IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 2, May 2026
Impact Factor: 8.2

Weather Forecasting and Logging Station using BME280 & NodeMCU

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Abstract: *Weather has a significant impact on human activities and important decisions, such as planning a trip, landing an airplane, and planting crops. These decisions are greatly aided by precise weather prediction and monitoring. This study presents the design and construction of a low-cost, mobile weather monitoring and forecasting system capable of gathering, reporting, and storing various meteorological parameters. The system was initially designed using Proteus software and implemented with a BME280 sensor, which measures environmental variables including altitude, wind speed, precipitation, temperature, pressure, humidity, and heat index. This sensor was integrated with an STM32-bit microcontroller that processes the weather parameters. A storage module was embedded to store data, while real-time weather conditions are displayed on an LCD screen. The system processes the weather information and displays the current weather conditions on the LCD. The corresponding data, stored in the embedded storage system, is collected and presented in this study. The results demonstrate the system's ability to accurately present real-time weather conditions based on sensor data. The constructed system is portable, cost-effective, and accurate in providing weather information across different locations.*

Keywords: Weather Monitoring, Forecasting System, BME280 Sensor, STM32 Microcontroller, Real-Time Data

I. INTRODUCTION

Monitoring precise weather and soil conditions plays a key role in agricultural production. Storing and analysing the historical data of temperature and local humidity helps in future seed selection, crop rotation activities. Knowing the precise amount of moisture that is beneficial for the soil, helps farmers to regulate the water resource effectively. As an application, a farmer can use the proposed system in the agricultural field to monitor the temperature, humidity, pressure around the crops precisely. It is embedded with a rain sensor that detects rainfall and alerts the farmer intime. The system has a hybrid power module that can charge the device with the help of solar power. The weather station transmits a live feed of readings from the field, where the equipment is placed. This system is considered to be a smart system and embedded with sensors, microcontrollers with software application becomes a self-monitored system. Weather monitoring is an important aspect of various industries from agriculture to disaster management, transportation, urban planning and environmental research. Timely and accurate weather information is critical for enabling informed decision making, risk management and optimizing operational efficiency [1]. While effective, such traditional approaches to weather monitoring are costly, bulky devices designed for fixed locations and cannot be suited for small or bespoke applications. However, these limitations encouraged the usage of modern microcontroller technology along with Internet of Things (IoT) to develop low-cost and scalable weather monitoring systems [4]. Solve the problems. In this paper we describe the design and realization of an ESP8266- based weather station, presenting its potential as a novel tool for real-time environment monitoring. Due to its functionality, it is a great platform for IoT Based applications. It's small, cheap, and energy efficient, allowing systems to be compact and portable while still working hard for less energy [6]. This project is based on the ESP8266 microcontroller and is a weather station that can monitor important environmental factors like temperature, humidity, atmospheric pressure, and light intensity [10]. The data collected using the microcontroller's wireless communication is then sent to the cloud platform to perform remote monitoring and analysis. Ease of use. Conventional methods are capital-intensive and need infrastructure: they are not so suitable for the individuals, small farmers and researchers on a remote area [12]. LowCost, User-Friendly ESP8266 Meteorological Stations Combining ESP8266 Meteorological Stations to Overcome These Constraints The vision of the project would be a system that would follow the system design, which is scalable and thus allows users to add specific needs such as rainfall measurement, wind speed measurement, or air quality measurement sensors. This is a key point in making a weather station [18]. Low-power mode support is added to the ESP8266 microcontroller [5]. Weather stations are capable of operating independently of a power supply, can also include renewable energy sources such as solar energy, making them well self-sufficient for target or remote areas where electricity is typically not available. This part of the program has Promise which Strengthens its Impact particularly in Underserved regions [9]. As users send real-time data into the system, the cloud platform makes it accessible anywhere in the world via a web dashboard or mobile application with weather data [15]. In addition, this feature makes it easy and accessible in the short-term, while laying the groundwork for long-term data storage and analysis. also, historical climate data is crucial because it can help with the trend, providing for agriculture, infrastructure, tour protection [21]. Compact and portable design. Unlike traditional weather stations that need to be built in concrete, ESP8266 based weather stations can be easily set up and dismantled as and when needed. Its flexibility makes it the best candidate for localized or temporary monitoring applications, including construction sites, field surveys, and emergency events, reliability, and energy efficiency [22]. Through rigorous and analysis, this study focuses on the efficiency of microcontroller systems connected to the Internet of Things that creates new and effective systems for weather monitoring [18]. By involving all types of partners in one round, the project looks to propel bade to be at the forefront of solutions, focusing on affordability, accessibility and efficiency within IoT. This is useful to several groups ranging from farmers, researchers, and educators to policymakers [24]. The pervasive nature and scalability of the system concept engrains itself into diverse scenarios wherefrom use cases as simple as personal use to business and education [6]. The project also shows how IoT devices can be used to update old processes and provide real-time weather monitoring and decision-making information [14]. This could help develop independent and reliable monitoring of weather. Affordable, easy to use, and featureful, the project showcases how IoT is maturing into a powerful solution for tackling realworld problems [19]. The outputs of this research can be the basis for future developments about IoT sensor network-based green environmental monitor; it would be wise to channel the building up into smart, intelligent ways.

