International Journal of Artificial Intelligence Trends (IJAIT)
Vol. 2, Issue 4; No. 45, April, 2023, pp. 475-487

MINIMIZING ENERGY CONSUMPTION USING IOT BASED SMART TECHNOLOGIES: A SMART HOME SCENARIO

Eze, Marcel N[1], Onuigbo, Chika M[1] and Iyidiobi Jonathan C[1]
[1] Department of Electrical and Electronic Engineering, Enugu State University of Science and Technology, Enugu State, Nigeria.

Article Info
Received: 11/04/ 2023
Revised: 27/04/2023
Accepted 02/05/2023

Corresponding Author's Email:
ezenduka56@gmail.com

Corresponding Author's Tel:
+2347061010273

ABSTRACT

This paper presents a model called Energy Management System (EMS) for minimizing energy consumption in smart homes. IoT sensors are installed throughout the building to provide real-time energy usage data to a central data center for analysis. The proposed EMS regulates energy consumption by appliances through sequential moderation. A network of home appliances equipped with Zigbee sensors and switches is set up, allowing communication between the appliances and a main computer using Arduino. The EMS provides a visual interface for users to monitor and control energy consumption. The appliances can be controlled through remote control sensors or the EMS software interface. The Zigbee protocol, coordinated by Arduino, enables low-power and low-cost wireless communication within a range of 10 to 100 meters. Application results demonstrate that implementing this system leads to a continuous reduction in energy consumption in smart homes.

Keywords: **Internet of Things (IoT), IoT sensors, EMS, Arduino, Zigbee, Switches.**

1. INTRODUCTION

The Internet of Things (IoT) is heralded as a significant technological and economic shift in the international sector. Data is shared and exchanged among the billions of physical items that are currently connected to the Internet (Al-Hawawreh et al, 2022).A smart home is a home that uses internet-connected gadgets to provide remote monitoring and administration of systems and appliances, such as lighting and heating. According to Callaham (2022), a smart home is one which is equipped with devices capable of automating tasks and also allowing remote access. There are several reasons why a smart home is desirable. These include:

- To simplify life.
- To save energy and also money.
- To improve security.
- For better handling of household tasks.
- For entertainment purposes.

Minimizing energy consumption is a cardinal consideration in contemporary application of technology and devices. Power producing firms continue to be concerned about predicting power consumption because of the rising demand for energy brought on by the rapid growth in global population. According to scientists, if energy usage is not managed, it could eventually result in a shortage of energy. There are two ways to address the energy shortage: either by increasing energy production or by decreasing the use of already available energy resources and reducing waste (Shah et al, 2019).However, according to (Chen et al, 2009), energy generation is a very expensive and time-consuming solution to the issue, but on the other side, by implementing some preventative actions, energy consumption can be minimized. IoT sensors can be installed all throughout a building, and they can feed real-time data on energy use back to a data center for analysis. IoT enables businesses to individually monitor massive objects like equipment, water heating systems, large refrigeration units, and lighting systems. Pourbeik (2022) opined that once sufficient information has been centrally gathered over time, AI algorithms could be used to examine the IoT data and identify historical trends.

It has been opined over the years that bulk of energy consumption takes place in homes and commercial establishments. This means that if losses are to be minimized in energy consumption, efforts should be concentrated in buildings, both residential and commercial (Moreno et al, 2014). Extension of the foregoing position should also go to corporate offices and the likes, where frequent consumption of energy occurs from time to time, no matter how minimal the usage is. According to studies carried out, between 20% and 40% of the total energy consumed in developed countries are recorded in building related environments (Dane et al, 2009). It is expected that by 2025, global energy demand will increase by 40% while the residential and commercial energy demand put together will increase by 25% (Energy Reports, 2019). This is due mainly to population growth and industrialization. Thus, the need to embrace the IoT enabled smart home scenario in order to minimize energy consumption in this era should be canvassed and pursued vigorously. This underscores the reason why this research is emphasizing a smart home scenario of applying IoT devices in energy minimization efforts.

1.1 The Internet of Things (Iot) Phenomenon

The term "Internet of Things" was first used by Kevin Ashton in 1999, but it took at least another ten years for technology to catch up with the concept (Ranger, 2020). The "Internet of Things," or "IoT," describes the countless numbers of physical objects that are currently online and collecting and exchanging data. With the advent of incredibly affordable computer chips and the widespread use of wireless networks, anything may become a component of the Internet of Things, from a pill to an airplane. By connecting all these various items and equipping them with sensors, digital intelligence is added to otherwise dumb gadgets, allowing them to relay real-time data without a human being's involvement. The world around us is becoming smarter and more responsive thanks to the Internet of Things, which is fusing the digital and physical worlds.Any physical thing that can be connected to the internet in order to be controlled or to transmit data, can be turned into an IoT device.

