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(Review Article)

Internet of things weather monitoring system

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Abstract

The IoT Weather Monitoring System aims to develop a comprehensive and efficient solution for real-time weather data collection, analysis, and dissemination using theInternet of Things (IoT) technology. With the increasing need for accurate and up-to-date weather information, this project leverages interconnected sensors, data processing techniques, and cloud computing to create a reliable and accessible weather monitoring system.

The system comprises a network of weather sensors strategically deployed in various locations to capture meteorological parameters such as temperature, humidity, air pressure, and rainfall. These sensors are integrated with microcontrollers and wireless communication modules to transmit data to a central data hub. The data hub employs advanced data processing algorithms to clean, aggregate, and analyze the incoming data streams, ensuring the accuracy and quality of the information.

To enhance user accessibility, the processed weather data is made available through a user-friendly web application and mobile interface. Users can view current weather conditions,historical trends, and receive alerts for severe weather events based on the analyzed data. Additionally, the system's cloud-based architecture allows for scalability and remote management, ensuring seamless operation and easy expansion to accommodate growing demands.

Keywords: Internet of Things (IOT); Sensor Network; Real-time Data Collection; Cloud Computing; Wireless Communication, Microcontroller.

1 Introduction

Internet of Things (IoT) is a network of physical objects people called “things” embedded with software, electronics, network, and sensors that allow these objects to collect and exchange data. The goal of IoT is to extend internet connectivity from standard devices like computers, mobile, tablets to relatively dumb devices like a toaster. IoT makes virtually everything “smart” by improving aspects of our life with the power of data collection, AI algorithms, and networks. The IoT process starts with the devices themselves like smartphones, smartwatches, and electronic appliances like TV and Washing Machine,which helps communicate with the IoT platform (Smith, 2021).

Sensors or devices are a critical component that helps to collect data from the surrounding environment. All this data may have serious levels of complexities. It could be a simple temperature monitoring sensor, or it may be in the video feed. A device may have various sensor that perform multiple tasks apart from sensing. A mobile phone has multiple

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sensors like GPS and a camera. Sensors are essential components in many applications Zureiqat et al., (2017), not only in the industries for process control but also in daily life for the safety of buildings and security monitoring, traffic flow measuring, weather condition monitoring, to mention a few. For instance, temperature, humidity, and pressure need to be measured in weather monitoring.

Weather condition or climate changes plays a vital role in human life. Human beings' thermal comfort is influenced by six parameters, i.e., air temperature, radiation, airflow, humidity, activity level, and clothing thermal resistance. The advancement in technology has made these small and reliable electronic sensors capable of favorably monitoring environmental parameters (Zureiqat *et al*., 2017).

Several studies have been conducted to investigate the feasibility and effectiveness of the IoT weather monitoring system. These studies have focused on different aspects of the system, including design, implementation, and evaluation. For instance, Al-Turjman et al.,(2019), developed an IoT-based weather monitoring system that uses various sensors to monitor weather conditions in real-time. The system was tested in a real-world environment, and the results showed that it is highly effective in providing accurate and timely weather information.

Another study by Zhang et al., (2018), developed an IoT-based system, IoT-enabled air quality monitoring systems provide real-time data on air pollutants, enabling better understanding of pollution sources, dispersion patterns, and the overall state of the environment. This information is crucial for environmental agencies and researchers to track air quality changes over time and assess the effectiveness of pollution control measures.

Al Amin et al., (2019), proposed a cloud-based IoT system for monitoring crop growth. The system uses various sensors to monitor soil moisture, temperature, and humidity, which can help optimize crop growth and yield.

2 Materials

2.1 Microcontroller

Microcontrollers play a significant role in developing intelligent systems as the brain is given to the system. Microcontrollers have become the heart of the new technologies introduced daily.

Figure 1 below shows a microcontroller which is mainly a single-chip microprocessor suited for controlling and automating machines and processes. Today, microcontrollers are used in many disciplines to carry out automated tasks more accurately. Almost every modern-day device, including air conditioners, power tools, toys, office machines, employ microcontrollers for their operation (Baligar et al., 2019).

