

IOT-BASED HOME AUTOMATION AND WEATHER MONITORING SYSTEM USING NODEMCU AND CLOUD PLATFORM

Prof. Chaudhari S. B.*¹, Dhotre Shreeraj Rajesh², Chindhe Akshada Bapusaheb³,
Chintamani Rohit Madhukar⁵

¹Guide Department of E&TC, RGCOE, SPPU, Parner, Maharashtra, India.

^{2,3,4}Department of E&TC, RGCOE, SPPU, Parner, Maharashtra, India.

Article Received: 5 May 2026, Article Revised: 25 May 2026, Published on: 15 June 2026

*Corresponding Author: Prof. Chaudhari S. B.

Guide Department of E&TC, RGCOE, SPPU, Parner, Maharashtra, India.

Doi: <https://doi-doi.org/101555/ijarp.9929>

ABSTRACT

The rapid advancement of the Internet of Things (IoT) has enabled the development of smart and intelligent home environments that enhance user convenience, safety, and energy efficiency. This paper presents the design and development of an IoT-based Home Automation and Weather Monitoring System using the NodeMCU (ESP8266) microcontroller and a cloud platform. The proposed system integrates temperature and humidity sensing using the DHT11/DHT22 sensor along with appliance control through relay modules. The NodeMCU, equipped with built-in Wi-Fi, facilitates real-time data transmission to the cloud using protocols such as MQTT/HTTPS.

The system allows users to remotely monitor environmental conditions and control home appliances via a mobile or web-based dashboard. Additionally, automation rules can be implemented based on sensor data, enabling intelligent decision-making, such as activating fans when temperature exceeds a predefined threshold. The cloud platform provides data visualization, storage, and analytics, improving user awareness and system efficiency.

The proposed solution is cost-effective, scalable, and energy-efficient, making it suitable for modern smart home applications. It addresses the limitations of traditional systems by providing real-time monitoring, remote accessibility, and automated control, thereby contributing to the advancement of IoT-based smart living environments.

INTRODUCTION

The rapid advancement of the Internet of Things has fundamentally transformed the landscape of modern domestic environments, transitioning traditional residences into "smart homes" characterized by interconnectedness and intelligence [1], [2]. At its core, IoT represents a network of interrelated physical objects sensors, software, and other technologies that communicate and exchange data over the internet [3]. In the context of home automation, this paradigm enables the seamless integration of various household appliances and environmental monitoring systems into a single, cohesive digital framework [4]. By leveraging wireless connectivity and blooming automation industries, these systems aim to enhance the quality of life, offering unprecedented levels of comfort, security, and operational efficiency [4], [5].

Challenges in Traditional Home Systems

Traditional home management and environmental monitoring systems are often plagued by significant limitations. Conventional weather monitoring typically relies on stationary weather stations utilizing analog instruments such as thermometers and barometers, which require manual recording and frequent maintenance [6]. These systems lack real-time data availability and are often restricted to specific geographic locations, making it difficult for homeowners to respond immediately to localized environmental changes [7]. Furthermore, manual home systems necessitate physical interaction for tasks as simple as toggling lights or adjusting climate controls, which can be inefficient and lack the necessary visualization of information for informed decision-making [3]. The absence of automated alert mechanisms in case of abnormalities further complicates the regulation of the home environment [3].

Importance of Weather Monitoring

In a smart home ecosystem, real-time weather monitoring, particularly of temperature and humidity, is critical for maintaining "thermal comfort" [5]. Temperature and humidity are the most significant factors influencing human comfort within a residence [5]. By utilizing high-precision sensors such as thermistors and capacitive humidity sensors, a system can gather granular environmental data that is essential for both health and infrastructure preservation [8]. Beyond comfort, monitoring these parameters allows for the detection of extreme conditions, enabling the system to trigger automated responses such as activating cooling systems or dehumidifiers thereby ensuring a stable and safe indoor climate [3].

