Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X
Volume 3, Issue 7, 2025

INTELLIGENT BLUETOOTH-DRIVEN AUTOMATION:MULTI- SENSOR INTEGRATION FOR REAL-TIME SMART HOME CONTROL

Farhat M. Khan[1], Saqib Munawwar[2], Syed Saad Ali[3], Khurram Iqbal[4], Mahrukh Shoaib[5], Shumaila Qamar[6], Hamza Saleem[7], Bilawal Raza[8]

[1,3,5,8]*Nazeer Hussain University, Karachi, Sindh, Pakistan*
[2,4]*Department of Computing, Faculty of Engineering Science and Technology, Hamdard University, Pakistan. Department of Computer Science,* [6,7]*Faculty of Engineering Science and Technology, Iqra University, Pakistan.*

[*1] saad.ali@nhu.edu.pk

DOI: https://doi.org/10.5281/zenodo.15805419

Keywords
Smart Home Systems, IoT, Energy Consumption, Smart Living Solutions.

Article History
Received on 28 May 2025
Accepted on 28 June 2025
Published on 04 July 2025

Corresponding Author: Syed Saad Ali

Abstract

The integration of IoT into smart home systems addresses the growing demand for advanced home automation by enabling adaptive, intelligent decision-making. While contemporary smart homes leverage IoT, existing systems often lack adaptability, leading to inefficiencies in user experience, energy consumption, and security. This study explores the challenges, opportunities, and implications of implementing intelligent-based smart home technology, proposing a framework that utilizes machine learning and computer vision to create systems capable of learning user behaviors, anticipating needs, and optimizing home management in real time. The study highlights the limitations of current technologies, including their inability to dynamically adjust to user preferences and on-demand accessibility. A prototype smart home system was developed, employing algorithms to analyze usage patterns and autonomously manage lighting, temperature, and security. Deployed in real-world settings, the system's performance was evaluated through user feedback and operational data. Results demonstrated significant improvements in user satisfaction (due to personalized automation), energy efficiency (through optimized resource usage), and security (via proactive threat detection). Additionally, the system's adaptive capabilities reduced energy waste by intelligently adjusting to occupancy and environmental conditions. This study underscores the transformative potential of AI-driven smart homes, offering a sustainable alternative to conventional systems by prioritizing user-centric design and responsiveness. The findings advocate for broader adoption of intelligent technologies to create homes that not only automate tasks but also evolve with residents' needs, fostering a more efficient, secure, and comfortable living environment. Ultimately, this research validates AI's role in redefining human-home interactions, paving the way for future innovations in smart living solutions.

INTRODUCTION

The domestic household produces emissions to attain sustainability to integrate innovative technologies to increase power efficiency with less environmental affect. To optimize power consumption this study investigates the variation for sustainability evolutions. The system needs multi-level perspective architecture to address the major challenge [1]. The IoT based system innovate the system with low power consumption and cost effective solution with wireless connections. This study presents revolution in Bluetooth equipment for the utilization of cloud system for ecosystem. This system is designed to control the system via

automation for the purpose of security and energy management. The future integration of deep learning and AI increase the system efficiency for sustainable solution [2]. The automation system need more functions includes temperature and power consumptions of the appliances. The proposed system uses sim function, Bluetooth and IoT based technologies to design the smart ecological system. This analytical analysis automates the system using AI technology integrated with IoT to minimize the power usage. The proposed study investigates the economical solution to secure and minimize the power consumptions [3].

The IoT integration with home automation control the domestic application via cloud based technology. The study investigates the impact of automation to control the challenges for the state of art employment. The study thoroughly discussed the parameters to deploy the smart robotic system [4]. The ecological monitoring provides the inside appliances controlling via machine learning. The Bluetooth technology is cost effective solution to monitor the system. The proposed system demonstrates the Bluetooth based smart system to detect the security system for the selected area. The designed system attains accuracy neat to 97% for machine learning testing models [5]. The implementation of IoT based system provides sustainable solution to automate and secure the human life's. This study explores the application of

cloud bases system for impaired persons. The components contain Bluetooth based car and IoT based fire alarm and servo motor. This study provides porotype for the future implementation [6]. The renovating the way of living people uses IoT based cloud system to control and manage the domestic appliances. This innovation in technology provides difficult and efficient framework for wireless connection. The control including ecological, security and power system were analyzed in this study for domestic and commercial application. The future integration of AI based system further improves systems [7]. The automation system transforming the globe with smart control and way of living. This study thoroughly discussed the technical innovations especially deep learning, IoT and artificial intelligence flexibility of designed system. The system utilizes for different proposes includes energy, security and health monitoring system for the domestic application [8].

