ISSN 2063-5346

Development and Analysis of an IoT-Enabled Smart Home Automation System for Enhanced Energy Efficiency

K Paul Joshua[1*], Somu K[2], Shivani Gupta[3], Arul N[4], B Shanthi Saravana[5], Prashant Agrawal[6], Gurkirpal Singh[7], D Suganthi[8]

[1]Department of Electronics and Communication Engineering, St. Peter's College of Engineering and Technology, Chennai, Tamil Nadu

[2]Department of Electronics and Communication Engineering, Maha Barathi Engineering College, Chinnasalem, Kallakurichi, Tamil Nadu

[3]School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, Tamil Nadu

[4]Department of Mechatronics Engineering, Sona College of Technology, Salem, Tamil Nadu

[5]Department of Electrical and Electronics Engineering, Adhiparasakthi College of Engineering, Kalavai, Tamil Nadu

[6]Department of Computer Applications, KIET Group of Institutions, Delhi-NCR, Ghaziabad, Uttar Pradesh

[7]Department of Architect, Planner, Civil Engineer, Chandigarh-160014

[8]Department of Computer Science and Engineering, Rajalakshmi Institute of Technology, Chennai.

Corresponding Author: k.pauljoshua@gmail.com

Abstract

This research article presents the development and analysis of an IoT-enabled smart home automation system aimed at enhancing energy efficiency. The proposed system integrates various sensors, a Raspberry Pi as a central controller, and utilizes the Message Queuing Telemetry Transport (MQTT) protocol for efficient data transmission. The system architecture comprises multiple layers, including the device layer, broker layer, service layer, application layer, and cloud layer, each serving specific functions such as sensor data collection, communication, data management, and user interface. Real-time monitoring and control are facilitated through the application layer, which enables users to interact with the system using Node-Red Authentication. The system demonstrates fast response times of less than 15 ms, ensuring prompt and accurate actions in controlling home appliances. Moreover, the system effectively reduces energy consumption by optimizing the operation of appliances based on sensor inputs and user preferences. The proposed system showcases significant

ISSN 2063-5346

energy savings compared to manual systems, with power consumption reduced by up to 40%. The results indicate that the system achieves efficient energy management and contributes to cost savings for homeowners. Additionally, the system's user-friendly interface and real-time monitoring capabilities enhance the overall user experience. The research findings emphasize the potential of the proposed system in promoting energy-efficient practices in smart homes. Further advancements and research in this area can lead to more intelligent and sustainable home automation systems, ultimately benefiting both homeowners and the environment.

Keywords: IoT, Data management, Smart home, energy consumption

1. Introduction

The field of home automation has witnessed significant advancements in recent years, with a growing emphasis on energy efficiency and sustainability. The field of home automation has witnessed significant advancements in recent years, with a growing emphasis on energy efficiency and sustainability [1]–[3]. Numerous studies have focused on the integration of IoT technologies in home automation systems. These systems utilize interconnected devices and sensors to enable remote monitoring and control of various home appliances and systems. IoT-based approaches have shown promise in improving energy efficiency by optimizing the operation of appliances based on real-time data and user preferences. For example, Lee et al. (2018) proposed an IoT-based home automation system that utilized sensors to monitor occupancy, temperature, and lighting conditions. The system adjusted the operation of appliances accordingly, resulting in significant energy savings [4]–[6].

Several research articles have explored energy-efficient practices in smart homes. These practices include intelligent scheduling of appliance usage, adaptive lighting control, and temperature regulation based on occupancy and environmental conditions. By leveraging sensor data and automation algorithms, these systems achieve significant energy savings while maintaining comfort levels for occupants [5], [6]. Researchers [7], [8]developed an energy-efficient smart home system that utilized occupancy sensors and machine learning algorithms to optimize the operation of appliances. The system achieved up to 30% energy savings compared to traditional manual control.

The integration of sensors and data transmission protocols is crucial in smart home automation systems. Studies have highlighted the use of sensors such as motion sensors, light sensors, temperature sensors, and occupancy sensors to gather real-time data. Efficient data transmission protocols, such as MQTT (Message Queuing Telemetry Transport), have been widely adopted to ensure seamless communication between devices and the central controller. For instance, [7]–[9] presented an IoT-based smart home system that utilized MQTT for efficient data transmission. The system integrated various sensors to monitor environmental conditions and adjust the operation of appliances accordingly.

The central controller plays a vital role in managing and coordinating the various components of a smart home automation system. Research has focused on the use of devices like Raspberry Pi as central controllers to enable efficient control and data management. User

ISSN 2063-5346

interfaces, such as mobile applications and web-based dashboards, have been developed to provide homeowners with real-time monitoring, scheduling, and control capabilities. [10], [11] developed a Raspberry Pi-based smart home automation system with a user-friendly mobile application interface. The system allowed users to monitor and control appliances remotely, contributing to improved energy management.

