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Low-Powered IoT-Based Real-Time Weather Monitoring and Location Tracking using MQTT

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Abstract. Accurate weather conditions monitoring and precise geographical location is vital requirement in an IoT applications. The proposed article presents Low power IoT based Real time weather monitoring and geographical location tracking system. The proposed system incorporated Low power embedded platform as Raspberry Pi. Weather monitoring parameters as Temperature and Humidity is measured using the precise sensor. Location tracking is implemented using GPS module. The Raspberry pi board measured weather monitoring data and geographical location using sensors and submodules. The measured data is transferred to Lightweight mobile application. The data is transferred securely through MQTT – IoT based Protocol. The proposed system is scalable as it is design on the low power platform with IoT protocol. The proposed system is integrated with Telegram bot which enables remote access of real time environment.

Introduction

Weather monitoring and accurate geographical location tracking is one of the fundamental requirement for real time embedded systems. Electronic sensors and GPS technology can fulfil this requirement. However, precision and accuracy are essential for parameters. The precise sensors need to interface with low power embedded and IoT modules. Embedded modules are used to process the sensor data while IoT modules used to transfer data through wireless media.

With the rapid advancement in the field of Embedded and IoT solutions, it becomes a potent resource in real-time environments and location monitoring, especially in sectors such as agriculture, logistics, defense surveillance, and disaster management. With the development of IoT, we can collect and transmit live weather m and geolocation data, which is essential for efficient and informed decision-making. Nonetheless, IoTs, sensors, and low-power controllers can allow monitoring of weather conditions in real-time. However, edge-based devices have limited resources, and computational limitation makes a constraint on the implementation of these devices. Hence, weather monitoring and GPS systems are expensive, complex, and require high-end infrastructure with continuous internet connectivity, which might not be possible in various remote or rural areas. A cost-effective and energy-efficient wireless sensor design for recording temperature and humidity, integrated into a wireless network, is suggested for the unlicensed 2.4 GHz band [1]. The suggested wireless sensor network is appropriate for Smart Home applications. Li et al. [2] proposed a method for sensor calibration in open space. With the help of a microcontroller and a LoRa wireless module, we were able to create a cloud-based intelligent calibration system for temperature and humidity that uses several nodes.

In [3], the effects of weather and humidity on animals' well-being were discussed. An effective system for environmental monitoring was established, utilizing the Sigfox IoT network, in both

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the stockyards and the shade of shelters for cattle. The measured peaks of the TX current are slightly bigger than the LoRa values. An advanced system has been implemented to oversee medication distribution and control the temperature of pharmaceuticals during transit, mitigating the risks posed by environmental influences [4]. The suggested system utilizes mobile applications as user interface, incorporates Arduino, MQTT, and a temperature sensor, and employs a compact portable cooling unit. The system's accuracy is reflected in an F1-score of 68%.

To overcome these challenges, this study presents a compact, cost effective and scalable IoT Bases system designed to monitor weather conditions as well as the geographic location information. The proposed system is portable and can be deployed easily. The system primarily uses Raspberry Pi Zero W as the main processor which when interfaced with the DHT-11 sensor and NEO-6M GPS Module which is mainly used for measuring the temperature and humidity, and the GPS module which will provide the geographical coordinates which includes latitude, longitude and altitude. Furthermore, the system uses MQTT (Message Queuing Telemetry Transport) protocol and transmit the collected data to compatible MQTT public client. In addition to this, a notification mechanism is being implemented to generate alerts when temperature rises above a specified threshold, for this purpose a telegram bot is deployed to notify the end user in real time.

The overall structure of the paper is as follows: Section 2 presents the Methodology, introducing hardware system integration. Section 3 shows the experimental results, and a comparison with other systems is presented. Finally, a conclusion with a feature scope is given in Section 4.

