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Design and Implementation of a Real-Time IoT-Based Weather Monitoring System

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ABSTRACT

This paper presents the design and development of a real-time Internet of Things (IoT) based weather monitoring system aimed at providing accurate and accessible environmental data. Utilizing the ESP8266 NodeMCU microcontroller and integrated digital sensors, the system captures key atmospheric parameters such as temperature, humidity, and rainfall, and transmits them via Wi-Fi to a cloud server for real-time visualization and alerting. The implementation is a cost-effective, scalable alternative to traditional meteorological systems, supporting improved decision-making in agriculture, climate research, and disaster preparedness. The system demonstrates high reliability, energy efficiency, and user accessibility, paving the way for broader adoption in developing and remote areas.
Keywords: Cloud Integration IoT, ESP8266, Weather Monitoring, Wireless Sensor Networks, Real-Time Data

1. INTRODUCTION

Accurate and real-time weather data are critical across sectors such as agriculture, health, transportation, and urban planning. Traditional weather stations are often costly, complex, and geographically limited, making them unsuitable for decentralized or resource-constrained environments. The emergence of IoT has enabled the development of low-power, remotely accessible systems for environmental monitoring. This study proposes an IoT-based system using affordable sensors and microcontrollers to provide scalable, continuous weather data.

2. RELATED WORK

Previous works have introduced various smart weather solutions using Arduino, GSM, and Wi-Fi technologies. Patel (2019), proposed a GSM-based alert system for agriculture, while Mekala & Viswanathan (2018), introduced a Wi-Fi-enabled dashboard for smart cities. Mabrouki et al. (2021), emphasized the need for cloud storage and mobile interfaces in weather systems. Akyildiz et al. (2002), surveyed the structure, characteristics, and applications of wireless sensor networks. The study highlighted key challenges such as energy consumption, limited processing capacity, routing, and scalability. It concluded that efficient and reliable network designs are essential for the successful deployment of sensor-based monitoring systems.

However, challenges such as energy consumption, unreliable connectivity, and scalability persist. This paper addresses these challenges with a cloud-integrated, mobile-accessible solution using ESP8266 and Arduino IoT Cloud.

3. METHODOLOGY

3.1. System Design and Architecture

3.3.1. Hardware Components

Table I lists the major hardware components used in the design and their specifications.

Table 1: Hardware Components and Specifications

Component	Specification
ESP8266 NodeMCU	80 MHz, 160 KB RAM, Wi-Fi-enabled
DHT11 Sensor	Temp: 0–50°C, Humidity: 20–90% RH
Rain Sensor	Digital output, adjustable sensitivity
Power Supply	3.7V 2200mAh Li-ion batteries
PCB & Enclosure	Weather-resistant, IP65 rated

3.3.2. Software Integration

The Arduino IDE was used for programming in embedded C++. Data is sent to the Arduino IoT Cloud using MQTT protocol. The cloud interface provides graphical data visualization and SMS/email notifications based on predefined thresholds.

Figure 1 illustrates the overall system architecture; Figure 2 shows the system block diagram while Figure 3 displays the system circuit diagram.