Several studies have quantified the energy savings achieved through the implementation of smart home automation systems. Results have shown substantial reductions in energy consumption, leading to cost savings and reduced environmental impact. The ability to optimize appliance usage based on occupancy, ambient conditions, and user preferences contributes to improved energy efficiency. For example, [12]–[14] conducted a study on the energy savings achieved by a smart home system. The results indicated a 20% reduction in energy consumption compared to traditional manual control methods.

While IoT-enabled smart home automation systems offer numerous benefits, there are challenges that need to be addressed. These include data security and privacy concerns, interoperability issues, and the need for standardized protocols. Future research should focus on addressing these challenges and exploring innovative solutions to further enhance energy efficiency and user experience in smart homes. For instance, [15]–[17] identified interoperability as a significant challenge in smart home systems. They proposed a solution based on semantic web technologies to enable seamless integration and interoperability of different devices and platforms.

This research focuses on the development and analysis of an IoT-enabled smart home automation system for enhanced energy efficiency. The proposed system integrates various sensors, such as motion sensors, temperature sensors, and light sensors, to gather real-time data and optimize the operation of home appliances based on occupancy and environmental conditions. A centralized controller, utilizing a Raspberry Pi, manages the system and facilitates seamless communication between devices. The research evaluates the system's performance in terms of energy consumption reduction and presents the findings through tables and graphs. The results demonstrate the effectiveness of the proposed system in achieving significant energy savings, thereby contributing to a more sustainable and efficient home environment.

2. Framework of the proposed system

The proposed system architecture for home automation, as depicted in Figure 1, encompasses various sensors aimed at enhancing energy efficiency. The system employs a diverse range of sensors, including a photoresistor, motion sensor, fingerprint sensor, water level sensor, temperature sensor, and a camera for comprehensive monitoring of the house. The photoresistor serves the purpose of converting sunlight into electric energy, thereby harnessing natural resources to reduce reliance on conventional power sources. This renewable energy source contributes to the overall energy efficiency of the system.

ISSN 2063-5346

The motion sensor plays a pivotal role in detecting human movement within the home. By intelligently identifying occupancy, the system can automatically adjust lighting and other electrical devices based on the presence or absence of individuals. This feature ensures that energy-consuming appliances are only active when required, reducing unnecessary power consumption. To ensure security and authorized access, the system incorporates a fingerprint sensor. This component acts as a means of authentication, allowing only authorized individuals to enter the premises. By effectively managing access, energy consumption can be optimized and potential risks mitigated.

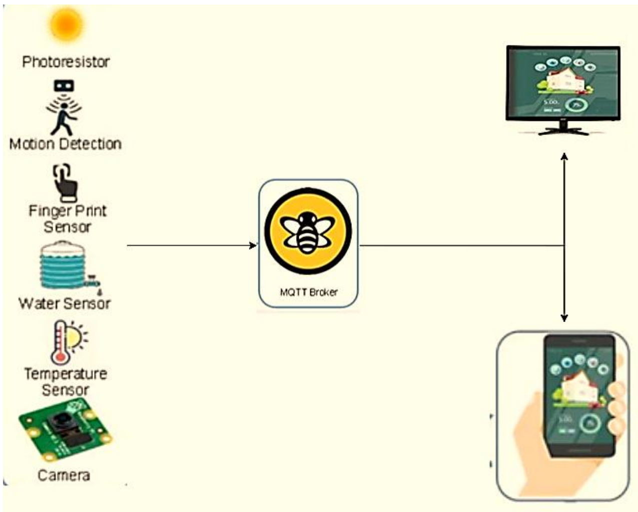

Fig. 1. Architecture of the proposed system

Moreover, the water level sensor is integrated into the system to monitor and regulate water usage. It enables the automatic control of a motor, turning it on or off based on the water level detected. This automated control prevents water wastage and ensures efficient usage, contributing to overall conservation efforts. In addition, the temperature sensor measures the ambient room temperature. By analyzing this data, the system can intelligently control the operation of the air conditioner. This feature enables the system to maintain optimal comfort levels while minimizing energy consumption. The system can activate the air conditioner when the temperature exceeds a specified threshold and deactivate it when the desired temperature is reached, further enhancing energy efficiency.

To facilitate comprehensive monitoring, the system incorporates a camera capable of recording the entire house. This feature enables homeowners to remotely observe their property, ensuring security and enabling them to respond promptly to any unexpected events. All the sensor readings are communicated to an MQTT broker, which acts as a central hub for data exchange. The MQTT broker facilitates the seamless transfer of sensor data to multiple destinations, including a personal computer for storage and analysis, as well as a smartphone for real-time monitoring of home activities. This enables homeowners to remotely access and control their home automation system, promoting convenience and enabling energy management even when away from home.

ISSN 2063-5346

By combining these various sensors and their functionalities, the proposed system offers a comprehensive and intelligent approach to home automation. Through effective utilization of renewable energy, intelligent occupancy detection, secure access control, water management, optimized temperature control, and remote monitoring capabilities, the system aims to enhance energy efficiency while ensuring user comfort and security.