II. LITERATURE SURVEY

• In this research, we design a weather system that enables users to monitor, collect, store, and forecast weather conditions using a standalone hardware setup without requiring additional installations. The system utilizes sensors capable of measuring humidity, temperature, pressure, precipitation, wind speed, altitude, and heat index. These measurements can be used to program actions for electrical devices within a network based on environmental data. The hardware setup consists of a portable electronic device interfacing with a microcontroller.

• It monitors realtime conditions through the sensors, allowing users to determine the current state of the weather [3]. Most existing advanced weather forecasting systems require extensive infrastructure and high operational capacity. This underscores the complexity of weather prediction, which relies on efficient observation, data analysis by computers and meteorologists, and rapid communication systems. Weather forecasting has existed for a long time and has evolved through various approaches, including traditional and professional methods.

• Earlier weather prediction methods were based on personal experience without experimental validation [4]. Given that several critical decisions, such as those related to agriculture [5], [6], depend on accurate forecasting, achieving high precision is essential.

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• Kedia [7] developed a localized weather monitoring system that used sensors such as the DHT11 and BMP180 to measure variables like temperature, humidity, pressure, wind speed, and precipitation. However, the system exhibited an average error margin of approximately 10%, making it less reliable in predicting accurate weather conditions.

• Ukhurebo [8] proposed a machine learning-based weather monitoring system using an affordable Arduino-based setup. This design included an Arduino Mega 2560 microcontroller, multiple weather sensors, a real-time data logger, and an LCD display. The system measured parameters such as temperature, humidity, pressure, light intensity, dew point, and altitude. Its readings were consistent with those from standard weather systems.

• Kapoor [2] implemented a weather station using the Internet of Things (IoT) to enhance the accuracy of weather prediction. The system measured climate parameters such as temperature, humidity, wind velocity, and precipitation. Additionally, it featured cloud data storage via Wi-Fi using a Raspberry Pi Zero board, enabling users to access weather information remotely through cloud computing.

• Gaurav et al., [9] developed a real-time weather prediction system that integrated IoT and machine learning technologies. The system, applicable in environments such as stadiums, agricultural fields, schools, and industries, used key weather parameters-temperature and humidity (measured by DHT11), and light intensity (measured by an LDR). Sensor data was transmitted to the ThingSpeak cloud server via the NodeMCU and ESP8266-01 Wi-Fi module [10], and displayed on a customized HTML webpage. The system used previously recorded data to train a machine learning model, which was deployed using a Jupyter notebook in a Python environment. Real-time sensor readings were used to validate the model, with LED indicators flashing to display predicted values.

• In [11], a low-cost, user-friendly neighborhood weather station was introduced. This station employs inexpensive sensors to improve the accessibility and usability of environmental monitoring. It effectively measures various environmental parameters such as temperature, air pressure, relative humidity, CO_2 levels, and particulate matter (PM1, PM2.5, PM10), which can be remotely monitored. This work aims to design a portable, low-cost system capable of accurately monitoring, collecting, storing, and forecasting real-time weather conditions. The microcontroller autonomously controls devices based on data received from the sensor module.