IoT devices include everything that can be controlled by a smartphone app, including connected streetlights, smart thermostats in offices, and motion sensors. A child's toy or a driverless vehicle could serve as an example of an IoT gadget. Several tiny Internet of Things (IoT) components may be included in some larger things. For instance, a jet engine might now have thousands of sensors that gather data and send it back to check on how it is doing. To comprehend and manage the environment, smart cities projects are covering entire regions in sensors on a larger scale. IoT refers to a group of connected devices that can interact with the network without human intervention and are not typically required to have an internet connection. As a result of this, despite the fact that smart phones are loaded with sensors, neither a PC nor a smartphone are typically regarded as IoT devices. However, a smart watch, fitness band, or other wearable devices may be considered an IoT device.

The IoT was first most attractive for business and manufacturing, where its use is frequently known as machine-to-machine (M2M). However, the emphasis is now on bringing smart gadgets into our homes and workplaces, making it important to practically everyone. Blogjects (things that blog and record information about themselves to the internet), ubiquitous computing (or "ubicomp"), invisible computing, and pervasive computing were some of the early concepts for internet-connected items. Internet of Things and IoT, however, has steadily gained wide popularity as virtually everything can enjoy its application for enhanced operation.

It is neither intended to either exhaustively discuss the IoT expansive technology (which is not a puny exercise anyway) nor the amazing smart home scenario (which would have been unimaginable years ago) in this single presentation. It is rather the focus of this work to treat the how and means of energy usage minimization in a modern day contemporary home as we have it today. This is the crux and focus of this work.

2. Related Works Review

A reasonable number of researches have been carried out in this area in times past. These reviews are meant to induce more understanding of the subject and also show the depth of research already carried out in this field of study.

The work of Al-Obaidiet al (2022) examined IoT principles, models, applications, trends, and issues that can be encountered in a built environment in detail, utilizing a systematic review. The results showed limits in IoT strategy development in cities and buildings by experts in this field due to inadequate understanding of technologies and their applicable approaches. The study also discovered limitations to using IoT when it is integrated into the built environment as well as an endless implementation. The report outlined key points and suggested actions for utilizing IoT efficiently in terms of energy use. According to the review's conclusions, IoT integration in the contexts of buildings and cities has beneficial effects on energy conservation. There were no precise instructions on how to position IoT sensors in buildings for various environmental situations.

Narkar et al, (2018) identified that a network path was needed to connect, exchange data, or control one another in IoT-based power usage. According the authors, keeping track of your electricity usage for verification requires visiting the meter reading room and record readings, which is a laborious task. A system with efficient device operation modes that will reduce energy waste in residential settings was advised. The web portal created by the authors made it simple to access the monitoring using internet notification offered by Wi-Fi module. Web users can view the most recent reading. Appliance ON/OFF automation was incorporated. Even though android implementation was intended, setting the threshold value and sending the notification were additional tasks.

Aldabbagh et al, (2020) focused on utilizing ICT tools for applications related to smart homes. It showed how a system was designed and put into action to track and evaluate energy usage, turn on lights when necessary, program the temperature by detecting occupant absence, and set the temperature appropriately high or low. The system also employed colored LEDs to notify residents of various parameters, to turn on and off their loads based on the cost of electricity use, and to allow them to control some of their home appliances through a mobile application in order to minimize energy waste and cut down on electricity usage. However, the system does not provide the owner an opportunity to add new acquired household appliances for monitoring.

Enas et al. (2022) presents an IoT-based optimal energy management approach for smart homes, utilizing PV and wind renewable energy systems along with energy storage systems to reduce dependence on the grid. The proposed algorithm incorporates demand response to price variations and applies Time-of-Use pricing to control household appliances. The IoT system uses ZigBee wireless technology for data exchange and communication with the control center, while the Harmony Search optimization technique is employed to save energy and reduce electricity bills in smart homes. The algorithm's effectiveness is demonstrated through results obtained from a five-floor building simulation, and its performance is compared against four other AI algorithms, showing superior cost-saving and runtime improvements. Overall, this research offers a promising solution for efficient energy management in smart homes.