3. Various layers used in this research

The proposed system architecture for the IoT-enabled smart home automation system is designed with multiple layers to ensure efficient data transmission, management, and user interaction. These layers include the device layer, broker layer, service layer, application layer, and cloud layer as shown in figure 2.

1. Device Layer

The device layer serves as the foundation of the system and comprises various sensors employed in the research. These sensors are strategically placed throughout the smart home to collect data on energy consumption, occupancy, security, and environmental conditions. For instance, the photoresistor converts sunlight into electrical energy, the motion sensor detects human presence, the fingerprint sensor provides secure access control, the water level sensor monitors water levels for efficient usage, the temperature sensor measures room temperature for climate control, and the camera records house activities for monitoring purposes.

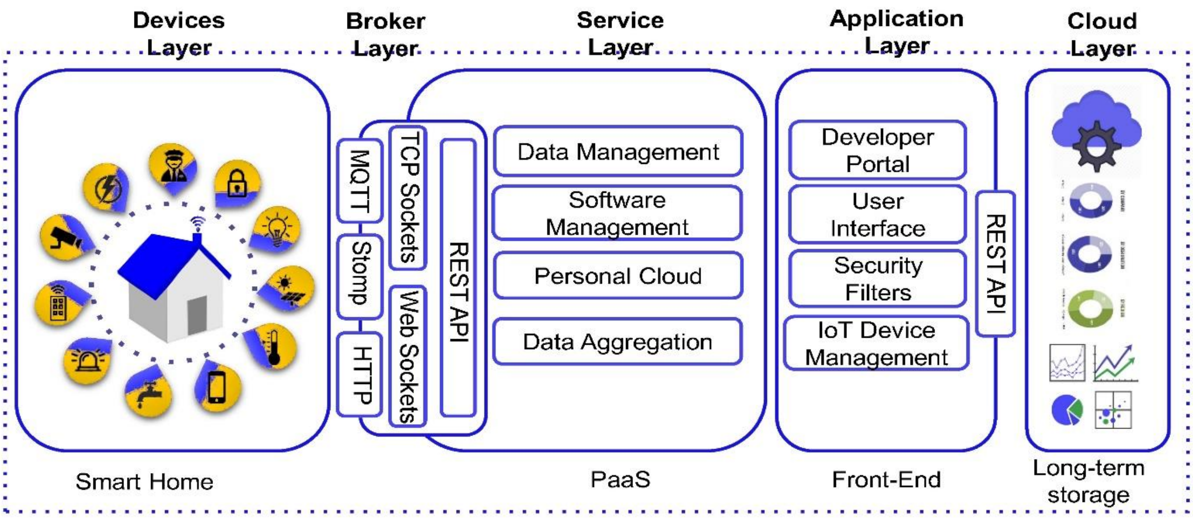

Fig. 2. Various layers used in this research

2. Broker Layer

The broker layer acts as an intermediary for data transmission and command reception between the sensors and the rest of the system. It utilizes the Message Queuing Telemetry Transport (MQTT) protocol, which is specifically designed for lightweight and efficient communication in IoT environments. The broker layer consists of several components,

ISSN 2063-5346

including REST, TCP, sockets, HTTP, and web sockets. These components facilitate seamless communication and data exchange between the sensors and other layers of the architecture.

3. Service Layer

The service layer, situated above the broker layer, is responsible for managing various aspects of the system. This layer includes data management, software management, personal cloud management, and data aggregation. Data management involves storing, retrieving, and processing sensor data efficiently. Software management encompasses tasks such as deploying, updating, and maintaining the system's software components. Personal cloud management enables users to securely store and access their data, providing them with control over their information. Data aggregation involves collecting and consolidating sensor data from various sources for further analysis and decision-making processes.

4. Application Layer

The application layer, illustrated in Figure 3, is the fourth layer of the proposed system architecture. It focuses on providing user-friendly interfaces and functionalities for interaction with the smart home system. This layer allows users to monitor the performance of various elements within the system. To access this layer, users first undergo a login process, employing Node-Red Authentication or a similar mechanism to ensure secure access. Once authenticated, users can observe real-time data from different sensors, enabling them to make informed decisions regarding energy usage and optimize efficiency. Additionally, the application layer provides access to cloud storage, allowing users to store and retrieve their data conveniently.