Methodology

As highlighted earlier in the introduction section, large portion of the existing of literature focuses on the temperature monitoring, gas detection, and other environmental condition monitoring using various sensors. Much of the exiting work revolves around Arduino UNO as their primary microcontroller due to it’s the flexibility and easy to use functionality makes it popular choice in IoT based applications. Hoverer it inherits certain limitation each include limited processing power and computational capacity and memory, as well the unavailability of built in Wi-Fi, restricts its performance in more complex and larger systems. The proposed system uses Raspberry Pi (RP) over Arduino Uno. The integrated Wi-Fi network simplifies network connectivity and provides better connectivity in comparison to a separate Wi-Fi module connected to the central system.

In this work, MQTT protocol is employed for data transmission. Although TCP/IP can be used, MQTT offers serval advantages that makes it more suitable for IOT applications, one of the key advantage here is that MQTT has a very small header size which is as low as 2bytes whereas the raw TCP/IP communication requires custom packet structure and larger headers. This light weight nature makes the MQTT protocol ideal for low bandwidth and resource constrained device. Moreover, MQTT works on the publish and subscribe model which improves stability and simplify the system design. These features make MQTT a suitable choice for application development, ensuring low latency and reliable data transfer.

The presented system is divided into two main subsystems. The first subsystem consist the sensor and control unit, and the second subsystem is responsible for data acquisition and transmission.

Subsystem-1: Hardware System Integration

Here the Raspberry Pi zero w is employed as the main controller of the system, with that DHT-11 sensor and NEO-6M GPS module are integrated for the data collection. All the data processing which includes sensor data acquisition and communication operations are executed using python scripts. The block diagram of the proposed system along with components is shown in Figure 1.

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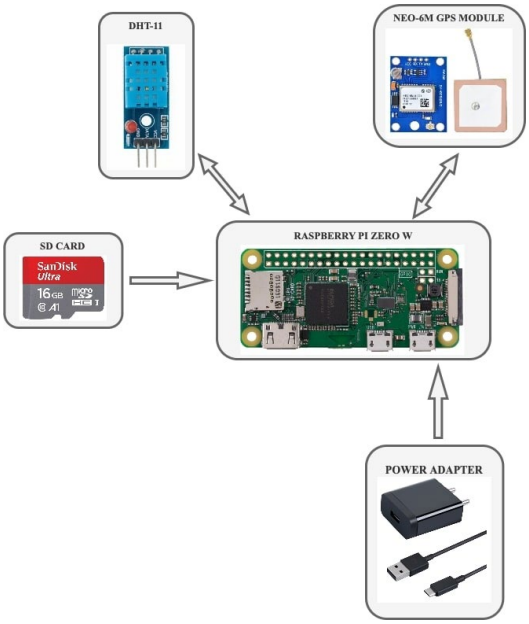


Figure 1: Block Diagram for Proposed Approach

The Raspberry Pi (RP) functions as the central processing and control unit of the proposed system. Raspberry Pi is ARM11 based Gigahertz based processor which supports High level language and IoT utilities. On chip GPIOs of the boards facilitate ADC conversions for sensors operations. Furthermore, Raspberry pi supports Linux Environment which is essential for IoT applications. Temperature and Humidity parameters measures through Single sensor known as DHT11. DHT11 is easily compatible with the Raspberry pi. The sensor measures the temperature in form of degree Celsius and humidity is measured in form of %. It integrates Raspberry Pi Zero W through the GPIO pins. The DHT-11 VCC and GND pins are connected to the Pi's pin1 and pin6, respectively. The data pin is connected to GPIO 4 of the Raspberry Pi. To read the sensor data, the Adafruit_DHT library is utilized, which will facilitate the process of collecting the data from the DHT-11 sensor and getting accurate environmental readings. Figure 2 shows this sensor module.

