

IoT Based Weather Monitoring System

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Abstract

The Internet of Things (IoT)-Based Weather Monitoring System is developed to provide accurate, real-time monitoring of essential environmental parameters, including temperature, humidity, and atmospheric pressure. The system integrates high-precision sensors with a microcontroller, enabling continuous data acquisition from the surrounding environment. Collected data is transmitted wirelessly to a dedicated IoT platform via an internet connection, allowing remote users to access and visualize the information through web or mobile interfaces. This capability ensures timely and location-independent monitoring, which is particularly valuable in applications requiring constant weather awareness. The system's design emphasizes efficiency, affordability, and automation. Low-cost hardware components and open-source IoT frameworks make it economically feasible for widespread deployment, while automated data collection minimizes the need for manual intervention. The platform can also store historical weather data, enabling trend analysis, predictive modeling, and decision-making support. Potential applications span multiple domains, such as agriculture, where precise weather data aids in irrigation planning and crop protection; smart cities, where it supports infrastructure management and disaster preparedness; and environmental monitoring, where it assists in tracking climate patterns and detecting anomalies. By combining sensor technology with IoT connectivity, the system offers a scalable and adaptable solution for diverse weather monitoring needs, promoting data-driven decision-making and contributing to sustainable resource management.

Keywords: IoT-based weather monitoring, temperature and humidity sensing, environmental data acquisition, real-time monitoring

INTRODUCTION

The Internet of Things (IoT) is revolutionizing how data is collected, processed, and used across various domains, one of the most impactful being environmental and weather monitoring. Weather parameters such as temperature, humidity, atmospheric pressure, and rainfall play a crucial role in influencing agriculture, disaster preparedness, public health, and various day-to-day human activities. Accurate and timely weather information is essential for decision-making in sectors like farming, where it affects irrigation scheduling, pest control, and crop yield optimization; in disaster management, where it aids in early warning systems for floods, storms, and droughts; and in healthcare, where it helps track the spread of weather-sensitive diseases [1].

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However, traditional weather monitoring systems often present significant limitations. They tend to be expensive, rely on sophisticated infrastructure, and require regular manual intervention for data collection and maintenance. Such systems are typically centralized, limiting their coverage and making them less practical for large-scale deployment. Furthermore, their installation and upkeep in remote or resource-limited areas can be challenging, leading to gaps in data availability and reduced accuracy in weather forecasting models. To

address these shortcomings, modern approaches leverage emerging technologies such as the Internet of Things (IoT), wireless sensor networks, and cloud-based platforms [2]. These solutions enable low-cost, automated, and scalable weather monitoring, providing real-time data access from virtually any location. IoT-based systems reduce dependency on manual labor, enhance data accuracy, and offer integration with analytical tools for predictive modeling. By overcoming the constraints of conventional methods, such systems hold the potential to transform weather monitoring into a more accessible, reliable, and actionable resource, ultimately supporting sustainable agriculture, effective disaster management, improved public health responses, and better planning of everyday human activities. The IoT Weather Monitoring System offers a smart, automated, and cost-effective approach to real-time environmental data acquisition, addressing the growing demand for accurate and continuous weather information [3–5].

The system integrates a variety of embedded sensors, such as DHT11/DHT22 for measuring temperature and humidity, BMP180/BME280 for atmospheric pressure, and rain sensors for precipitation detection. These sensors interface with microcontrollers like NodeMCU ESP8266 or ESP32, which serve as the central processing units for data collection and control. Wireless communication technologies, including Wi-Fi or GSM modules, enable seamless transmission of the acquired data to a secure cloud platform. This allows remote access to weather information through web dashboards or mobile applications, providing users with up-to-date environmental readings from any location. Additionally, the cloud platform facilitates data storage, historical analysis, and visualization, enabling pattern recognition, trend forecasting, and informed decision-making. The design emphasizes affordability by using readily available, low-cost components, making it suitable for deployment in rural, urban, and industrial settings. Automation reduces human intervention, ensuring consistent and reliable monitoring without manual effort [6]. Applications of this system span multiple domains, including agriculture for optimizing irrigation schedules and crop management, smart cities for improving environmental quality and disaster preparedness, and research institutions for studying climate variations. By leveraging IoT connectivity and modern sensor technology, the system not only enhances the accuracy and availability of weather data but also contributes to sustainable environmental monitoring practices. Its scalability and adaptability make it a practical choice for both small-scale and large-scale implementations. The collected information can be visualized through platforms such as *ThingSpeak*, *Blynk*, or *Firebase*, which offer user-friendly interfaces accessible via web dashboards or mobile applications. These platforms allow not only real-time observation but also storage of historical weather records, enabling users to analyze trends and patterns over time. This historical insight supports predictive modeling and facilitates more informed decision-making. Such a system is highly beneficial in multiple domains. In *precision agriculture*, it helps optimize irrigation schedules, protect crops, and improve yield. For *climate research*, it aids in data collection for long-term environmental studies. In *urban planning*, it assists in designing infrastructure resilient to weather extremes. In *disaster forecasting and management*, it provides early warning signals to mitigate risks [7].