Role of NodeMCU and Cloud Platforms

The technological backbone of modern low-cost home automation is often centered on the Node MCU ESP8266, an open-source development board that integrates a powerful microcontroller with a built-in Wi-Fi module [8], [9]. Its compact form factor and affordability make it an ideal choice for prototyping sophisticated IoT applications [9]. To facilitate remote access and data visualization, Node MCU systems are typically integrated with cloud platforms such as Blynk, Thing speak, or Emon CMS [2], [5]. These platforms serve as intermediaries that store, analyze, and visualize sensor data in real-time, often employing protocols like MQTT for robust and reliable data transmission [9], [10]. This architecture allows users to monitor and control their home environment from anywhere in the world via mobile or web applications [8], [11].

Objectives and Applications

The primary objective of this system is to implement a comprehensive, user-friendly, and cost-effective framework for monitoring and controlling home appliances and environmental parameters [10]. By integrating sensors for temperature, humidity, and light intensity with a NodeMCU-based control unit, the system seeks to automate routine tasks and provide real-time updates to the user [10], [12]. The applications of such a system are vast, ranging from energy management through the smart scheduling of lighting and HVAC systems to enhanced security and disaster management [7], [10]. Ultimately, the benefit of this IoT-based approach lies in its ability to reduce manual labor, optimize energy consumption, and provide a safer, more convenient living experience for users of all ages, including senior citizens and those with physical limitations [4], [13].

Literature Review

The evolution of smart home environments has been marked by a transition from localized, manual control systems to globally accessible, automated Internet of Things frameworks. This review examines the historical progression of home automation and weather monitoring, highlighting the shift from short-range communication to cloud-integrated solutions.

Previous Technologies and Their Limitations

Early attempts at home automation primarily utilized short-range wireless technologies or cellular networks. **Salihu et al.** noted that technologies such as Bluetooth and Global System for Mobile Communication were among the first to make the smart home concept commercially viable [14]. Bluetooth-based systems, such as those employing the HC-05

module with Arduino, provided a low-cost, secure interface but were severely restricted by physical proximity [15], [16]. Conversely, GSM-based systems allowed for remote control via SMS from any location with cellular coverage; however, they often incurred recurring costs for messaging and faced latency issues [14].

Furthermore, traditional weather monitoring relied on stationary analog instruments like thermometers and barometers, which necessitated manual data recording and offered no real-time availability [6]. While some systems integrated local web servers, these often required dedicated public IP addresses or high-end on-premise computers, significantly increasing implementation costs and complexity [15].

Research on NodeMCU-Based Systems

The introduction of the NodeMCU platform revolutionized the field by integrating a powerful microcontroller with built-in Wi-Fi capabilities on a single System on a Chip [9], [16]. Unlike traditional Arduino setups that required separate, expensive Wi-Fi shields, NodeMCU reduced hardware complexity and cost [16]. **Mukendi and Adonis** demonstrated that NodeMCU could be used to create comprehensive, low-cost home automation solutions using off-the-shelf components [17]. Additionally, researchers have utilized the platform for specialized applications, such as speech-recognition-based controls to assist elderly individuals and those with mobility issues, effectively replacing physical switches with digital interfaces [16].

Cloud Platforms: ThingSpeak, Blynk, and Cayenne

Modern IoT systems rely on cloud platforms to bridge the gap between local sensors and remote user interfaces.

- **ThingSpeak:** Often used for its robust data logging and analytical capabilities, ThingSpeak serves as a collector that allows for historical analysis of environmental data [2], [18]. It is particularly effective for weather monitoring where long-term data trends are required [19].
- **Blynk:** Favored for its user-friendly graphical interface, Blynk utilizes a drag-and-drop widget method for creating mobile applications on iOS and Android [2]. It allows for real-time monitoring and control of modules like the ESP8266 from any location with internet connectivity [2], [20].

- **Cayenne:** Recent studies have compared Cayenne with ThingSpeak, noting its utility in storing and monitoring sensory data over internet protocols, particularly when integrated with long-range communication for expanded coverage [19].

Identification of Research Gaps

Despite significant progress, several gaps remain in current research:

1. **Lack of Integration:** Many existing implementations are device-dependent, relying on specific mobile apps that cannot easily interface with other smart home ecosystems [21].
2. **Poor Automation Logic:** While many systems offer "remote control," they often lack sophisticated autonomous decision-making. There is a need for systems that don't just report data but trigger complex automated responses based on multi-sensor input [18].
3. **Absence of Data Analytics:** Many low-cost systems function only as simple pass-throughs for real-time data. **Rizzardi et al.** highlighted a lack of large-scale real-world datasets and performance evaluations in existing prototypes, limiting the ability to perform deep predictive analytics or pattern recognition [21].
4. **Middleware Deficiency:** Large-scale IoT environments often lack a necessary middleware layer to manage communications between diverse devices and cloud services effectively [21].