Al-Obaidi et al. (2022) addresses the growing utilization of the Internet of Things (IoT) in smart buildings and cities to reduce energy consumption, highlighting a knowledge gap in effectively applying IoT in the built environment for energy efficiency. The study aims to bridge this gap by providing an extensive review of IoT applications in buildings and cities, offering guidance to built environment experts. Through a systematic review, the paper examines IoT concepts, models, applications, trends, and challenges relevant to the built environment. The findings reveal limitations in developing IoT strategies due to a lack of understanding of technologies and their application methods. Moreover, the study identifies implementation issues and constraints when integrating IoT into the built environment. The paper concludes by providing critical arguments and suggesting the next steps for effectively utilizing IoT to enhance energy efficiency. This research contributes valuable insights to the field of IoT and serves as a resource for professionals seeking to leverage IoT technologies in the built environment.

Ghulam et al. (2020) presents an energy management strategy for IoT-enabled residential buildings in smart cities to address the future shortage of electrical energy. The proposed strategy utilizes a wind-driven bacterial foraging algorithm (WBFA) to optimize power usage and manage peak-to-average ratio, electricity costs, and user comfort. The WBFA-based strategy effectively responds to price-based demand response (DR) programs, overcoming the limitation of consumer knowledge. Extensive simulations demonstrate that the WBFA-based strategy outperforms benchmark strategies in terms of energy consumption, cost, peak-to-average ratio, and user comfort. This research contributes to the sustainability of IoT-enabled residential buildings and offers a promising approach for efficient energy management in smart cities

Filipe et al. (2023) focuses on the design and implementation of a home energy management system (HEMS) leveraging the Internet of Things (IoT) and cloud computing. The HEMS collects and stores energy consumption data from appliances and the main load of a home. Two scenarios were developed: a local HEMS using an edge device for processing and storage, and a Cloud HEMS utilizing Amazon Web Services (AWS) IoT Core for data management and data-driven services. A testbed was conducted in Valparaiso, Chile, over one year, collecting energy consumption data from appliances and the main load. The study provides the first electrical energy dataset with a 10-second sampling rate from a real household in Valparaiso. Results indicate that both implementations effectively perform the baseline tasks of a HEMS. This work contributes by offering a comprehensive technical implementation of HEMS, supporting the development and implementation of HEMS solutions for various smart home applications, benefiting researchers and engineers in the field.

Singh et al. (2019) provided a comprehensive review of the electrical network, covering generation, transmission, distribution, and consumer aspects. It explores network architecture, energy monitoring points, causes of energy losses, and potential strategies for reducing those losses. The chapter also delves into load shedding, utility demand energy management systems, and the role of buildings in energy conservation. It offers an overview of energy management devices, automation protocols, smart devices, and applicable standards in substations. The importance of energy conservation in consumer households using IoT devices is highlighted, along with discussions on smart home components, automation techniques, and future technological prospects. Data security models, encryption, and practical approaches for smart homes are examined, along with the use of artificial intelligence and signal processing through IoT-based devices.

2.1 Research Gap

While the reviews touch upon various energy management approaches such as demand response programs, HEMS, and smart grid applications, there may be a need for more detailed studies that investigate the effectiveness, scalability, and limitations of these strategies in real-world scenarios.

3.0 METHODOLOGY

In this research, it is intended to monitor the electrical appliances in a modern home with a view to minimizing energy usage. A model, known as Energy Management System (EMS) is proposed for minimizing energy consumption in homes, regulating energy consumptions by appliances, applying sequential moderation. A network of home appliances that can communicate with one another and with a main computer using Arduino is set up with Zigbee sensors and switches. Figure 1 shows a schematic diagram of smart home withEnergy Management System (EMS) automation.

Figure 1: Schematic Diagram of Smart Home with EMS (Energy Management System) Automation

The EMS enables the user to have a visual interface of the energy consumptions. It is developed to work on a graphical user interface (GUI). A GUI demonstrates to the user how to carry out tasks via windows, icons, menus, and buttons. This can be accomplished with a touch screen, keyboard, or pointer. For instance, one can use mouse to point and click to open a file icon on the desktop. For desktop environments, examples of well-liked contemporary graphical user interfaces include Microsoft Windows, macOS, Ubuntu Unity, and GNOME Shell. For mobile platforms, examples include Android, Apple's iOS, BlackBerry OS, Palm OS-WebOS, Windows 10 Mobile, and Firefox OS. The appliances can be controlled using remote control sensor or using EMS software interface. Table 1 shows appliances commands control using EMS.

Table 1: EMS Commands to Control Appliances

Action	Command Execution
Main Switch On	MainSON (MS_ON)
Main Switch Off	MainSOFF (MS_OFF)
Room 1 Light On	Rm 1 LightON (R1L_ON)
Room 1 Light Off	Rm 1 LightOFF (R1L_OFF)
Room 2 Light On	Rm 2 LightON (R2L_ON)
Room 2 Light Off	Rm 2 LightOFF (R2L_OFF)
Refrigerator On	RefgtorON (RFGT_ON)
Refrigerator Off	RefgtorOFF (RFGT_OFF)
Television Set On	TVSetON (TVS_ON)
Television Set Off	TVSetOFF (TVS_OFF)

The MAIN TAB of the Energy Management System is shown in Figure 2. Line voltage, load current, and various extra controls, like alarms and on/off controls, are all listed in the MAIN tab. The energy management center (EMC) application software is turned on or off using the on/off control, and any erroneous functioning of the device or hardware fault is reported using the alarm control.

