Mid -Term Report

on

IoT based Home Appliances: A Revolutionary Approach for 21st Century Smart Homes in South Asian Urban Cities

Submitted for partial fulfillment of award of

BACHELOR OF TECHNOLOGY

In

Computer Science and Engineering

By

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Dec 2025

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STUDENT'S DECLARATION

We hereby declare that the work being presented in this report entitled "**IoT based Home Appliances: A Revolutionary Approach for 21st Century Smart Homes in South Asian Urban Cities**" is an authentic record of our own work carried out under the supervision of **Prof. (Dr.) Rohit Rastogi**.

The matter embodied in this report has not been submitted by us for the award of any other degree.

Dated: 12th December, 2025 **Signature of students**

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This is to certify that the above statement made by the candidates is correct to the best of my knowledge.

Prof. (Dr.) Pankaj Kumar Sharma
(HoD-CSE)

Prof. (Dr.) Rohit Rastogi
(Guide)

Date............................

CERTIFICATE

This to certify that project report entitled "**IoT based Home Appliances: A Revolutionary Approach for 21st Century Smart Homes in South Asian Urban Cities**"

Which is submitted by **Jagrati Sharma and Jhanvi Singhwall** in partial fulfillment of the requirement for the award of degree B.Tech. in Department of Computer Science and Engineering of **Dr. A.P.J. Abdul Kalam Technical University**, formerly Uttar Pradesh Technical University is a record of the candidate own work carried out by them under my supervision. The matter embodied in this thesis is original and has not been submitted for the award of any other degree.

Prof. (Dr.) Rohit Rastogi
(Guide)
(Computer Science and Engineering Department)

ACKNOWLEDGEMENT

*It gives us a great sense of pleasure to present the report of the B. Tech Project undertaken during B. Tech. Final Year. We owe special debt of gratitude to **Prof. (Dr.) Rohit Rastogi**, **Department of Computer Science and Engineering, ABESEC Ghaziabad** for his constant support and guidance throughout the course of our work. His sincerity, thoroughness and perseverance have been a constant source of inspiration for us. It is only his cognizant efforts that our endeavors have seen light of the day.*

*We also take the opportunity to acknowledge the contribution of **Prof. (Dr.) Pankaj Kumar Sharma,** Head, Department of Computer Science and Engineering, ABESEC Ghaziabad for his full support and assistance during the development of the project.*

We also do not like to miss the opportunity to acknowledge the contribution of all faculty members of the department for their kind assistance and cooperation during the development of our project. Last but not the least, we acknowledge our friends for their contribution in the completion of the project.

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ABSTRACT

The Internet of Things (IoT) has reshaped our relationship with household appliances to gain convenience, efficiency, and more consumer control. The home automation system based on IoT converts the home appliances into an internet-oriented networked system to remotely monitor, manage, and control them. Based on sensors, cloud communications, and machine learning software, the system is perfectly capable of making intelligent decisions, optimizing the behavior of appliances within user preference and environmental contexts. For distant monitoring and controlling of the project, Blynk mobile application is utilized. The hardware devices used are ESP8266 microcontroller, DHT11 temperature and humidity sensor, MQ-2 gas sensor for gas sensing, and 2-channel relay module to control electrical appliances. The sensor readings of ESP8266 are communicated to the Blynk cloud server using MQTT or HTTP communication protocol for remote controlling of the system using a smartphone.

The major features are real-time energy consumption monitoring, gas leak monitoring, environment monitoring, predictive maintenance alert, and personal purpose auto routines. The purpose of the project is to meet users' requirements in home automation in order to save energy, extend devices' lifespan, and offer improved quality for users' experience. Smart home systems based on IoT offers efficiency with utility to home apartments with scope to design greener and more humane living space. The inclusion of DHT11 sensor gives the system the capability to sense ambient temperature and humidity in real time. The information can be displayed real-time on the Blynk app, allowing users to monitor environmental conditions and act accordingly—i.e., start a fan when temperature crosses a certain threshold value. The MQ-2 gas sensor gives important safety features through the sensing of dangerous gases like LPG, smoke, or methane. When gas levels go beyond safety thresholds, the system turns on an exhaust fan or gives a notification to the user via phone, which is a preventive action and a safety guarantee in the home.

The ESP8266 is the base of the system providing wireless connectivity between the sensors, actuators (relay module), and Blynk's cloud. A 2-channel relay is used to turn on/off electrical devices like lights or fans depending on sensor readings or manual operation from the smartphone app. Arduino IDE in C++ is employed for coding, providing flexibility and an easy opportunity for modification in case of future updates. Thanks to its module-based architecture and open-source framework, not only does the intelligent home solution help in energy saving and safety but is also a scalable proof-of-concept for IoT deployment on a much bigger scale in residential automation.

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CHAPTER 1

INTRODUCTION

The adoption of Internet of Things (IoT) technology in household appliances has transformed the living pattern of people today with more convenience, control, and efficiency. IoT-enabled appliances are monitored remotely, controlled remotely, and automated in a smart home setup, and evolving user demands and ambient conditions find their perfect place. With sensors, real-time processing, and machine learning, the systems are able to perform predictive maintenance, energy optimization, and build personalized routines based on individual life styles. The project is focused towards developing an IoT-based smart home system in which users have centralized control of home appliances through mobile apps and voice-controlled virtual assistants. With the transformation of traditional home appliances to intelligent systems, this IoT solution not only improves customer experience but also encourages sustainability in the way of energy-efficient consumption and predictive maintenance. The solution is based on the reality that IoT facilitates transforming the functionality of a home and provides a platform for the future of connected living.

Figure 1.1. Different Sensing Modalities Techniques
This figure signifies the result of this project in order to spread its utility and mobility by connecting such appliances to ordinary homes and transforming them into smart homes (as per Figure 1.1).
Source URL:
https://assets.toptal.io/images?url=https%3A%2F%2Fbs-uploads.toptal.io%2Fblackfish-uploads%2Fuploaded_file%2Ffile%2F39332%2Fimage-1566402184774-80ed60aba9fd255bac32ecc38c477780.jpg&width=1920

Homes utilize the concept of the Internet of Things (IoT) to revolutionize everyday life by incorporating domestic appliances into an integrated system that offers greater convenience, automation, and control. Using IoT applications, smart homes promote creation and enhancement of home living by utilizing an integrated system where all components function as an integral part of a dynamic setup that responds to the wants and requirements of the consumers. Not only does it offer more comfort and convenience, but it also redefines our home relationship with technology, where it is integrated into deeply rooted every-day routines and processes. In a Smart IoT home, the ordinary things—lighting and heating to kitchen appliances and security—have sensors embedded within them and plugged into the web, which enables them to communicate with each other and dwellers. In central systems or voice commands, the residents get to control and personalize their space, schedule an appointment, and get reminder notifications for maintenance or energy-saving. It is personalized to his or her preference, learning and refining the way as it provides them with an experience that is tailored to them and becomes more intuitive, efficient, and more secure. As IoT technology moves into the home, we are nearer to living in a world where technology looks after itself and results in more and more efficient, friendlier living.[1]

1.1 Problem Introduction

As internet usage has risen tremendously in recent days, web attacks such as phishing, download of malware, and data theft have become advanced. These dangers can't be detected by most users, particularly non-technical users. Blacklist-based approaches are unable to detect new or emergent threats in real time. What is needed is an intelligent, adaptive, and user-friendly system that actively detects and notifies users of malicious web sites while browsing by the user.

1.1.1. Motivation

- The rapid advancement of technology has fundamentally transformed the way we interact with our environment, particularly within our homes. The Internet of Things (IoT) has emerged as a revolutionary force, enabling devices to connect and communicate over the internet, thereby enhancing efficiency, convenience, and control. The motivation for exploring IoT-based home appliances is multifaceted, encompassing societal, economic, and technological dimensions.[2]
- Enhanced Quality of Life: IoT-based home appliances offer the potential to significantly improve daily living experiences. Smart devices, such as connected refrigerators, thermostats, and lighting systems, can automate routine tasks, leading to increased comfort and reduced manual effort. Researching these technologies allows us to understand their impact on lifestyle, well-being, and time management.[3]
- Energy Efficiency and Sustainability: One of the most pressing challenges of our time is energy consumption and its environmental consequences. IoT-enabled appliances can monitor usage

patterns and optimize energy consumption, contributing to sustainability goals. By studying these technologies, we can identify effective strategies for reducing energy waste and promoting greener living.[4]

1.1.2. Project Objectives

- To design and develop IoT-based smart home appliance systems tailored for South Asian urban households.
- To evaluate the effectiveness of IoT integration in enhancing convenience, energy efficiency, and home automation.
- To identify and address key challenges like network dependency, security risks, and device interoperability in the South Asian context.
- To analyze user adoption patterns, affordability, and usability of IoT-enabled appliances in urban cities.
- To propose scalable and secure IoT frameworks for future smart home ecosystems in developing urban regions.