The design and construction of intelligent system uses AT Medga32HP microcontroller, ESP 32 CAM board to control and manage the system functions. The camera is the major control unit of the system integrated with Wi-Fi to communicate with controller to manage the security and protection system. The system produces alarm and vibration when someone uses it forcefully [9]. tion need controller to manage and control the system via cloud based system [10]. The increase in daily cyber threats there is need to implement system with high cyber security. This study presents the sustainable solution for cybersecurity. This work explains the integration of block chain in wireless system and its pros and cons [11].

.The interconnectedness of smart home devices relies on various wireless protocols, and while some proprietary options exist, the majority of devices operate on one of the following five widely used protocols: Z wave, zigbee, Wi- Fi (2.4 G and 5.0 G), Bluetooth low energy (BLE), and Thread. The study focuses on the conformity and incorporation of these protocols in the selected smart home platform and discusses the modularity whereby users can use protocols from different groups in their homes. By delving into the intricacies of these connectivity protocols, the study purposes to deliver a complete solution of the design and fundamental infrastructure essential for the application of smart smart home technology. Diverse protocols in the realm of smart home technology exhibit varying requirements, with some necessitating a hub or bridge for operation, while others rely solely on a Wi-Fi router or smartphone [12].

The worldwide utilization of ioT in business centers and this study focuses Internet of things

for different sectors. This work proposes collection of data for the IoT technology to improve the Bangladesh financial conditions. Further enhancement in application of artificial intelligence improve the different sectors [13]. This work construct prototype for home automation able to operate home appliances includes fans and other electronic devices using we application. This prototype uses ESP32 microcontroller and BlynK application to access the load via web application. This system is designed to reduce the power wastage [14]. The current domestic automation system reduces the labor efforts and operate the system automatically. This study integrates IoT with different sensors to provide data in attached LCD transmit data via cloud networks via Blynk Application. This system controls the energy appliances as well as smoke detection. The system combines with solar panel for clean energy production [15]. This study focusses impaired persons to provide system that detects the obstacles. The gloves integrated with microcontrollers and sensors to translates sign languages using innovative technology IoT [16].

MATERIAL AND METHODS

Hardware Setup:

On the structural level, the primary concept of a smart home is implemented through creating connections. Preliminary essentials needed for smart homes include a stable internet connection, a Wi-Fi router, and a set of smart products which can be a home's lights, locks, thermostats, speakers, and security cameras, preferably a mesh router for larger home networks or a large number of connected devices.

Further, another component essential to a smart home is the use of a Smart Home application or platform for the configuration of devices as well as their programming. To be able to control those devices, different interfaces like smartphone applications, tablets, or voice-assisted smart speakers are quite necessary. The communication in smart home gadgets relies heavily on wireless protocols and the thesis emphasizes the need to acknowledge these wireless protocols [8]. The interconnectedness of smart home devices relies on various wireless protocols, and while some proprietary options exist, the majority of devices operate on one of the following five widely used protocols: Z wave, zigbee, Wi-Fi (2.4 G and 5.0 G), Bluetooth low energy (BLE), and Thread. The study focuses on the conformity and incorporation of these protocols in the selected smart home platform and discusses the modularity whereby users can use protocols from different groups in their homes. By delving into the intricacies of these connectivity protocols, the research aims to provide a comprehensive understanding of the design and fundamental infrastructure essential for the implementation of intelligent-based smart home technology. Diverse protocols in the realm of smart home technology exhibit varying requirements, with some necessitating a hub or bridge for operation, while others rely solely on a Wi-Fi router or smartphone. Notably, these protocols collectively align with Matter, an emerging open standard designed to establish a universal communication framework for devices, presenting itself as a cohesive force in the smart home landscape. Matter, excluding Bluetooth primarily used for onboarding, has the potential to unify devices across different protocols, contingent upon the decisions of individual manufacturers. Effective utilization and configuration of smart devices demand the use of dedicated apps on smartphones or tablets. Although most devices come equipped with their proprietary apps, the expanding array of smart home devices often prompts users to seek a unified platform for centralized control. This centralized approach not only streamlines device management but also facilitates the creation of interconnected routines and automation involving devices from various manufacturers [10]. Five prominent platforms, all compatible with Matter, serve as the primary contenders for smart home integration. These are Amazon Alexa, Apple Home, Google Home, Samsung SmartThings, and Home Assistant. Additionally, a range of smaller platforms caters to more

specific needs and intricate setups. A comprehensive guide on selecting a suitable smart home platform has been developed, complemented by in- depth explorations into each major platform to aid users in navigating the diverse landscape of smart home technology