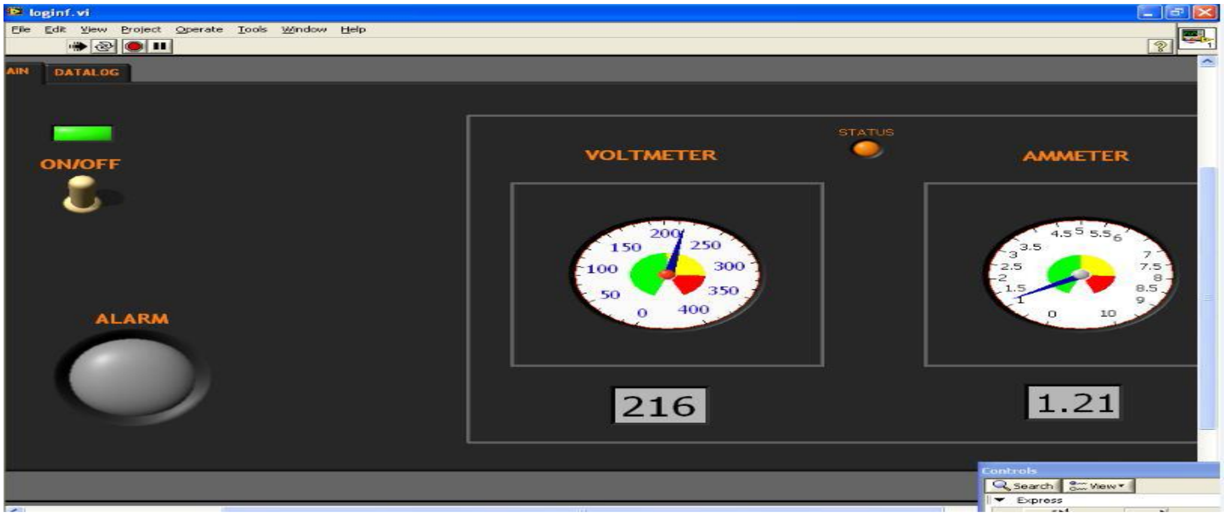

Figure 2: EMC (Energy Management Center) MAIN Tab

❖ **The Ardiuno Uno**

A low-cost, adaptable, and simple-to-use programmable microcontroller board called Arduino UNO is available for use in a range of electronic applications. Relays, LEDs, servos, and motors can be controlled by this board as output devices, and it can communicate with other Arduino boards, Arduino shields, and Raspberry Pi boards. To put it briefly, an Arduino is an open hardware development board that makers, hobbyists, and tinkerers may use to create and construct objects that interact with the physical environment. It appears in the form shown in Figure 3.

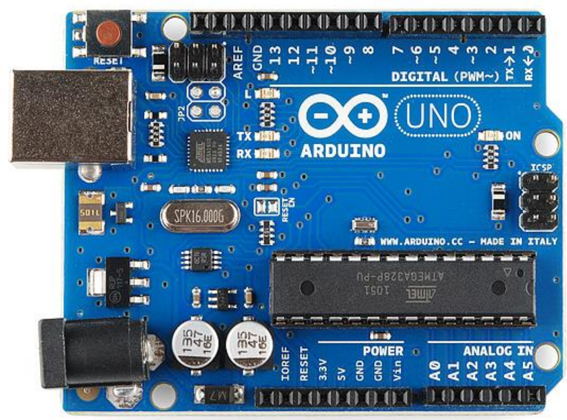

Figure 3: The Arduino Uno

The Arduino development environment is connected to the Arduino board through USB when it is attached to a computer (IDE). The user creates the Arduino code in the IDE, uploads it to the microcontroller, and the code is then executed by the microcontroller while interacting with inputs and outputs like sensors, motors, and lights.

