



Modbus TCP Communication with Node MCU and Node-RED for Smart Environmental Alerts

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ABSTRACT

In recent years, the integration of Internet of Things (IoT) technology with industrial communication protocols has gained significant attention for real-time environmental monitoring. This paper presents the design and implementation of an IoT-based weather monitoring system that employs a DHT11 sensor to measure temperature and humidity. The data sensed is sent from a Node MCU ESP8266 microcontroller to a NodeRED dashboard through the Modbus protocol, providing safe and organized communication. There is a real-time alert system, which includes an automatic email alert when the environmental factors cross specified limits. The system proposed is of low cost, easy to scale, and remotely accessible, thus well-placed for use in applications related to smart agriculture, industrial monitoring, and environmental studies. Experimental outcomes show precise sensing, dependable Modbus data transmission, and efficient realtime alerting functionality.

Keywords: Industry 4.0, Node MCU 8266, mode bus (TCP), Node-RED, Industrial Internet of Things, Email Alert

1. Introduction

The advent of Industry 4.0 has transformed the process of monitoring, analyzing, and controlling environmental and industrial parameters. Industry 4.0 through the combination of high-end sensors, communication protocols, and smart data processing makes it possible to develop smart, connected systems that can function autonomously and efficiently. In the context of this concept, Internet of Things (IoT) platforms like Node-RED have been very popular because of their flexibility, seamless integration, and compatibility with industrial communication protocols. Node-RED is an open-source flow-based development tool for rapid hardware device integration, API integration, and integration of online services. Due to its support for protocols like Modbus, MQTT, and HTTP, it can be applied in both industrial and environmental monitoring. Node-RED can also function as a centralized control and visualization platform in the case of weather monitoring and provide real-time data acquisition, processing, and decision-making. This work discusses the design and development of an IoT weather monitoring system based on a DHT11 sensor that detects temperature and humidity. The sensor information is gathered by a Node MCU ESP8266 microcontroller and sent to a Node-RED dashboard through the Modbus protocol. The system also includes a mail alert system that informs the user once the environmental parameters cross set limits, thereby facilitating preventative action. The suggested system is economical, scalable, and flexible for implementation in smart agriculture, industrial process monitoring, and environmental science, which are in accordance with Industry 4.0 goals.

2. Methodology

The envisioned IoT-based weather monitoring system is intended to offer precise and real-time measurement of environmental conditions, with embedded warning mechanism for anticipatory action. The system has three central elements: data acquisition, data transmission, and data visualization & warning.

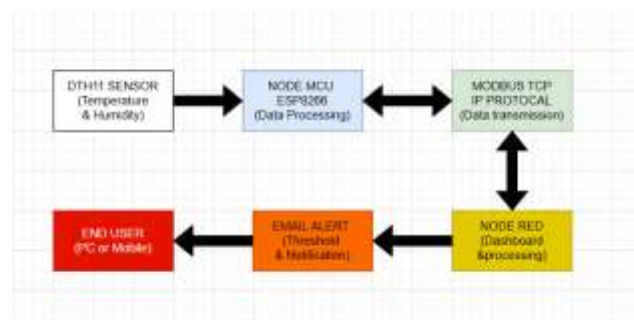


Fig. 1. Block Diagram

1.– A DHT11 sensor is interfaced to capture temperature and humidity parameters in real-time. The sensor is directly interfaced with a NodeMCU ESP8266 microcontroller that serves as the central data acquisition and preprocessing unit. The microcontroller ensures filtering of sensor readings, conversion to digital, and formatting for structured transmission to higher-level platforms. The low cost of the DHT11 combined with the Wi-Fi-enabled ESP8266 makes the system highly efficient for IoT-based monitoring. 2. Data Transmission – The processed data is wrapped up and sent over to the Node-RED server via the Modbus protocol, which enables structured, standardized, and fault-tolerant communication. Modbus is extensively used across industrial automation and monitoring systems, and hence the design is inherently scalable for embedding in Industry 4.0 settings. The design ensures not just robust point-to-point data transfer but also compatibility with other industrial devices, programmable logic controllers (PLCs), and supervisory control and data acquisition (SCADA) systems.

