International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 11 (2017) pp. 2731-2737

Towards the Design and Implementation a Smart Home Automation System Based on Internet of Things Approach

***Mohamed S. Soliman[1,2], Majed O. Dwairi[1,3],Iman I. M. Abu Sulayman[1], Sami H. A. Almalki[1]**

[1]Department of Electrical Engineering, Taif University, Taif, Kingdom of Saudi Arabia.
[2]Department of Electrical Engineering, Faculty of Energy Engineering, Aswan University, Aswan, Egypt.
[3]Department of Communication Engineering, Faculty of Engineering Technology, Al-Balqa' Applied University, Jordan.
****ORCID: 0000-0002-1899-0896***

Abstract
This paper presents a design concept for smart home automation system based on the idea of the internet of things (IoT) technology. The proposed system has two scenarios where first one is denoted as a wireless based and the second is a wire-line based scenario. Each scenario has two operational modes for manual and automatic use. In Case of the wireless scenario, Arduino-Uno single board microcontroller as a central controller for home appliances is applied. Cellular phone with Matlab-GUI platform for monitoring and controlling processes through Wi-Fi communication technology is addressed. For the wire-line scenario, field-programmable gate array (FPGA) kit as a main controller is used. Simulation and hardware realization for the proposed system show its reliability and effectiveness.

Keywords: Smart Home; Arduino-Uno; Matlab-GUI platform; Manual mode; Automatic mode; FPGA

INTRODUCTION

Recently, man's work and life are increasingly tight with the rapid growth in communications and information technologies. Internet of things (IOT) concept will cause a revolution in informational society which will reflect on the human being's way of life as well as challenged the traditional residence. Followed by the rapid economic expansion, living standard keeps raising up day by day that made the people have a higher requirement for dwelling functions. The modern society brings varied information where safe, comfortable and convenient life has become the ideal for new technology end-users. For that, the internet of things technology becomes a hot research topic especially it will become the main feature for the coming 5G communication technology [1-4].

It is will know that the concept of smart home has focused the attention of researchers, lifestyle practitioners, and the consumers to be directed forward the usage of the recent technology. Considerable efforts have been made to the development of remote control systems for home automation. The earlier work of such systems are mainly based on the use of phones, such as a phone-based system for home automation using remote controlling some of them based on a personal computer approach[5,6]. These kinds of systems which make use of the phone as the remote control input device have some way to be connected through any user interface. The proliferation of telecommunications technology has made most of recent home automation scenarios focus on using wireless communication to communicate the home appliances.

The concepts of modern smart home are referred to the home automation systems which are designed based on deferent technologies. One of the modern designed systems work with the new wireless technologies like a Bluetooth, GSM, RF Zig-Bee ,…etc for remote control household devices [7-13]. It has a limit for the area of home control.

Pavana H. in [14] was used the PLC to build the monitoring and controlling system by sending the data based on wireless device. R. A. Ramlee in [15] has introduced the idea of using Bluetooth wireless technology as a cable replacement that exploited the wireless interconnectivity which can be implemented using android system to control the home devices. Nausheen Belim in [16] has designed a home automation system that used switch ON and OFF to get the status of the home appliances by using computer based on Zigbee wireless technology. System that uses a GSM-Bluetooth based controller and remote monitoring system is proposed in [17]. This system is scalable and permitted any number of different appliances to be added with no major changes in its core. But this system is not efficient in some situations that required strong real-time applications. Carl et.al. in [18] has proposed a cost effective and flexible automation system that implemented through FPGA controller and mobile phone Bluetooth network. This method provides a parallel implementation of hardware results using fast algorithm execution. A WiFi based automation system is also implemented in [19] where a microcontroller and WiFi technology for appliances remote control have been used. They showed that from point of view of the scalability and flexibility are better than those methods using the commercially available home automation systems. Zhang et.al. in [20] showed that a home automation system based on electric power communication (PLC) that uses household electric wire for communication and internet control with logging facilities. Although this system procedure overcome the shortcomings of communications techniques, but still need some improvement. Some of them use the PC as interface of the system which is limiting the using for find the PC to run the system [21]. A.J Patilin [22] discusses the approach of real-time system development using the LabView platform. The system can monitor the home devices. Sandeep Kumar in [23] design the application of AI is limited as most of the part can be designed and implemented using some electronic circuit which make this system is more complicated.

