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Research Article

Towards the development of an energy-efficient smart home through IoT

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Abstract
Smart home is one of the emerging technologies in the Internet of Things (IoT) era that decorates house equipment into being more intelligent, remote controllable, and interconnected. For this reason, researchers have made significant advancement in developing smart home. However, there is scarcity of a complete system in the market that provides a total solution. In this paper, a complete 3-room apartment automation system developed using Arduino, Bluetooth and Android has been proposed. Our proposed system can control several home appliances such as lights, fans, bulbs and many more using on/off relay and android application. The system has been implemented for a 3-room apartment that confirms cost and energy efficient than the manual system which is 28% less in terms of cost.

Keywords
IoT, Smart apartment, Android, Bluetooth, Arduino.

1.Introduction
Currently, we are living in the era of IoT (Internet of Things) where individual to corporate consumers are embraced the revolution brought by the IoT [1]. Around 6 trillion US (United States) dollar is estimated to be spent on the IoT solutions in the next 5 years [2] and every leading global companies are willing to take this advantage by their products and innovative services. For this, they focused on developing smart home, smart traffic management of cities, etc. Among them, smart home is one of the most attractive fields as around 119.26 billion USD are being targeted to earn by the year of 2022 from the global smart home market [3]. Due to huge advantages, people are interested to use the automation system in their home or in their job place that is energy-efficient and can manage common electrical appliances, such as lights, fan, air-conditioner, TV, fridge, etc. easier. For example, running air-conditioners at over 25 degree Celsius alone can save 67,644 US dollars a day in Bangladesh and IoT can ensure that [4].

Though the smart home has a huge market value, but not widely used yet due to lack of smart home infrastructure [5] as well as the ignorance of smart home service adoption also diffusion is considered as barriers [6]. In addition, smart home system faces four main challenges: high cost of ownership, inflexibility, poor manageability and security [7, 8]. Moreover, only a few devices are managed randomly in almost all available solutions.

So, in this work, a complete 3-room automation system is implemented automation using Bluetooth and Arduino that are cheap and reduce cost [9], energy [10, 11] also capable of controlling and managing all the home appliances by an android application via Bluetooth through an easy user interface.

2.Related work
Nowadays, Smart home [12] helps people to enjoy a comfortable living. For this reason, more and more researchers are attracted to work in this area.

Sriskanthan et al. [13] presented a model based on Bluetooth system via a personal computer (PC). They used Bluetooth technology via PC for

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controlling the appliances. The system contains a remote host, but it is unable to support mobile technology.

Piyare and Tazil [14] proposed a home automation system based on wireless and it is a low-cost solution. But only Symbian's cell phone supports this automation. But the Symbian system is now out of the market.

Another design was implemented by Al-Ali and Rousan [15] in the Java platform. However, it is difficult to prove physically such a system as a low-cost one.

With the help of a web server, a device controlling system is developed by Ramli et al. [16]. But server dependency and cost are the main drawbacks of this system.

Erol et al. [17] designed a telephone and PIC-based cabling system which is not really suitable to use.

Another system proposed by Kanma et al. [18] that can be accessed remotely using GPRS. A phone with Bluetooth connectivity that is accessed remotely through GPRS.

Most of the proposed approaches described above are experimental and mainly focused on wireless technology [19]. But Bluetooth is easier to use. This has motivated us to develop a three-room apartment automation system.

3.Existing systems

3.1GSM based home automation system

GSM based system [20] is developed using GSM communication technology. The system controls the home appliances by PIC16F887 microcontroller. The user commands are transferred to a server which is usually done by a PC. The home server generally builds up by the help of an SMS, mobile cell module and microcontroller.

3.2Phone based home automation

Phone based system [18] mainly uses a remote-control system. To transmit a command, this kind of system uses telephone line. The automation system mainly consists of a DTMF (dual tone multi frequency) receiver, an I/O interface unit and a PC.

3.3Wireless control system

Wireless Control System [21] is based on Wi-Fi or Bluetooth based technology. It uses network technology to establish connection with the appliances. The home appliances are controlled via different network technologies.