Figure 1 ESP8266 Microprocessor (Al-Turjman F., 2019)

2.1.1 Sensors

The sensor consists of a different types including temperature , humidity sensor (DHT11) and CO sensor , These sensors helps to measure the primary environmental factors, temperature, humidity, and CO levels. All these sensors will give the analog voltage representing one particular weather factor. The microcontroller will convert this analog voltage into digital data. DHT examines the temperature and humidity values based on the adjusted digital signal output after a particular period. Due to the digital signal and data visualization Temperature and Humidity (H) sensing module. The sensor is stable and reliable . DHT is constructed of elements with resistivity that reads humidity and a –ve Temperature coefficient element that reads temperature.. DHT distributed with 8-bit microcontroller displays reliability, sensitivity, stability, very elevating response, no interference, and meager cost. The deployed (DHT) is given by 3-pins known as VCC connected with 5V of Arduino, GND connected with Arduino GROUND, and DATA pin is connected to the digital pin of Arduino board.

Temperature Sensor and Humidity Sensor

The DHT11 is an essential, ultra-minimal effort computerized temperature and Humidity sensor. It utilizes a capacitive humidity sensor and a thermistor to gauge the surrounding air and releases digital data on the data pin (no analog information pins required). The maingenuine drawback of this sensor is getting new information from it once every 2 seconds, so when utilizing our library, sensor readings can be up to 2 seconds old. It works on a 3to 5V power supply. Suitable for 20 – 80% humidity readings with 5% accuracy and 0- 50A C temperature readings A += 2AoC accuracy (Shires et al., 2021).

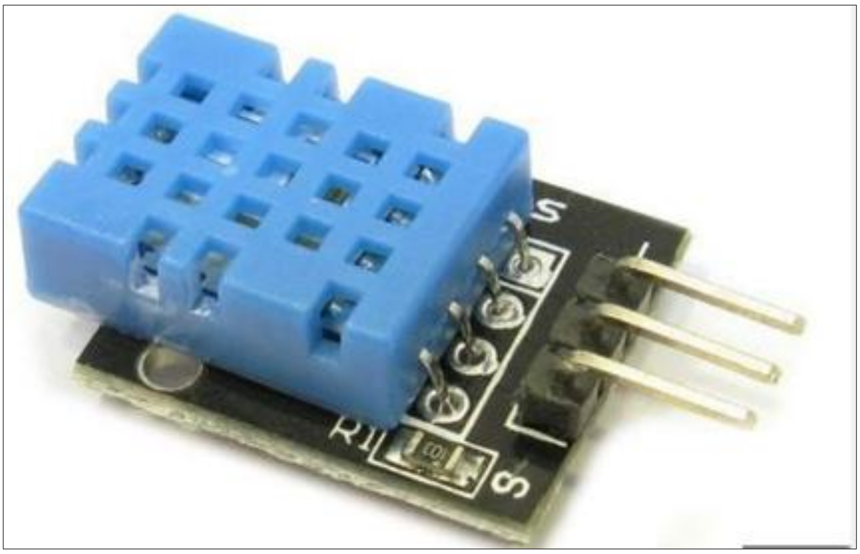

Figure 2 DHT11 Relative Humidity Sensor (Gazis A.,2021)

2.1.2 Carbon Monoxide (CO) Sensor

Carbon Monoxide (CO) sensor, suitable for sensing CO concentrations in the air. Carbon monoxide sensor, suitable for sensing CO concentration in air. The MQ-6 can sense Co- gas concentration somewhere in the range of 20 to 2000ppm. This sensor has a high affectability and quick reaction time. The sensor's yield is an analog resistance . The drive circuit is exceptionally straightforward; you should control the heater curl with 5V, includea load resistance, and associates the output to an ADC. The standard reference strategy for estimating carbon monoxide concentration in air depends on the ingestion of infrared radiation by the gas in a no dispersive photometer. This technique is reasonable for stable establishments at fixed –site monitoring stations. As of late, convenient carbon monoxide analyzers with data- logging have become accessible for individual presentation observing. These estimations depend on the electrochemical responses between carbon monoxide and de-ionized water, which are detected by exceptionally planned sensors. These days, the electrochemical analyzer's determination, strength, and affectability are inside the details of the reference technique, and, together with the data-logging systems, they fit into a bit of rucksack or even a pocket (Shires et al., 2021).

Figure 3 Carbon Monoxide (CO) Sensor(Lobos., 2018)

ESP8266 Wi-Fi Module

ESP8266 is a 32-bit microcontroller with a Tensilica processor, produced by Express if Systems. It has sixteen configurable GPIOs, and build-in most popular interfaces like UART, SDIO, SPI, 12C, GPIO, ADC, PWM. It can run with a clock speed of 160MHz (default is 80MHz). So you can use it like any other microcontroller to control your devices. What makes its unique is its self-contained Wi-fi capabilities. It integrates antenna switches, power amplifier, filters, and power management modules.