III. SYSTEM ARCHITECTURE

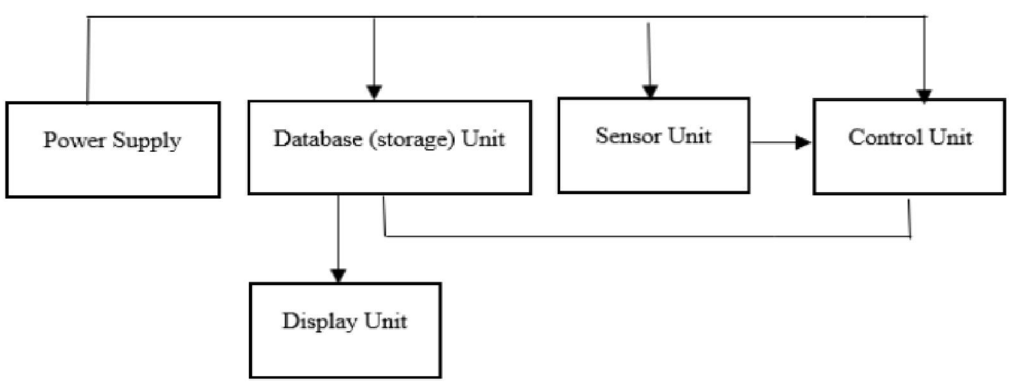

Fig. 1. Block Diagram

In IOT enabled weather monitoring system project, Arduino Uno measures 4 weather parameters using respective 4 sensors. These sensors are a temperature sensor, humidity sensor, light sensor, and rain level sensor. These 4 sensors are directly connected to Arduino Uno since it has an inbuilt Analog to digital converter. The weather monitoring system gives high accuracy and reliability for weather monitoring and climate changing. It uses the renewable energy source like solar panel for charging the connected battery. Through the web, it access real time weather information and data. This system can be communicated over general packet radio service (GPRS) network. Low maintenance is required for end users. It is capable for storing data and providing it to the users as required.

The implemented system consists of a microcontroller (ESP8266) as a main processing unit for the entire system and all the sensor and devices can be connected with the microcontroller. The sensors can be operated by the microcontroller to retrieve the data from them and it processes the analysis with the sensor data and updates it to the internet through Wi-Fi module connected with via blynk app then we can measure temperature, humidity, pressure and rain fall.

A. ESP8266 Node Mcu:

The ESP8266 is a low-cost Wi-Fi microprocessor manufactured by Espressif Systems in Shanghai, China. It has a full TCP/IP stack and can function as a microcontroller. In August 2014, the ESP-01 module from a third-party company, Ai-Thinker, drew the attention of Western manufacturers. The ESP8266 connects microcontrollers to Wi-Fi networks and uses Hayes-style commands to make simple TCP/IP connections. Initially, there was little English-language documentation available about its chip and its order. The ESP8285 is a version of the ESP8266 with 1024 kB of built-in flash, making it possible to create single-chip Wi-Fi devices. The Node MCU ESP8266 development board includes the ESP-12E module, which contains the ESP8266 chip, powered by a Ten silica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and can operate at a configurable clock frequency of 80.00MHz to 160.00MHz. The Node MCU has 128 KB of RAM and 4096 KB of Flash memory to store data and programs. it is suitable for IoT projects due to its high processing power, built- in Wi-Fi and Bluetooth capabilities, and higher Sleep Operating capabilities.

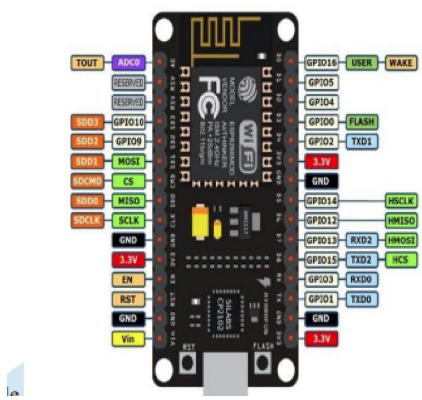

Fig. 2 ESP8266 node Mcu

B. BME280 Sensor:

The BME280 is a sensor used to detect atmospheric weather conditions. It is capable of measuring three primary weather parameters-temperature, humidity, and pressure-as well as additional environmental phenomena such as cloudiness, precipitation, and sunlight. In essence, the BME280 is essential for extracting environmental weather parameters and serves as a transducer capable of sensing and converting the parameters of interest. The BME280 was selected to fulfill the objectives of this research work. Its compact size and low power consumption make it well-suited for mobile applications, which are key design constraints. This integrated environmental sensor combines high-linearity temperature, humidity, and pressure sensing capabilities in a single device. Developed by Bosch, the BME280 represents the next generation of digital environmental sensors and serves as a successor to the BMP180, BMP085, and BMP183 sensors. BME280 is used in a range of industrial projects and electronic devices and provides high performance in all applications where pressure and humidity measurement is required. From gaming controls to weather monitoring to altitude measurement, this module serves the purpose of all with high precision and accuracy. The device comes with many filtering and sampling options that can be customized to make it compatible with the scores of applications.