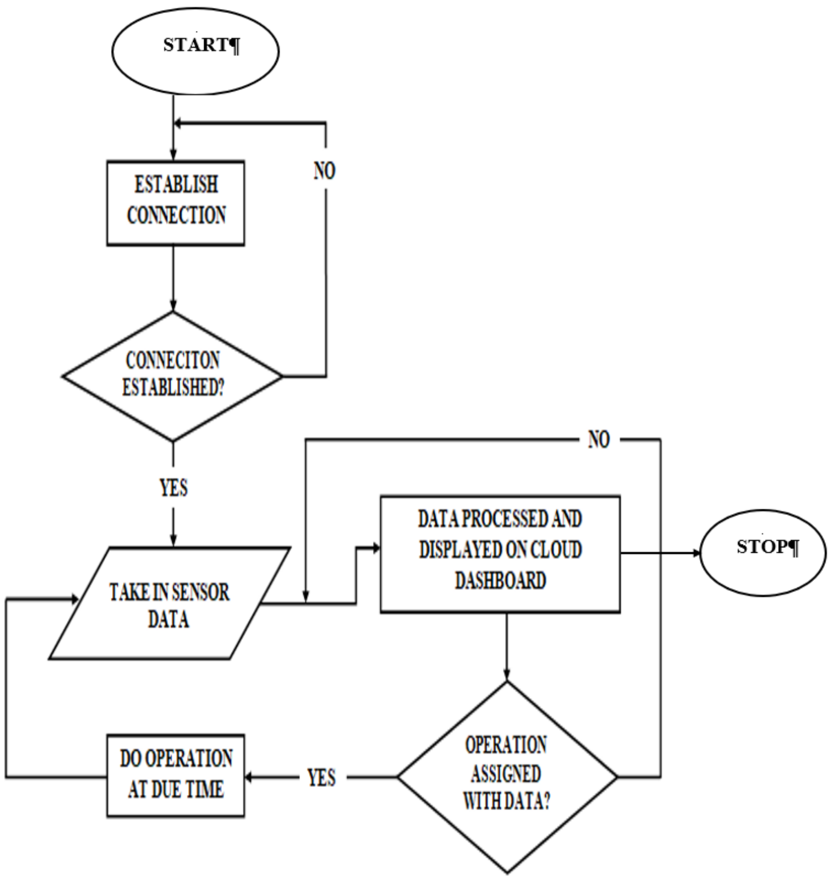

Figure 1: Diagram of System Flow Chart

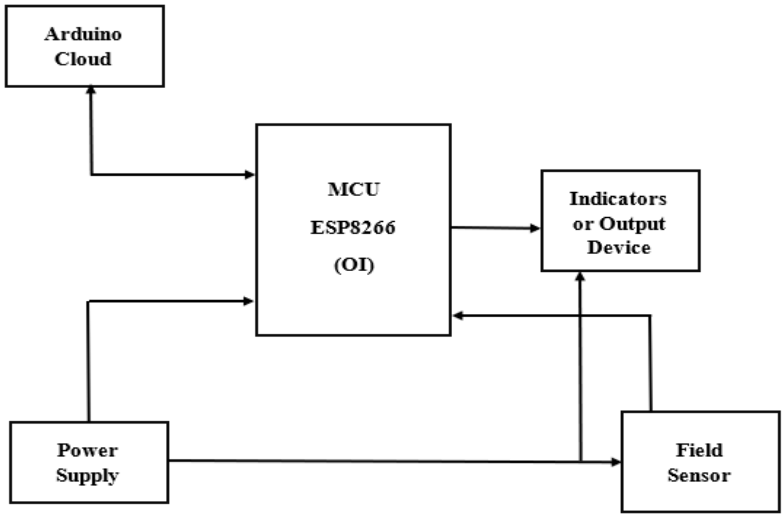

Figure 2: System Block Diagram

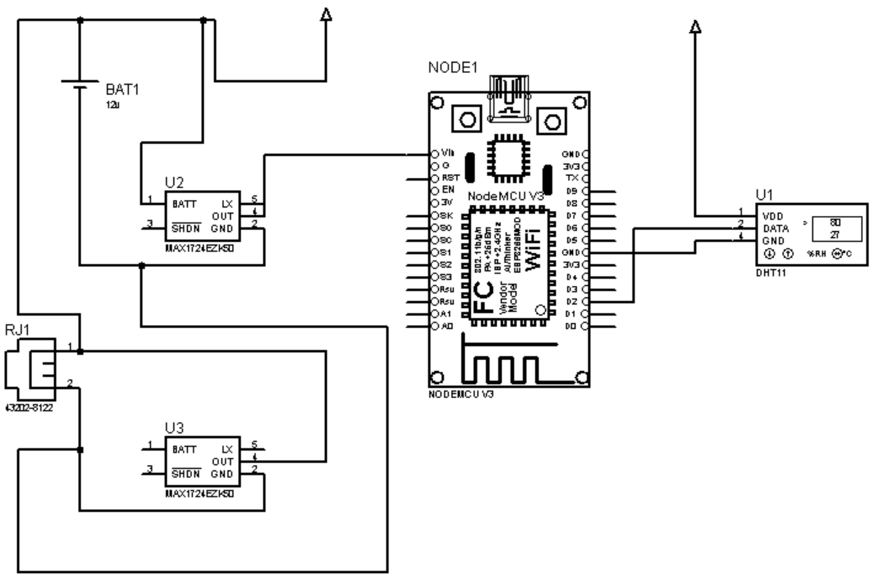

Figure 3: System Circuit Diagram

3.3.3. Network Architecture

The system follows a client-server model. Sensor data are collected at the node (ESP8266), processed, and published to the cloud. Users access data via smartphone or browser dashboard. This design allows remote access and real-time decision-making.

Sensor Node → ESP8266 → Wi-Fi → Arduino IoT Cloud → User Interface

4. RESULTS AND DISCUSSION

4.1. Implementation and Testing

4.1.1. Prototype Setup

The hardware was mounted on a veroboard and enclosed for field deployment. Sensors were calibrated against standard thermometers and hygrometers. Test readings were taken over several days to validate accuracy and stability. Figure 2 shows the physical layout of the prototype.

Figure 4 shows the inner view and connections of the newly built weather monitoring system using IoT

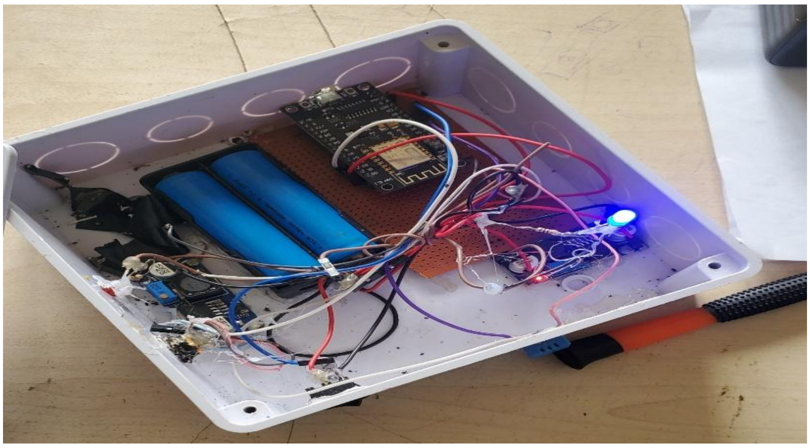

Figure 4: System Inner View Connections

Figure 5 shows when the newly built system measuring the Humidity of a weather condition.

Figure 5: System Inner View Connections

Figure 6 shows when the newly built system measuring the Temperature of a weather condition.

Figure 6: System Inner View Connections

4.1.2. Performance Metrics

The system was evaluated using standard performance metrics shown in Table 2.

Table 2: System Performance Evaluation

Metric	Value
Temperature Accuracy	±0.5°C
Humidity Accuracy	±2% RH
Data Latency	<4 seconds
Battery Life	~24 hours continuous operation
Wi-Fi Range	Up to 20 meters indoors

4.2. Discussion

The developed system demonstrates strong performance in accuracy, responsiveness, and ease of deployment. Its low-cost architecture makes it ideal for rural deployments. Limitations include Wi-Fi dependency and limited sensing range. Future versions could incorporate GSM modules or LoRa for long-range communication and solar panels for extended autonomy.

Additionally, data logging frequency and cloud storage constraints must be addressed for long-term deployment. Improvements in enclosure design can enhance durability for harsh outdoor conditions.

5. CONCLUSION

A low-cost, real-time IoT-based weather monitoring system was successfully designed and implemented. The solution provides accurate, accessible weather data suitable for smart agriculture, early warning systems, and academic research. Future enhancements will include integration of additional sensors (e.g., pressure, UV), energy harvesting, and AI-based data analytics for weather forecasting.

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