3.4ZigBee based home automation

ZigBee system [22] is mainly a wireless technology system based on PIC microcontroller and a voice recognition system. Here the system use mike for voice command. ZigBee is a low range communication system, as a result, it cannot be controlled from a far-away location.

3.5Bluetooth based system

Bluetooth based [23] system mainly uses Bluetooth technology to control the home appliances. The system can transmit information across 100 meters. The Bluetooth module is connected to the android application. The Arduino and other sensors are relating with the help of wire.

4.Methodology

4.1Proposed Bluetooth based system

Our proposed system consists of two modules: software module and hardware module. The schematic diagram and the flowchart of the system are shown in *Figure 1* and *Figure 2* respectively. A brief description of the modules is described below.

4.2Functionalities of the system

Our home automation system includes the following functionalities that enable the system beneficial to the users:

- Door control
- Light control
- Fan control
- Television control
- Real time status of appliances

It performs the following operations:

- Fan on/off
- Light on/off
- TV on/off
- Door lock/unlock
- On/off other devices

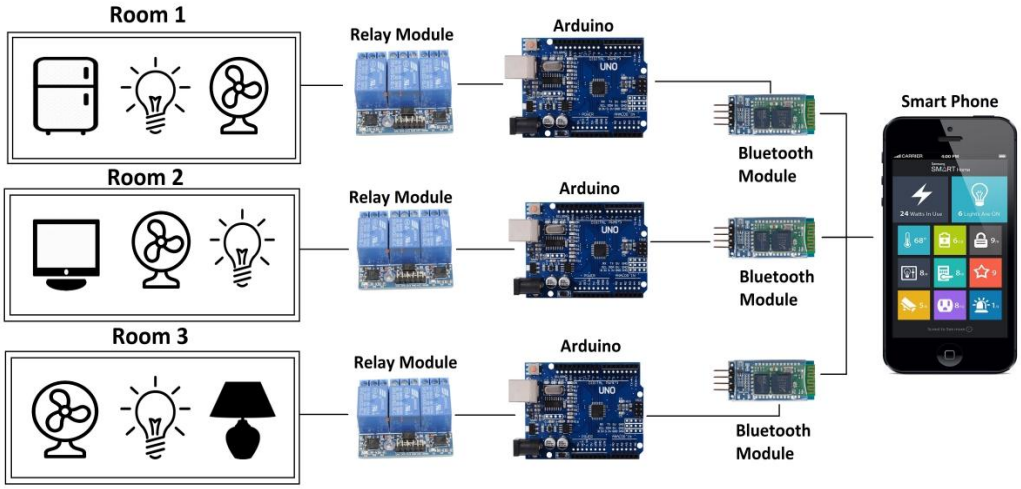

Figure 1 Schematic diagram of the system

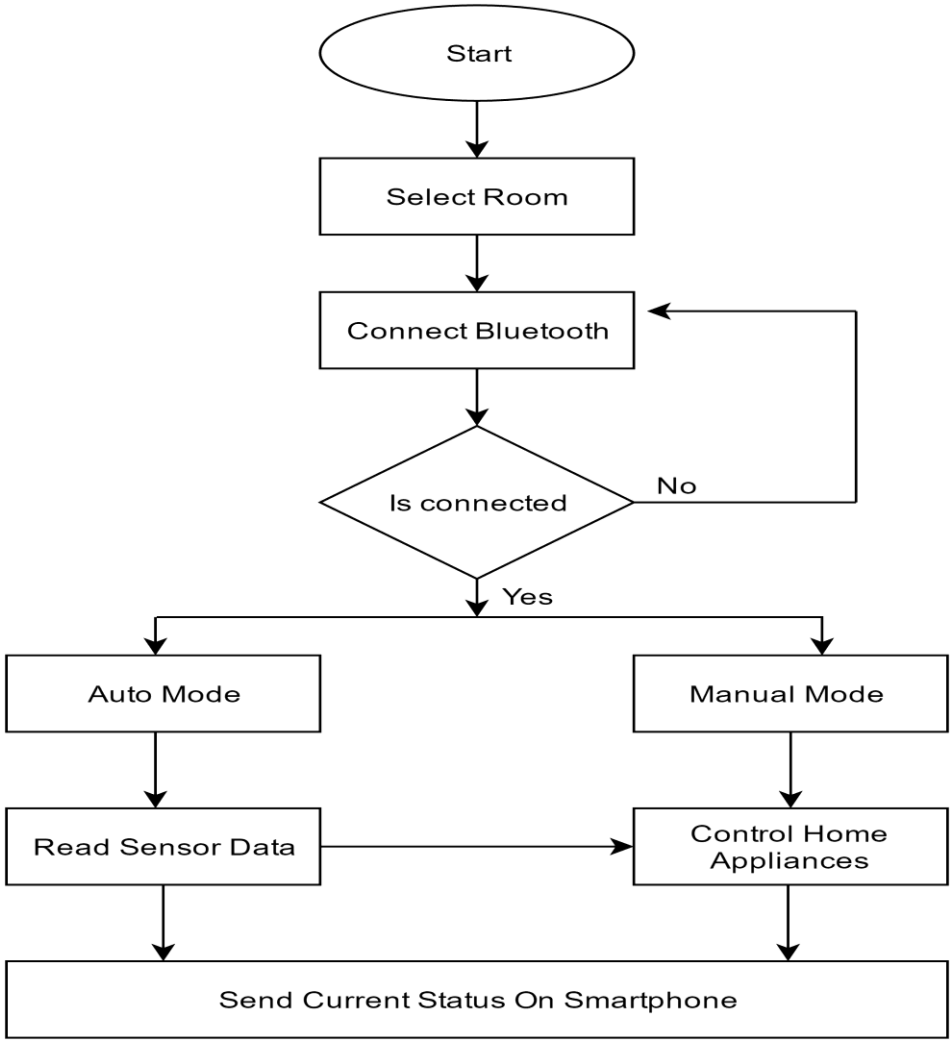

Figure 2 Flow chart of the proposed system

4.3Software module

To operate the system, we develop an android based mobile application. The application communicates with the hardware through Bluetooth network. *Figure 3* shows the graphical user interface that is very user friendly to operate the whole system. The home screen of the application includes room selection button and a side navigation button on the top bar. The side navigation button shows the menu bar for settings and section of the application. By clicking on the room selection button, it expands the layout of the three different room-button for selection. Selecting each room button, it will take to the new page where user can find the Bluetooth connection button and another button for controlling home appliances like light, fan, TV, etc. Also the app includes an auto mode button for automatically starting to manage the appliances.