❖ **The Zigbee**

Zigbee is a wireless protocol for battery-operated devices possessing both low power and low cost. Although there are regional differences, it typically runs in the 2.4GHz band and enables data rates of 20 to 250 kbits/s. However, the transmission range is modest when compared to technologies like LoRa. It can transmit for 10 to 100 meters, enough to cover a home, whereas LoRa can do it for a few kilometers. Another thing to keep in mind is that if there is no line of sight between the transmitter and receiver, Zigbee communication is not very effective. But two Zigbee modules can communicate with one another and subsequently transmit the result to an arduino thereby obviating the problem of line of sight communication which could occur in a home environment. Figure 4 shows an Xbee module which can effectively communicate with an arduino, while the pin configurations are presented in the figure 5. The arduino and the zigbee module are connected in the manner shown in Figure 6.

Figure 4: XBee PRO 538 (Zigbee) Module

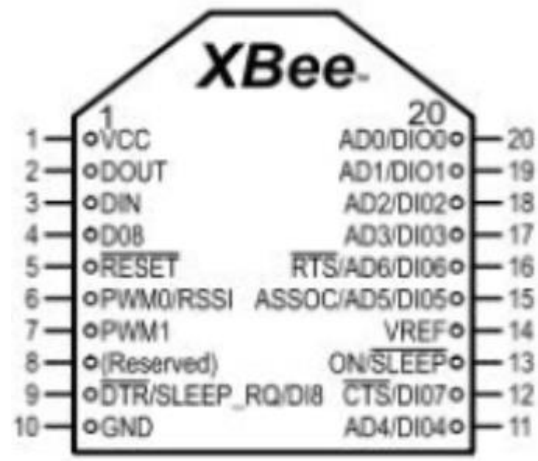

Figure 5: The XBee PRO pin Configuration

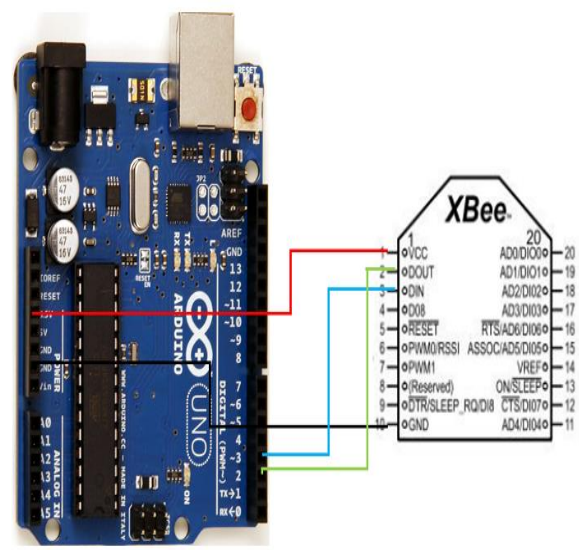

Figure 6: The arduino and the zigbee module

From the figure 6; there is a connection of the Arduino's pins DOUT (TX) and DIN (RX) so that pin 2 will serve as Receiver (RX) and pin 3 will serve as Transmitter(TX), respectively. Similarly, the pins Vcc and GND have been linked up. On the receiving end, the connections will be similar. If an antenna has already been installed, that is preferable; otherwise, there will be need to attach an antenna to the UFL socket.

The code is really simple to understand. Not all digital pins on boards other than the Arduino Uno might support SoftwareSerial.

The following code will be written on the transmitting end to automate the process;

```
#include <SoftwareSerial.h>
SoftwareSerialxbeeSerial(2,3); //RX, TX
void setup()
{Serial.begin(9600);
xbeeSerial.begin(9600);}
void loop()
{if(Serial.available() > 0){
char input = Serial.read();
xbeeSerial.print(input);}
}
```

As can be seen, whatever the user sends to the XBee module via the Serial Monitor is sent and received by the XBee module on the other end.

On the receiving side, the code should be as follows:

```
#include <SoftwareSerial.h>
SoftwareSerialxbeeSerial(2,3); //RX, TX
void setup()
{ Serial.begin(9600);
xbeeSerial.begin(9600);}
void loop()
{ if(xbeeSerial.available() > 0){
char input = xbeeSerial.read();
Serial.print(input)}}
```

Everything that is received from the XBee is sent to the Serial Monitor. Whatever is typed on the serial monitor on the transmitter side should print on the serial monitor on the receiver side when testing the combined system.

The practical circuitry interface of Arduino with Zigbee is shown in Figure 7.

