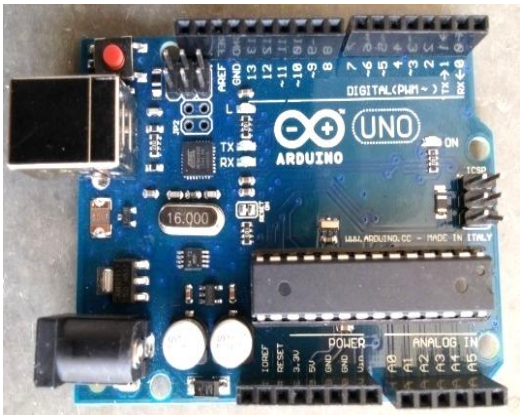

Fig. 6. Arduino UNO R3

TABLE IIII: TECHNICAL SPECIFICATIONS OF ARDUINO UNO R3 [4].

Microcontroller	**ATmega328P**
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) Of which 0.5 KB used by the boot loader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

E. PIR Motion Sensor

PIR sensors allow you to sense motion as shown in figure 8. It used to detect whether a person has moved in or out of the sensor's range. They are small, inexpensive, low power, easy to use, pretty rugged, easy to interface with, and it has a wide lens range. Therefore, they are commonly found appliances used in homes or businesses.

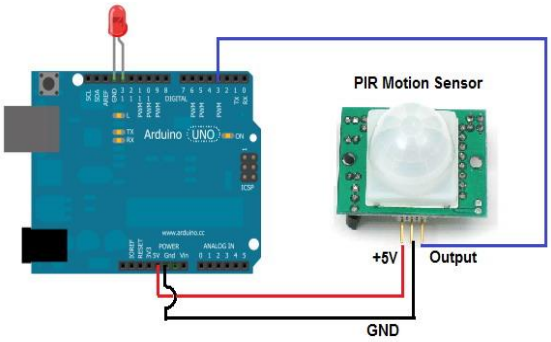

Fig. 7. Connection Circuit of PIR Motion Sensor

That need to detect when a person has entered or left the room or the house, or have approached, PIR sensor sends signal to the Arduino UNO to turn on or off lights, electrical fan or alarm system [5]. We have used it in our system to turn lights on or off. Figure 7 shows a PIR sensor connection circuit to Arduino UNO R3.

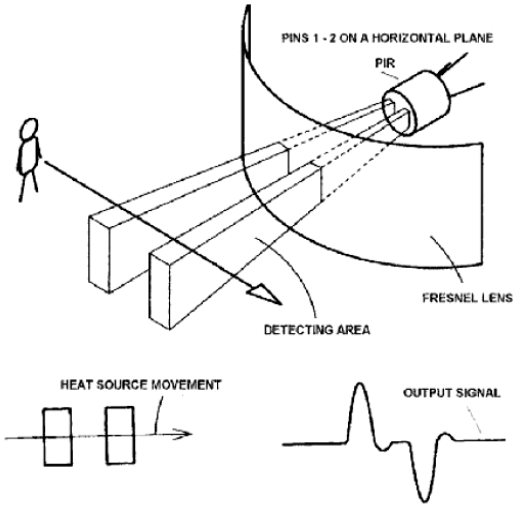

Fig. 8. The Motion Detection by PIR Sensor within the system.

F. Temperature and Humidity Sensor

DHT11 digital temperature and humidity sensor is a composite Sensor contains a calibrated digital signal output of the humidity and temperature.

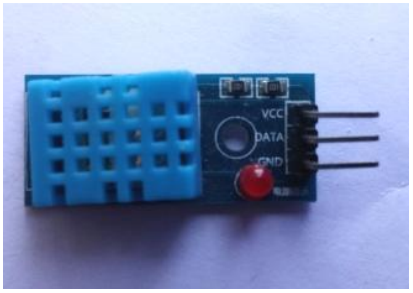

Fig. 9. Temperature and Humidity Sensor

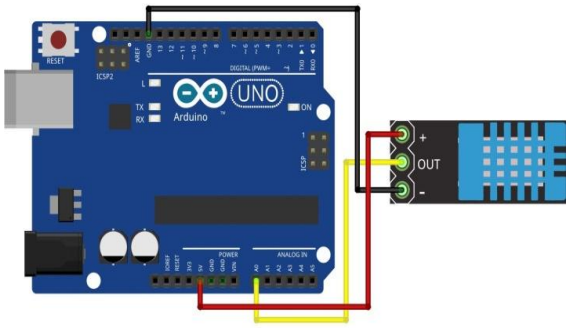

Fig. 10. Connection Circuit of Temperature and Humidity Sensor

The product has high reliability, excellent long term stability, the range of humidity measurement: 20% to 95%, its humidity measurement error: 5%, the range of its temperature measurement: 0-50, measurement error: 2 degrees, operating voltage 3.3V-5V and digital output. The sensor includes a resistive sense of wet components [6]. It connected with an Arduino UNO R3 as shown in figure 10.