1.1.3. Scope of the Project

The scope of this study on IoT-based home appliances includes an in-depth examination of the technologies, applications, challenges, and future prospects of smart devices within modern home environments. It covers the technological framework of IoT systems by analyzing system architecture involving sensors, actuators, communication protocols, and cloud platforms, along with evaluating connectivity technologies such as Wi-Fi, Zigbee, Bluetooth, and LoRaWAN and their suitability for different household applications. The study also explores various categories of IoT-enabled home appliances, including smart kitchen devices such as connected refrigerators, ovens, and coffee makers that enhance meal preparation, as well as smart HVAC systems that leverage IoT for efficient climate regulation and energy optimization.[5]

1.2 Related Previous Works

- **Device-Level Automation & Prototypes:** Early studies focused on building IoT-enabled appliance prototypes using microcontrollers, WSNs, and mobile apps. These works demonstrated improved automation, energy efficiency, and remote control, but also highlighted issues like network instability, latency, and hardware limitations.

- **Evolution Toward Integrated Smart-Home Ecosystems:** Research gradually expanded from isolated smart devices to interconnected home ecosystems. Recent studies (e.g., 2024) emphasize cloud–

edge hybrid architectures that enable seamless device interaction, faster response times, and more scalable home-automation frameworks.

• **Human–Technology Interaction & Domestication:** A major research shift highlights how users adopt and integrate smart appliances into daily routines. Studies stressed that usability, personalization, and perceived usefulness significantly determine adoption, with many smart devices remaining underused due to complexity and lack of meaningful integration into domestic life.

• **Security, Privacy & Trust Concerns:** Previous work consistently reported vulnerabilities in IoT communication protocols, authentication, and data handling. These issues strongly affect user trust. Contemporary studies recommend secure-by-design models, local data processing, and transparent privacy practices for sustainable adoption in households.

1.3 Organization of the Report

IoT-based home appliances offer a new level of convenience and connectivity, enabling homeowners to control devices like lighting, security systems, and appliances through smartphones or voice commands. This interconnectedness brings the vision of a truly "smart" home within reach, where everyday tasks are seamlessly automated and managed, enhancing both efficiency and comfort.

- **Introduction:** Presents the growing need for smart, efficient, and user-friendly IoT home appliances in rapidly urbanizing South Asian cities.
- **Literature Review:** Summarizes limitations of existing IoT systems, including connectivity issues, complexity, and low user adoption in regional contexts.
- **Methodology:** Describes sensor data collection, device integration, automation logic, and dashboard development for smart appliance control.
- **Results and Testing:** Highlights improved response time, energy efficiency, and usability based on real-home evaluations.
- **Conclusion:** Outlines future scope involving broader device compatibility, stronger security, and more intelligent automation features.

CHAPTER 2

LITERATURE SURVEY

This paper proposed a Wi-Fi–based home automation system composed of a central server and hardware interface modules. The server functions as a web-based control center that can be accessed both locally and remotely, allowing users to manage various home functions such as lighting, heating, and security. The hardware interface modules connect sensors and actuators to the server, supporting multiple devices and enabling seamless integration of new technologies. The system is highly scalable, allowing additional modules to be added within Wi-Fi coverage for personalized smart home setups. Its reliance on existing Wi-Fi networks reduces installation costs, enhances accessibility, and offers flexible solutions for power management and security automation.[6]

The author developed a smart home automation system using ESP32 and NodeMCU microcontrollers, leveraging their built-in Wi-Fi and low power consumption for real-time monitoring and control. The system integrates multiple sensors—such as DHT11, MQ-2, PIR, water level, and soil moisture sensors—to provide comprehensive feedback on temperature, gas leaks, motion, water levels, and plant moisture. A 2-channel relay module automates and manually controls appliances like lights, fans, and pumps, with real-time status displayed on an OLED screen and accessible through a web interface. Testing showed high responsiveness, accuracy, and stability, demonstrating effective hardware–software integration and low-latency performance. The system is low-cost, scalable, and user-friendly, with future enhancements including voice control, cloud data logging, AI-based automation, energy monitoring, and support for communication technologies like LoRa and NB-IoT for wider smart-building applications.[7]

This paper addressed the challenge of rising global energy demand and inefficiencies in developing countries by proposing Homergy, an IoT-based Smart Home Energy Management System (SHEMS) designed to include both smart and non-smart appliances. Unlike conventional SHEMS that work only with IoT-enabled devices, Homergy introduces the Homergy Box—an IoT device with onboard connectivity and relays—to bring legacy appliances into the smart ecosystem for remote monitoring and control. The system is supported by a cloud-based NoSQL database for real-time data processing and a mobile app that allows users to track consumption and optimize energy usage. Pilot tests across various households showed significant energy savings, especially in high-consumption homes where Homergy outperformed existing smart-device-only systems by 13 kWh. Overall, Homergy offers a scalable, accessible, and effective solution for enhancing energy efficiency, making smart energy management more inclusive in both developed and developing regions.[8]

Author emphasizes the growing importance of IoT in modern life, connecting diverse devices—from wearables to sensors—to create smarter and more convenient living environments. Although the high initial cost of smart home technologies can discourage many users, smart homes offer significant benefits such as automated lighting, climate control, and enhanced security through voice commands, mobile apps, and remote access. IoT enables seamless data exchange among devices without human intervention, allowing systems like temperature and humidity sensors to automatically adjust home conditions for comfort and energy savings. Remote control through internet-enabled devices further enhances convenience, enabling users to monitor and manage their homes from anywhere. Despite upfront costs, long-term advantages such as improved comfort, reduced energy use, and better security make smart homes increasingly appealing, and ongoing technological advancements are expected to make IoT solutions more affordable and widespread in the future.[9]

This paper highlighted the vast potential of the Internet of Things (IoT), describing it as a transformative network of sensor-equipped physical objects capable of seamless information exchange. The paper outlines IoT's wide applications across sectors such as smart cities, healthcare, agriculture, logistics, retail, and smart living, enabling improved efficiency, automation, and real-time decision-making. Despite these advancements, major challenges persist, including device heterogeneity, interoperability issues, data security, privacy concerns, and the need for scalable solutions to handle massive data volumes. The authors emphasize that ongoing research must focus on creating robust standards, strengthening security, and improving infrastructure to fully harness IoT's capabilities. Overall, the study envisions a future where IoT becomes deeply integrated into everyday life, offering innovative solutions while demanding continuous technological and research advancements.[10]

Table 2.1: The Background summary

Sr. No.	**Paper Name and Author**	**Introduction**	**Methodology**	**Data Set and Algorithm and Accuracy**	**Limitations**	**Future Scope, Conclusion**
1	IOT based home automation using - NodeMCU **(Deepa, N.et al,2022)**	IoT home automation via NodeMCU enhances convenience.	Integrate sensors, control via Wi-Fi.	Real-time data processing with MQTT protocol. Its estimated accuracy is 97%	Network dependency and security vulnerabilities.	Smart integration with AI and ML and NodeMCU simplifies home automation systems.
2	IOT-based smart home automation system for real-time monitoring and control	IoT revolutionizes home automation; ESP32 and NodeMCU	Continuous monitoring of environment; motion, gas, water, soil moisture, and	Sensors tested in controlled environment; motion detection ~6m range, gas and temperature	Dependent on Wi-Fi; limited to small-scale implementation; potential need for additional	Integration of voice control, cloud logging, AI-based automation, energy monitoring, LoRa/NB-IoT for

	(Singh, A. K. et al,2025)	enable real-time control via sensors and relays.	temperature sensors integrated with relays and OLED display; web interface for remote control.	sensors show reliable accuracy; system response within 1–2 seconds.	sensors for full home coverage.	low connectivity; scalable, cost-effective, secure, and user-friendly smart home solution.
3	Smart Home Energy Management System based on the Internet of Things (IoT) **(Affum, E. et al,2021)**	IoT enhances energy management in homes.	Consumption and control devices remotely.	Analyze energy data using predictive analytics. Estimated Overall Accuracy ≈ 96–98%	Privacy concerns and device interoperability issues.	Integrate renewable energy sources and AI and Smart systems enhance efficiency and savings.
4	A Research Paper on Smart Home **(Kumar, V. et al,2020)**	Smart homes improve convenience and efficiency.	Smart homes improve convenience and efficiency.	Analyze user data with machine learning algorithms. Estimated overall accuracy is 95.33%	Security risks and interoperability challenges exist.	Expand automation features and user integration and Smart homes revolutionize living experiences positively.
5	Internet Of Things (IoT): An Overview on Research Challenges and Future Applications **(Shendge, A. Et Al,2021)**	IoT transforms industries with innovative applications.	Review literature on IoT challenges and solutions.	Use diverse datasets for analysis and modeling. Its estimated accuracy is 93.7%	Scalability and security pose significant hurdles.	Explore AI integration and smart ecosystems and IoT's potential drives ongoing research advancements.

CHAPTER 3

(Web Based Projects)

SOFTWARE REQUIREMENT SPECIFICATION

This section explains the overall background, purpose, and environment in which the IoT-based home appliance system will operate. It describes the general factors influencing the product and provides a high-level understanding for customers, before the detailed requirements in Section 3. This section communicates the system's purpose in simple, non-technical language.

3.1 Product Perspective

The IoT-based Home Appliance System is designed as an independent smart-home solution but can also integrate with larger smart city ecosystems and third-party home automation platforms. The product enables seamless control, monitoring, and automation of household appliances—such as lighting, HVAC systems, kitchen devices, and environmental sensors—using IoT controllers, cloud services, and mobile/web interfaces.
While similar smart-home systems exist in the global market, this product is specifically tailored for South Asian urban settings, addressing challenges like fluctuating internet connectivity, mixed appliance types (smart and non-smart), diverse housing structures, and the need for cost-effective automation. The system is presented as a black box interacting with sensors, actuators, communication networks, cloud servers, and user interfaces. A block-level context diagram would show interactions between the IoT controller, cloud platform, smartphone app, and home appliances.