Sharon Panth discusses the home automation system using Android for mobile phone based on the inbuilt Bluetooth facility which referred us to the limitation in use area [24]. Investigated the problem of cost- effectively arranging network objects to form a green IoT by proposing a novel deployment scheme for achieving green networked IoT. Experimental analysis for energy consumption and smart location-based automated energy control framework designs resulting creating an intelligent home space, and low cost ubiquitous sensing system [25-27]. In [28] presented and analyzed object group localization in IoT scenarios using object group mobility OGM to increase location accuracy and reduce the consumption of network resources. Arduino modules with Smartphone was used to implement some controllable devices by raising the smartphone to point to a device, the phone's screen automatically pops out on the control panel of the device, the scheme was evaluated through simulation and hardware implementation successfully[29]. In [30], an evaluation study based on the ability of users to install their own smart home in a box (SHiB) is proposed. The results show the effectiveness and limitations of the proposed SHiB design. In [31], the load balancing and the related IT architecture for monitoring and controlling of distributed smart grad energy systems are based on the smart metering and smart home technologies.

Based on all the preceding materials, a design concept for a smart home automation system is proposed. The system has two scenarios where first one is a wireless based and the second is a wire-line based. Each scenario has two operational modes for manual and automatic use. An Arduino-Uno single board microcontroller as a central controller for home appliances is applied for the proposed wireless scenario. Cellular phone with Matlab-GUI platform for monitoring and controlling processes through Wi-Fi communication technology is addressed. For the wire-line scenario, field-programmable gate array (FPGA) kit as a main controller is used. To support our claim, Simulation and hardware realization for the proposed system is developed to verify the effectiveness and the limitations of the proposed system.

The remainder of this paper is organized as follows: section 2 describes the design aspects of the proposed wireless smart home automation system. The system hardware implementation and its results are presented in section 3.Section 4 introduced the proposed wire-line scenario. Finally, the conclusions of this paper are reported in section 5.

WIRELESS SCENIRO

The core of the proposed wireless smart home automation system consists of two main hardware components: the PC home main server and the Arduino uno microcontroller board which introduce a variety of digital and analog inputs, serial interface and digital and PWM outputs. It is connected and communicated with the PC through a USB cable. Also, it has free software. The architecture of the proposed system is shown in figure 1. A PC home includes the Matlab-GUI platform management and Arduino uno control algorithm that enables the user to remotely access the home appliances through cellular phone. Some appliances and sensors are connected to ports of the microcontroller board. The home Appliances can be monitored and accessed remotely by user cellular phone.

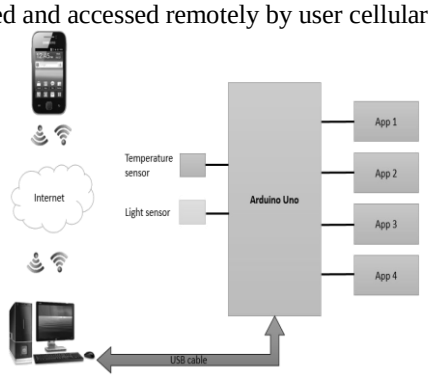


Figure 1. Proposed wireless home automation system architecture.

The proposed two operation modes of the system can also manage by using a designed Matlab-GUI interface which is appear in the screen of mobile phone and allow any user to control the home devices from any place of the world and in any time. The Arduino uno kit added to the system many advantages because it connect to computer by USB cable , one of these advantages is cheaper than a lot of electronic devises control , easy to program, variety of digital and analog inputs/outputs give the designers more idea to develop and increase the system applications.

Figure 2 and 3 illustrate the flow chart diagrams for the program implemented in Arduino uno kit microcontroller. The flows chart in figure 2 shows the automatic scenario which the arduino uno kit will manage and process the home devices by using the signals which is coming from sensors. In this scenario the user can only monitor the system from Matlab-GUI in the screen of his mobile phone.

The second flow chart shown in figure 3 for the manual mode, In this case the user can manage and monitor the home devices by selecting the device from Matlab-GUI and turn ON/OFF, the arduinuo uno kit in this scenario will detect the status of the home devices to inform the user about the device condition.

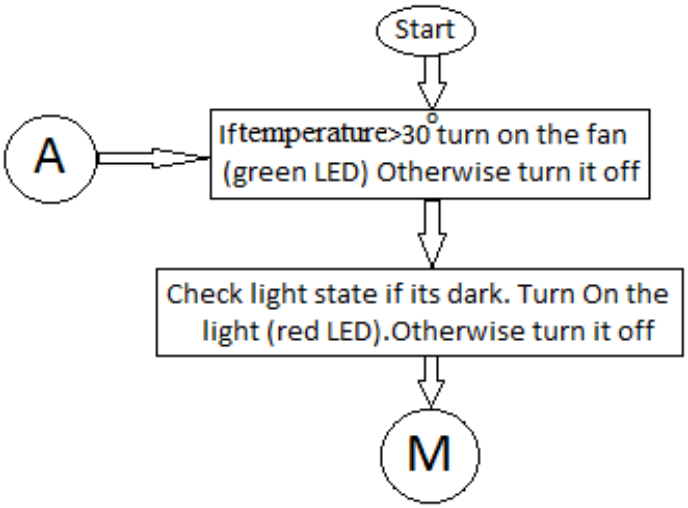


Figure 2. Flow chart for the proposed automatic mode.