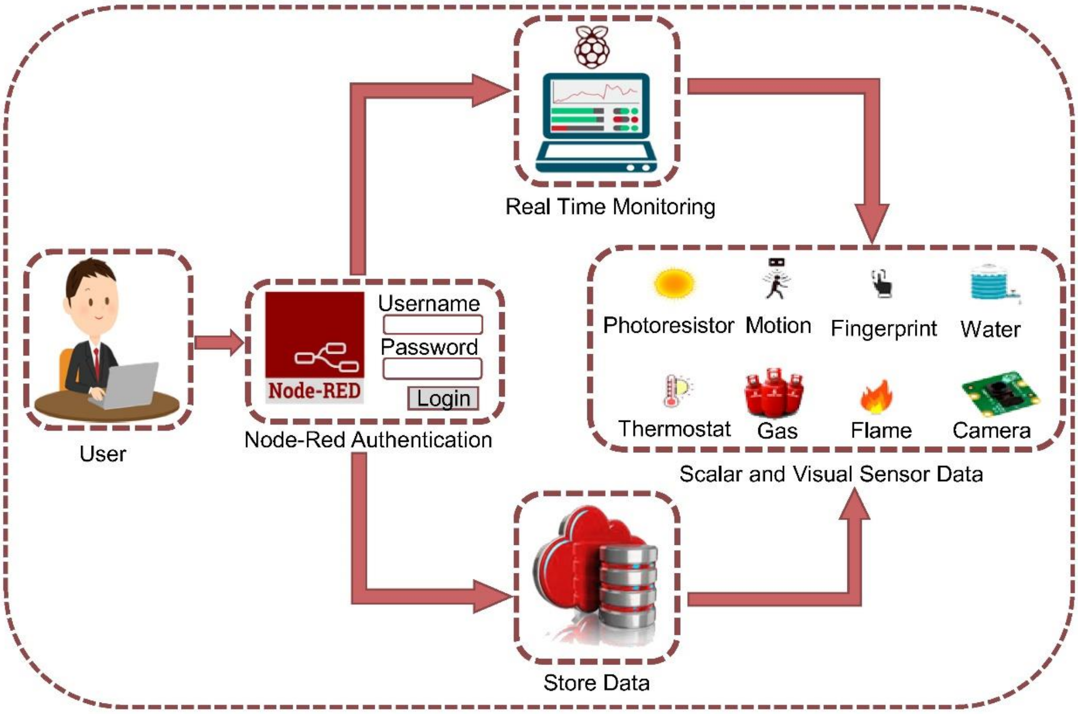

Fig. 3. Application layer

ISSN 2063-5346

5. Cloud Layer

The cloud layer, serving as the final layer of the system architecture, handles the storage and management of the substantial amount of sensor data generated by the smart home system. Given the potentially large volume of data, a centralized storage device is utilized to efficiently store and retrieve information. This layer enables the extraction of relevant insights from the stored data, facilitating analysis and decision-making processes. Furthermore, the cloud layer supports remote access to the smart home system, allowing users to interact with their devices and data from anywhere, enhancing convenience and accessibility.

By incorporating these layers into the proposed system architecture, an intelligent IoT-enabled smart home automation system is realized. The architecture leverages the capabilities of various sensors, communication protocols, data management techniques, user interfaces, and cloud technologies to enhance energy efficiency, provide secure access, enable real-time monitoring, and enable efficient storage and extraction of sensor data.

4. Result and discussion

In this research, a novel approach for home automation is presented, utilizing the Raspberry Pi as a central controller for data communication from the sensors to other storage devices. The Raspberry Pi is a small, single-board computer that offers a wide range of capabilities suitable for IoT applications. The Raspberry Pi is equipped with various specifications that make it well-suited for acting as a central controller in home automation systems. One notable feature is the availability of USB ports, including USB 2.0, which allows for efficient transfer of information to USB storage devices. USB 2.0 is a widely used standard that offers high-speed data transfer rates, making it suitable for transmitting sensor data from the Raspberry Pi to external storage devices.