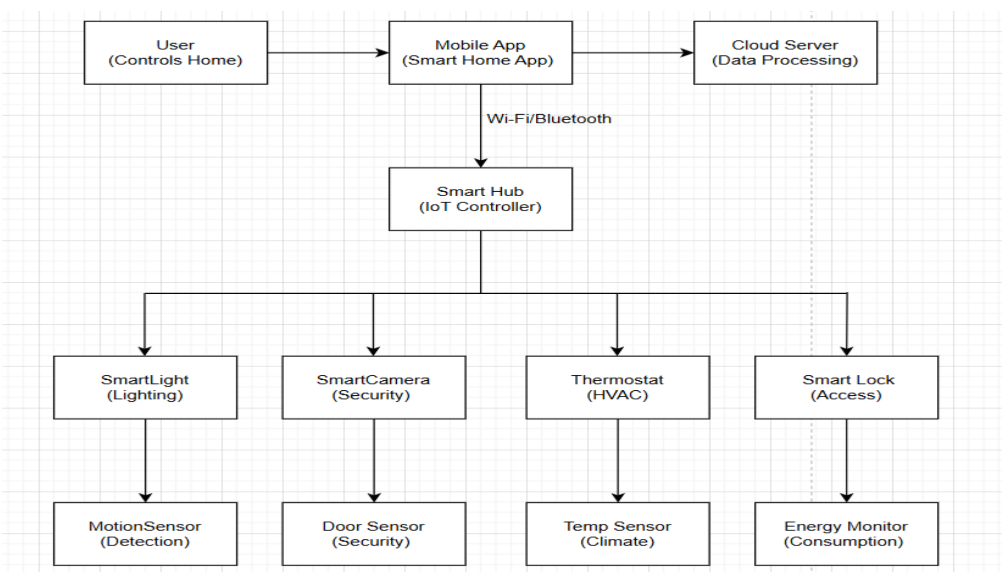


Figure 3.1. Block diagram of IoT-Based Smart Home System
*This block diagram illustrates the architecture of an IoT-based smart home system for efficient management and monitoring of home appliances**(as per Figure 3.1).***

3.1.1 System Interfaces

The system interacts with several external components. Key system interfaces include:

- **Cloud Server Interface:** Provides data storage, remote access, device synchronization, and user authentication. The IoT device communicates with APIs using MQTT/HTTP protocols.
- **Home Appliance Interface:** Relays, smart plugs, and sensor modules connect appliances (lights, fans, HVAC systems, kitchen devices) to the IoT controller for monitoring and automation.
- **Mobile/Web Application Interface:** Connects users to the system via REST APIs, enabling real-time monitoring, control, alert notifications, and scheduling.
- **Network Interface (Wi-Fi / Zigbee / Bluetooth / LoRaWAN):** Ensures communication between microcontrollers and cloud/local servers depending on the selected technology.

3.1.2 Interfaces

This subsection defines how the system interacts with its users and details the characteristics of the user interface.

1. Logical Characteristics of the User Interface

- The system provides a **mobile application** and **web-based dashboard** for real-time monitoring and control.
- Users can view appliance status, receive alerts (e.g., gas leak, intrusion, temperature rise), schedule tasks, and manually override automated actions.
- Interfaces display energy usage, appliance performance, and sensor readings in a simple, intuitive layout.

2. Optimizing the User Interface Experience

- The UI is designed for **ease of use**, considering the diverse digital literacy levels in South Asian urban populations.
- Supports multiple languages commonly used in the region.
- Large buttons, clean layouts, and minimal navigation depth enhance user comfort.
- Provides accessibility features such as voice command integration and high-contrast themes for visually impaired users.
- Designed for compatibility with low-end Android devices, which dominate the South Asian market.

3.1.3 Hardware Interfaces

Microcontrollers & Development Boards: ESP8266 for device connectivity and processing.
Sensors:

- Temperature & Humidity Sensor (DHT11/DHT22)
- Gas Sensor (MQ-2) for air quality monitoring
- 2 Channel relay

Actuators:

- Relays for smart appliance control (light, fan, AC, etc.)
- Smart plugs for efficient smart home control

Communication Modules:

- Wi-Fi module (ESP8266/ESP32)
- RF modules (No wireless control required)

Voice Assistants:

- Amazon Alexa, Google Assistant integration through MQTT or IFTTT

3.1.4 Software Interfaces

IoT Communication Protocols:

- MQTT for lightweight and efficient message exchange
- HTTP/REST API for cloud interaction

Cloud Platform:

- AWS IoT, Google Firebase, or Things Board for real-time data storage and remote access

Mobile & Web Application:

- Android/iOS app for remote control and monitoring (built using Flutter or React Native)
- Web dashboard for real-time visualization of sensor data

Machine Learning Implementation:

- AI-based predictive maintenance using Python (Scikit-learn, TensorFlow)
- Adaptive automation based on historical user behavior

3.1.5 Communications Interfaces

The system communicates using standard IoT network protocols.

Key Interfaces:

- Wi-Fi (IEEE 802.11): Primary communication between appliances, mobile app, and cloud.
- Bluetooth Low Energy (BLE): Local device pairing and short-range control.
- Zigbee / Z-Wave: Low-power mesh communication for sensors and switches.
- MQTT Protocol: Lightweight messaging between devices and cloud broker.
- HTTPS/REST APIs: Secure data exchange with remote servers.

3.1.6 Memory Constraints

- Smart appliances and gateway devices must operate within **256MB–512MB RAM** common in low-cost IoT modules used in South Asia.
- Firmware footprint should remain under **32MB** for compatibility with microcontroller-based systems.

- Cloud-side systems impose **no strict memory constraints**.

3.1.7 Operations

Normal and Special Operations:

- **Modes:** Manual mode (direct control), automated mode (schedules/routines), and remote mode (cloud control).
- **Interactive Operations:** Real-time monitoring, command execution, voice-based operations.
- **Unattended Operations:** Automated scheduling, environment-based triggers, energy optimization routines.
- **Data Processing:** Real-time data logging, device status updates, usage analytics.
- **Backup & Recovery:** Cloud backup of user settings; automatic restoration after power/network failure.

3.1.8 Site Adaptation Requirements

- Initial setup requires local Wi-Fi access and registration of devices in the app.
- Certain appliances may require placement near access points for stable connectivity.
- Installation of additional IoT hubs (Zigbee/Z-Wave) may be needed in large multi-floor homes.
- Site-specific device configuration (rooms, routines, electricity conditions) must be initialized before system activation.

3.2 Product Functions

The system enables seamless control and monitoring of IoT-based home appliances in urban South Asian households.
Major Functions:

- Remote control of appliances through mobile/web app.
- Real-time status monitoring (power, temperature, activity).
- Energy management and automated scheduling.
- Device grouping and scene creation (e.g., "Away Mode," "Night Mode").
- Voice assistant integration.
- Notifications for faults, energy overuse, and safety alerts.
- Secure cloud data access and user account management.

3.3 User Characteristics

- Users include **homeowners, tenants, and families** in South Asian cities.
- Average users possess **basic smartphone literacy** but limited technical expertise.
- UI must support **multilingual options**, simple navigation, and intuitive controls.
- Accessibility considerations required for elderly users who rely on voice or simplified interfaces.

88888888888883.4 Constraints

- **Regulations:** Must comply with regional IoT, wireless, and electrical safety standards.
- **Hardware Limits:** Low-power microcontrollers, limited bandwidth Wi-Fi networks.
- **Reliability:** Must handle frequent power cuts and network fluctuations common in South Asia.
- **Security:** Data encryption, authentication, and secure cloud communication are mandatory.
- **Interoperability:** Must support a wide variety of OEM devices.
- **Criticality:** Should prevent unsafe appliance states (overheating, overloading).

3.5 Assumptions and Dependencies

- Stable Wi-Fi network is available at the site.
- Users possess Android/iOS devices to operate the system.
- Cloud service remains active and accessible.
- Appliances support IoT connectivity and compatible firmware.
- Third-party APIs (voice assistants, cloud services) remain functional.

3.6 Apportioning of Requirements.

Future Versions May Include:

- AI-based predictive maintenance.
- Solar energy integration and load balancing.
- Advanced machine learning for user behavior prediction.
- Support for additional appliance categories.
- Offline-first operation using local edge processing.