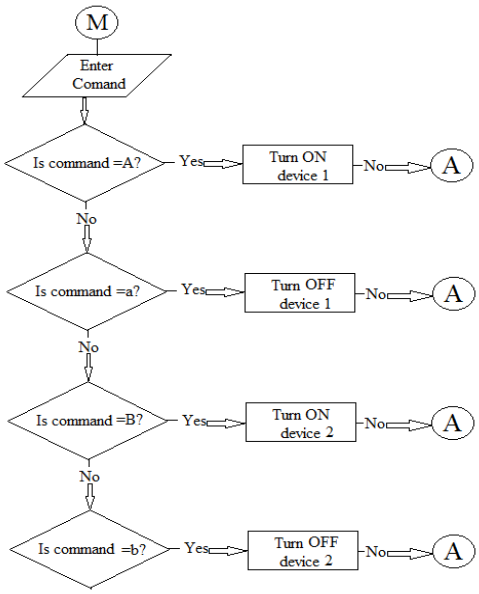


Figure 3. Flow chart for the proposed manual mode.

HARDWARE IMPLEMENTATION

To validate the performance of the proposed system a hardware implementation is done.

1. Manual-mode implementation:-

In figure 4, the hardware implementation for manual mode is illustrated. For any home device the user can remotely control it by using ON or OFF buttons in Matlab-GUI software interface which is appear in mobile screen.

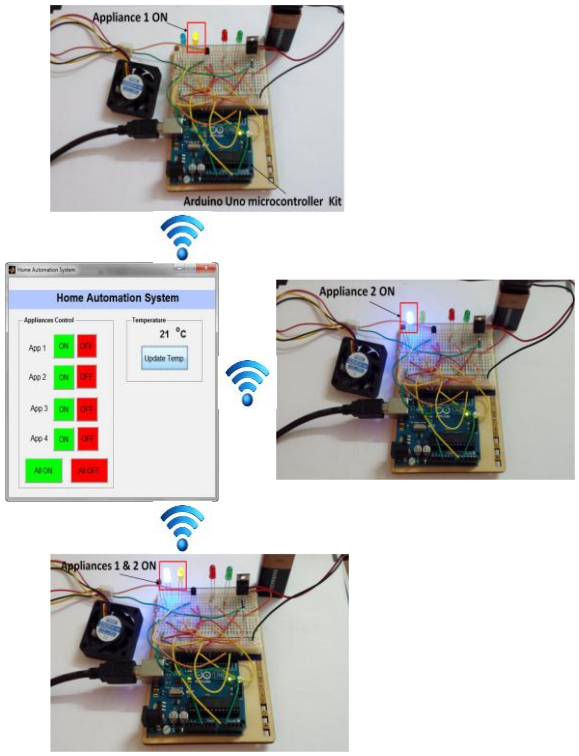
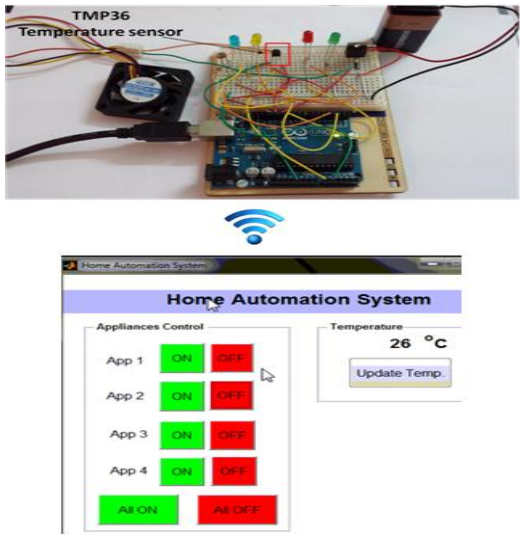


Figure 4. Proposed system manual scenario scheme.

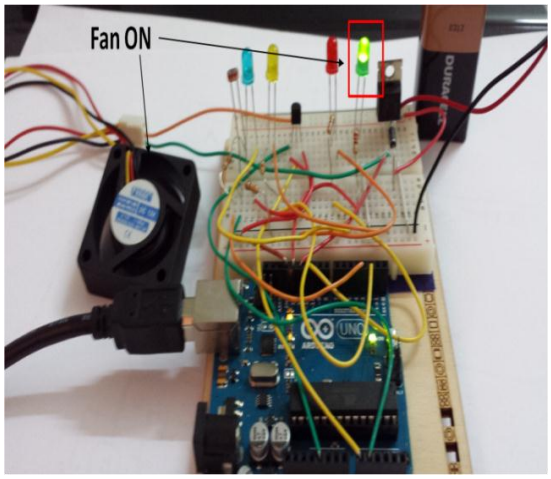
2. Automatic –mode implementation :-

In figure 5, the hardware implementation for automatic mode is illustrated. The automation of the home devices is controlled by arduino uno kit based on the signals which is coming constantly from the sensors. Two home devices is taken and implement as examples.