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G. Relay Module

The relay module has used to control the appliances by turn it ON or OFF. It's controlled by an Arduino UNO R3 microcontroller. This relay module used 5V to operate and already provided by the microcontroller. The type of relay chosen is a four channel relay module as shown in figure 11 because of compatible voltage to operate with microcontroller and low cost. The LED also arranged across the relay and it will light up when the relay is turned ON to indicate the status of the relay. The relay module connected with an Arduino UNO R3.

Fig. 11. Relay Module

IV. SOFTWARE DESIGN

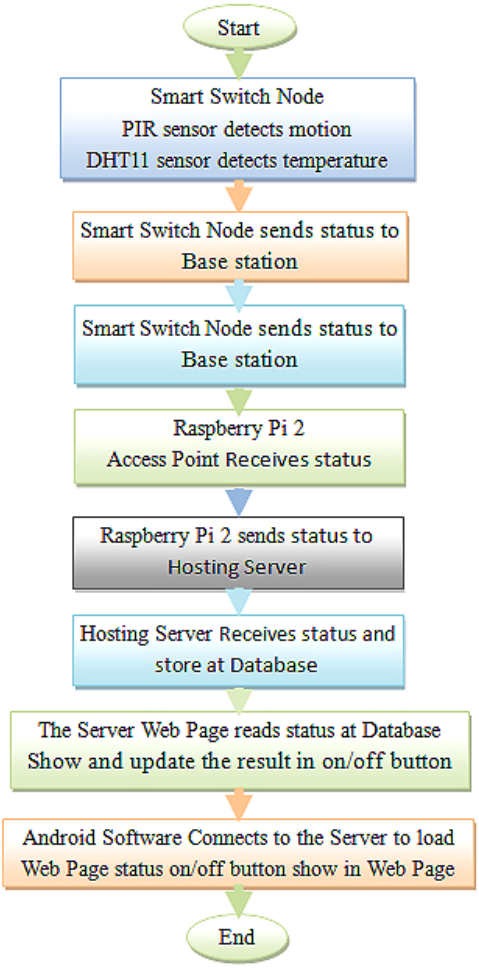

Fig. 12. Flow chart for smart switch node sends status to Android app.

The design of Software for development an embedded system is essential. The hardware needs to be programmed using specific software to make the embedded system work. Figure 12 shows the flow chart for smart switch node sends status to Android app. The name smart switch node is used because it is also the name of address for smart switch device. Figure 15 shows a flow chart for Android application sends status to smart switch node.

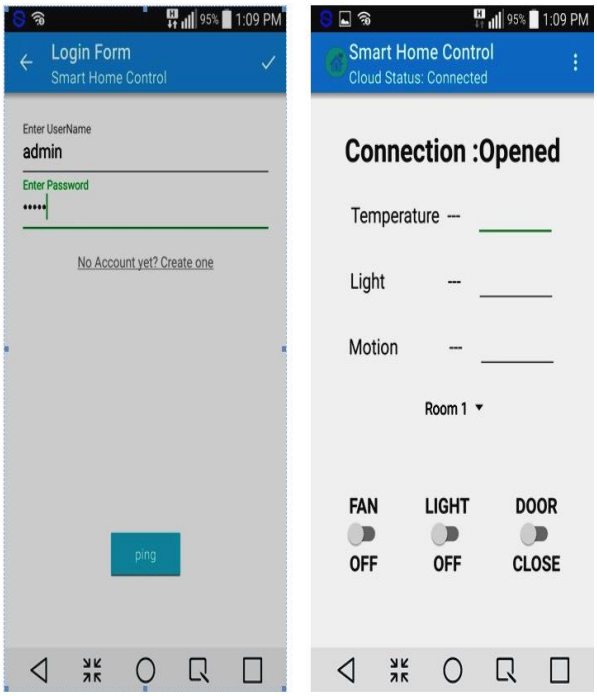

Fig. 13. Screenshots of Login and Room 1 Control of the smart home application.

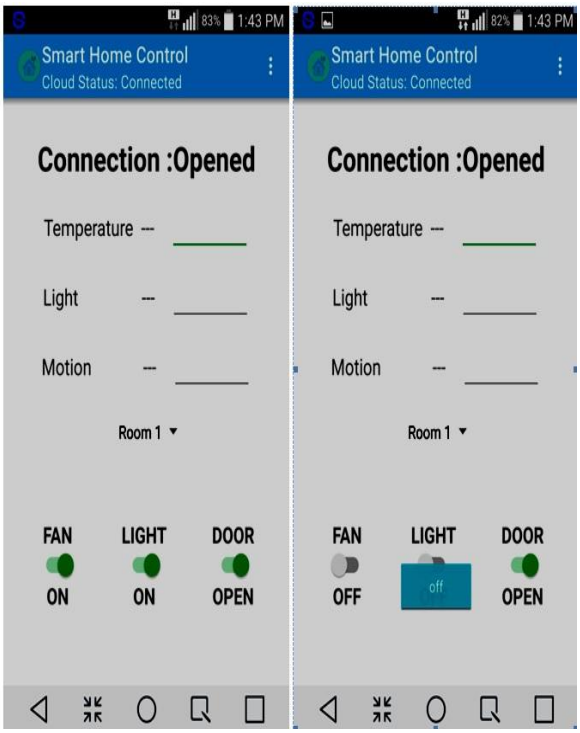

Fig. 14. Screenshots of Room 1 Control ON/OFF of the smart home application.