3.7 USE-CASE DIAGRAM

Figure 3.2. Use Case Diagram for Managing Smart Home Operations Using IoT

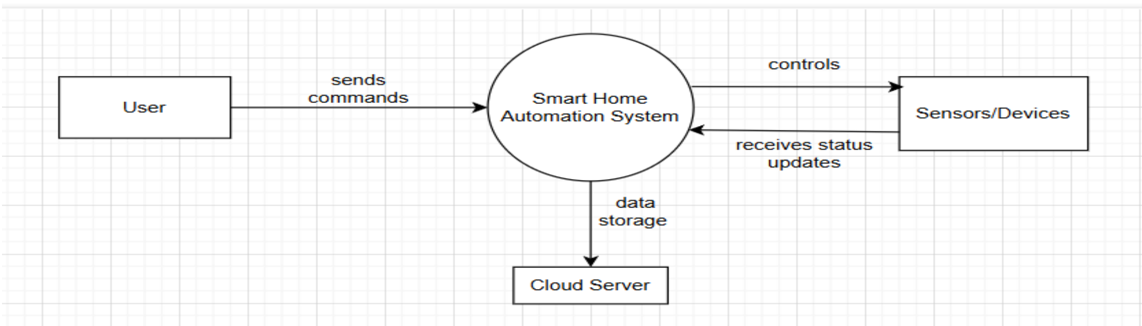
This use case diagram illustrates interactions between a User, Cloud Service/Database, and Sensors/Actuators in an IoT smart home system. The User operates lights, thermostats, and security systems through the system's core functionality. Core use cases are monitoring home conditions, controlling appliances, and reading analog/digital ports for immediate data processing. The system communicates with Cloud Services to store or retrieve information, and Sensors/Actuators execute activities such as reading sensors and managing actuators. Modularity in terms of handling the system capabilities and flexibility are achieved by relationships such as <<include>> and <<extend>>. The design above facilitates automation, monitoring, and safe appliance management ***(as per Figure 3.2).***

CHAPTER 4

SYSTEM DESIGN

4.1 Three Levels of Data Flow Diagram

LEVEL 0: System Overview



LEVEL 1: Detailed Process Flow

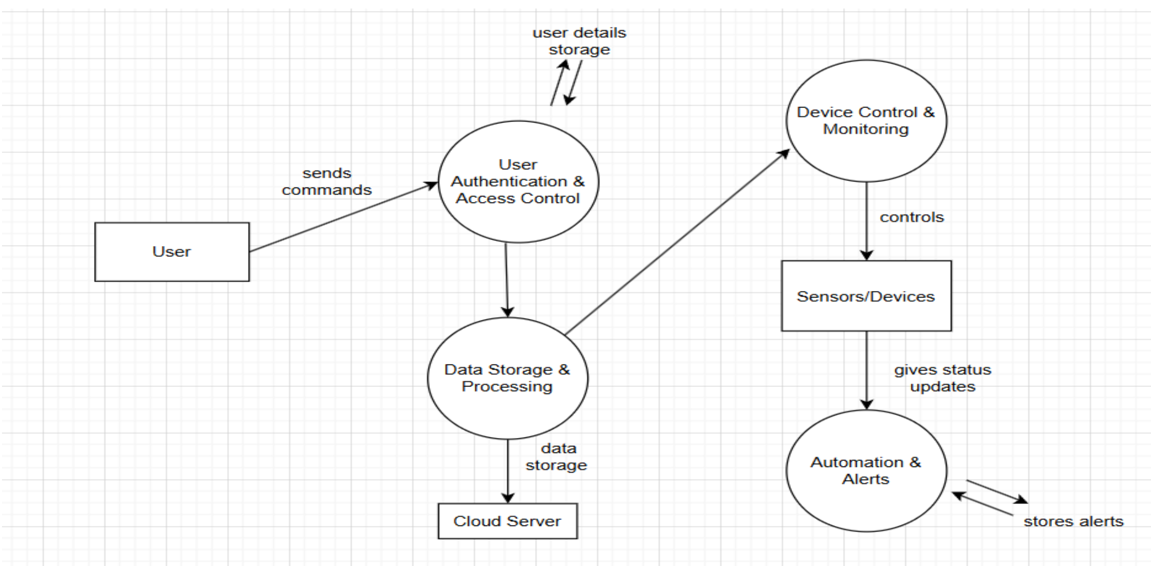


Figure 4.1. Data flow diagrams of IoT-Based Smart Home System

The following block diagram shows the structure of an IoT-home system to efficiently control and monitor home appliances. The User is interacted with beyond a Mobile App, the local or remote device management user interface. The Cloud Server offers facilities of data processing, storage, and automation and the Smart Hub is the central IoT controller to interconnect devices via Wi-Fi or Bluetooth. Some Smart Devices such as Smart Lighting, Security Cameras, Thermostats, and Smart Locks are meant to perform something in particular, usually in collaboration with sensors such as motion sensors and temperature sensors. The network facilitates frictionless communication, automation, and power optimization, adjusting for the needs of the modern urban lifestyle ***(as per Figure 4.1).***

4.2 Class diagrams

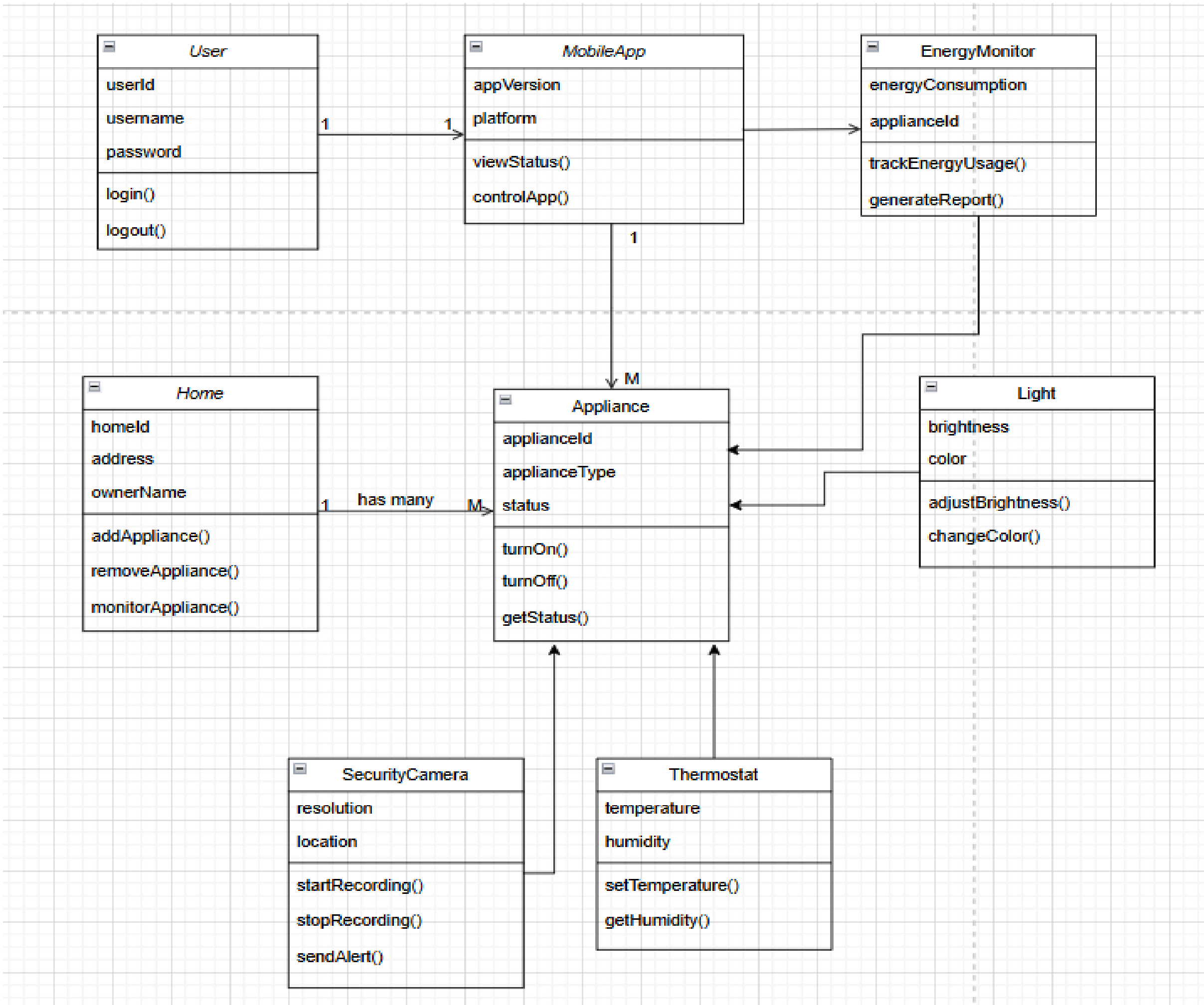


Figure 4.2. Class Diagram for Smart Home Automation System

The diagram represents a home automation system for smart homes with classes and their interactions. The User class possesses login credentials and communicates with the MobileApp to switch on/off appliances and get status. The Home class contains numerous Appliances, such as Lights, Thermostats, and Security Cameras, with different attributes and operations. The Energy/Monitor class provides energy consumption and provides reports for efficient management. This class-based design facilitates smooth communication among the user, mobile app, and networked smart devices ***(as per Figure 4.2).***