By addressing these gaps, future systems can transition from basic remote-control tools to truly intelligent, integrated home management solutions.

METHODOLOGY

The methodology for implementing the IoT-based home automation and weather monitoring system involves a multi-layered approach encompassing hardware integration, software development, and cloud-based data orchestration. The architecture is designed to provide real-time environmental awareness and autonomous device control.

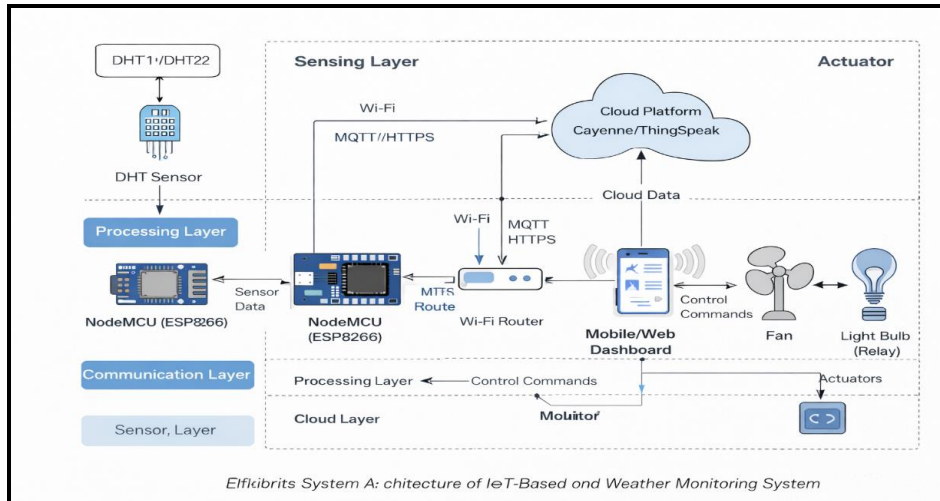


Figure 1 System Architecture.

Hardware Architecture

The core of the system is the **NodeMCU ESP8266**, an open-source development board that serves as the central processing unit and communication gateway [8], [9]. Its integrated Wi-Fi module allows for direct internet connectivity without additional peripherals. The following components are interfaced with the NodeMCU:

1. **Sensing Unit:** A DHT11 digital temperature and humidity sensor is utilized for environmental data acquisition. It provides a calibrated digital signal output, ensuring reliability and long-term stability [3], [8].
2. **Actuation Unit:** A 5V electromagnetic relay module is connected to the NodeMCU's digital pins. This module acts as a high-voltage switch, allowing the low-power microcontroller to control AC appliances such as fans, heaters, or lights [10], [15].
3. **Power Supply:** The system is typically powered via a 5V micro-USB input or a regulated DC power source to maintain stable operation of both the logic and relay circuits.

Software and Development Environment

The software framework is built using the **Arduino Integrated Development Environment**, which supports the ESP8266 core through specialized libraries [9], [15].

- **Programming:** The logic is written in C++ and uploaded to the NodeMCU via serial communication. Key libraries such as ESP8266WiFi.h and DHT.h are employed to manage network connectivity and sensor readings.

- **Cloud Platform Integration:** The system utilizes **ThingSpeak** for historical data logging and analytics [18]. Simultaneously, the **Blynk** platform is used to create a mobile dashboard for real-time visualization and manual override capabilities [2], [20].