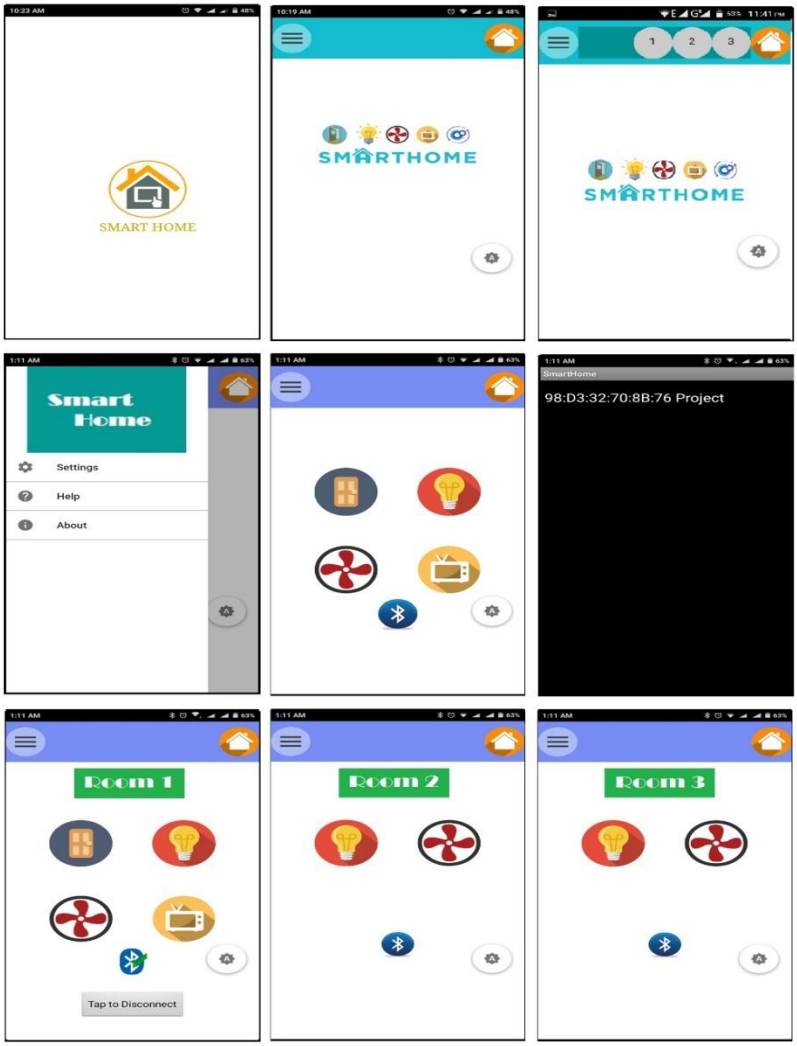

Figure 3 User ınterface of the android application

4.4Hardware module

Our home automation system is implemented with some hardware interfaces which are controlled through Bluetooth technology. The hardware components are:

- Arduino UNO
- Bluetooth Module
- LM-35
- LDR Sensor
- Sonar Sensor
- Servo Motor.

Figure 4 to Figure 8 show some hardware modules that are used in the system. A brief description of the hardware modules is given below.

Arduino Uno. The Arduino Uno [24] is a microcontroller board based on the ATmega328p. Arduino is an open source, cost-efficient platform for designing and implementing different projects in the field of embedded system and IOT [25]. There are 14 digital input/output pins including 6 analog pins and 6 PWM pins.

Bluetooth Module. Bluetooth [26] is used for establishing a wireless Bluetooth network. Using Bluetooth network host and client can interchange data and files. A HC-05 Bluetooth module offers a coverage area of 10-100 meters. The HC-05 Bluetooth module contains 6 pins which are ENABLE, VCC, GND, TX, RX, and STATE.

LM-35. LM-35 is a low-cost temperature sensor. It consists of three pins which are GND, VCC and OUTPUT. Output pin gives numerical data output which can be converted to any kind of temperature units like Celsius or Fahrenheit.

LDR Sensor. LDR sensor is a light dependent register. It senses day light when the value of resistance decreases to a minimum numeric value of resistance and it senses darkness while the LDR gives an output of maximum value of resistance. LDR includes only two pins, which are GND and Analog Output.

Servo Motor. A servo motor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback.