METHOD[2]

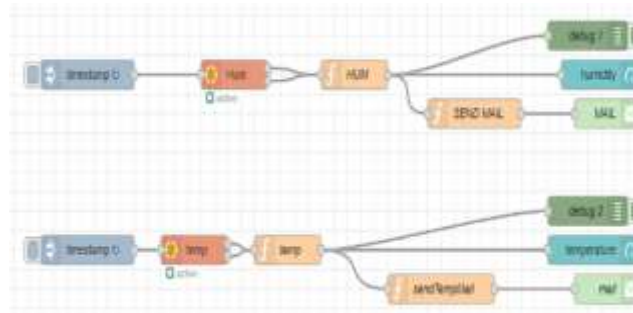


Fig. 2. Flow structure in Node-RED

3. Data Visualization & Alerting – Node-RED serves as the integration, processing, and visualization gateway. A real-time dashboard is created that is available through any web browser where real-time sensor values are graphically represented to be easily interpreted by users.

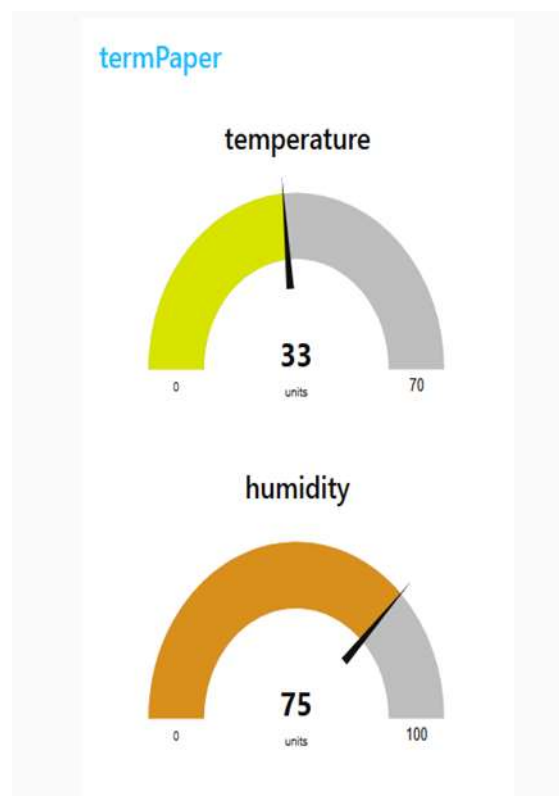


Fig.3.Dash Board View

Also integrated into Node-RED is an email and alert notification system. Upon reaching preconfigured safety levels for temperature or humidity, immediate alerts are forwarded to users who are registered. Such integration allows for predictive and preventive strategies, minimizing risks in mission-critical applications. This architecture provides a low-cost, scalable, and remotely accessible weather monitoring system that is appropriate for smart agriculture, environmental monitoring, and industrial safety systems.