The first one is the cooling system in the house. The suitable electronic sensor for this case is TMP36 temperature sensor. In the Arduino Uno kit programming the temperature is setting up to be down of 30ºC, when any factor change the temperature of the home the main controlling item " Arduino Uno kit " will take the suitable decision to stay the temperature in 30ºC. For example, if the temperature increase above of 30ºC the suitable decision here to turn ON the fan to reduce the temperature. In other hand, if the temperature decrease blows the 30ºC the suitable decision is to turn OFF the fan to raise the temperature. See figure 5.



(a)



(b)

Figure 5. Temperature automatic mode system.
a. temperature is below of 30ºC,
b. temperature is above of 30ºC

The second one is Lighting system in the house; Light Dependent Resistor (LDR) is detecting sensor for the light state which is selected in this case. The LDR helps the Arduino Uno kit to detect the light state at home by sending the signal constantly for make a good deal with the state light. In other words, when the dark occur at home the light system at home will turn on by Arduino Uno kit and vice versa with the light state and the good deal from Arduino Uno kit. See figure 6.

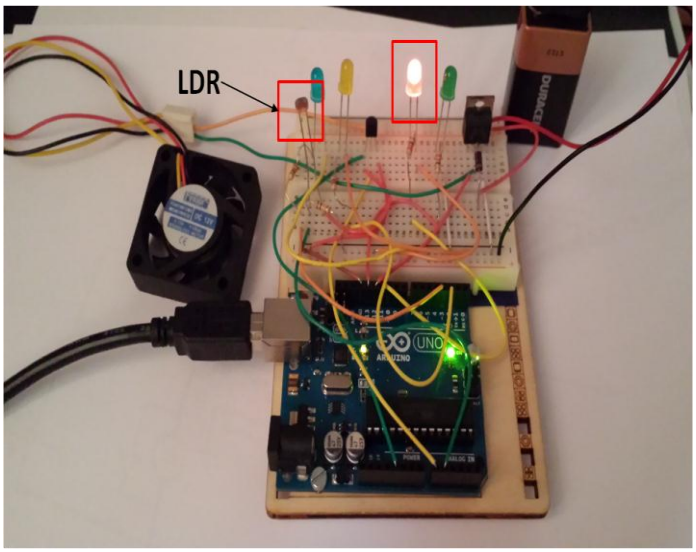


Figure 6. Light automatic system.

WIRE-LINE SCENARIO

This section describes the complete wire-line based home automation system operating in two different modes; manual mode and self-automated mode. The block diagram of the system developed is shown in figure 7. It includes an open phone call line circuits, dual tone multi-frequency (DTMF) or touch-tone circuit, Feedback tone circuit, a central FPGA controller that communicates with all elements through interfacing circuits, and a number of appliances and sensors connected to the FPGA.

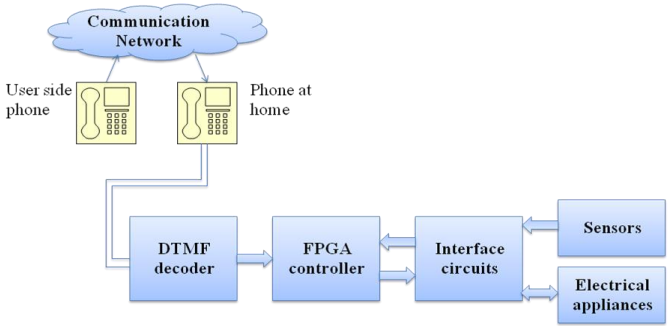
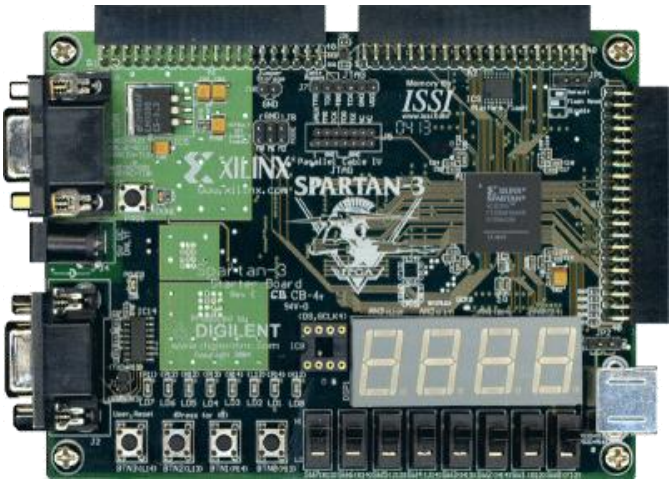