Figure 4 Arduino Uno board

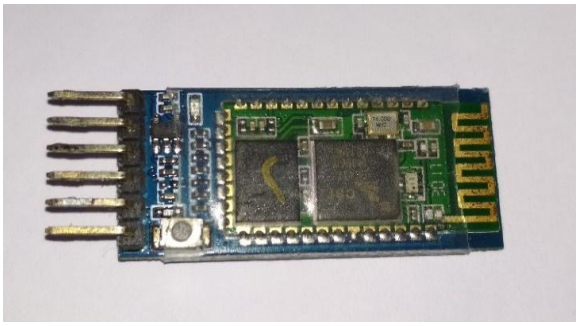

Figure 5 Bluetooth HC-05 module

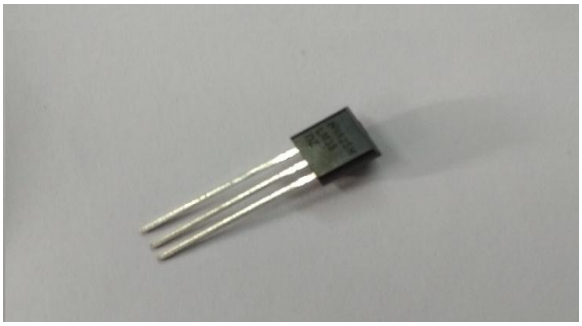

Figure 6 LM 35 sensor

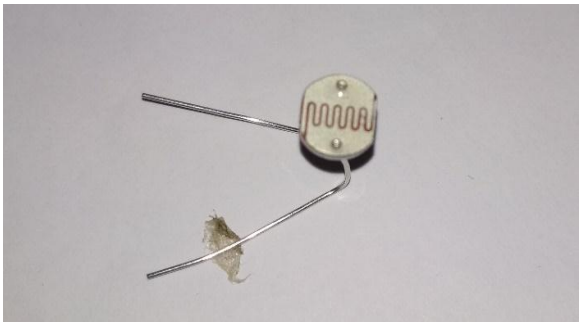

Figure 7 LDR sensor

Figure 8 Servo motor

4.5Circuit design

The system automates a complete apartment with three rooms. Room-1 contains the devices like light, fan. Room-2 consists of common appliances like fan, light and dim light. 3rd room includes a ceiling fan and light. *Figure 9, 10, 11* respectively show the circuit diagrams of the system for room number one, two, three, respectively. One Arduino board, LM- 35, LDR sensor, electric bulb, electric fan, Bluetooth module, resistance and a relay module are being used for three individual rooms.

The establishment of connecting an Arduino board and the Bluetooth module are described below.

Step 1: Connect the Bluetooth module with the Arduino GND and VCC pin.
Step 2: Connect the relay module with the Arduino ground and VCC pin.
Step 3: Connect the sensor with the Arduino ground and analog input pin.

The power supply of the Bluetooth module came from Arduino GND and VCC pin. TX pin of Bluetooth module is connected with Arduino board's RX pin. If the Bluetooth module sends data then the Arduino receives the data by RX pin. Similarly, if the Arduino board sends data through TX pin then the Bluetooth module receives the data by RX pin.

We use relay module for performing multiple devices like light, fan, television etc. For a four-channel relay module we have four individual input pins to connect four devices with it. As we have three rooms so that we use three relay modules for performing our desire home appliances.

The LM-35 contains three pins where analog output pin will connect with the Arduino analog input pin and the other two pins will connect with the GND and VCC pins of the Arduino board. Digital pin 7 in Arduino board is connected to the servo motor and digital pin 3 in Arduino board is also connected to the servo motor.

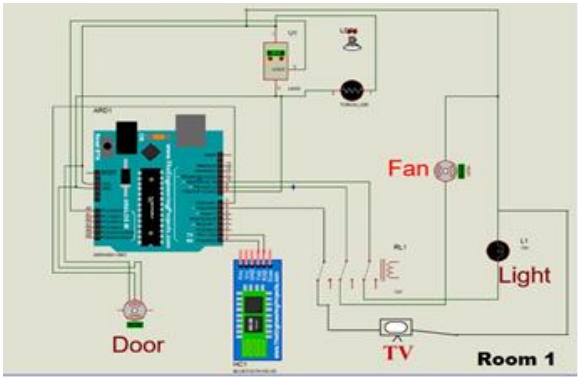

Figure 9 Circuit diagram of Room 1

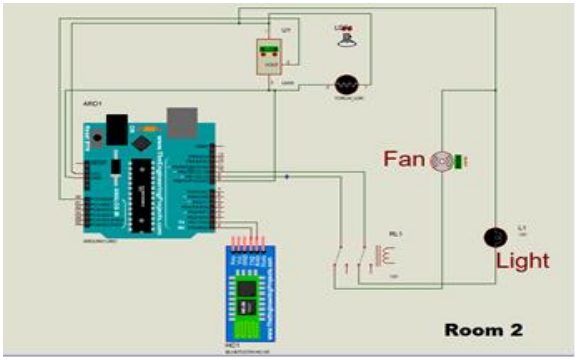

Figure 10 Circuit diagram of Room 2

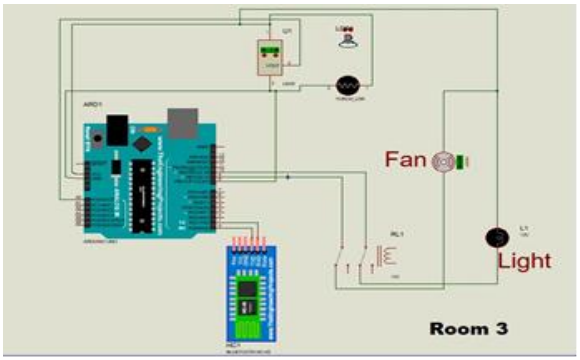

Figure 11 Circuit diagram of Room 3

5.Experimental results and discussions

In this work, we have implemented the control of the various electrical appliances for a complete 3-room apartment by using Arduino board along with an android smart phone. The implementation is shown in the *Figure 12*. We have successfully controlled the fan, light, door, TV of each room through Bluetooth network and android application. We have doe experimentation to estimate the energy saving for a month for this smart apartment.