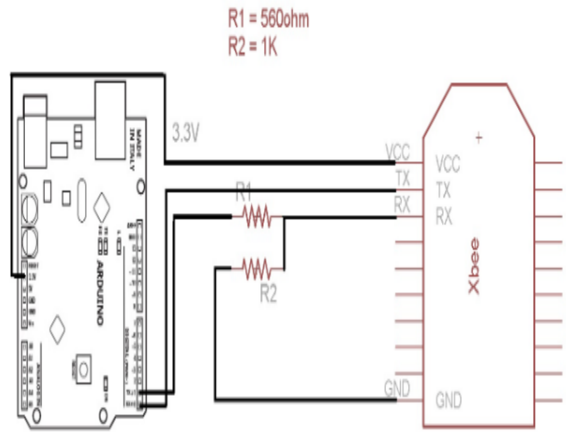

Figure 7: Arduino interfaced with Zigbee

4. RESULTS AND DISCUSSION

The results obtained from the application of the scheme implemented in this presentation are shown in table 2 and graphically demonstrated in the bar chart of Figure 8.

Table 2: Generated Data Log Tab

Date	Time	Voltage	Current
20/12/2022	3:15:01pm	220.00	1.1301665
20/12/2022	3:15:20pm	220.00	1.0806543
20/12/2022	3:15:41pm	220.00	1.0611265
20/12/2022	3:16:01pm	220.00	1.0701345
20/12/2022	3:16:23pm	220.00	1.0612430
20/12/2022	3:16:45pm	220.00	1.0913000
20/12/2022	3:17:05pm	220.00	1.1001000
20/12/2022	3:17:25pm	225.00	1.0513100
20/12/2022	3:17:46pm	230.00	1.0058010
20/12/2022	3:18:03pm	217.00	1.0256401
20/12/2022	3;18;26pm	219.00	0.9841530
20/12/2022	3:18:48pm	219.00	1.0553410
20/12/2022	3:19:10pm	219.00	1.1240011
20/12/2022	3:19:30pm	219.00	1.1024012

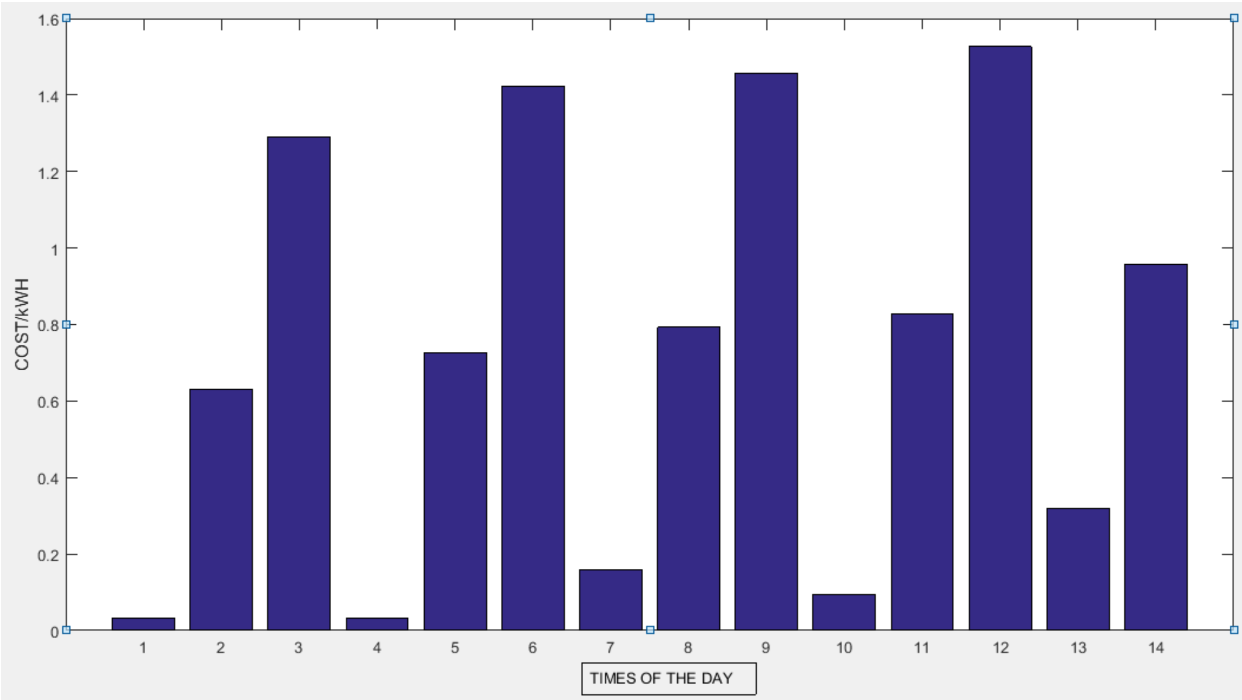

Figure 8: Bar Chart of Forecasted Cost/kWh versus Times of the Day

The pie chart representation of the current forecast is shown in Figure 9.