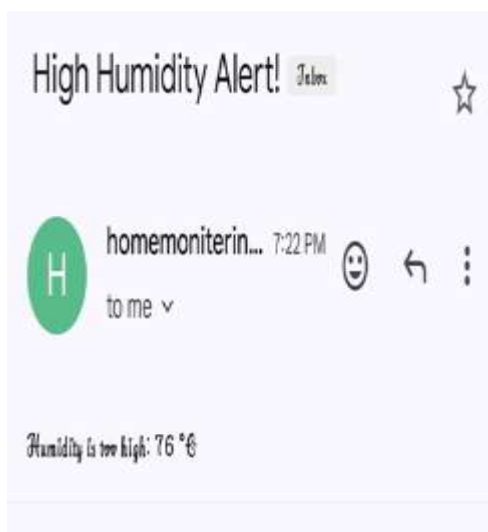


Fig. 4. Humidity Alert

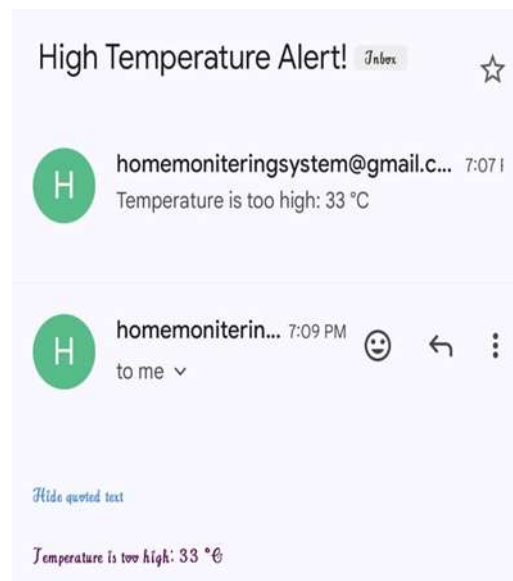


Fig. 5. Temperature Alert

Leverage Node-RED's visual programming and Modbus's reliability, the system proposed here is well able to bridge sensor networks with intelligent decision-making platforms, consonant with the goals of Industry 4.0.

3. TESTING PROCESS

The testing stage was performed to ensure the functionality, correctness, and dependability of the suggested IoT-based weather monitoring system. The testing process includes both hardware verification and software validation.

1. Sensor Calibration and Accuracy Testing - The DHT11 sensor was tested using a calibrated digital hygrometer and thermometer to ensure that the temperature and humidity reading is accurate. - The readings were taken at various times of the day to ensure consistency with changing environmental conditions. - The measured deviation was within $\pm 2^{\circ}\text{C}$ for temperature and ± 5
2. Modbus Communication Testing - Node MCU ESP8266 was set up as Modbus TCP client, and Node-RED was utilized as the Modbus TCP server. - A Modbus simulator was utilized to validate proper data packet formatting, transmission, and reception. - 24-hour continuous polling tests were performed to confirm communication stability with no loss of data.
3. Visualization Testing on Dashboard - Real-time visualization of data on the Node-RED dashboard was checked for lag and update frequency. - The dashboard was invoked using several devices (PC, tablet, smartphone) across the same network to verify cross-platform support.
4. Testing Email Alert Functionality - Threshold values for temperature and humidity were configured within Node-RED. - The system was tested by emulating high-temperature and high-humidity scenarios to activate the email alerts. - Emails were triggered within 5–10 seconds of threshold violation, validating real-time alerting functionality.
5. Long-Duration Performance Testing - The system was run continuously for 72 hours to test reliability with extended use. - No failure or communication loss was seen, confirming the stability of the system. The satisfactory execution of these tests guaranteed that the system satisfies the functional needs of real-time monitoring, secure communication, and proactive alarming, which are the goals of Industry 4.0-based monitoring systems.

4. REAL SCENARIO APPLICATION

The suggested system for IoT-based weather monitoring, utilizing Node-RED, Modbus communications, and email alert systems, has widespread real-world applications. Its low-cost hardware, scalable design, and Industry 4.0-friendly protocols make it flexible across various industries:

1. Smart Agriculture - Use Case: Precision farming relies heavily on environmental factors like temperature and humidity to help crops develop and yield. - **System Role:** The field conditions are continuously monitored by the DHT11 sensor and communicated through Modbus to a centralized Node RED dashboard. - **Impact:** Automated email notifications can be sent to farmers in the event of extreme temperature or humidity changes, enabling them to take timely action such as switching on irrigation systems or protective covers. - **Benefit:** Improved crop management, minimized losses from weather extremes, and enhanced productivity.

2. Industrial Environmental Monitoring - Application: Numerous processing and manufacturing facilities need to have tight environmental control in order to ensure product quality and employee safety. - **System Function:** The system can be deployed in production zones to measure temperature and

humidity in real time. - Effect: Irregularities in established environmental levels can send automatic email alerts to facility managers to allow for swift remedial action. - Advantage: It guarantees compliance with quality requirements and reduces downtime due to environmental problems.