Components:

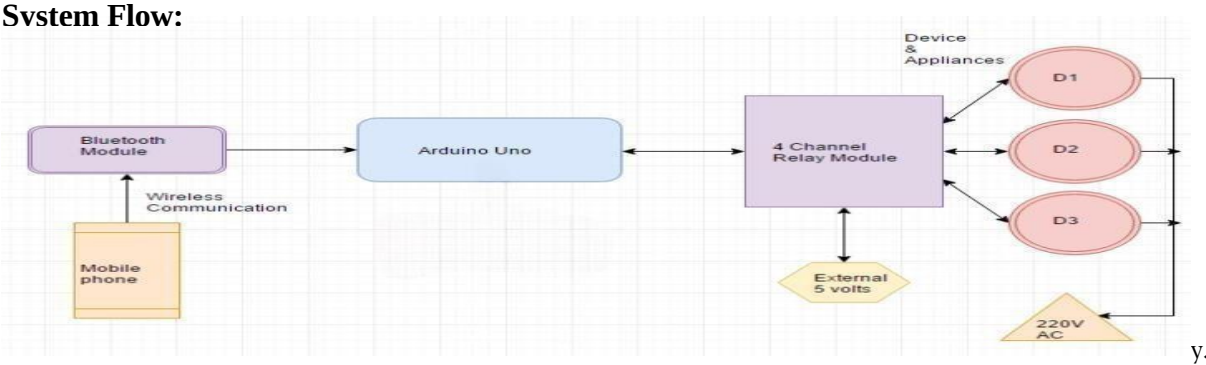
Arduino UNO: The Arduino UNO is a pivotal component in IoT-based smart home systems, serving as the central microcontroller. Figure 1 discloses the constituent parts of Arduino Uno, its role in the system on this setup is to provide a processing unit in which the control signals the various interconnected devices. The Arduino UNO is a very versatile board that is developed for simplicity and convenience; it has both; analog and digital pins which make it easy to interface with sensors, actuators, and communication modules. Its open-source characteristic enables developers to design and develop applications to suit particular Smart home needs.

Figure 1. Components of Arduino UNO board Bluetooth Module: A Bluetooth module, such as the HC-05 or HC-06, is instrumental in enabling wireless communication within the smart home network as shown in Figure 2. Functioning as a communication bridge, it allows devices to establish connections and exchange data with the Arduino or other compatible devices. This wireless capability enhances the flexibility and mobility of smart home components, supporting a dynamic and responsive IoT environment.

Figure 2. Bluetooth Modules

Sensors: The sensors include temperature, sensor motion sensor LDR (Light Sensor), and Bluetooth signal. Sensors can be categorized as the key input data acquisition devices for the smart home system. Temperature, humidity, and motion-sensitive instruments give data about conditions correspond ding to their sensitivity

Svstem Flow:



y.

Figure 3. System Flow

RESULTS AND DISCUSSION

The smart home automation system containing integrated sensors and Bluetooth communication ran different tests resulting in the data shown in Table 1. The sensor functions for activating the fan at 30°C triggered within 150-200 milliseconds while light activation and curtain opening from low light detection also worked as programmed. Testing of sensor-based operations demonstrated successful execution for all activators when the temperature exceeded 30°C or motion detection and low-light conditions activated within 150–200 milliseconds. The system demonstrated successful operation during temperature decreases since it used the fan shutdown protocol. A 400-millisecond response delay with warning status occurred during Bluetooth signal strength reductions below -90 dBm. The system demonstrated accurate operation but showed minor interruptions when Bluetooth signals weakened.