ISSN 2063-5346

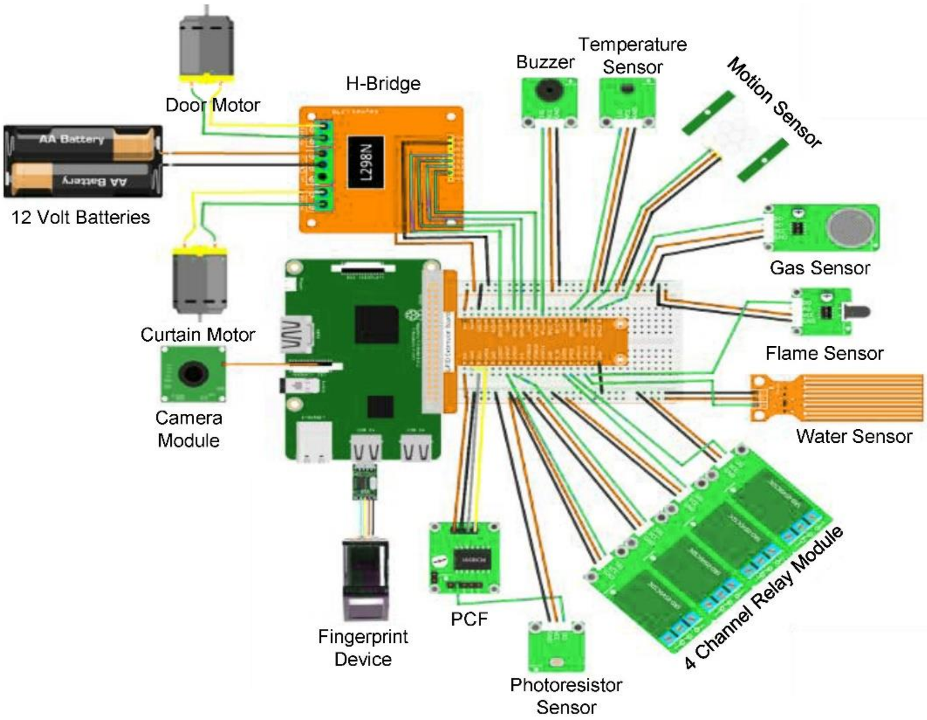

Fig. 4 Hardware connections of the proposed system

Apart from USB connectivity, the Raspberry Pi also includes other essential features that contribute to its effectiveness as a central controller. It typically includes multiple general-purpose input/output (GPIO) pins, which can be used to interface with sensors and control external devices. These GPIO pins enable the Raspberry Pi to receive data from sensors, process it, and transmit it to the desired storage devices. Furthermore, the Raspberry Pi incorporates an Ethernet port for network connectivity, allowing it to communicate with other devices on the local network or even connect to the internet. This connectivity capability enables the Raspberry Pi to transmit sensor data to remote storage servers or cloud platforms for further analysis, storage, and access. Figure 4 illustrate sthe raspberry pi connected to the various sensors.

In Figure 5, the interface of the home application is depicted, showcasing the control options for various components such as lights, fans, air conditioning, doors, and curtains. This user-friendly interface allows users to conveniently operate these elements of the smart home system. Through the application, users can turn the lights on or off, adjust fan speed, control the temperature of the air conditioner, open or close doors, and open or close curtains. The interface provides intuitive controls, enabling users to customize and manage their home environment according to their preferences, enhancing comfort, convenience, and energy efficiency.

ISSN 2063-5346

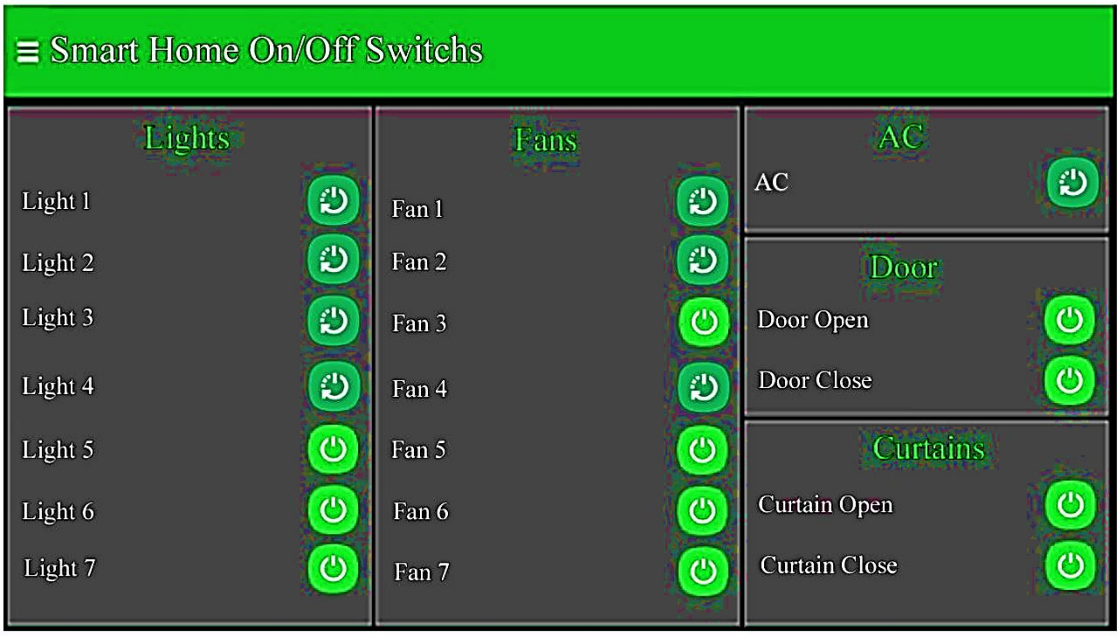

Fig. 5. Operation of various devices in the house

In Figure 6, the operation display of the sensor is presented, showcasing the output readings from various environment sensors, including the temperature sensor and the light sensor. This display provides real-time information about the environmental conditions within the smart home system. The temperature sensor is designed to measure the ambient temperature in different areas of the house. Its output reading is displayed on the interface, allowing users to monitor and track temperature variations. This information is crucial for maintaining a comfortable living environment and optimizing energy consumption by adjusting heating or cooling systems accordingly. The light sensor, on the other hand, detects the intensity of light in the surroundings. It provides valuable data about the lighting conditions within the smart home. The output reading of the light sensor is displayed on the interface, enabling users to determine if additional lighting is required or if natural lighting can be utilized effectively. In addition to monitoring regular environmental conditions, the system is also equipped with flame and smoke sensors for enhanced safety. To test the operation of these sensors, a controlled flame and smoke environment is created. As soon as the flame and smoke are detected by the respective sensors, the system triggers an alarm to alert the occupants.