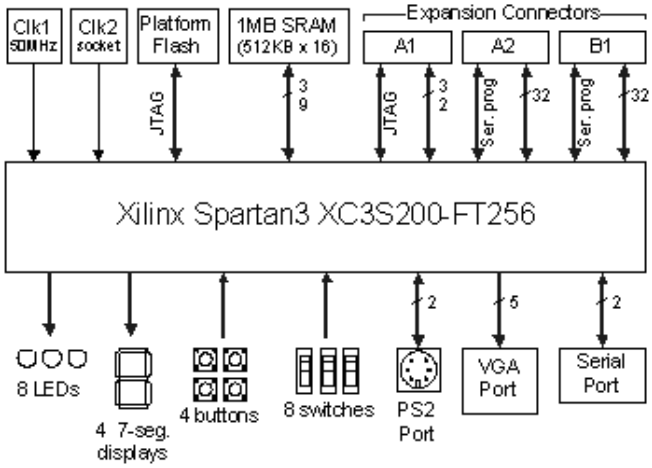
Figure 7. Proposed block diagram of the wire-line automation system.

DTMF as the name suggests uses a combination of two sine wave tones to represent a key. These tones are called row and column frequencies as they correspond to the layout of a phones keypad. It is used to select the modes also for monitoring and controlling the devices in manual mode.

The proposed system can be implemented on the XILINX FPGA kit [32] by using the VHDL code. FPGA is a device that contains a matrix of reconfigurable gate array logic circuitry. When an FPGA is configured, the internal circuitry is connected in a way that creates a hardware implementation of the software application. One of the primary means for programming FPGAs is VHDL (Very High Speed Integrated Circuit hardware description language). In VHDL, a design consists at a minimum of an entity which describes the interface and an architecture which contains the actual implementation as shown in figure 8.



(a)



(b)

Figure 8. FPGA kit.
a. Real kit, b. Block diagram of the kit

1. The manual mode

The appliances in home are remotely controlled using phone calling or voice calling. The user can control the devices by using DTMF system as shown in figure 9. The user can set the system in manual mode (mode 1) and identify the password of the system by calling the home telephone number, after that he will hear the feedback tone to enter the password (4 digits),

If the password is correct, the correct action (confirmation) tone will be heard. Otherwise, the failed action tone will be heard. Then the password needed to be re-enter again (maximum three trials are allowed).

If the password is accepted then enter the number of the appliance to be controlled, after hearing the feedback tone the status of the device will be defined. To control another appliance, the related telephone keypad number for each appliance need to be known. The number for each appliance is arranged as in table 1.

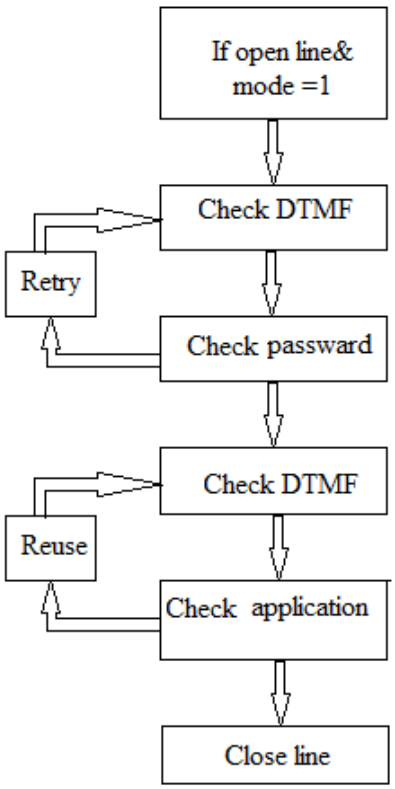


Figure 9. Manual mode.

Table I. THE ARRANGEMENT OF THE APPLIANCES ACCORDING TO THE TELEPHONE KEYPAD NUMBERS.

Appliance	Number
Air condition	0
Open door sensor	1
Security alarm (On)	2
Home light (On/Off)	3
Light /Dark sensor	4
Smoke alarm	5
Baby cry sensor	6

2. The Self-automated mode

In case of the self-automated mode, the system needs to be set for mode 0. In such a case, the appliances are automatically controlled. The self-automated mode process is shown in figure 10. Table 2 illustrates the action and reaction processes for such cases.