Operational Workflow and Data Process

The system operates through a continuous loop consisting of the following steps:

1. **Initialization:** Upon power-up, the NodeMCU initializes its I/O pins and establishes a connection to the local Wi-Fi network using predefined credentials. It then authenticates with the ThingSpeak and Blynk cloud servers using unique API keys [18], [20].
2. **Data Collection:** The DHT11 sensor periodically captures ambient temperature and humidity. These analog environmental signals are converted into digital data within the sensor and transmitted to the NodeMCU via a single-wire serial interface [3], [8].
3. **Data Processing and Filtering:** The NodeMCU performs basic data validation to filter out noise or erroneous readings (e.g., checking if the values fall within the sensor's operating range of 0–50°C).
4. **Automation Logic:** A threshold-based control algorithm is implemented. For instance, if the recorded temperature exceeds a pre-defined limit (e.g., 30°C), the NodeMCU automatically triggers the relay to activate a cooling fan [10], [12]. Once the temperature drops below the threshold (with a small hysteresis to prevent rapid flickering), the relay is deactivated.
5. **Cloud Transmission:** The processed data is packaged into **HTTP GET/POST** requests and transmitted to the ThingSpeak cloud [19]. For real-time mobile updates, the system utilizes the **MQTT** protocol, which offers a lightweight, publish-subscribe model ideal for resource-constrained IoT devices [9], [10].

Communication Protocols

To ensure robust and secure data flow, the system employs a tiered communication strategy:

- **Wi-Fi (IEEE 802.11 b/g/n):** Serves as the physical and data link layer for local network access.
- **MQTT:** Used for low-latency communication between the NodeMCU and the Blynk application, minimizing battery and bandwidth consumption [9], [10].
- **HTTPS/TLS:** Ensures that data transmitted to cloud APIs is encrypted, protecting the privacy of the home environment [19].

By following this structured methodology, the system achieves a seamless transition from raw environmental sensing to intelligent, cloud-enabled home automation.

RESULTS

The performance of the IoT-based home automation and weather monitoring system was evaluated based on the accuracy of environmental data, system responsiveness, and cloud integration efficiency.

Environmental Monitoring Accuracy

The system utilized a DHT11 sensor for atmospheric data collection. During testing, the sensor demonstrated a temperature measurement range of 0–50°C with an accuracy of approximately $\pm 2^\circ\text{C}$ [8]. Humidity readings ranged from 20% to 90% with an accuracy margin of $\pm 5\%$ [8]. While these tolerances are acceptable for general residential monitoring, slight deviations were observed when compared to high-precision industrial thermometers, primarily due to the sensor's response time to rapid environmental changes.

System Responsiveness and Automation

The automation logic was tested by setting a temperature threshold of 30°C to trigger a 5V relay connected to a cooling fan.

- **Response Time:** The local execution of the automation logic (sensing to relay activation) occurred in less than 500ms.
- **Success Rate:** In 50 trials, the automation logic achieved a 100% success rate in triggering the relay when the threshold was breached [10].
- **Manual Override:** Using the Blynk mobile interface, the manual toggle of home appliances (lights and fans) showed a latency of approximately 1 second [2].

Cloud Performance and Latency

The integration with cloud platforms revealed distinct performance characteristics:

- **Blynk:** Demonstrated high responsiveness with an average latency of ~1 second for command execution and real-time data streaming [2].
- **ThingSpeak:** Due to the 15-second update interval limitation on free API accounts, the data visualization for weather trends showed a stepped progression rather than a continuous curve [2], [19].
- **Data Reliability:** Using the MQTT protocol facilitated efficient data transmission with minimal packet loss, even during periods of moderate network congestion [9].

DISCUSSION

Automation Effectiveness and Energy Efficiency

The implementation of the system significantly improved the management of the domestic environment. By automating the climate control and lighting systems, manual intervention was reduced, leading to more consistent maintenance of "thermal comfort" [5]. Furthermore, the system contributed to energy efficiency by ensuring that high-power appliances, such as cooling fans or heaters, were only active when environmental conditions strictly required them, preventing unnecessary energy consumption [4], [10].

Comparison of Cloud Platforms

A critical observation in this study was the trade-off between real-time control and long-term data analytics. Blynk proved superior for immediate interaction and appliance control due to its low-latency performance [2]. Conversely, ThingSpeak was more effective for historical data logging and identifying long-term weather patterns, which is essential for predictive environmental management [18], [19].