The proposed system is cost-effective, energy-efficient, and easily deployable, making it suitable for both large-scale implementations and small-scale local monitoring stations. By integrating IoT connectivity with reliable sensing technology, it offers a scalable, automated, and accessible solution for weather tracking. This approach not only empowers decision-makers with timely and relevant data but also promotes sustainable environmental management through data-driven strategies. Moreover, the system supports data logging, remote alerts, and can be extended using AI/ML algorithms for predictive analytics. With solar power integration, these systems can be made energy-efficient and sustainable, ideal for deployment in remote or off-grid locations. In summary, the IoT-based weather monitoring system is a crucial step toward smart environmental management, offering reliability, scalability, and real-time awareness that traditional systems often lack.

LITERATURE SURVEY

Several research papers and previous projects have shown the implementation of IoT in weather monitoring. In traditional systems, weather data collection was manual and often delayed. Recent

developments have used DHT11/DHT22 sensors, NodeMCU/ESP8266 boards, and cloud platforms like ThingSpeak or Blynk. The integration of IoT not only enhances accuracy but also allows remote access and real-time updates. Studies suggest that IoT-based systems are scalable, low-cost, and effective for agricultural and environmental applications. A study demonstrated a High speed area efficient FPGA implementation of AES algorithm [8]. Moreover, researchers have also emphasized the importance of cloud platforms such as ThingSpeak, Blynk, and Firebase, which are widely used for data logging, visualization, and remote access [9]. These platforms provide APIs for trend analysis, paving the way for smart agriculture and climate-aware urban development, enable mobile app integration and remote dashboards, improving the accessibility of real-time data from anywhere in the world. The scalability of IoT systems is another key advantage. Modular designs allow additional sensors (e.g., for rainfall, UV index, or air quality) to be added as needed. Furthermore, these systems can run on solar power, reducing their carbon footprint and allowing deployment in off-grid regions. Studies also suggest that such systems can be combined with machine learning algorithms for weather prediction, anomaly detection, and pattern recognition.

PROPOSED METHODOLOGY

The methodology outlines the step-by-step approach used to build the IoT Weather Monitoring System (Figure 1). This process involves the integration of sensors, microcontroller programming, cloud communication, and data visualization, resulting in a complete system that captures environmental data and makes it accessible in real time.

Working

The IoT-Based Weather Monitoring System works on the integration of multiple environmental sensors with an internet-enabled microcontroller to collect, transmit, and display real-time atmospheric data. The working of the system is divided into three main stages: Sensor Data Collection, Wireless Data Transmission, and Real-Time Monitoring [10].

Sensor Data Collection

At the heart of the system are the environmental sensors that gather weather-related information from the surroundings:

- DHT11 Sensor measures temperature and humidity. It detects heat and moisture levels using a thermistor and a humidity-sensing component. These values are converted into digital signals.
- Rain Sensor (Y1-83/FC-37) detects rainfall by sensing water droplets on its conductive board. It outputs both analog and digital signals based on the intensity of rain.
- MH Sensor Series (e.g., MQ-135) detects air quality by identifying pollutants like CO₂, CO, and other gases. It plays an important role in monitoring environmental pollution levels [11].
- Each sensor is connected to the ESP8266 module through appropriate GPIO pins. The sensors constantly monitor the environment and send the data in real time to the microcontroller.

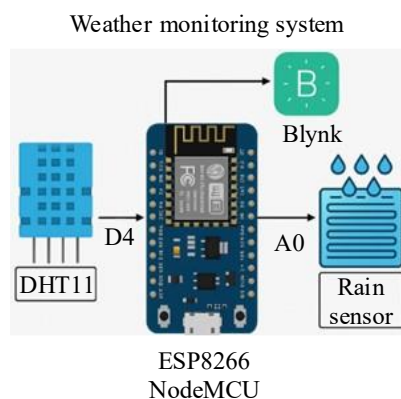


Figure 1. Block diagram.

Wireless Transmission Using ESP8266

Once the data is collected, it is processed by the ESP8266 Wi-Fi Module, which plays a dual role:

- Acts as the central controller for receiving input from all sensors.
- Establishes a Wi-Fi connection to transmit the data wirelessly [12].