Table II. MODE (0) ACTIONS AND REACTIONS

Action	Reaction	
High temperature	Air condition	ON
Low temperature	Air condition	OFF
Smoke detection	Smoke alarm	ON
Water detection	Alarm	ON
Light detection	Home light	OFF
Dark detection	Home light	ON
Open door detection	Open door alarm	ON

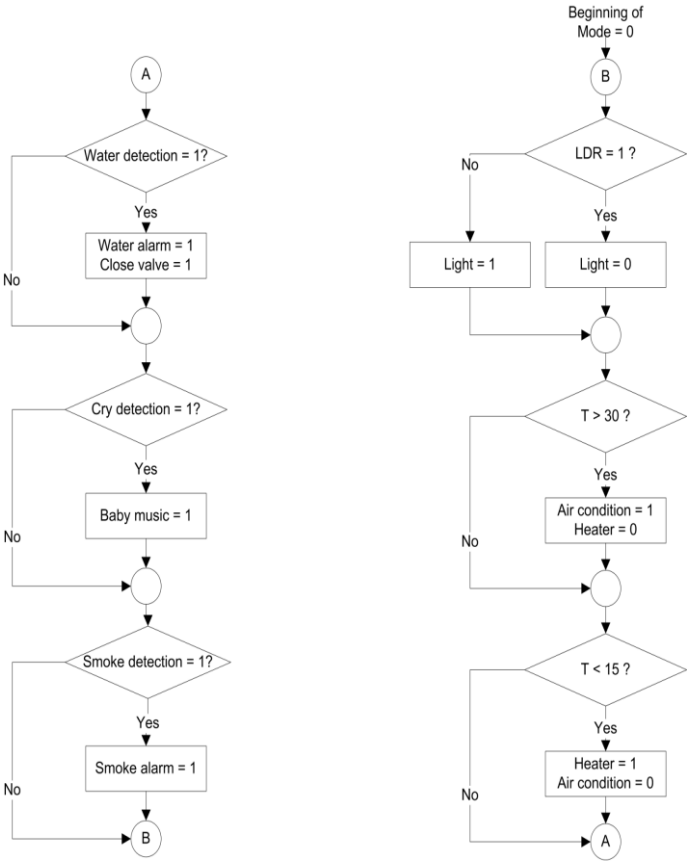


Figure 10. Self-automated mode.

The Very High Speed Integrated Circuit (VHSIC) Hardware Description Language (VHDL) code is developed to model the proposed home automation system (mode 1 and mode 0).VHDL test beches were designed to test all the developed VHDL code to verify the correct operation of the designed system. The timing diagram for each mode self and automatic is obtained as simulation for the VHDL code of the proposed system. For the self automated mode simulation the system will control the household appliances automatically by the response signals which come from the sensors as illustrated in the simulation of figure 11.

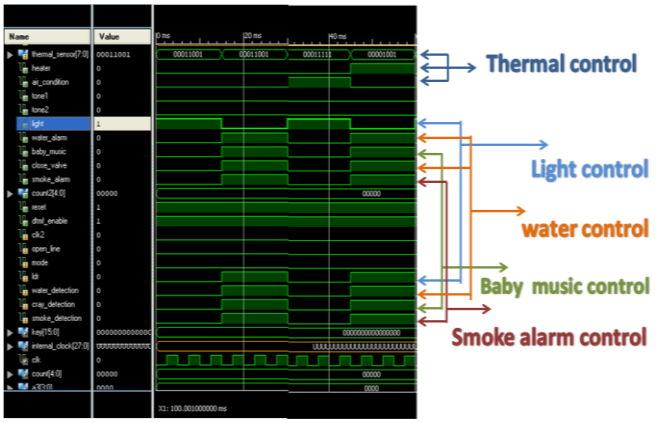


Figure 11. Self automated mode timing diagram.

The other hand of the system can be take place in simulation by the timing diagram for the VHDL code. By one security user condition, the password was entered successfully from user as considered. The manual mode simulation timing diagram gives the concept of the user control for the system by the keypad of the phones or telephone land. For example, the thermal option is consider as 4 number in the keypad. Also the numbers 1 and 2 in the keypad of the phones is consider as on and off respectively for the appliances status control. As the note is seen in the figure 12 when the DTMF of the key pad equal to 4 the system is ready to receive the command on or off from the user (1 or 2). The user can monitor the temperature before taking the decision to run or stop the air condition. By the tone 1 and 2 the user knows the temperature level. If the temperature level above 30 C° degree, the tone 1 will be on (1). Otherwise the tone 2 will be on (1). After that the user can take the right decision to press 1 or 2, in other word to run the air condition or to stop it. If the user press 1 the air condition will be on (1). Otherwise the user presses 2 and the air condition will be off (0).