Table 1 Devices Response and Test Results

Sensor Type	Input Condition	Output
Temperature Sensor	Temp > 30°C	Fan turned ON
Motion Sensor	Motion Detected	Light turned ON
LDR (Light Sensor)	Ambient light < 300 lux	Curtains opened
Temperature Sensor	Temp < 25°C	Fan turned OFF
Bluetooth Signal	Weak (RSSI < -90 dBm)	Delay observed (400ms)

Remote Monitoring and Controlling: One obvious and indispensable feature of smart homes, that remote monitoring and control provide users with the ability to monitor and command their homes from the comfort and convenience of their device of choice and location regardless of their physical proximity to the home. This capability spans physical locations and empowers users to operate their homes in real-time more effectively for safety. Smart thermostats offer their users an opportunity to control the temperatures even when they are not at home, and the house will be warm when they arrive.

Security camera feeds are in real-time motion video surveillance, with improved security

through which owners can monitor property and act immediately on any incidents. Additionally, the functionality to switch off lights or control other gadgets reduces energy consumption and at the same time enables management of home appliances with a simple touch of the smartphone application. Such levels of connection offer the users the ability to have peace of mind with being in control, transforming the way they interact with and manage their homes. and, therefore, provide value for sustainable energy consumption and environmental protection when compared to the overall goal of energy consumption for residential need.

Energy Efficiency: One of the major benefits of smart home systems is the energy efficaciousness of resource consumption, which creates a new paradigm of mindful consumption. Smart thermostats for example enable users to have accuracy in heating and cooling systems since they can program it or adjust timings and power remotely based on when the house is occupied or empty.

Similarly, in the aspect of efficiency, users are also allowed to set the lights to work according to their needs, people's presence, or natural light. Further, the integration of energy usage tracking features helps in achieving awareness of the consumption patterns of the various devices. Such integrated management of energy is not only effective in entitling the users to manage their daily schedules but also has the possibility of minimizing the costs with the intersection of time. Thus, smart home systems save energy that does not meet the requirements of the inhabitants.

Security Enhancement: With the use of smart homes comes not just a new way of protecting homes, but also a new feeling of safety among users. Modern smart home security systems come with many advanced features such as motion sensors that rapidly identify instances of activities, door and window sensors that notify users of probable breaches, and surveillance cameras with options to monitor in real time. These systems provide the user with real-time notifications that can be accessed remotely, and the threats or incidents can be addressed within a short time. The real- time observation of the home from anywhere helps a lot in bringing about some sense of security, especially when away. These security elements are closely tied up in fostering integrated home protection that makes it very difficult for any unauthorized person to access the home, enhancing overall home safety. For this reason, smart home alarm systems update traditional conceptions of safeguarding and deliver advanced and proactive approaches to securing their living spaces.

Privacy Enhancement: The interconnected of smart home devices provides benefits of convenience and automation control, yet this system poses real privacy and security threats. Such fears arise due to the collection, transmission, and risk of such personal information via these devices from hacking expeditions. Connected devices in a smart home establish a tendency to collect data about the occupants and their activities including preferences, profiles, schedules, and potentially video or audio recordings, where the devices include cameras or smart speaker assistants. The transmission of such data over networks whether they are local or through the cloud results in potential points of weakness through which the unfavorable parties can easily take advantage. Unauthorized access to personal information poses a serious risk, these lead to privacy violations and breaches likely to be established on sensitive information. Ensuring robust security measures to protect smart home devices is important to minimize these risks. However, this may not be easier, especially for users who may have little or no technical expertise. Computer users are aware of basic security measures such as creating strong passwords, using encryption systems, and updating the firmware of computing devices, among other practices but they may fail to adhere to these best practices or even fail to do it properly due to lack of proper knowledge in

cybersecurity. These instances exemplify the challenges associated with compatibility, fostering confusion and frustration among users and contributing to the subsequent issues in the smart home landscape. Navigating the landscape of smart home devices becomes complex as it's challenging to determine which gadgets are compatible with your existing setup.

System Interface: Figure 4 shows the hardware implementation of the proposed energy system. The hardware setup includes a microcontroller, energy meter, sensors, and bulbs as the load.