Using built-in Wi-Fi capabilities, ESP8266 connects to a cloud platform such as ThingSpeak, Firebase, or Blynk. The collected data is uploaded to the cloud at regular intervals, enabling remote access from anywhere in the world. This makes it ideal for smart agriculture, environmental research, and public safety systems.

Real-Time Monitoring Process

Once the data is uploaded to the cloud, it can be accessed and visualized through dashboards or mobile applications. The real-time monitoring process includes:

- *Graphical Representation:* Display of temperature, humidity, air quality, and rainfall levels in the form of charts and gauges.
- *Data Logging:* Continuous storage of weather data for future analysis or pattern recognition.
- *Alert System (optional):* Custom thresholds can be set for parameters (e.g., high temperature, poor air quality). When values exceed these limits, the system can send email or app alerts to notify the user instantly.

Hardware Description

ESP8266 Nedelcu

The ESP8266 is a highly integrated Wi-Fi-enabled microcontroller used for connecting the sensor data to the internet (Figure 2). It supports multiple GPIO pins, making it suitable for IoT applications [13].

Key Features

- Built-in Wi-Fi for real-time data transmission to cloud servers or dashboards.
- Compatible with Arduino IDE for easy programming.
- Small in size and affordable, ideal for DIY weather stations.
- Can act both as a host and client in a network.

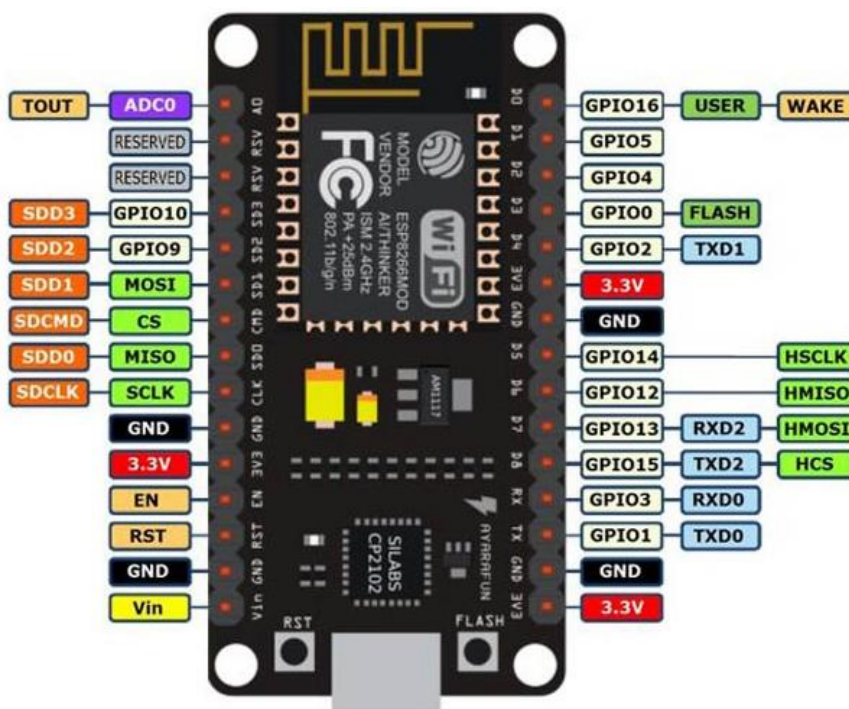


Figure 2. ESP8266 board.

DHT11 Sensor

The DHT11 sensor is widely used to measure the surrounding air temperature and humidity levels (Figure 3).

Key Features

- Measures temperature (0–50°C) and humidity (20–90%) with decent accuracy.
- Provides digital output, making it simple to interface with microcontrollers.
- Used to monitor environmental conditions crucial for agriculture, health, and safety.

Rain Sensor

This module detects rainfall or the presence of water using a conductive plate (Figure 4). It can help track precipitation trends and detect rain events.

Key Features

- Analog and digital output options.
- Helps identify wet or dry conditions instantly.
- Useful for irrigation control, urban flood alerts, and weather analysis.