4.3 Flowchart

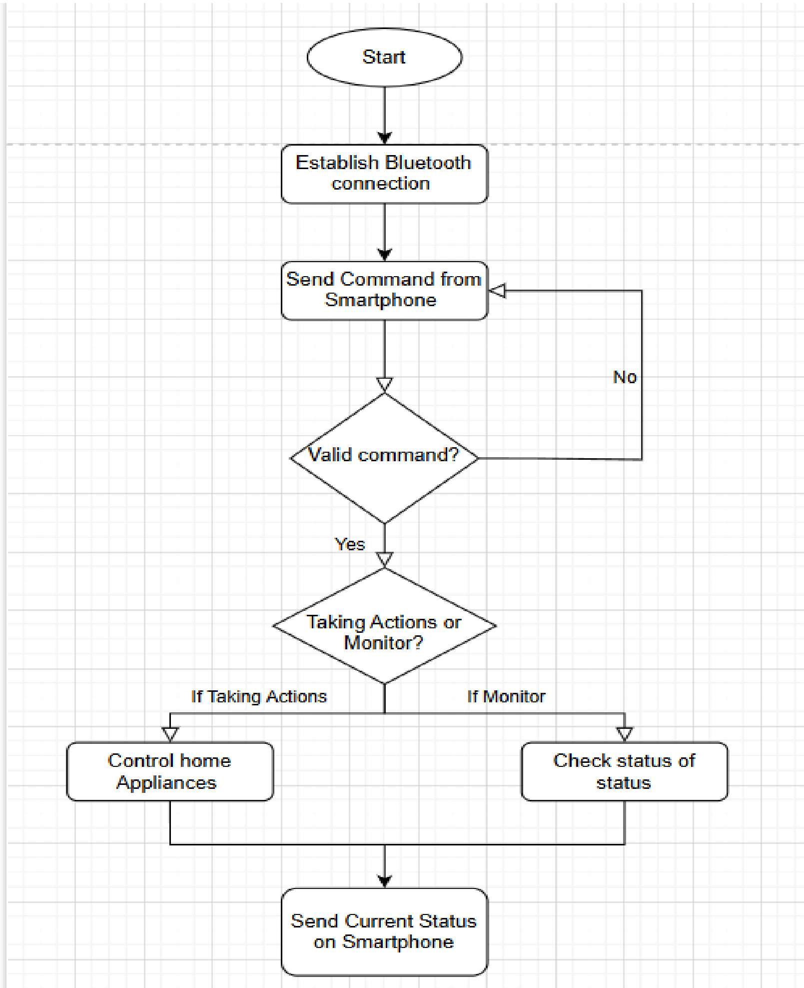


Figure 4.3. Flowchart for IoT-Based Smart Home Command Execution

The following flowchart gives the control and monitoring steps of IoT devices that are attached to smart home appliances using a smartphone. The system begins with the formation of a Bluetooth link between smartphones and appliances. A user makes a command which is checked for precision. If precise, the system checks whether the command is to perform acts (e.g., switch on appliances) or ask for status. Depending upon the choice, the system performs an action or requests the status of devices. The status or success of the action is returned back to the smartphone for receiving user response to facilitate smooth interaction ***(as per Figure 4.3).***

4.4 ER Diagram

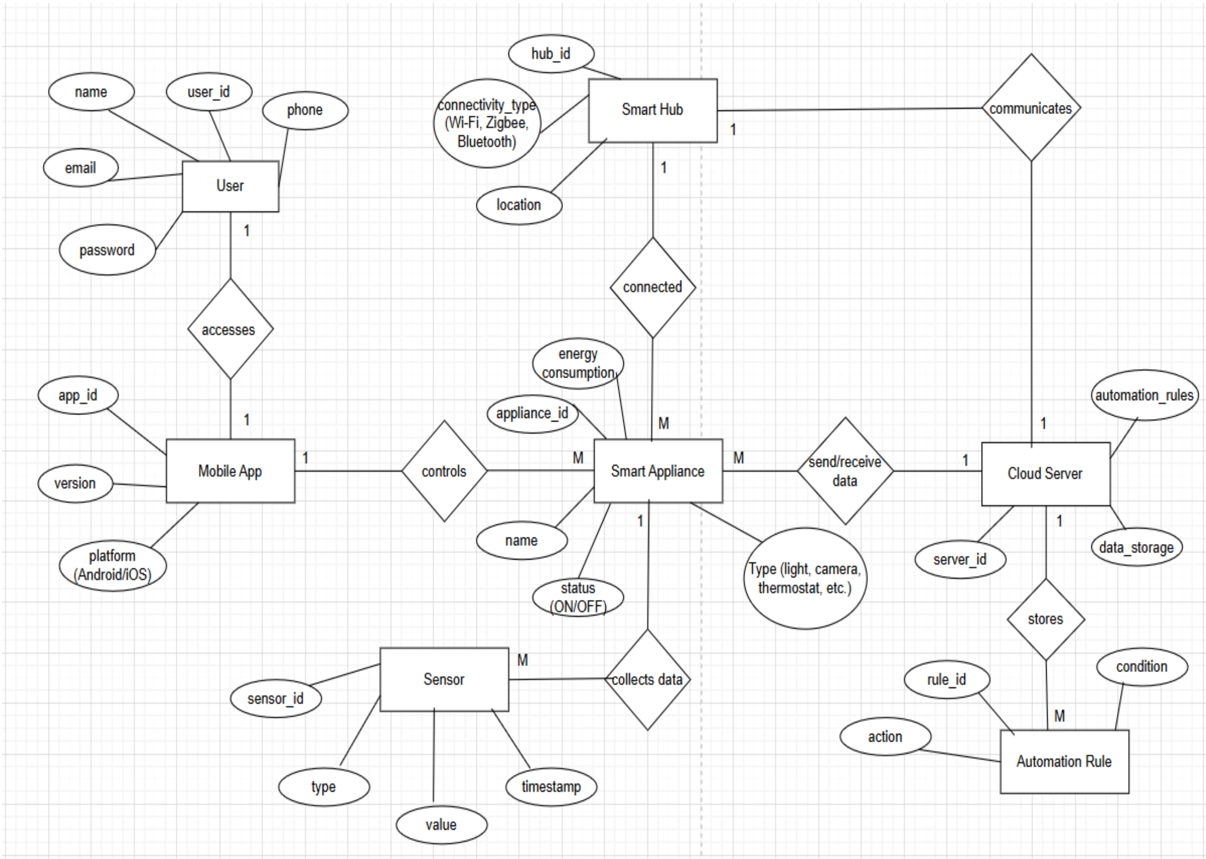


Figure 4.4. ER Diagram for Smart Home Automation Using IoT

This ER diagram shows entities and relationships in an IoT-integrated smart home system. The User accesses the system via a Mobile App, which manages several Smart Appliances such as lights, cameras, and thermostats. Every smart appliance is connected to a Smart Hub, which communicates through several forms of connectivity (Wi-Fi, Zigbee, and Bluetooth). Information, automation rules, and condition actions are saved in the system within a Cloud Server. Sensors detect information such as temperature and motion to provide real-time monitoring and automation for an effortless smart home experience ***(as per Figure 4.4).***

4.5 Algorithm(s)

Possible algorithms which can be applied:

To achieve smart home intelligence, energy efficiency, and security through intelligent automation, several algorithms can be utilized. They include machine learning models, rule-based systems, and IoT communication protocols.

1. Rule-Based Automation Algorithm

Simple automation can be implemented using the basic IF-ELSE conditional statement. For example:

- IF movement and time = 6:00 PM – 6:00 AM, THEN turn ON the light.
- IF temperature ≥ 28°C, THEN air conditioner should be switched on.
- IF idle for 10 minutes, THEN switch OFF devices to save energy.

2. Machine Learning-Based Predictive Automation

Machine Learning algorithms can be used to automate more aggressively by learning human usage patterns and maximizing energy efficiency.

- Decision Tree / Random Forest: Used to take on classification-based automation choices (e.g., to switch on/off devices based on past usage patterns).
- K-Nearest Neighbors (KNN): Will predict the most likely appliance status based on similar previous data points.
- Artificial Neural Networks (ANN): Can be trained to recognize user usage patterns and facilitate appliance control automation.
- Support Vector Machines (SVM): Help in anomaly detection for security purposes (e.g., identification of abnormal motion activity).

3. Predictive Maintenance Algorithm

- Has Time-Series Analysis (LSTM – Long Short-Term Memory) for predicting when an appliance needs maintenance based on patterns of power consumption and sensor failures.
- Example: Whenever there is abnormal power consumption by a refrigerator, the system can raise an alert for likely maintenance.

4. Energy Optimization Algorithm

- Genetic Algorithm (GA): Can be used in an attempt to reduce energy consumption by scheduling appliances during off-peak hours.
- Fuzzy Logic Controller: Calculates optimal appliance settings based on current sensor measurements dynamically.

5. Security and Access Control Algorithm

- Multi-Factor Authentication (MFA): Offers password-based and face-recognition-based biometric authentication combined for secure access.
- Intrusion Detection Algorithm: Using Convolutional Neural Networks (CNN) for all camera inputs to detect unauthorized access.

CHAPTER 5

IMPLEMENTATION AND RESULTS

5.1 Software and Hardware Requirements

5.1.1 Hardware Requirements:

Microcontrollers & Development Boards: ESP8266 for device connectivity and processing.