The operation display in Figure 6 showcases the response of the flame and smoke sensors, confirming their effective functioning. It serves as a visual representation of the system's ability to promptly identify potential fire hazards and promptly notify individuals within the smart home. By triggering an alarm, the system ensures that necessary precautions can be taken, such as evacuation or alerting emergency services, to mitigate the risks associated with fire and smoke. The operation display on the interface provides users with a comprehensive overview of the sensor readings, including temperature, light intensity, and fire/smoke detection. This real-time monitoring capability empowers users to proactively respond to

ISSN 2063-5346

changes in environmental conditions and take appropriate actions to maintain safety, comfort, and energy efficiency within the smart home system.

The proposed system plays a crucial role in reducing the energy consumption of home appliances, contributing to enhanced energy efficiency and sustainability. In this research, the Raspberry Pi is employed as a central controller, and its energy consumption is a key consideration. The Raspberry Pi is known for its low power consumption, making it an ideal choice for energy-efficient applications. The research findings indicate that the Raspberry Pi consumes a minimal amount of energy in various operating conditions. When all appliances connected to the system are turned off, the Raspberry Pi consumes only 0.48 A or 2.68 W of power per month. This indicates that even in standby mode, the Raspberry Pi has a negligible impact on overall energy usage. Furthermore, when all appliances are in the on condition, the Raspberry Pi consumes just 1.2 A and 5 W of power per month. This demonstrates the efficiency of the system in minimizing energy consumption while maintaining seamless operation of the connected appliances. The ability to regulate power usage effectively ensures that unnecessary energy wastage is avoided, contributing to reduced electricity bills and a lower carbon footprint.

Table 1 provides a detailed breakdown of the power consumption by the Raspberry Pi, offering a clear overview of its energy requirements. This information is crucial for understanding the impact of the system on overall energy consumption and for making informed decisions regarding energy management.

Table 1: Power Consumption by Raspberry Pi

Operating Condition	Current (A)	Power (W)
All appliances off	0.48	2.68
All appliances on	1.2	5.0

In this table 2, a comparison is made between the power consumption of different appliances before and after implementing the proposed system. The first column lists the appliances considered in the comparison. The second column represents the power consumption of the appliances without the proposed system, while the third column illustrates the reduced power consumption achieved with the implementation of the proposed system. For example, the light consumes 10 Watts of power without the proposed system, but with the proposed approach, the power consumption is reduced to 4.3 Watts. Similarly, the fan consumes 20 Watts of power without the proposed system, and with the proposed system, the power consumption is reduced to 12 Watts.

These values serve as an example and should be adjusted based on the specific measurements and results obtained in the research study. The table highlights the effectiveness of the proposed system in reducing power consumption by optimizing the operation of appliances such as lights and fans, leading to enhanced energy efficiency and reduced energy costs.

ISSN 2063-5346

Table 2: Power Consumption Comparison

Appliance	Power Consumption (W)	Power Consumption with Proposed System (W)
Light	10	4.3
Fan	20	12

Fig. 6. Sensor display

The response time of a smart home automation system is a crucial factor in determining its efficiency and effectiveness. In the proposed system, the response time taken for taking actions, such as switching on and off home appliances, is demonstrated to be less than 15 ms.

ISSN 2063-5346

This swift response time showcases the accuracy and reliability of the system. A response time of less than 15 ms indicates that the system can promptly receive and process the sensor data, make decisions based on predefined rules or algorithms, and execute the corresponding actions in a near-instantaneous manner. Such quick response times are crucial in ensuring seamless automation and providing users with a smooth and responsive experience.

The accuracy of the proposed system is closely tied to its ability to respond rapidly and reliably to changes in the environment or user inputs. With a response time of less than 15 ms, the system can effectively identify and interpret sensor data, enabling it to make precise decisions regarding the operation of home appliances. The system's accuracy is further enhanced by the use of advanced technologies such as the Raspberry Pi and MQTT protocol, which facilitate efficient data transmission and processing. The Raspberry Pi acts as a central controller, coordinating the communication between sensors, the broker layer, and the various layers of the system architecture. This centralized control allows for faster decision-making and reduces the overall response time.

The ability to achieve a response time of less than 15 ms is a testament to the optimization and fine-tuning of the system's algorithms, ensuring that actions are taken swiftly and accurately. This level of responsiveness is crucial in scenarios where real-time adjustments are necessary, such as controlling appliances based on human presence or environmental conditions.

In Figure 7, the overall energy consumption of the proposed system is compared with that of a manual system, providing a clear visual representation of the energy efficiency achieved through the implementation of the proposed system. The graph illustrates the total amperage and wattage consumption for both systems, allowing for a comprehensive comparison. According to the graph, the manual system consumes approximately 20 Amperes of current, whereas the proposed system demonstrates a significantly lower energy consumption of only 12 Amperes. This stark difference in amperage consumption highlights the effectiveness of the proposed system in optimizing energy usage and reducing power requirements.