RESULTS

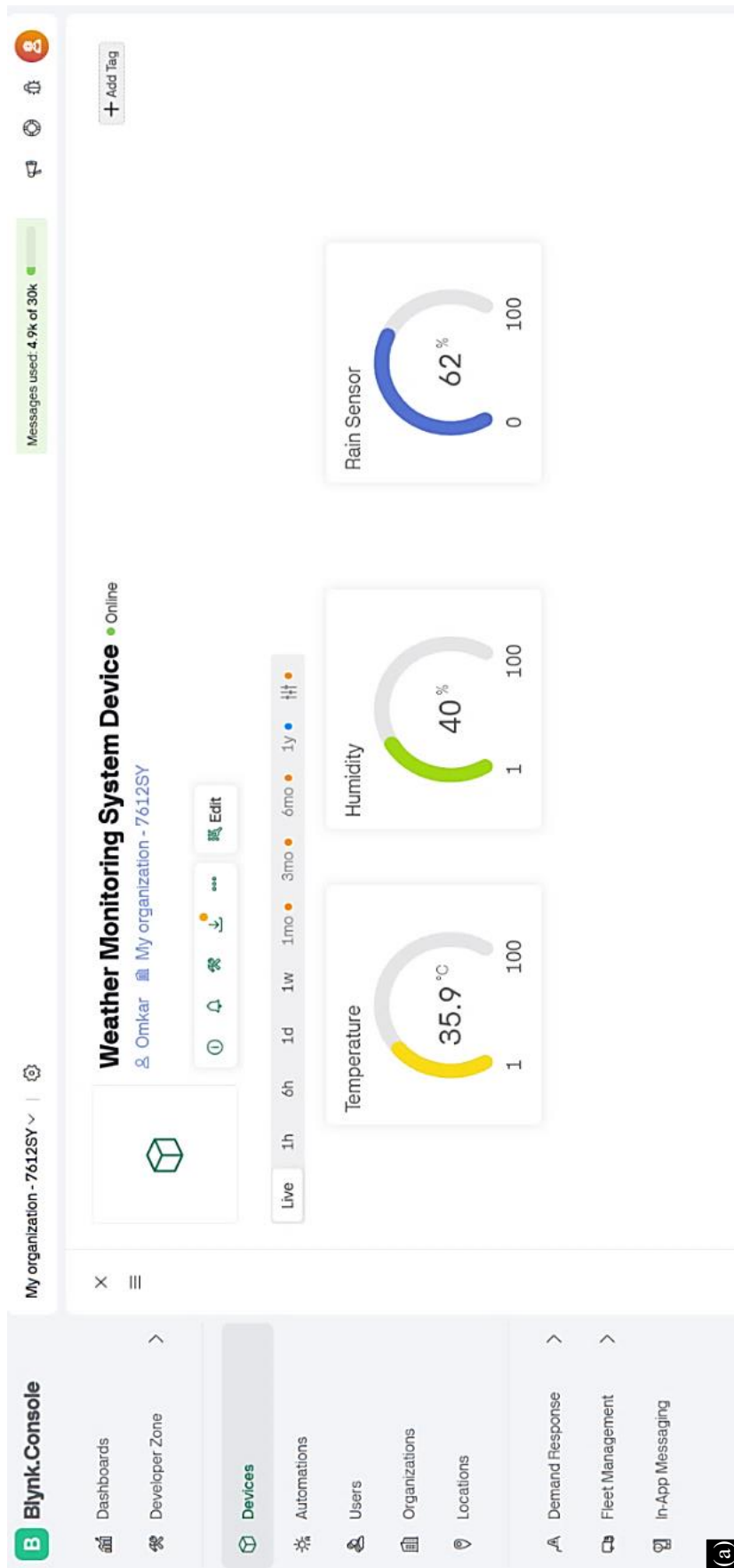
The testing phase plays a vital role in verifying the performance and reliability of the IoT-Based Weather Monitoring System. This section provides a detailed account of how the system was tested using simulated weather conditions and offers an analysis of its overall performance in real-time data acquisition and transmission.



Figure 3. DHT11 sensor.



Figure 4. Rain drop sensor.