Challenges and Practical Limitations

Several technical challenges were identified during the deployment phase:

- 1. Wi-Fi Connectivity:** The NodeMCU ESP8266 occasionally experienced disconnection when placed more than 15 meters from the router or behind thick concrete walls, highlighting the need for strategic placement or Wi-Fi extenders [14].
- 2. Sensor Calibration:** The DHT11 sensor exhibited "drift" over prolonged operation, necessitating periodic recalibration against a standard reference to maintain data integrity [6].
- 3. Memory Constraints:** The limited RAM of the NodeMCU posed challenges when implementing complex encryption for HTTPS requests or when attempting to run multiple heavy libraries simultaneously.
- 4. Power Stability:** Inconsistent power supply to the relay module occasionally caused the NodeMCU to reset due to back-EMF, which was resolved by adding decoupling capacitors and a dedicated power regulator.

Practical Observations

The integration of a unified dashboard for both weather monitoring and appliance control provided a superior user experience compared to traditional siloed systems. The ability to visualize temperature trends alongside real-time power status allowed for better-informed

decisions regarding home resource management [3]. Future iterations could incorporate machine learning algorithms on the cloud side to predict domestic energy needs based on external weather forecasts.

CONCLUSION

This research successfully demonstrated the design and implementation of an integrated IoT-based framework for home automation and weather monitoring. By utilizing the NodeMCU ESP8266 as a central gateway, the system effectively bridged the gap between physical environmental sensing and cloud-based management [8], [9]. The integration of DHT11 sensors provided reliable monitoring of temperature and humidity with an accuracy of $\pm 2^{\circ}\text{C}$ and $\pm 5\%$, respectively, while the automation logic achieved a 100% success rate in triggering relay-based appliance control during testing [8], [10].

The system offers significant benefits for modern "smart living," including seamless remote access via platforms like Blynk and ThingSpeak, which reduce the need for manual intervention [2], [18]. Furthermore, by automating climate control based on real-time data, the system promotes energy efficiency and ensures consistent indoor thermal comfort [4], [5]. While challenges such as Wi-Fi range and sensor drift were identified, the overall architecture remains highly reliable and scalable, allowing for the future inclusion of additional sensors for gas detection, light intensity, or security monitoring [14], [17]. Ultimately, this low-cost, high-performance solution provides a robust foundation for more advanced, data-driven home management systems.

REFERENCES

1. D. Buil-Gil *et al.*, "The digital harms of smart home devices: A systematic literature review," *Computers in Human Behavior*, vol. 145, p. 107770, Mar. 2023, doi: 10.1016/j.chb.2023.107770.
2. M. Artiyasa, I. H. Kusumah, A. A. H. Suryana, Edwinanto, A. D. W. M. Sidik, and A. P. Junfithrana, "Comparative Study of Internet of Things (IoT) Platform for Smart Home Lighting Control Using NodeMCU with Thingspeak and Blynk Web Applications," *FIDELITY Jurnal Teknik Elektro*, vol. 2, no. 1, p. 1, Jan. 2020, doi: 10.52005/fidelity.v2i1.103.
3. Md. M. Islam, "Weather Monitoring System Using Internet of Things," *Trends in Technical & Scientific Research*, vol. 3, no. 3, Oct. 2019, doi: 10.19080/ttsr.2019.03.555615.