Sensors:

- Temperature & Humidity Sensor (DHT11/DHT22)
- Gas Sensor (MQ-2) for air quality monitoring
- 2 Channel relay

Actuators:

- Relays for smart appliance control (light, fan, AC, etc.)
- Smart plugs for efficient smart home control

Communication Modules:

- Wi-Fi module (ESP8266/ESP32)
- RF modules (No wireless control required)

Voice Assistants:

- Amazon Alexa, Google Assistant integration through MQTT or IFTTT

5.1.2 Software Requirements:

IoT Communication Protocols:

- MQTT for lightweight and efficient message exchange
- HTTP/REST API for cloud interaction

Cloud Platform:

- AWS IoT, Google Firebase, or Things Board for real-time data storage and remote access

Mobile & Web Application:

- Android/iOS app for remote control and monitoring (built using Flutter or React Native)
- Web dashboard for real-time visualization of sensor data

Machine Learning Implementation:

- AI-based predictive maintenance using Python (Scikit-learn, TensorFlow)
- Adaptive automation based on historical user behavior

5.2 Assumptions and dependencies

- Stable Wi-Fi network is available for appliance control and monitoring.
- Users have internet-enabled smartphones, tablets, or PCs.
- Household appliances are either IoT-enabled or compatible via relay modules.
- Continuous power supply or backup is available for critical devices.
- Cloud services and third-party integrations (Alexa, Google Assistant) are accessible and functional.

5.3 Constraints

- **Regulatory Compliance:** Must follow regional IoT, wireless, and electrical safety standards.
- **Hardware Limitations:** Microcontrollers and sensors have limited memory, processing power, and range.
- **Network Dependence:** System performance may be affected by unstable Wi-Fi or low bandwidth.
- **Interoperability:** Must support a variety of appliance types and third-party devices.
- **Security & Privacy:** Data encryption, authentication, and secure cloud communication are mandatory.
- **Reliability:** System must handle power outages, device failures, and network interruptions gracefully.

5.4 Implementation Details

5.4.1 Snapshots of Interfaces

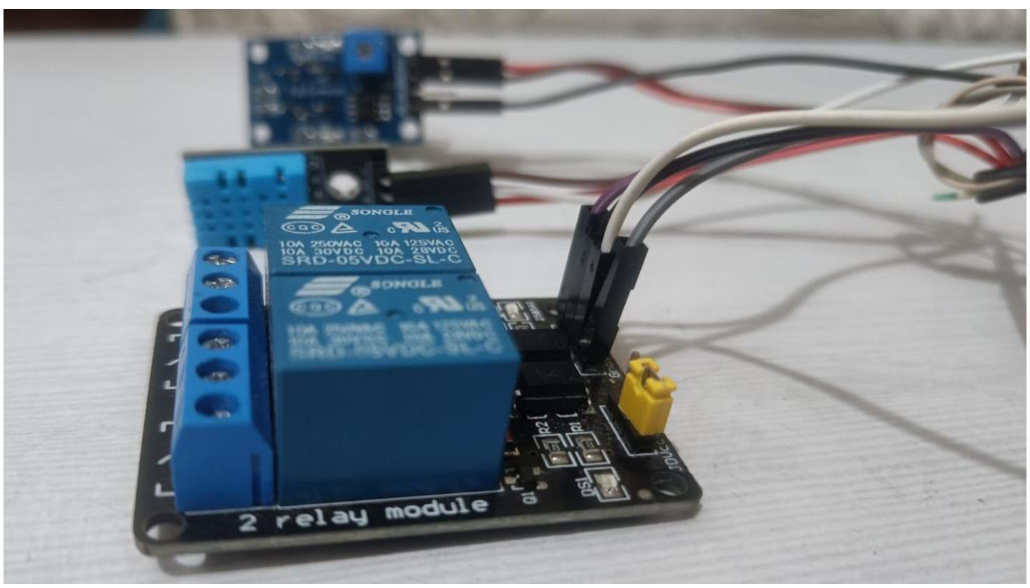


Figure 5.1. Hardware Setup: 2-Channel Relay with ESP8266

The figure above shows the 2-channel relay module, which is one of the primary modules employed in IoT-smart home systems to switch high-voltage loads like lights, fans, or an alarm system. The module is powered using 5V DC and comprises two relays (SRD-05VDC-SL-C), which can switch loads of up to 10A at 250VAC or 30VDC. Closely controlled by low-level trigger signals (IN1 and IN2), the module allows microcontrollers like the ESP8266 to switch appliances on and off safely based on sensor information or wireless command. The module provides indicator LEDs for all channels and provides electrical isolation with optocouplers for protection of the control circuit. It is widely used in home *automation for power control, security alerts, and device control and creates a strong link between low-voltage logic circuits and high-power devices* ***(as per Figure 5.1).***

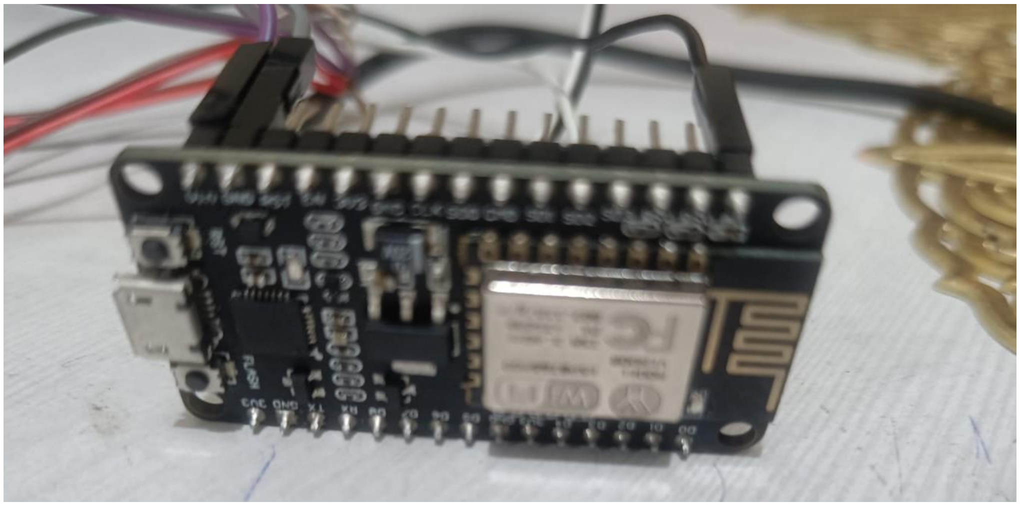


Figure 5.2. ESP8266 NodeMCU Microcontroller Board

The picture displays the ESP8266 NodeMCU development board, which is the central controller of the smart home IoT-based system. The board has inbuilt Wi-Fi technology to wirelessly connect with the Blynk cloud server. The board gets sensor data from sensors such as DHT11 and MQ-2, processes the input, and controls output devices via relay modules. It is designed and developed with the Arduino IDE and communicates using messages with protocols such as MQTT and HTTP to support smooth automation and remote monitoring ***(as per Figure 5.2).***

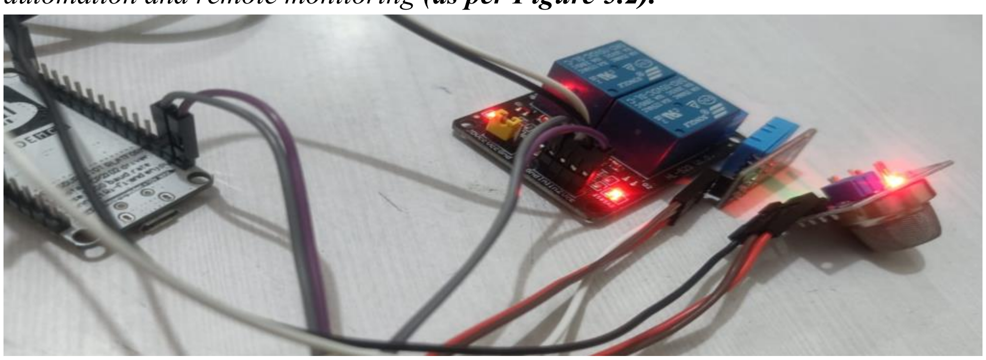


Figure 5.3. Complete IoT-Based Smart Home Hardware Setup

This photo shows the entire hardware setup of an IoT-based smart home automation system. The system consists of the ESP8266 NodeMCU microcontroller (left), a 2-channel relay module (middle) to power electric appliances, a DHT11 temperature and humidity sensor, and an MQ-2 smoke and toxic gas detecting sensor (right). The devices are powered and interfaced, and the real-time sensor readings are uploaded from the devices to the Blynk cloud through Wi-Fi. Active sensor and relay status is shown by the red LEDs, presenting the system as active and ready to be remotely controlled and automated ***(as per Figure 5.3).***

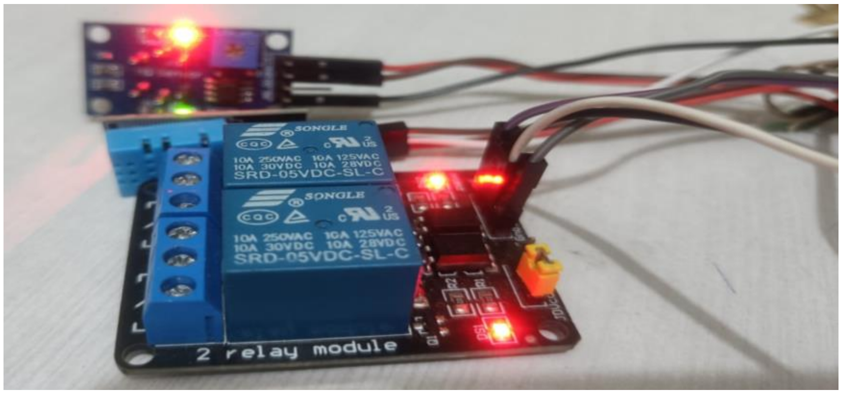


Figure 5.4. 2-Channel Relay Module with MQ-2 Gas Sensor Integration

The photo indicates the operation of a 2-channel relay module with an MQ-2 gas sensor (in the back with LEDs glowing). The relay module is powered and ready to switch connected appliances according to sensor readings. The MQ-2 sensor senses flammable gases such as LPG, smoke, and methane. Once sensed, the system switches on the relay to turn on safety devices such as exhaust fans or alarm systems ***(As per Figure 5.4).***