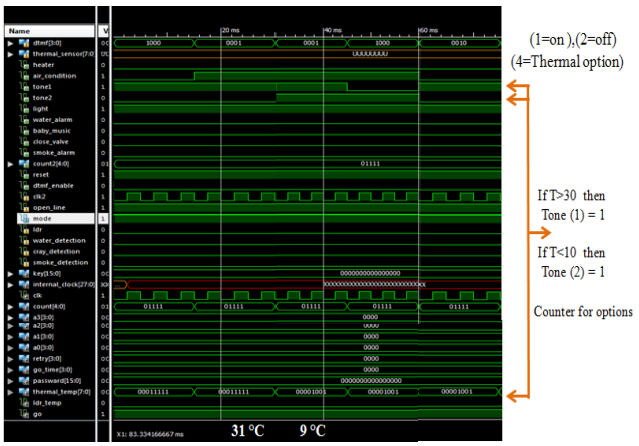


Figure 12. Manual mode timing diagram.

CONCLUSION

In this paper, a design concept for smart home automation system based on the idea of the internet of things (IoT) technology has been obtained. The proposed system provided two scenarios where first one was a wireless based in which users can monitor and control their home appliances from anywhere over the world using cellular phone through Wi-Fi communication technology. The second scenrio was a wire-line based which depend on the land-telphone line potrocal. Each scenario has two operational modes for manual and automatic use. Simulation and hardware realization for the proposed system show its reliability and effectiveness. The implemented system was a simple, low cost and flexible that can be expanded and scaled up. A future improvement can be added to the proposed system using wireless sensor technologies. The proposed system can be developed and fabricated as a commercial hardware package.

REFERENCES

[1] A. Zanella, N. Bui, A. Castellani, L. Vangelista and M. Zorzi, "Internet of Things for Smart Cities," in IEEE Internet of Things Journal, vol. 1, no. 1, pp. 22-32, Feb. 2014

[2] Liu, Chien-Yuan Juang, " A Smart Home Automation System" Proceedings of the 3rd International Conference on Intelligent Technologies and Engineering Systems (ICITES2014) Volume 345 of the series Lecture Notes in Electrical Engineering pp 381-388, Springer, 2014.

[3] Aggarwal, Charu C. , Ashish, Naveen ,Sheth, Amit "The Internet of Things: A Survey from the Data-Centric Perspective -Managing and Mining Sensor Data" pp 383-428, Springer, 2012.

[4] J. A. Stankovic, "Research Directions for the Internet of Things," in IEEE Internet of Things Journal, vol. 1, no. 1, pp. 3-9, Feb. 2014.

[5] Yang, Shuang-Hua,"ZigBee Smart Home Automation Systems- Wireless Sensor Networks": Principles, Design and Applications, Springer-Verlag London 2014.

[6] Amirah Aisha Badrul Hishama, Mohamad Hafis Izran Ishaka, Chan Kok Teika , Zaharuddin Mohameda, and Nurul Hawani Idrisb, "Bluetooth-Based Home Automation System Using an Android Phone," Jurnal Teknologi (Sciences & Engineering), Vol.70, No.3, pp.57–61, 2014.

[7] Mahesh N. Jivani, "GSM Based Home Automation System Using App-Inventor for Android Mobile Phone," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, No. 9, September 2014.

[8] Cong Hui Huang; Yih Feng Su; Yu Tang Su; Wei Hao Su; Jun Jie Chen; Wei Jie Zhou," Design and Application of ZigBee Wireless Techniques for an Intelligent House Lighting Control System" International Symposium on Computer, Consumer and Control,2014, Tiwan PP. 19 – 22,2014.

[9] Y. Usha Devi, "Wireless Home Automation System Using ZigBee," Affliated to JNTU Kakinada, International Journal of Scientific & Engineering Research, Vol. 3, No. 8, pp. 1-5, August 2012.

[10] Chindujaa.C, Lubisha Mary. J., Ragavee. B., Mr. Sakthi. S., and UG Scholar, "Development Of In-Home Display and Smart home System," International Journal for

Research and Development in Engineering, pp. 532-537, 2014.

[11] V. Sathya Narayanan and S. Gayathri, "Design of Wireless Home automation and security system using PIC Microcontroller," International Journal of Computer Applications in Engineering Sciences, Vol. 3, No. 13, pp.153-140, August 2013.

[12] D.NARESH1, B.CHAKRADHAR2, and S.KRISHNAVENI, "Bluetooth Based Home Automation and Security System Using ARM9," International Journal of Engineering Trends and Technology, Vol. 4 ,No. 9, pp. 4052- 4058,Sep 2013.

[13] S. R. Bharanialankar and C. S. Manikanda Babu, "Intelligent Home Appliance Status Intimation Control and System Using GSM," International Journal of Advanced Research in Computer Science and Software Engineering, Vol. 4, No. 4, pp.554-556, April 2014.