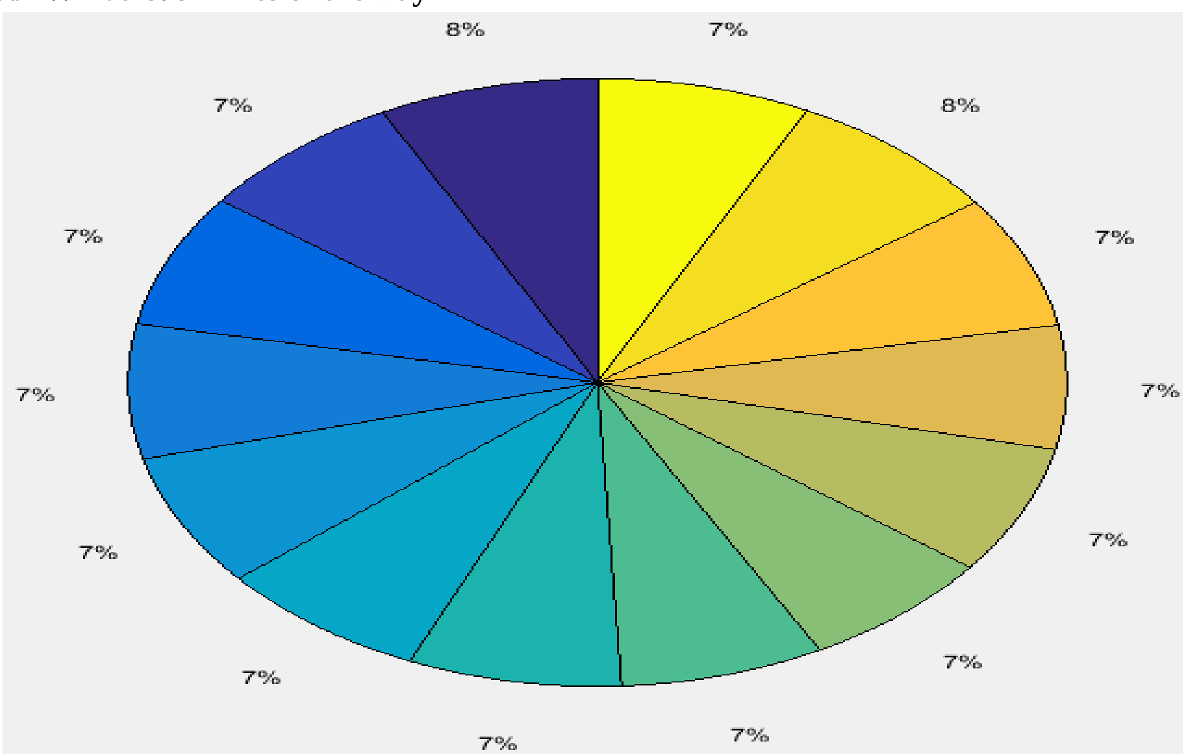

Figure 9: Forecasted Value of the Current

The data generated and shown in table 2 are used to produce the bar chart of Figure 8 as well as the pie chart of Figure 9. The bar chart of Figure 8 shows the forecasted cost of energy usage per kilowatt with respect to times of the day, making reference to table 2. Similarly, the pie chart of Figure 9 gives an idea of the current flow with respect to the times of the day, also given the data presentation of table two. As could be observed, this a continuous reduction in energy consumption in any given home where this system is applied. The proposed system is modest and relatively cost effective considering its merits. It will reduce the general and overall cost of maintaining household electrical and electronics appliances with respect to energy cost and expenses.

5. CONCLUSION

This study emphasizes the importance of minimizing energy consumption in contemporary homes, particularly in the context of smart homes. The proposed Energy Management System (EMS) provides an effective solution for regulating energy consumption by appliances through sequential moderation. By leveraging IoT sensors and Zigbee communication, the EMS enables real-time monitoring and control of energy usage, empowering users to make informed decisions and take necessary actions to reduce energy consumption. The application results demonstrate the effectiveness of the EMS in achieving a continuous reduction in energy consumption within homes. This study highlights the potential of technology and smart systems in addressing energy efficiency challenges and promoting sustainable practices in residential buildings. Implementing such energy management systems not only benefits individual households but also contributes to the larger goal of creating a more energy-efficient and environmentally conscious society. Further research and development in this area can lead to more advanced and innovative solutions for minimizing energy consumption and promoting sustainable living in the future.

6. RECOMMENDATION

Based on the study, the following recommendations can be made for future work:

1. Further research should be conducted to investigate the potential of using other communication protocols besides Zigbee to achieve even better energy management results.
2. The study focused on minimizing energy consumption in homes. Future work should expand the scope of the study to include commercial buildings and industrial settings.
3. The current system uses a touch screen, keyboard or pointer as an interface for users to control the appliances. Future work should investigate the potential of integrating voice-activated interfaces such as Amazon Alexa or Google Assistant for a more user-friendly experience.
4. The study was carried out in a simulated environment. Future work should test the system in real homes to validate the results and determine how the system can be optimized for different types of homes and appliances.