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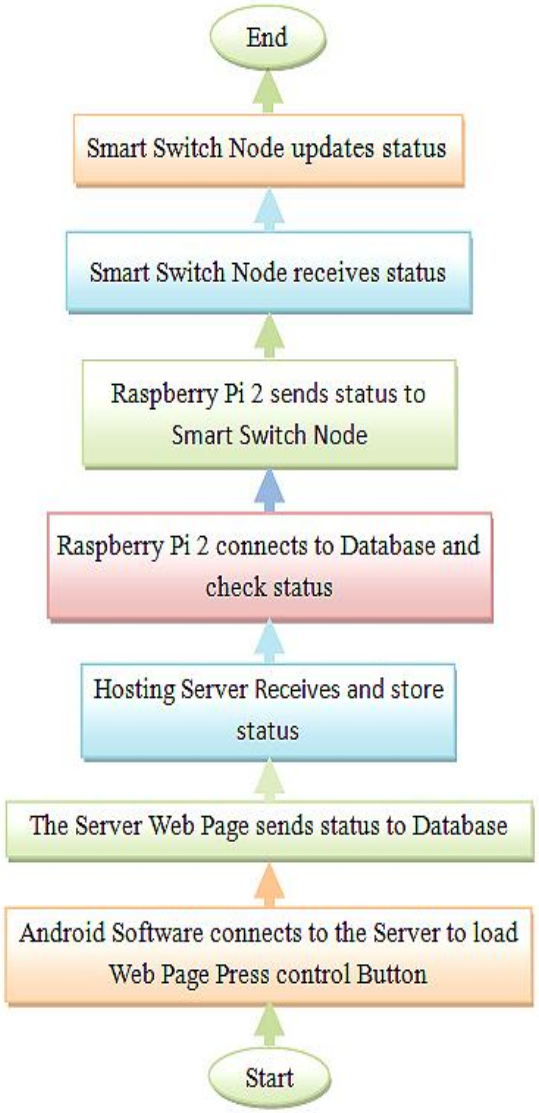

Fig. 15. Flow chart for Android app sends status to smart switch node.

V. RESULT AND SPECIFICATIONS

The user's application program runs on the microcontroller or microprocessor platform. As a result, it better significantly reduces the complexity of wireless sensor network system development as shown in figures 13,14. The detailed design and measurement results presented in this paper declare the usefulness of such a system.

As future work, the system design presented in this paper can be expanded in a number of different aspects. For example, additional sensing modalities can be integrated with sensor nodes to achieve the needs of various monitoring applications. Also, the web interface can be developed for implementation more functionality in data visualization, management, and analysis to provide better interface and experience to the user. Considering the limited storage space on the Raspberry Pi, it is also useful to use a second database server on the Internet or in the cloud storage service, and then upload and/or synchronize the database between the two data storage servers.

V. CONCLUSION

A Smart Home is an expression used to define a home that has highly advanced automatic systems for temperature, lighting control, security, multimedia, windows and door automation and many other functions. A wireless sensor network with Arduino UNO R3, Raspberry Pi, and a number of open-source software packages has a number of attractive features including compact, low cost, scalable, easy to customize, easy to deploy, and easy to maintain. One major advantage of the design lies in the integration of the node of wireless sensor network, database server, and web server into one single compact, low-power, small size computer Raspberry Pi, which can be easily configured to run (i.e., without monitor, keyboard, and mouse). Such a design is useful in many monitoring and data collection applications.

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BIOGRAPHIES

Hamid Hussain Hadwan is research M.E. Mechanical Engineering, Mechatronics degree at SCOE college, Savitribai Phule Pune University, received B.Sc. Degree from the department of Mechanical engineering, University of Babylon – Iraq, interest is in the research areas of Home Automation, Robotics, Microcontrollers, Smart Home Control System and database management systems (DBMS).

Y. P. Reddy, Professor in Mechanical engineering department and Head of PG Studies of Sinhgad College of Engineering, Ph.D. (Mechanical Engineering), Member of Senate, Board of Studies, Local enquiry committee, Faculty of Production and Industrial Engineering at Savitribai Phule Pune University, Area of Interest: Manufacturing systems, Petrinets/Max Plus algebra, Production Management, Fracture Mechanics, and Manufacturing Process.