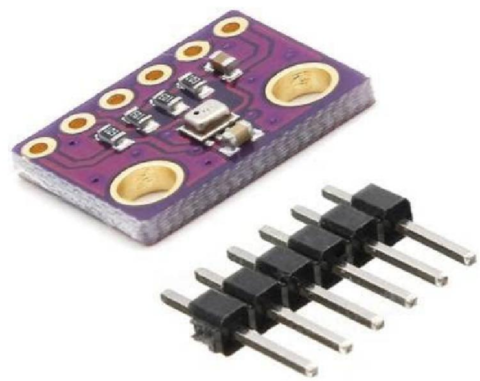

Fig. 3. BME280 Sensor

C. LM2576 DC-DC (Step-down Switching Regulator):

An LM2576 voltage regulator was used in the design. The system was powered by a DC source; however, an AC source could also be used, provided it is rectified before interfacing with the board. The input DC voltage was regulated down to 5 V, as required by the system components. A high-efficiency DC-DC converter was employed for this purpose. Regulation was achieved using a switched-mode power supply (SMPS), which offers significantly higher efficiency compared to a linear regulator. The power losses associated with a switching regulator are considerably lower than those of a linear regulator, thereby ensuring prolonged system operation depending on the battery's capacity and the power consumed. If a linear regulator had been used, a significant portion of the power drawn from the battery would have been lost as heat, reducing overall system efficiency.

D. LCD Display:

The 16x2 LCD Display with IIC/I2C interface featuring a green backlight and black characters is an efficient and user-friendly display module for embedded systems. It is widely used in electronics projects due to its compatibility with I2C communication, which minimizes the number of GPIO pins required for interfacing.

This display is ideal for various applications like robotics, IoT devices, home automation systems, and educational projects. Its green backlight ensures excellent readability, while the adjustable contrast allows users to fine-tune the display for optimal performance in different environments

Fig.5. 16x2 LCD Display

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IV. RESULT & DISCUSSION

The designed weather forecast system was constructed, as shown in Fig. 8, and deployed at the Nigerian Air Force Base in Kaduna, Nigeria, where a mini airport is located. The system successfully monitored real-time weather conditions and collected meteorological parameters using a sensing device called the BME280. It continuously stored up-to-date weather information-including temperature, pressure, wind speed, humidity, altitude, and precipitation-on a memory card The completed circuit was set up at the Nigerian Air Force (NAF) Base in Kaduna State. The system was configured to generate data samples at a rate of one sample per second. It was allowed to operate continuously for seven days, with each day's data extracted and recorded separately. The data obtained were stored in CSV format. The weather system recorded three distinct stages of weather conditions: acquiring, stable, and unstable.

A. Acquiring Stage:

At the initial stage of powering up the weather monitoring system, the term “weather condition acquiring data” refers to the process of collecting real-time atmospheric data. This data includes key meteorological parameters such as precipitation, pressure, wind speed, temperature, and humidity. The system utilizes the collected data to establish a reference point for the current weather conditions, which is essential for initializing forecasting models. By integrating this real-time information, the system enables the forecasting models to effectively simulate weather patterns and predict upcoming conditions. This initial data acquisition phase forms the foundation for generating reliable weather forecasts.

B. Stable Stage:

During the stable stage of the weather forecasting system following the initial data collection - “stable weather condition data” refers to the consistent and reliable set of atmospheric information accumulated and verified over time. This data typically reflects steady weather patterns with minimal fluctuations in key variables such as temperature, pressure, wind speed, and humidity. At this stage, the system has processed the initial real-time data and adjusted its models to account for short-term variations, enabling it to produce more accurate and stable forecasts. The system’s output during this phase provides clearer and more predictable weather forecasts. This stage ensures that the forecasting system operates with a higher degree of certainty and precision.

V. CONCLUSION

By In this paper, a weather monitoring system was successfully designed and implemented to detect and record essential meteorological parameters such as altitude, precipitation, wind speed, temperature, humidity, pressure, and heat index. By utilizing the BME280 sensor for precise environmental measurements and interfacing it with an STM32 microcontroller, the system effectively captures and processes real-time weather data. The integration of an LCD display allows users to view current conditions instantly, while a memory card provides reliable long-term data storage for further analysis. Additionally, the system incorporates a robust condition-detection algorithm that accurately classifies environmental data into four distinct weather conditions: windy, sunny, cloudy, and rainy. This feature enhances the system’s ability to provide meaningful insights into local weather patterns. With potential applications in agriculture, environmental research, aviation, and outdoor activity planning, the system presents a reliable, compact, and cost-effective solution for continuous weather monitoring. Future enhancements may include the addition of more sensors, wireless communication for remote access, and real-time data analytics to improve forecasting accuracy and support decision-making processes.

ACKNOWLEDGMENT

It gives us great pleasure in presenting the paper on “Weather Forecasting & logging Station using BME280 & NodeMcu”. We would like to take this opportunity to thank our guide, Prof. Pagire R.R., Professor, Electrical

Department, Adsul's technical Campus, Ahilyanagar, for giving us all the help and guidance we needed. We are grateful to him for his kind support, and valuable suggestions were very helpful.

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