5. Finally, future work should focus on improving the security of the system. Since the system relies on wireless communication, measures must be taken to protect it from hacking and other cyber threats.

7. REFERENCES

Abdul Salam Shah, Haidawati Nasir, Muhammad Fayaz, AdidahLajis and Asadullah Shah (2019). A Review on Energy Consumption Optimization Techniques in IoT Based Smart Building Environments. Information (Switzerland) · March 2019, doi:10.3390/info10030108.

Al-Obaidi, K.M.; Hossain, M.; Alduais, N.A.M.; Al-Duais, H.S.; Omrany, H.; Ghaffarianhoseini, A. A Review of Using IoT for Energy Efficient Buildings and Cities: A Built Environment Perspective. Energies 2022, 15, 5991. https://doi.org/ 10.3390/en15165991

AnketNarkar, Karan Kunnumal, SagarKanteliya, Suvarna More and Vikrant More (2018). Power Consumption Monitoring and Home Automation using iot. International Conference on Innovative and Advanced Technologies in Engineering (March-2018), IOSR Journal of Engineering (IOSRJEN) www.iosrjen.org, ISSN (e): 2250-3021, ISSN (p): 2278-8719Volume 8, PP 51-54

Chen, H.; Cong, T.N.; Yang, W.; Tan, C.; Li, Y. and Ding, Y. (2009). Progress in Electrical Energy Storage System: A Critical Review. Progress in Natural Science, 2009, 19, 291–312.

Dane, P., Steele, J., Wilkerson and J. WattBot (2009). A Residential Electricity Monitoring and Feedback System. In Proceedings of the CHI'09 Extended Abstracts on Human Factors in Computing Systems, Boston, MA, USA, 4–9 April 2009.

Enas Magdi Saadawi, Abdelaziz Said Abohamama, Mohammed Fathi Alrahmawy et al. IoT-based Optimal Energy Management in Smart Homes using Harmony Search Optimization Technique, 22 July 2022, PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-1817009/v1]

Energy Reports (2019). Available online: http://www.enerdata.net/enerdatauk/press-andpublication/energyfeatures/enerfuture-2007.php (accessed on 10 February 2019).

Felipe C., Jose M., Ali M., Young C., Mohammed A. (2020)" Design and Implementation of a Cloud-IoT-Based Home Energy Management System"Journals Sensors; Volume 23; Issue 1; 10.3390/s23010176

GhadahAldabbagh, RaneenAlzafarani and Ghadi Ahmad(2020). Energy Efficient IoT Home Monitoring and Automation System (EE-HMA). International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-8 Issue-5, January 2020

Ghulam Hafeez; Zahid W., Imran U., Mukammad U., (2020)" Efficient Energy Management of IoT-Enabled Smart Homes Under Price-Based Demand Response Program in Smart Grid"Journals; Sensors; Volume 20 ; Issue 11;10.3390/s20113155

John Callaham (2022). What is a smart home, and why should you want one? Android Authority, 2022.

Karam M. Al-Obaidi, Mohataz Hossain, Nayef A. M. Alduais, Husam S. Al-Duais, HosseinOmrany and AmirhoseinGhaffarianhoseini (2022). A Review of Using IoT for Energy Efficient Buildings and Cities: A Built Environment Perspective. Energies 2022, 15, 5991. https://doi.org/10.3390/en15165991, www.mdpi.com/journal/energies

M. Victoria Moreno, Benito Úbeda, Antonio F. Skarmeta and Miguel A. Zamora (2014). How can We Tackle Energy Efficiency in IoT Based Smart Buildings? Sensors 2014, 14, 9582-9614; doi:10.3390/s140609582.

Muna Al-Hawawreh, Ibrahim Elgendi, and KumuduMunasinghe (2022). An Online Model to Minimize EnergyConsumption of IoT sensors in Smart Cities. IEEE Sensors Journal, Vol. XX, No. XX, XXXX, 2022

PouyanPourbeik (2022). How to use IoT for energy efficiency and sustainability. TechTarget, 2022.

Singh, Prithvi & Khosla, Praveen & Mittal, Mamta. (2019). Energy Conservation in IoT-Based Smart Home and Its Automation. 10.1007/978-981-13-7399-27

Steve Ranger (2020). What is the IoT? Everything you need to know about the Internet of Things right now.ZDNET, A Red Ventures Company, Copyright, 2020.