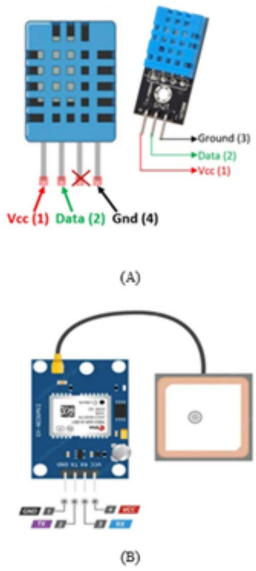


Figure 2: (a) Temperature and Humidity Sensor (DHT-11) module, (b) GPS Module for location access.

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To access the geographical location, a GPS is also integrated into the proposed system. THE NEO-6M GPS module is responsible for providing geographical coordinates, including Latitude, Longitude, Altitude, and timestamp in UTC. The module communicates with RP using the UART (Universal Asynchronous Receiver/Transmitter) protocol. The TX pin of the GPS module relates to the RX (GPIO 15) of the RP. The RX pin of the GPS module will be left unconnected, as we are not receiving any data; the data transmission is unidirectional. The module output is in NMEA (National Marine Electronics Association) format, which is formatted and parsed using the Python library GPSD. Tools such as 'cgps' and 'gpsmon' are used to visualize the GPS data on the terminal.

Subsystem-2: Data acquisition and Transmission

Data acquisition and Transmission is carried out using sensor measurement, IoT protocol, IoT Broker and lightweight mobile utility viz telegram bot. Figure 3 presents functional flow diagram of proposed system. As shown in Figure. 3, environment data is measured by the sensors and geographical location is measured using GPS module. Environment data is processed by the Raspberry pi board. Raspberry pi board also record geographical data using GPS module. The sensor data and geographical data are transferred wirelessly to IoT broker using MQTT protocol. At the client side, the telegram bot utility is implemented which enables alert system if Temperature and humidity data is increased above threshold value.

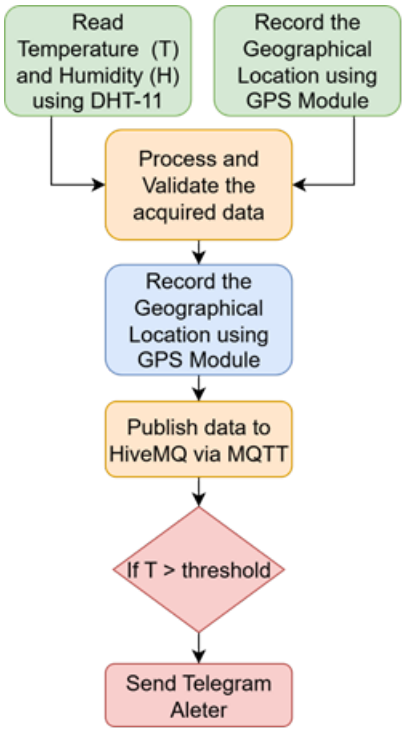


Figure 3: Flowchart of the Proposed System

Test Results and Discussion

This section depicts the outcome of the system. The principal aim of this project is to enable accurate, real-time environmental monitoring and reporting the geographical coordinates. The system successfully collects all the required data. Figure 4 showcases a screenshot of the sensor data obtained from the developed IoT system. The DHT-11 which was responsible for measuring

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the environments data which includes temperature and humidity, measured the daytime temperature of 33C and relative humidity of 65.0%, furthermore the NEO-6m GPS module accurately determined the geographical coordinates which includes latitude, longitude and altitude.