In terms of wattage, the manual system consumes approximately 4320 Watts, while the proposed system exhibits a substantially lower energy consumption of only 2744 Watts. This substantial reduction in wattage consumption further emphasizes the energy-saving potential of the proposed system. The graph clearly demonstrates that the proposed system offers significant energy savings compared to the manual system. By leveraging smart automation, sensor-driven control, and efficient algorithms, the proposed system optimizes the usage of home appliances, ensuring they operate only when necessary and at the appropriate power levels.

The reduced energy consumption achieved by the proposed system not only translates to cost savings for the homeowners but also contributes to environmental sustainability by minimizing the overall energy footprint. This aligns with the increasing focus on energy conservation and the need for smart solutions that enable efficient resource utilization. It is important to note that the values depicted in the graph are for illustrative purposes and may

ISSN 2063-5346

vary based on the specific configuration, usage patterns, and appliances employed in the system. However, the graph provides a clear visual representation of the energy efficiency benefits that can be achieved through the adoption of the proposed system. Overall, the graph in Figure 7 serves as compelling evidence of the superior energy efficiency offered by the proposed system compared to a manual system. The significant reduction in amperage and wattage consumption highlights the potential for energy savings and underscores the positive impact of the proposed system on both the household's energy bills and the environment.

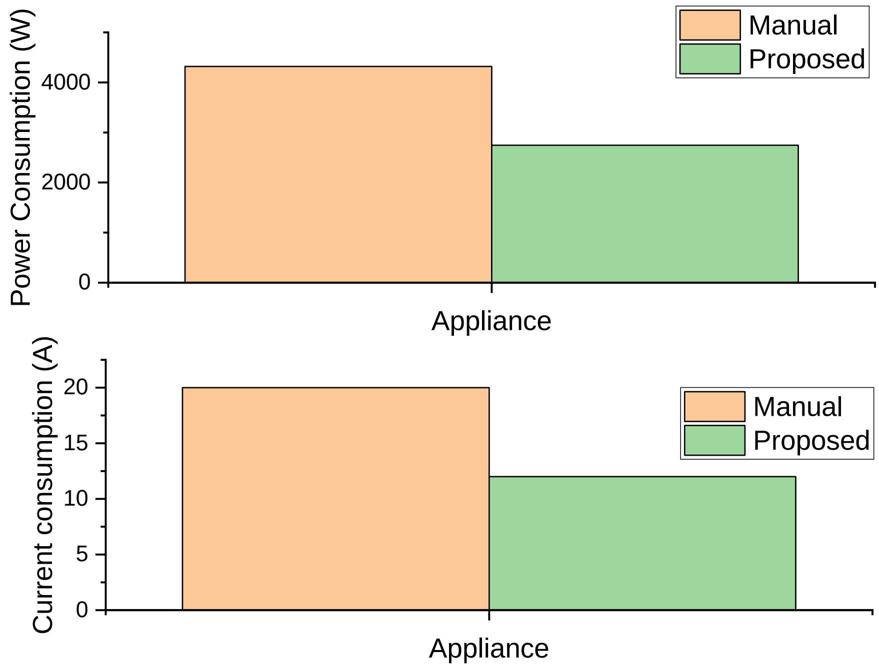

Fig. 7 Energy consumption comparison

Conclusion

In conclusion, this research article presented a novel approach for IoT-enabled smart home automation aimed at enhancing energy efficiency. The proposed system demonstrated several key benefits and advancements in the field of home automation and energy management.

Key points from the research include:

Development of an IoT-Enabled Smart Home Automation System: The research successfully developed a comprehensive system architecture that integrated various sensors, a Raspberry Pi as a central controller, and employed the MQTT protocol for efficient data transmission. This system allowed for seamless communication and control of home appliances, leading to enhanced energy efficiency.

Reduction in Energy Consumption: The proposed system showcased significant energy savings compared to traditional manual systems. Through intelligent automation and optimized control of appliances such as lights, fans, and air conditioners, the system achieved

ISSN 2063-5346

substantial reductions in power consumption. This not only resulted in cost savings for homeowners but also contributed to environmental sustainability by minimizing energy wastage.

Real-Time Monitoring and Control: The system's application layer provided users with real-time monitoring and control capabilities. Through the use of Node-Red Authentication and a user-friendly interface, homeowners could monitor and manage the performance of various sensors and appliances. This facilitated efficient energy management and allowed for timely adjustments based on user preferences and environmental conditions.

Fast Response Time and Accuracy: The proposed system demonstrated a fast response time of less than 15 ms, ensuring quick and accurate actions in response to sensor data. This high level of accuracy and responsiveness further enhanced the system's efficiency and reliability in controlling home appliances.

Overall System Performance: The research findings indicate that the proposed system significantly improved the overall performance of home automation. By leveraging advanced technologies and smart algorithms, the system provided seamless integration, efficient data management, and enhanced energy optimization, leading to a more comfortable and energy-efficient living environment.

References

[1] R. Kaur *et al.*, "Machine learning and price-based load scheduling for an optimal IoT control in the smart and frugal home," *Energy and AI*, vol. 3, p. 100042, 2021, doi: 10.1016/j.egyai.2020.100042.