Figure 4 shows as ESP8266 which is a Wi-Fi- enabled system on chip (SoC) module developed by the Express if System. It is mostly used to develop IoT (Internet of Things) embedded applications. (*"ESP8266 power modes – modern-sleep is the default mode for the esp8266, 2021*)

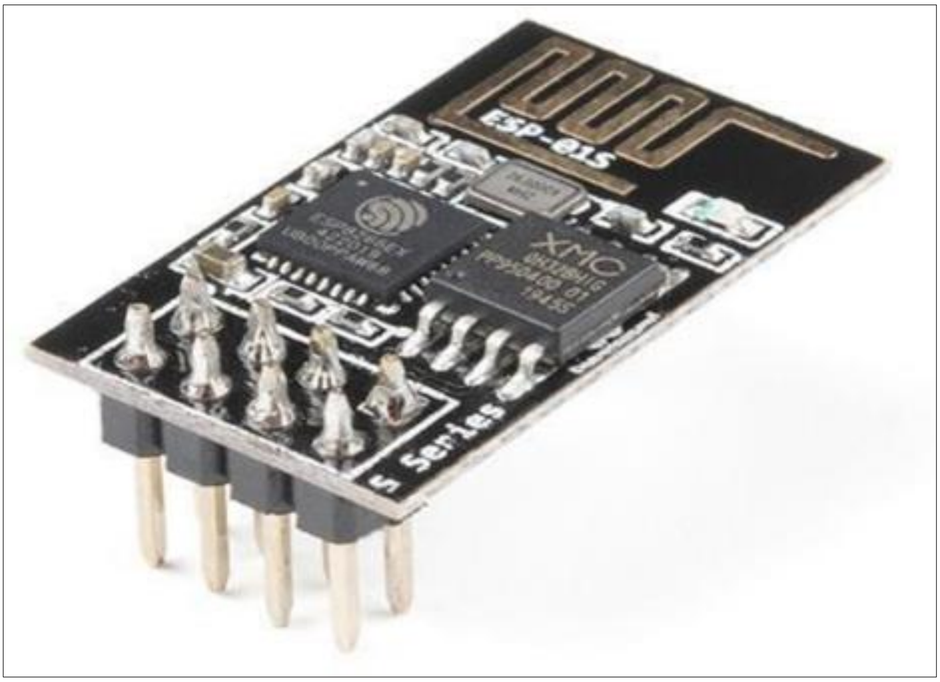

Figure 4 ESP8266 Wi-fi Module (Patel 2016)

The ESP8266 WiFi Module is a self contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your WiFi network. The ESP8266 is capable of either hosting an application or offloading all WiFi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware, meaning, you can simply hook this up to your Arduino device and get about as much WiFi-ability as a WiFi Shield offers (and that's just out of the box)! TheESP8266 module is an extremely cost effective board with a huge, and ever growing, community. This module has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module, is designed to occupy minimal PCB area. The ESP8266 supports APSD for Vo IP applications and Bluetooth co-existence interfaces, it contains a self-calibrated RF allowing it to work under all operating conditions, and requires no external RF parts. (Sakhardande P *et al.* 2016).

The ESP8266 module is not capable of 5-3V logic shifting and will require an external Logic Level Converter. Please do not power it directly from your 5V dev board. ESP8266-01 Wi-Fi Module. ESP8266 comes with capabilities of 2.4 GHz Wi-fi (802.11 b/g/n, supporting WPA/WPA2), general-purpose input/output (16 GPIO), Inter-Integrated Circuit (I2C) serial communication protocol , analog-to-digital conversion (10-bit ADC) Serial Peripheral Interface (SPI) serial communication protocol, I2S ((Inter-IC Sound) interfaceswith DMA (Direct Memory Access) (Sharing pins with GPIO), UART (on dedicated pins, plus a transmit-only UART can be enabled on GPIO2), and pulse- width modulation (PPWM) ("Wifi Module – ESP8266", 2021). It employs a 32-bit RISC CPU based on the Tensilica Xtensa L106 running at 80 MHz(oroverclocked to 160 MHz). it has a 64 KB boot ROM, 64 KB instruction RAM, and 96 KNdata RAM. External flash memory can be accessed through SPI. The ESP 8266 module is a low-cost standalone wireless transceiver used for end-point IoT developments. To communicate with the ESP8266 module, the microcontroller needs to use a set of AT commands. The microcontroller communicates with the ESP8266-01 module using UART having a specified Baud rate