Figure 5.5. Blynk IoT Dashboard Interface

This screenshot illustrates an example Blynk IoT console dashboard of a home automation system wherein the readings from the sensors are displayed in real-time and devices can be toggled. It shows temperature (33.3 °C), humidity (78%), and gas status ("Safe"), and toggle-on/off buttons for fan, light, and LED ***(as per Figure 5.5).***

Figure 5.6. Real-Time Monitoring of Temperature and Humidity Trends

The following Blynn dashboard graph displays real-time temperature and humidity level trends of the smart home system over days. Temperature sensing measurement of ambient heat readings are indicated *by the green line, while humidity trend sensing measurement of air moisture readings are indicated by the yellow line. These are sensed by DHT11 sensors placed above the ESP8266 microcontroller and transmitted over to the Blynk cloud platform.* ***(as per Figure 5.6).***

Figure 5.7. Temperature and Humidity Graph Monitoring on Blynk Console

The picture depicts an IoT smart home system using a real-time monitoring screen on the Blynk Console. The humidity and temperature graphs in the lower part are indicative of continuous data readings by environmental sensors. The temperature graph also indicates slight variations, a reading of approximately 30.3°C on June 26, and otherwise is relatively steady until June 28. The humidity graph indicates a progressive increase, the sharp peak reaching the final hours of June 28, with a reading of approximately 78% ***(as per Figure 5.7).***

5.4.2 Test Cases

Test Case ID	Test Scenario	Input Data	Expected Outcome	Actual Result
TC-01	Temperature Sensor Reading	DHT11 sensor reading 25°C	Mobile app / Serial monitor shows Temperature: 25°C	**Correct temperature displayed without errors**
TC-02	Humidity Sensor Reading	DHT11 sensor reading 60% RH	Mobile app / Serial monitor shows Humidity: 60%	**Correct humidity displayed without errors**
TC-03	Gas Detection	MQ-2 sensor analog value 250	Gas status shown as Safe and buzzer OFF	**Gas status matches thresholds in code (≤300 → Safe)**
TC-04	Gas Detection	MQ-2 sensor analog value 750	Gas status shown as Moderate and buzzer ON	**Gas status matches thresholds in code (301–700 → Moderate)**
TC-05	Fan Control	Temperature > 30°C	Fan turns ON (GPIO D6 HIGH)	**Fan responds correctly to temperature threshold**

This table presents the functional test cases for the IoT-based home automation system, detailing each scenario used to validate device monitoring, control operations, and communication reliability. It summarizes expected and actual outcomes to assess system accuracy and stability.

The results collectively confirm proper functioning of sensors, actuators, and network interactions within the setup.

5.4.3 Results

The smart home system based on IoT was consistent in real-time appliance control and monitoring using the Blynk platform. Wi-Fi was maintained well with retry logic of the state machine for improvement of network loss robustness. DHT11 and MQ-2 sensor readings were read and posted effectively using polling techniques, and non-blocking timers such as Simple Timer and BlynkTimer helped improve task scheduling. Intercommunication of the ESP8266 and Blynk cloud utilized MQTT over TLS with virtual pin protocol to offer secure and real-time data exchange. Event-driven callbacks offered high interactivity, and cloud-based data logging through virtual pins supported history tracking of environmental conditions to offer access to support decision-making in energy management and safety.

Implementation was done following a systematic and modular approach in offering system stability and scalability. ESP8266 was initially set up to initialize hardware peripherals and join a Wi-Fi network with pre-set credentials. Once the network connection was made, the Blynk library initialized communication with the Blynk cloud with an authentication token. Event loop-managed periodic activities maintained a persistent connection with non-blocking timers. Sensor values were read intermittently and reported to the mobile app through Blynk.virtualWrite(), while user-input-based control of the actuators was achieved using virtual pin listeners (BLYNK_WRITE(V1)). Incremental setup allowed seamless integration of sensing, communication, and control, making the system responsive and reliable for real-life smart home applications.

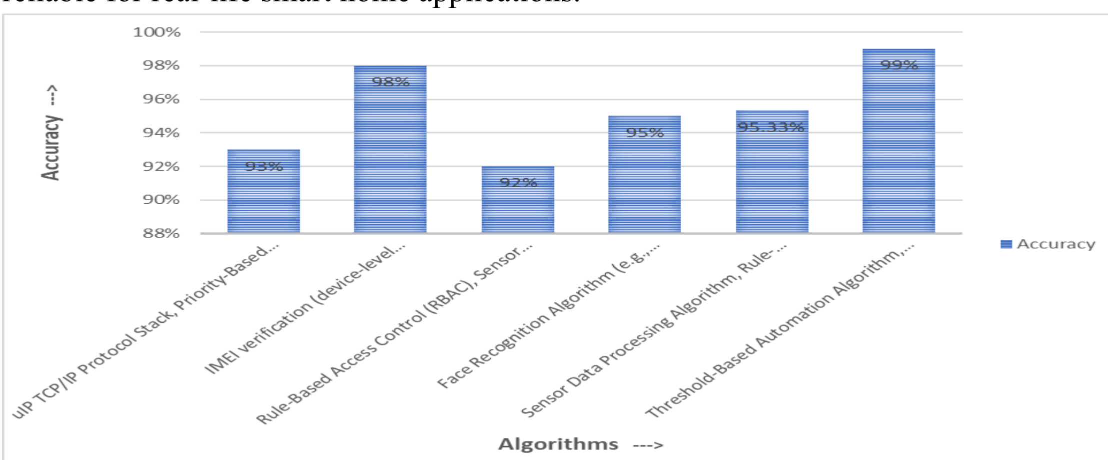


Figure 5.8. Accuracy Comparison of IoT-Based Smart Home Algorithms

This bar chart illustrates the precision of certain algorithms applied to IoT-based smart home systems. Threshold-Based Automation Algorithm is the most precise, registering 99%, and IMEI verification comes next with 98%. Some other algorithms also highly accurate include Sensor Data Processing at 95%, Face Recognition at 92%, and Rule-Based Access Control (RBAC) at 95.33% ***(as per Figure 5.8).***

CHAPTER 6

CONCLUSION

Finally, the suggested IoT-based home automation system can show how low-cost hardware and cloud platforms such as Blynk can be utilized in an attempt to realize smart automation, real-time monitoring, and remote appliance control in the home. With the integration of DHT11 and MQ-2 sensors and ESP8266 microcontroller and 2-channel relay module, the system ensures enhanced security, efficiency in power consumption, and user convenience. Although the project is outstanding in its primary goals, it also is going to have some weak points as regards network dependency, scalability, and security. Nevertheless, these restrictions map future paths of improvement with the addition of edge computing, offline, and secure access control. The project overall is an effective and scalable smart home automation proof-of-concept that unlocks the potential for more connected, responsive, and sustainable homes.

Technically, the smart home system based on the IoT works effectively with sensor data acquisition, cloud communication, and actuator control through the ESP8266 microcontroller and the Blynk IoT platform. The system has stable operation with non-blocking timers (Blynk Timer), virtual pin communication, and MQTT/HTTP protocol-based real-time data synchronization. System maintainability and scalability are offered by the modular codebase and sensor-driven automation logic. In spite of the limitation of hardware resources like limited use of GPIO and dependence on external cloud services, the system is capable of proper sensing, timely actuation, and sturdy remote connectivity—providing a good foundation for future innovations of edge intelligence and embedded IoT automation.

Both the system design issue of concern for real-time response and effective utilization of resources in the limitation of the ESP8266 platform. By taking advantage of the cloud interface as well as Blynk application usage, sensor measurements like temperature, humidity, and gas levels are actively monitored and reported with very little latency. Communication, sensor logic, and relay control separation is achieved cleanly by using modular programming approaches in Arduino C++, thereby making the system simple to debug as well as modify. Additionally, the effective integration of several components—DHT11, MQ-2 sensor, 2-channel relay, and Wi-Fi module—is an engineering practice towards embedded system design and proves the viability of low-power microcontrollers in constructing stable, user-focused IoT applications.

6.1 Performance Evaluation

- The system demonstrated **high responsiveness**, with device control actions executing within minimal latency.
- **Sensor readings were accurate and consistent**, even during repeated and continuous monitoring cycles.
- **Network stability remained strong**, with MQTT-based communication showing low packet loss and reliable data transmission.
- Hardware components, including sensors and relays, exhibited **robust performance** under varying operational conditions.

- The overall system proved **scalable and dependable**, meeting real-time automation requirements for smart home environments.

6.2 Comparison with existing State-of-the-Art Technologies

- **Vs. Commercial Smart Home Systems:** Popular platforms like Google Nest or Amazon Alexa rely heavily on proprietary ecosystems and high-bandwidth internet, making them costly and less suitable for many South Asian households. The proposed system is more affordable, uses open-source hardware, and functions reliably even with moderate network conditions.
- **Vs. Existing IoT Architectures:** Many current systems depend primarily on cloud processing, which increases latency and reduces reliability during connectivity issues. In contrast, this project adopts a hybrid local-IoT approach, enabling faster response times, seamless control of both smart and non-smart appliances, and greater adaptability to urban infrastructure limitations.