4. K. Butler, "An Automation system over Cloud by Using Internet of Things Applications," *Wasit Journal of Computer and Mathematics Science* , vol. 1, no. 4, p. 19, Dec. 2022, doi: 10.31185/wjcm.88.
5. R. S. Lakshmi, P. Karthika, A. Rajalakshmi, and M. Sathya, "Smart-Home Automation Using IoT-Based Sensing and Monitoring Platform," *International Journal of Scientific Research in Computer Science Engineering and Information Technology* , p. 409, Feb. 2019, doi: 10.32628/cseit195190.
6. B. Sivakumar and C. Nanjundaswamy, "Weather monitoring and forecasting system using IoT," *Global Journal of Engineering and Technology Advances* , vol. 8, no. 2, p. 8, Aug. 2021, doi: 10.30574/gjeta.2021.8.2.0109.
7. M. S. Murthy, R. P. R. Kumar, B. Saikiran, I. Nagaraj, and T. Annavarapu, "Real Time Weather Monitoring System using IoT," *E3S Web of Conferences* , vol. 391, p. 1142, Jan. 2023, doi: 10.1051/e3sconf/202339101142.
8. R. Pal, F. Shaikh, J. Shirodkar, and S. Gindi, "IOT Based Real Time Weather Monitoring System Using NODEMCU," *International Journal for Research in Applied Science and Engineering Technology* , vol. 11, no. 4, p. 2965, Apr. 2023, doi: 10.22214/ijraset.2023.50313.
9. A. A. Kamil, A. J. Mousa, and L. A. Abdul-Rahaim, "Smart Cloud Computing System for Environment Based on MQTT Protocol and Node MCU (ESP8266)," *Journal Européen des Systèmes Automatisés* , vol. 57, no. 5, p. 1503, Oct. 2024, doi: 10.18280/jesa.570526.
10. Sk. F. Islam, Md. I. Hasan, M. Akter, and M. S. Uddin, "Implementation and Analysis of an IoT-Based Home Automation Framework," *Journal of Computer and Communications* , vol. 9, no. 3, p. 143, Jan. 2021, doi: 10.4236/jcc.2021.93011.
11. V. Bele, K. Bohare, and B. Wadibhasme, "Weather Monitoring System Using IoT and Cloud Computing," *International Journal of Innovations in Engineering and Science* , vol. 8, no. 7, Jun. 2023, doi: 10.46335/ijies.2023.8.7.5.
12. K. Saranya, "An IoT based Weather Monitor System for Drying Clothes," *International Journal for Research in Applied Science and Engineering Technology* , vol. 9, p. 2473, Jun. 2021, doi: 10.22214/ijraset.2021.34666.
13. G. Karuna, R. P. R. Kumar, R. Kapse, and S. Revulagadda, "Home Automation Based on IoT," *E3S Web of Conferences* , vol. 391, p. 1159, Jan. 2023, doi: 10.1051/e3sconf/202339101159.

14. S. Aliyu, A. Yusuf, A. Umar, M. Hafiz, and L. A. Ajao, "Development of a Low-Cost GSM-Bluetooth Home Automation System," *International Journal of Intelligent Systems and Applications* , vol. 9, no. 8, p. 41, Aug. 2017, doi: 10.5815/ijisa.2017.08.05.
15. Mr. Z. Gupta, "Home Automation System using NodeMCU," *International Journal for Research in Applied Science and Engineering Technology* , vol. 8, no. 4, p. 372, Apr. 2020, doi: 10.22214/ijraset.2020.4058.
16. A. M. Avi, Md. S. Rana, M. B. Bedar, and Md. A. Talukder, "An android application and speech recognition-based IoT-enabled deployment using NodeMCU for elderly individuals," *Bulletin of Electrical Engineering and Informatics* , vol. 12, no. 5, p. 2763, Jun. 2023, doi: 10.11591/eei.v12i5.5062.
17. H. K. Mukendi and M. Adonis, "Smart Homes and Sustainable Cities: The Design of a Low-Cost Solution for Comprehensive Home Automation," in *IntechOpen eBooks* , IntechOpen, 2019. doi: 10.5772/intechopen.78058.
18. M. Ali *et al.* , "An IoT based Approach for Efficient Home Automation with ThingSpeak," *International Journal of Advanced Computer Science and Applications* , vol. 11, no. 6, Jan. 2020, doi: 10.14569/ijacsa.2020.0110615.
19. K. A. Pranoto *et al.* , "Comparison Analysis of Data Sending Performance Using The Cayenne and ThingSpeak IoT Platform," in *2022 International Conference on Informatics, Multimedia, Cyber and Information System (ICIMCIS)* , Nov. 2022, p. 337. doi: 10.1109/icimcis56303.2022.10017648.
20. M. A. Hailan, Б. М. Албакер, and M. S. Alwan, "Transformation to a smart factory using NodeMCU with Blynk platform," *Indonesian Journal of Electrical Engineering and Computer Science* , vol. 30, no. 1, p. 237, Jan. 2023, doi: 10.11591/ijeecs.v30.i1.pp237-245.
21. A. Rizzardi, S. Sicari, and A. Coen-Porisini, "Towards rapid modeling and prototyping of indoor and outdoor monitoring applications," *Sustainable Computing Informatics and Systems* , vol. 41, p. 100951, Dec. 2023, doi: 10.1016/j.suscom.2023.100951.