3. Cold Storage and Warehouse Monitoring - Use Case: Perishable products like food, pharmaceuticals, and chemicals need controlled storage conditions for safe storage. - System Role: The monitoring system monitors storage conditions and signals operators when temperature or humidity is out of safe limits. - Impact: Avoids spoilage, maintains regulatory compliance, and minimizes financial losses. - Benefit: Improved operational reliability and product safety. **4. Remote Weather Stations for Research - Use Case:** Environmental scientists need long-term weather data for climate research, ecological surveillance, and calamity prediction. - System Role: The system can be installed in remote locations, uploading data via Wi-Fi to a cloud-based Node RED dashboard. - Impact: Scientists get ongoing, reliable data without having to frequently visit the field. - Benefit: Reduced operation expenses and enhanced efficiency of data gathering.

5. Smart City Infrastructure - Use Case: Urban governments can incorporate such monitoring systems into smart city initiatives for live environmental monitoring. - System Role: Public dashboards and alert systems can be used to notify citizens of heatwaves, increased humidity, or air quality problems. - Impact: Facilitates urban planning, public health advisories, and disaster preparedness. - Benefit: Better quality of life and greater public safety. The flexibility of the system proposed is that it can be configured efficiently for various environments while keeping stable Modbus communication and fast alert features intact. Its application across various industries speaks volumes about its promise as an Industry4.0 scalable and cost-efficient solution.

5. CONCLUSION

This article introduced the design and deployment of an IoT-based weather monitoring system that incorporates a DHT11 sensor, Node MCU ESP8266 microcontroller, Modbus communication, and a Node-RED-based dashboard with real-time email alarm functionality. The system is effectively able to provide reliable data collection, systematic data transmission, and easy-to-understand visualization, all of which fall in line with the fundamentals of Industry 4.0. Test results validated that the suggested solution delivers precise environmental readings, stable Modbus communication, and timely alert indications, and hence, is appropriate for use in smart agriculture, industrial monitoring, cold storage management, and smart city infrastructure. The utilization of Node-RED provides great flexibility to customize the system quickly, while Modbus provides compatibility with industrial systems, making it easy to integrate into existing infrastructures. Additionally, the low-cost and scalable aspect of the design makes it feasible to implement for both small-scale deployment and large-scale industrial applications. Future development will involve upgrading the capabilities of the system by adding more environmental sensors (e.g., air quality, rain, wind speed), cloud data storage for long term analysis, and artificial intelligence to support predictive analytics. The system with these upgrades can become an intelligent and holistic environmental monitoring platform, further promoting the aims of Industry 4.0.

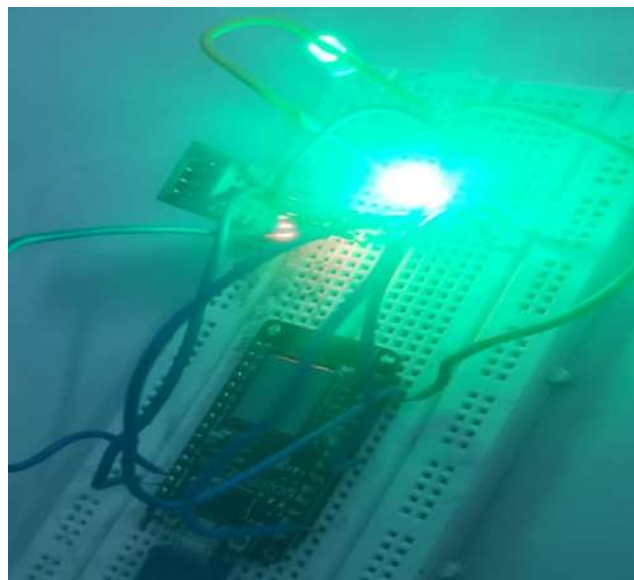


Fig. 6. Hardware Implementation

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