[14] Pavana H., Radhika G., and Remya Ramesan, "Plc Based Monitoring and Controlling System Using Wi-Fi Device," IOSR Journal of Electronics and Communication Engineering, Vol. 9, No. 4,pp.29-34, Aug. 2014.

[15] R. A. Ramlee, M. H. Leong, R. S. S. Singh, M. M. Ismail, M. A. Othman, H. A. Sulaiman, M. H. Misran, and M. A. Meor Said, "Bluetooth Remote Home Automation System Using Android Application," The International Journal of Engineering And Science, Vol.2, pp.149-153, 2013.

[16] Nausheen Belim, Harshada Bhambure, Priyanka Kumbhar, and Simranjit Tuteja, "Automate and Secure Your Home Using Zigbee Technology," International Journal of Innovative Research in Computer and Communication Engineering, Vol. 1, No. 1, March 2013.

[17] Vini Madan and S.R.N Reddy, "GSM-Bluetooth based Remote Monitoring and Control System with Automatic Light Controller," International Journal of Computer Applications, vol. 46, no. 1, pp. 20– 28, May 2012.

[18] Carl J. Debono and Kurt Abela, "Implementation of a Home Automation System through a Central FPGA Controller", 16th Electro-technical Conference (MELECON), IEEE, pp. 641-644, 25-28 March 2012.

[19] Ahmed ElShafee and Karim Alaa Hamed, "Design and Implementation of a WiFi Based Home Automation System", World Academy of Science, Engineering and Technology, Issue 68, pp. 2177-2183, Aug. 2012.

[20] Zhang, Ai-Rong and Zhang, Jin-Lan, "The Building of Home Automation Electricity Distribution System Based on PLC," SMIS 2011, International Conference on Smart Materials and Intelligent Systems, Chongqing, CN, Dec 23-25, 2011.

[21] Abhishek Vichare and Shilpa Verma, "Embedded Web Server for Home Appliances," International Journal of Engineering Research and Applications, pp. 190-193, March 2012.

[22] A.J. Patil, Rajesh R. Karhe, and Mahesh S. Patil, "Real Time System Development for Home Automation using LabVIEW," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, No.4, pp.1213-1219, April 2013.

[23] Sandeep Kumar and Mohammed Abdul Qadeer, "Application of AI in Home Automation," International Journal of Engineering and Technology, Vol.4, No.6, pp.803-807, December 2012.

[24] Sharon Panth and Mahesh Jivani, "Home Automation System (HAS) using Android for Mobile Phone," International Journal of Electronics and Computer Science Engineering, Vol.3, No.1, Jan 2011.

[25] J. Huang, Y. Meng, X. Gong, Y. Liu and Q. Duan, "A Novel Deployment Scheme for Green Internet of Things," in IEEE Internet of Things Journal, vol. 1, no. 2, pp. 196-205, April 2014.

[26] J. Pan, R. Jain, S. Paul, T. Vu, A. Saifullah and M. Sha, "An Internet of Things Framework for Smart Energy in Buildings: Designs, Prototype, and Experiments," in IEEE Internet of Things Journal, vol. 2, no. 6, pp. 527-537, Dec. 2015.

[27] S. D. T. Kelly, N. K. Suryadevara and S. C. Mukhopadhyay, "Towards the Implementation of IoT for Environmental Condition Monitoring in Homes," in IEEE Sensors Journal, vol. 13, no. 10, pp. 3846-3853, Oct. 2013.

[28] S. D'Oro, L. Galluccio, G. Morabito and S. Palazzo, "Exploiting Object Group Localization in the Internet of Things: Performance Analysis," in IEEE Transactions on Vehicular Technology, vol. 64, no. 8, pp. 3645-3656, Aug. 2015.

[29] M. S. Pan and C. J. Chen, "Intuitive Control on Electric Devices by Smartphones for Smart Home Environments," in IEEE Sensors Journal, vol. 16, no. 11, pp. 4281-4294, June1, 2016.

[30] Hu Yang,Tilke Dominique, Adams Taylor ,Crandall Aaron S.,Cook Diane J. ,Schmitter Edgecombe Maureen, "Smart home in a box: usability study for a large scale self-installation of smart home technologies"- Journal of Reliable Intelligent Environments, Volume 2, Issue 2, pp 93–106, Springer July 2016

[31] Kleineidam Gerhard,Krasser Marco,Reischböck Markus,"The cellular approach: smart energy region Wunsiedel. Testbed for smart grid, smart metering and smart home solutions" Electrical Engineering pp 1–6, Springer-Verlag Berlin Heidelberg, 2016.

[32] Web link: https://www.xilinx.com/products/boards-and-kits.html