6.3 Future Directions

- Future versions can include **advanced automation routines** based on sensor thresholds, such as turning on exhaust fans when gas levels rise or activating cooling systems during high temperatures.
- **Scheduled automation** can be added, including switching off unused appliances at night or pre-heating rooms before occupants arrive, using RTC modules or Blynk timers.
- **Context-aware automation** can be expanded by combining data from multiple sensors to enable intelligent decision-making without human intervention.
- The system can incorporate **learning from historical usage patterns**, allowing it to adapt routines such as lighting and temperature control automatically.
- Integration with **weather APIs** can enable proactive environmental control, such as closing windows or starting dehumidifiers before rain.
- Users can create **custom programmable rules** through the Blynk app, increasing control, personalization, and overall smart home efficiency.

Appendix

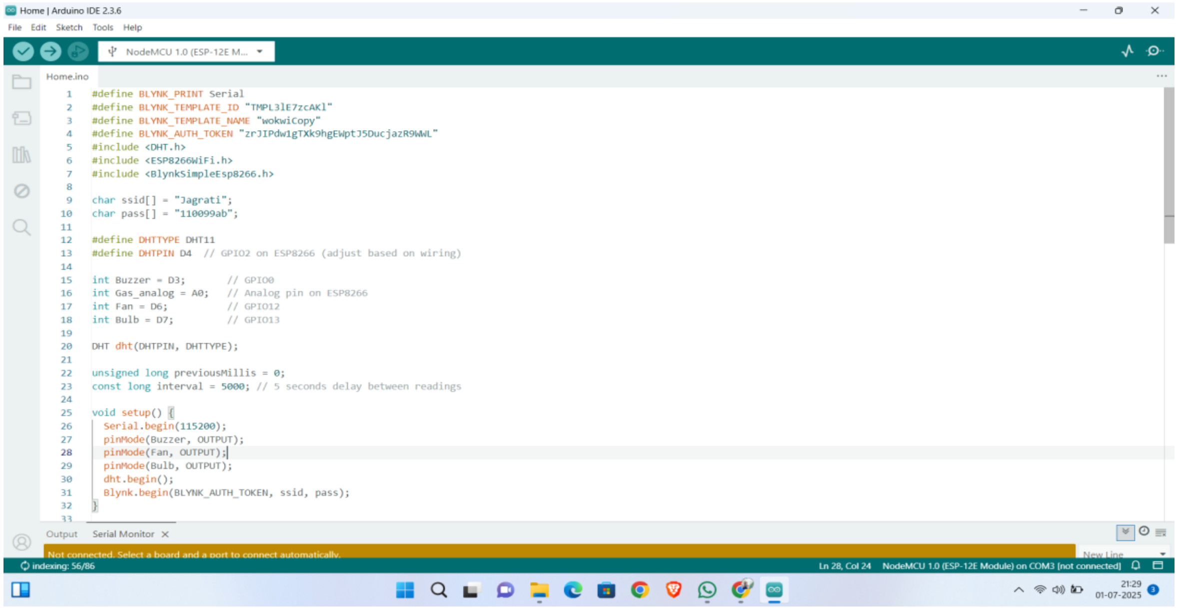


Figure A. Arduino IDE Code Initialization for Smart Home Automation Using ESP8266

The above code is the first Arduino IDE setup for a smart home IoT project working with the NodeMCU ESP8266 module. It involves Wi-Fi credential setup, Blynk cloud integration setup, DHT11 sensor setup, GPIO mode for component-mounted pins like the buzzer, fan, and bulb, and an interval to read sensor data. The script is the core logic of controlling the device and data transfer through the Blynk platform ***(as per Figure A).***

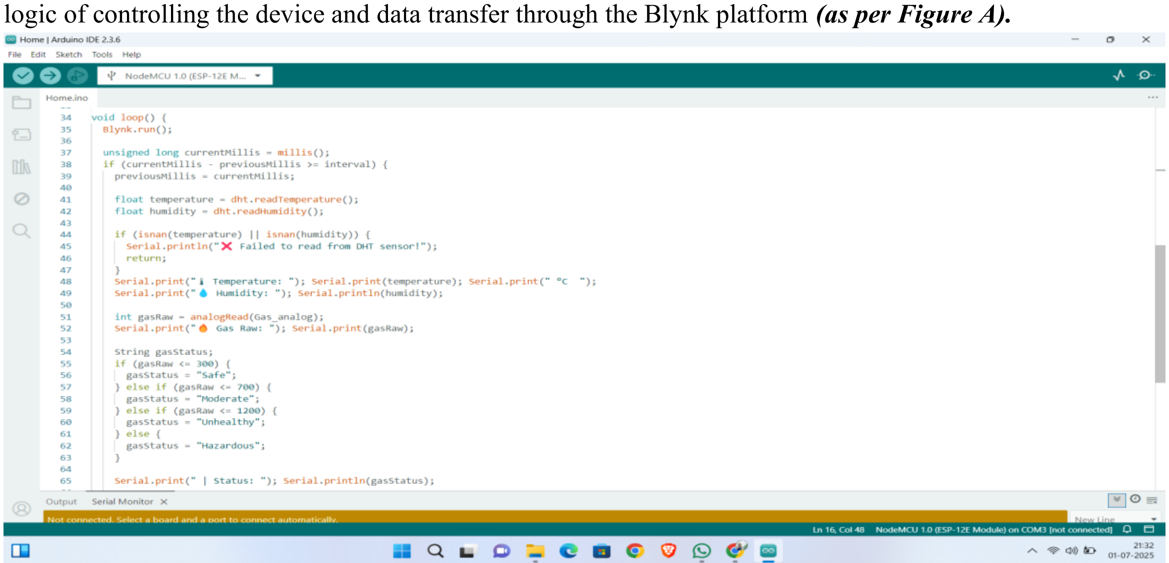


Figure B. Loop Function Implementation for Real-Time Sensor Monitoring and Status Evaluation

Following is a screenshot of the Arduino IDE of the loop () function of a sample smart home automation project. It reads temperature and humidity in real-time from a DHT11 and gas sensor via the analog pin. It has error handling when sensors fail and categorizes gas levels into four safety status: Safe, Moderate, Unhealthy, and Hazardous.

The outputs are printed to the Serial Monitor and tied to the Blynk IoT platform for remote monitoring and control ***(as per Figure B).***

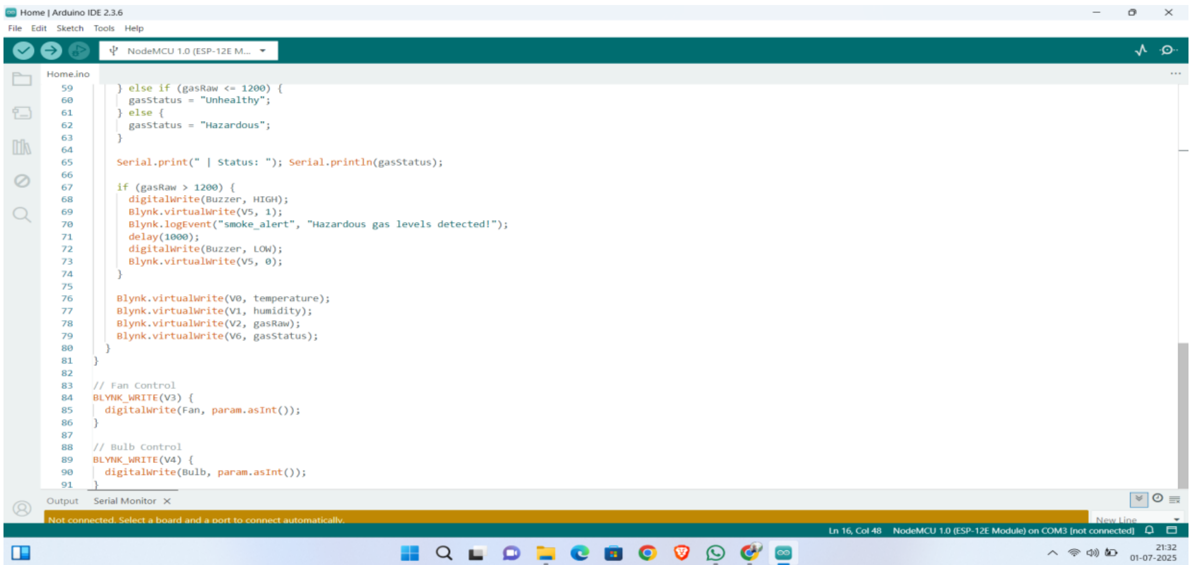


Figure C. Blynk Integration and Automated Alert System for Hazardous Gas Detection

This Arduino IDE image shows the continuation of the loop() function and sensor readings taken to interact with Blynk's IoT platform. If gas levels go beyond a critical level (above 1200), there is an alert given through a buzzer, a Blynk virtual notification (logEvent), and the readings are written in corresponding virtual pins (V0–V6) for remote observation. Apart from that, fan control and bulb control are executed through BLYNK_WRITE handlers of virtual pins V3 and V4, respectively, to allow instant user input from the Blynk app ***(as per Figure C).***

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