The *Table 1* shows the results after implementing our system in a 3-bedroom apartment for one month. The rooms contain three lamps (50 Watt each), three fans (75 Watt each), a CRT television (150 Watt) and a door motor which takes 20 second to open or close. After the completion of setup, we observe the consumption of energy and take the data with and without using our system. The experimental result in this small scale determines that our system is around 28% more energy efficient than the manually operated system.

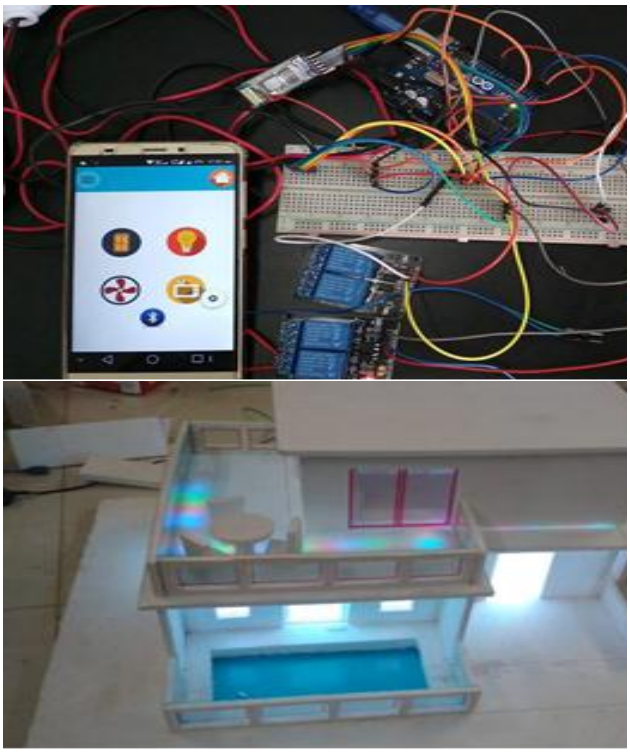

Figure 12 Experimental setup

Table 1 Monthly energy consumption (30 days)

	Usage of resources	
Components	**Manual mode**	**IoT mode**
3 Light	27	17.5
3 Fan	101	72.25
1 TV	26.25	21.5
1 Door Motor	2.25	2.25
Total Energy	156.5	113.5
Total Cost	9.39	6.81

6.Conclusion

The smart home has been experimentally proven to work satisfactorily by connecting the appliances to it and the appliances were successfully controlled from a wireless mobile device. The HC-05 Bluetooth module which we have used in our system successfully connect with different kind of Android smartphones. The system is feasible because the development cost is very low as compared to other existing systems and also optimize the energy cost than the manual system. The future endeavor of this research is to add a speech recognition module along with android application. It will also ensure a more user-friendly user interface for the elderly and disabled people.

Acknowledgment

None.

Conflicts of interest

The authors have no conflicts of interest to declare.

References

[1] Nakamura Y, Arakawa Y, Kanehira T, Fujiwara M, Yasumoto K. Senstick: comprehensive sensing platform with an ultra-tiny all-in-one sensor board for IoT research. Journal of Sensors. 2017.

[2] https://www.quora.com/What-is-the-future-of-IoT-in-Bangladesh. Accessed 22 May 2019.

[3] https://www.mordorintelligence.com/industry- reports/global-smart-homes-market-industry?gclid=CIjd6 M XjydYCFYYDKgod4ZQFaw. Accessed 22 June 2019.

[4] https://www.thedailystar.net/business/bangladesh-should-embrace-internet-things-experts-1502701. Accessed 22 May 2019.