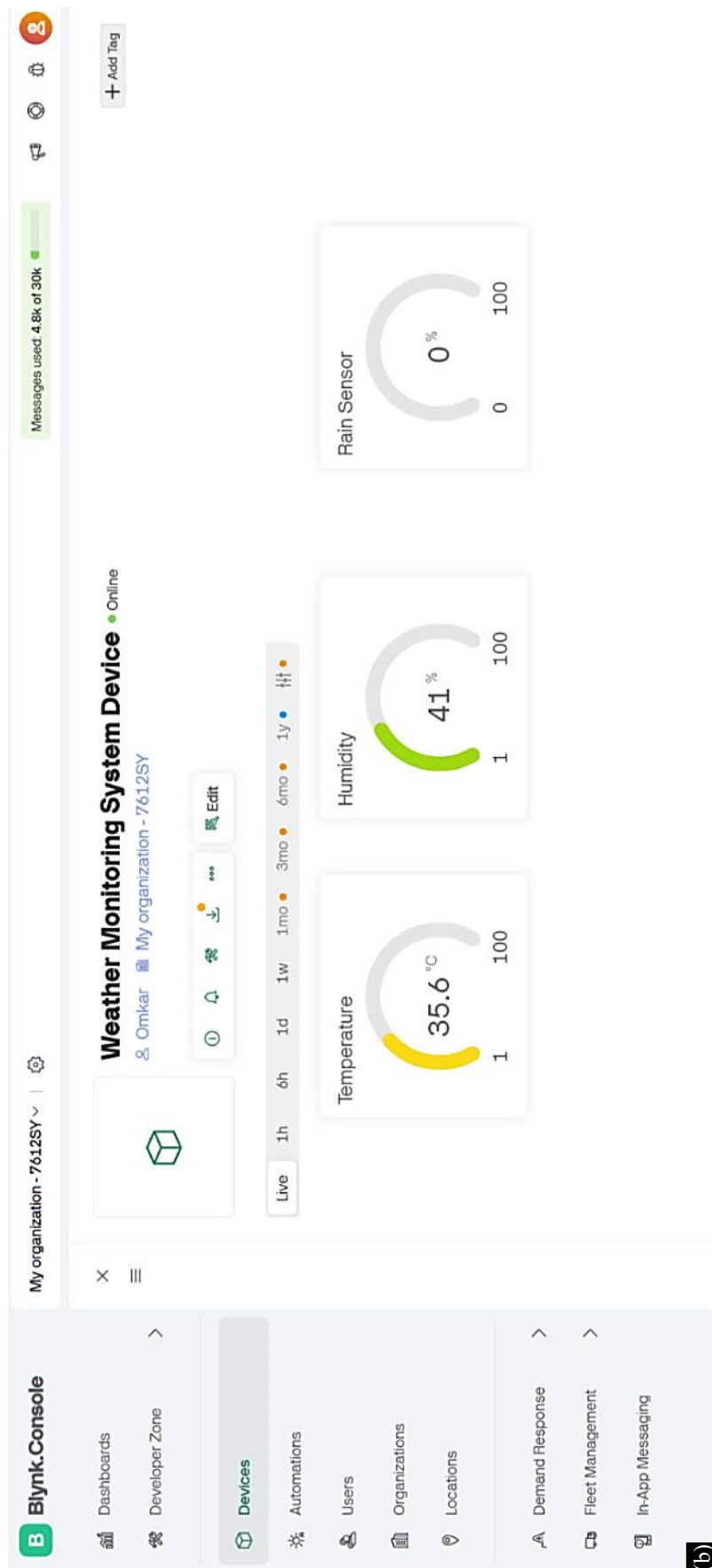


Figure 5. (a, b) Output of solar wireless EV charging system (LED Glows).

Testing with Simulated Weather Conditions

To thoroughly evaluate the system, various weather scenarios were simulated using different environmental triggers and manual controls. This included the generation of different temperature and humidity levels, artificial rainfall, and exposure to gaseous elements near the MQ-series sensor [14].

1. *Temperature and Humidity Testing*: The DHT11 sensor was placed in environments with varying heat sources (e.g., warm light or cold air) to simulate changing conditions. The sensor accurately measured temperature and humidity levels, which were then displayed on the LCD and logged to the cloud (Figure 5).
2. *Rain Sensor Testing*: A few drops of water were sprinkled over the rain sensor surface. The sensor immediately detected moisture, and the system updated its rain status accordingly in the serial monitor and cloud dashboard.
3. *Gas Sensor Testing (MQ Series)*: A mild amount of aerosol spray or gas was released near the sensor to check responsiveness. The readings spiked as expected, proving the sensor's capability to detect air quality fluctuations.

Wi-Fi and Data Transmission

The ESP8266 module was observed to maintain stable connectivity with the local Wi-Fi network [15]. Data was successfully transmitted at regular intervals to cloud platforms like ThingSpeak, where charts and visual logs confirmed consistent updates.

CONCLUSION

The IoT-Based Weather Monitoring System project successfully demonstrates how modern embedded systems and wireless communication technologies can be utilized to create a smart, efficient, and real-time environmental monitoring solution. By integrating sensors such as the DHT11 for temperature and humidity, a rain sensor for precipitation detection, and optionally gas or pollution sensors, the system provides reliable weather data that can be used for various applications ranging from agriculture to smart cities. The implementation of the ESP8266 Wi-Fi module allows real-time data transmission to cloud services or local servers, enabling continuous monitoring and remote access. The code structure, including sensor libraries and Wi-Fi configurations, was effectively designed to ensure stability and accuracy in data logging and communication.

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