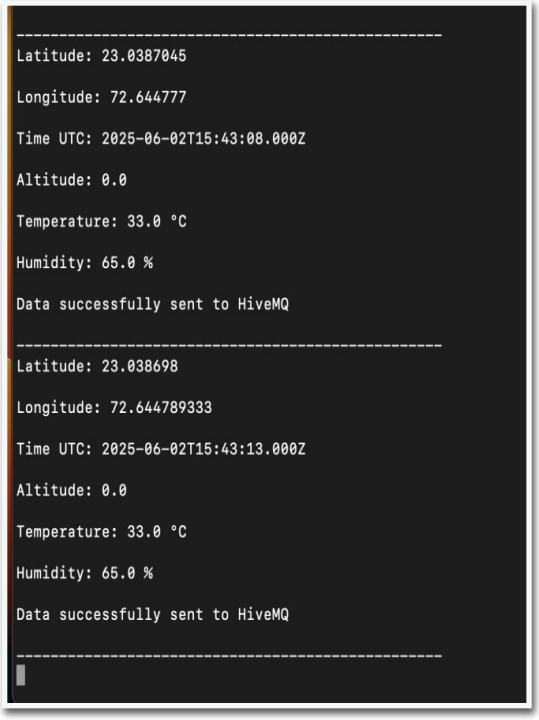


Figure 4: Sensors' data reading and acquisition

A HiveMQ interface is implemented in the proposed system to enable MQTT-based communication. Figure 5 displays the HiveMQ WebSocket client interface used for data exchange. The system includes a well designed dashboard that supports host configuration and port selection. Users can also control the connection setting by configuring a last-will message, which helps to ensure reliable operation in the event of an unexpected disconnection.Furthermore the dashboard provides options for publishing messages to specific topics and subscribing to a particular topic.As an example sensor data can be published to the topic "iot/sensor/data"through the "Publish" section, while the "Subscriptions" section allows the end user to monitor real-time updates from the same or related topics. The series of messages recorded via HiveMQ user interface. Each message published under the mentioned topic provides temperature, humidity, and geographical coordinates along with the corresponding time zone. This organized logging demonstrates that the system works as expected ,which is vital for continuous monitoring. Temperature readings range from 33.4 °C to 34.0 °C, while humidity remains steady at 65%, highlighting the system's accuracy and effectiveness in real-time environmental monitoring.