Figure 4. System Interface

CONCLUSION

In conclusion, this study set out on a journey to explore the world of smart home automation through the use of intelligent IoT technology and it is with the hope of contributing to the evolving landscape of modern living. The primary objective of this work was to create, deploy, and assess a novel complex based upon combining IoT and AI in smart homes. In the course of this study, we undertook a detailed analysis of the literature to provide a detailed understanding of the concept of smart home automation and what it holds regarding its advantages. The next successive chapters have delineated the conceptualization and design of the proposed framework along with enhanced implementation strategies to develop the intelligent IoT- based smart home automation system. The findings of this project prove the application of the proposed system will produce a revolutionary versatile evolution in the present systems in terms of energy consumption, security, and usability. Applying smart devices and systems, our technology can change the personal experience of the living environment and promote a smarter.

REFRENCES

H. Ramli, Z. M. Azizi, and N. Thurairajah, "Catalysing Urban Sustainability Transitions Through Household Smart Technology Engagement," Sustainability, vol. 17, no. 5, p. 1999, 2025.

G. Koulouras, S. Katsoulis, and F. Zantalis, "Evolution of Bluetooth Technology: BLE in the IoT Ecosystem," Sensors (Basel, Switzerland), vol. 25, no. 4, p. 996, 2025.

M. M. Kalpana, "Survey and Analysis of Home Automation System Encompassing Embedded Systems, the Internet of Things (IoT) and AI Algorithms," Vidhyayana- An Int. Multidiscip. Peer-Rev. E-J., vol. 10, special issue 4, 2025.

[4 A. E. Ezugwu, O. Taiwo, O. S. Egwuche, L. Abualigah, A. Van Der Merwe, J. Pal, ... M. O. Olusanya, "Smart Homes of the Future," Trans. Emerg. Telecommun. Technol., vol. 36, no. 1, p. e70041, 2025.

N. Koksal, A. Ghannoum, W. Melek, and P. Nieva, "Occupancy Monitoring Using BLE Beacons: Intelligent Bluetooth Virtual Door System," Sensors, vol. 25, no. 9, p. 2638, 2025. P. Jayapriya, "Smart Inventions: Internet of Things (IoT)-Based Daily Life Innovations," 2025.

[7]M. P. Anusha, P. D. Vijay, V. Reethika, G. G. S. Karthikeya, and V. K. Burugari, "Unveiling the Potential: An In-Depth Analysis of Empowering Smart Homes Through IoT-Based Sensing and Monitoring Platforms for Enhanced Automation," in Challenges in Information, Communication and Computing Technology, CRC Press, pp. 613–618, 2025.

[8]S. E. Ok, "A Detailed Review of the Progress in Home Automation Systems," 2025.

S. Owoeye, F. Durodola, A. Oyelami, R. Oladejo, S. Obasuyi, A. Qasim, and J. Ogundairo, "Implementation of a Smart Home Intruder Detection System Using a Vibrometer and ESP 32 CAM," ABUAD J. Eng. Res. Dev. (AJERD), vol. 8, no. 1, pp. 14–20, 2025.

M D. Dwivedi, S. Tiwari, A. Bhushan, A. K. Singh, and R. K. Yadav, "Analyzing the Energy Efficiency and Sustainability Implications of IoT Tools in Smart Homes," 2025.

R. Joshi, "Wireless Communication in Smart Environments," vol. 11, no. 6, pp. 66–71, 2025.

T. Magara and Y. Zhou, "Internet of Things (IoT) of Smart Homes: Privacy and Security," J. Electr. Comput. Eng., vol. 2024, no. 1, p. 7716956, 2024.

Islam, Z., Bhuiyan, M. R. I., Poli, T. A., Hossain, R., & Mani, L. (2024). Gravitating towards internet of things: Prospective applications, challenges, and solutions of using IoT. International Journal of Religion, 5(2), 436-451.

Alim, s. a., shobowale, k. o., nwafor, d. c., mahmood, m. n., & ismail, n. (2024). Development of smart home automation system for light, sockets and fan control with mobile application. development, 16(4), 40-54.

Mussa, A. S. M., Arif, M. T., Al Mamun, A., Hasib, A., Islam, A., Hossen, R., & Rahman, A. (2025). Deploying an IoT-enabled Integrated Comprehensive Home Automation System using WSN for Enhanced Continuous Optimization and Fault Identification System. Statistics, Optimization & Information Computing 14(1), 282-310.

Kanna, R. K., Pradhan, N. R., Panigrahi, B. S., Basa, S. S., & Mohanty, S. (2024). Smart Assist System Module for Paralysed Patient Using IoT Application. EAI Endorsed Transactions on Internet of Things, 10.