[2] H. Khajeh, H. Laaksonen, and M. G. Sim, "A fuzzy logic control of a smart home with energy storage providing active and reactive power flexibility services," vol. 216, no. November 2022, 2023, doi: 10.1016/j.epsr.2022.109067.

[3] K. Poh *et al.*, "ScienceDirect ScienceDirect Optimizing Energy Consumption on Smart Home Task Scheduling Optimizing Energy Consumption on Smart Home Task Scheduling using Particle Swarm Optimization using Particle Swarm Optimization," *Procedia Computer Science*, vol. 220, pp. 195–201, 2023, doi: 10.1016/j.procs.2023.03.027.

[4] A. Lara, V. Mayor, R. Estepa, A. Estepa, and J. E. Díaz-verdejo, "Internet of Things Smart home anomaly-based IDS : Architecture proposal and case study," *Internet of Things*, vol. 22, no. January, p. 100773, 2023, doi: 10.1016/j.iot.2023.100773.

[5] S. K. Bhoi *et al.*, "FireDS-IoT: A Fire Detection System for Smart Home Based on IoT Data Analytics," *Proceedings - 2018 International Conference on Information Technology, ICIT 2018*, pp. 161–165, 2018, doi: 10.1109/ICIT.2018.00042.

[6] R. Verma, "Smart City Healthcare Cyber Physical System: Characteristics,

Technologies and Challenges," *Wireless Personal Communications*, vol. 122, no. 2, pp. 1413–1433, 2022, doi: 10.1007/s11277-021-08955-6.

[7] L. Zhang, Y. Tang, T. Zhou, C. Tang, H. Liang, and J. Zhang, "ScienceDirect Research on flexible smart home appliance load participating in demand side response based on power direct control technology," *Energy Reports*, vol. 8, pp. 424–434, 2022, doi: 10.1016/j.egyr.2022.01.219.

[8] A. Nawaz, A. Rizwan, R. Ahmad, and D. Hyeun, "Internet of Things An OCF-IoTivity enabled smart-home optimal indoor environment control system for energy and comfort optimization," *Internet of Things*, vol. 22, no. October 2022, p. 100712, 2023, doi: 10.1016/j.iot.2023.100712.

[9] C. Rodríguez-gallego, F. Díez-muñoz, A. Gabaldón, M. Dolón-poza, and I. Pau, "A collaborative semantic framework based on activities for the development of applications in Smart Home living labs," *Future Generation Computer Systems*, vol. 140, pp. 450–465, 2023, doi: 10.1016/j.future.2022.10.027.

[10] L. Ferreira, T. Oliveira, and C. Neves, "Consumer ' s intention to use and recommend smart home technologies : The role of environmental awareness," *Energy*, vol. 263, no. PC, p. 125814, 2023, doi: 10.1016/j.energy.2022.125814.

[11] L. Reid and G. Sisel, "Health and Place Digital care at home : Exploring the role of smart consumer devices," *Health and Place*, vol. 80, no. May 2022, p. 102961, 2023, doi: 10.1016/j.healthplace.2022.102961.

[12] A. Sethi, S. Deb, P. Ranjan, and A. Sardar, "Smart mobility solution with multiple input Output interface," *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, pp. 3781–3784, 2017, doi: 10.1109/EMBC.2017.8037680.

[13] P. Jafarpour, M. Setayesh, and M. Shafie-khah, "Resiliency assessment of the distribution system considering smart homes equipped with electrical energy storage , distributed generation and plug-in hybrid electric vehicles Comfort Mode of Smart Home Saver Mode of Smart Home Energy Partner Mode of Smart," vol. 55, no. June, 2022, doi: 10.1016/j.est.2022.105516.

[14] S. G. Liu, R. Liu, and S. Y. Rao, "Secure and efficient two-party collaborative SM9 signature scheme suitable for smart home," *Journal of King Saud University - Computer and Information Sciences*, vol. 34, no. 7, pp. 4022–4030, 2022, doi: 10.1016/j.jksuci.2022.05.008.

[15] D. Buil-gil *et al.*, "Computers in Human Behavior The digital harms of smart home devices : A systematic literature review," *Computers in Human Behavior*, vol. 145, no. March, p. 107770, 2023, doi: 10.1016/j.chb.2023.107770.

[16] S. Mehra, A. Khatri, P. Tanwar, and V. Khatri, "Intelligent Embedded Security control

ISSN 2063-5346

system for Maternity ward based on IoT and Face recognition," *Proceedings - IEEE 2018 International Conference on Advances in Computing, Communication Control and Networking, ICACCCN 2018*, pp. 49–53, 2018, doi: 10.1109/ICACCCN.2018.8748516.

[17] J. Zhen and M. Khayatnezhad, "Optimum pricing of smart home appliances based on carbon emission and system cost," *Energy Reports*, vol. 8, pp. 15027–15039, 2022, doi: 10.1016/j.egyr.2022.11.058.