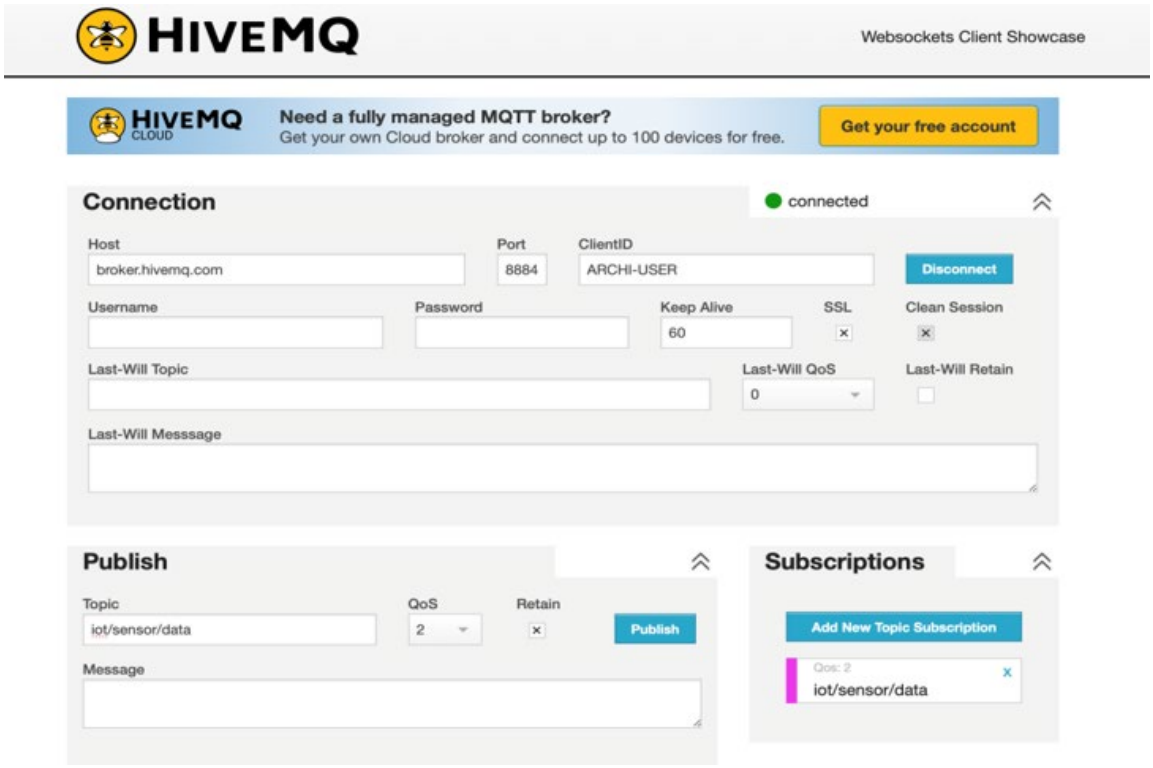


Figure 5 HiveMQ WebSocket Client Interface for MQTT Communication

The implemented system integrates an IoT tracking bot created on the Telegram platform to deliver real time alerts whenever the temperature exceeds certain threshold level.

The integration of IoT, sensors, and microcontroller units has demonstrated multifaceted approaches in the literature. Table 1 shows the comparison of the proposed system with a few recent studies. In [5], the authors used Arduino UNO and developed a user interface using the Blynk Application. However, their system lacks wireless communication and remote access, and it was designed with a focus on crop yield. In contrast, the author in [6] used the TCP/IP protocol for remote data transmission for the terrain region. The validation of systems in rural areas with low connectivity is required. The NodeMCU ESP8266 setup with rain sensors and the Blynk app was developed in [7]. However, real-time data logging and altering are weaknesses of their system. In [8], the author used an Atmega328 microcontroller to monitor temperature and humidity levels. They displayed the values on the LCD. Their system does not support real-time monitoring and data acquisition over time. The proposed RP-based system presents an innovative approach, making the design lightweight using the MQTT protocol and a Telegram bot. This provides scalability in the system. The user-friendly dashboard, utilizing HiveMQ and offering real-time temperature and humidity observations, stands out as a unique feature among all. Together, these systems illustrate the diverse possibilities and challenges in developing effective IoT solutions for climate monitoring and agricultural productivity.

Table 1. A comparison of the proposed design with other designs

Ref.	Design Components	Remarks
[5]	Arduino UNO + Blynk Application.	Still, it needs remote access and weather tracking to boost crop yields within the region. A buzzer sounds on the climate station.
[6]	Arduino UNO + ESP8266 + TCP /IP Protocol	Focused on weather monitoring in terrain. Urban and rural area testing is required.
[7]	NodeMCU ESP826 + Rain Sensor + Blynk app	A robust data logging system is required, as no alert or analysis is available on the dataset.
[8]	ATmega328 + Temperature & humidity sensor + LCD Display	The system is appropriate for various types of short-distance tasks. No data observation is conducted, and the dashboard is used.
Proposed System	Raspberry PI + Temperature and Humidity sensor + MQTT protocol + Telegram bot.	A scalable system providing real-time data analysis and an alert system using a Telegram bot.

Conclusion

IoT-based weather tracking system and GPS location using embedded Linux platform approach are introduced here. The main objective is to provide real-time data with a low-power resource-constrained device. The proposed system utilizes IoT to develop a system that monitors environmental data, specifically temperature, humidity, and GPS location. The RP serves as the heart of the system, and the sensors, which are a temperature and humidity sensor DHT-11 and a NEO-6M GPS module, are integrated with it. The received data is formatted and then shared wirelessly with a cloud-based MQTT broker using the MQTT Protocol. The MQTT broker utilized here is HiveMQ, where the data is published under a specific topic. Furthermore, the lightweight telegram bot utility is implemented at the client side, which enables alert system in case of increasing temperature and humidity. The system becomes efficient due to integration of MQTT and telegram bot in form of remote accessibility of real time data.

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