[5] Parise G, Parise L, Parise M. Evolution of human society and of things assisted by IoT. In international symposium on technology and society (ISTAS) 2018 (pp. 95-101). IEEE.

[6] Kumar S, Deswal M. Smart home system. In international conference on advances in computing and communication 2013.

[7] Krishna PN, Gupta SR, Shankaranarayanan PV, Sidharth S, Sirphi M. Fuzzy logic based smart home energy management system. In international conference on computing, communication and networking technologies 2018 (pp. 1-5). IEEE.

[8] Edwards WK, Grinter RE. At home with ubiquitous computing: seven challenges. In international conference on ubiquitous computing 2001 (pp. 256-72). Springer, Berlin, Heidelberg.

[9] Kamal MS, Parvin S, Saleem K, Al-Hamadi H, Gawanmeh A. Efficient low-cost supervisory system for internet of things enabled smart home. In international conference on communications workshops 2017 (pp. 864-9). IEEE.

[10] Zehnder M, Wache H, Witschel HF, Zanatta D, Rodriguez M. Energy saving in smart homes based on consumer behavior: a case study. In first international smart cities conference 2015 (pp. 1-6). IEEE.

[11] Papp I, Velikic G, Lukac N, Horvat I. Uniform representation and control of bluetooth low energy

devices in home automation software. In international conference on consumer electronics-Berlin 2015 (pp. 366-8). IEEE.
[12] Gaikwad PP, Gabhane JP, Golait SS. A survey based on smart homes system using internet-of-things. In international conference on computation of power, energy, information and communication 2015 (pp. 330-5). IEEE.
[13] Sriskanthan N, Tan F, Karande A. Bluetooth based home automation system. Microprocessors and Microsystems. 2002; 26(6):281-9.
[14] Piyare R, Tazil M. Bluetooth based home automation system using cell phone. In international symposium on consumer electronics 2011 (pp. 192-5). IEEE.
[15] Al-Ali AR, Al-Rousan M. Java-based home automation system. IEEE Transactions on Consumer Electronics. 2004; 50(2):498-504.
[16] Ramli MI, Wahab A, Helmy M, Ahmad N. Towards smart home: control electrical devices online. International Conference on Science and Technology Application in Industry & Education. 2006.
[17] Erol Y, Balik HH, Inal S, Karabulut D. Safe and secure PIC based remote control application for intelligent home. IJCSNS. 2007; 7(5):179-82.
[18] Kanma H, Wakabayashi N, Kanazawa R, Ito H. Home appliance control system over bluetooth with a cellular phone. IEEE Transactions on Consumer Electronics. 2003; 49(4):1049-53.
[19] Manikandan J. Design and evaluation of wireless home automation systems. In 1st international conference on power electronics, intelligent control and energy systems 2016 (pp. 1-5). IEEE.
[20] Yuksekkaya B, Kayalar AA, Tosun MB, Ozcan MK, Alkar AZ. A GSM, internet and speech controlled wireless interactive home automation system. IEEE Transactions on Consumer Electronics. 2006; 52(3):837-43.
[21] Lee KY, Choi JW. Remote-controlled home automation system via bluetooth home network. In SICE annual conference 2003 (pp. 2824-9). IEEE.
[22] Narayanan VS, Gayathri S. Design of wireless home automation and security system using PIC microcontroller. International Journal of Computer Applications in Engineering Sciences. 2013:135-40.
[23] Asadullah M, Ullah K. Smart home automation system using bluetooth technology. In international conference on innovations in electrical engineering and computational technologies (ICIEECT) 2017 (pp. 1-6). IEEE.
[24] Kushner D. The making of arduino. IEEE Spectrum. 2011.
[25] Vikram N, Harish KS, Nihaal MS, Umesh R, Shetty A, Kumar A. A low cost home automation system using wi-fi based wireless sensor network incorporating internet of things (IoT). In international advance computing conference (IACC) 2017 (pp. 174-8). IEEE.
[26] Koul K., Patil A. Tukaram V. Survey of bluetooth and applications. International Journal of Advanced Research in Computer Engineering & Technology.2014; 3(8):2832–7.

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