The below figure shows ESP-01 module pins

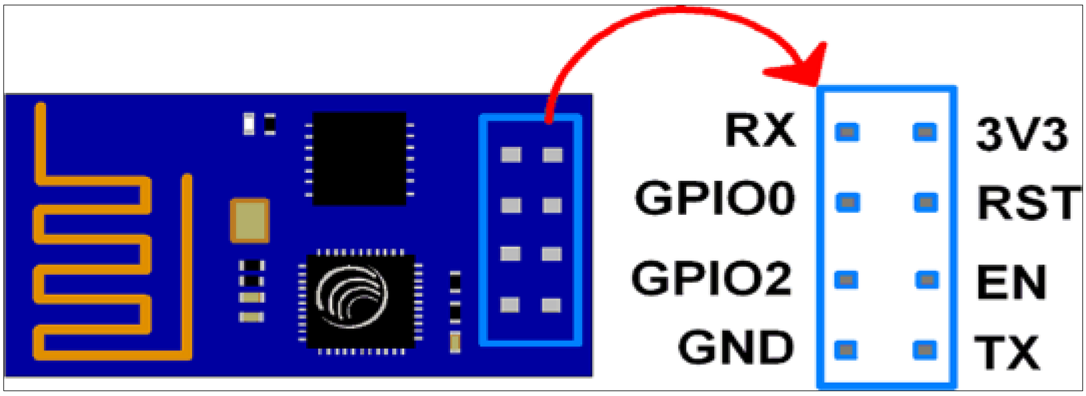

Figure 5 ESP8266-01 Module Pin (Zureiqat F., 2017)

ESP8266-01 Module Pin Description

ESP8266-01 Module Pins3V3: -3.3. V Power Pin. GND : - Ground Pin.

RST: - Active Low Reset Pin. EN:; - Active High Enable Pin.

TX: - Serial Transmit Pin of UART.RX: - Serial Receive Pin of UART.

GPIO0 and GPIO2: General Purpose I/O Pins. These pins decide what mode (boot or normal) the module starts up. It also decides whether the TX/RX pins are used for programming the module or serial I/O purposes.

To program the module using UART, Connect GPIO0 to the ground and GpIO2 to VCCor leave it open. To use UART for normal Serial I/O, leave both the pins open (neither VCC nor Ground).

2.2 Internet of Things and Its Application

The Internet of Things (IoT) is a network of connected devices, machines, and objects that can communicate and share data without human intervention. This concept has evolved through the convergence of technologies like real-time analytics, machine learning, and sensors. IoT builds upon traditional fields like embedded systems, wireless sensor networks, and automation, and is commonly associated with smart home devices and appliances that can be controlled via smartphones and smart speakers. However, the growth of IoT raises concerns about privacy and security, which are being addressed by industry and government initiatives. IoT has a wide range of applications across various sectors, including: Consumer: connected vehicles, home automation, wearable technology, connected health, and smart appliances; Commercial: medical and healthcare, transportation, building and home automation; Industrial: manufacturing and Infrastructure: energy management and environmental monitoring

2.3 Review of Related Works

Bhagat et al. (2019), designated that the IoT-based Weather Monitoring and Reporting System project is used to get live weather conditions. It will monitor temperature, humidity, moisture, and rain level. Suppose Scientists/ nature analysts want to monitor changes in a particular environment like a volcano or a rainforest. And these people are from different places in the world. In this case, SMS based weather monitoring system has some limitations since it sends SMS to a few numbers. And time for sending SMS increases as the number of mobile numbers increases. To know the information about the weather of aparticular place then they have to visit that particular sites where everyone can see it.

Nivedan.V (2019), proposed that this project predominantly combines the two-study fields-based control systems and data gathering techniques to create an extensive database systemdepending on the employed attributes to generate the presented data. The main things herehave been chosen based on the sensors used vividly to build the system to design a productive weather monitoring project. The recommended sensors are used here to measure and gather the Temperature and Humidity data.

Mabrouki (2021), proposed that the recent environmental monitoring systems are based on the sensors, such as temperature, humidity, and pressure sensors. Some of these sensorscan capture the corresponding physical or chemical weather values and convert them to anelectric signal. Hence, the captured values are transferred to an electronic card as an electric signal. Our system is based on internet of things technology. In our system, the Arduino card plays a fundamental role. It can process the measured value and make some decisions. It can also be considered the intermediate between the sensors and the monitoring application. The local and remote communications between our system and other correspondent devices are provided through Wi-Fi module.

3 Methodology

This system is designed to monitor weather temperature and humidity intensity of light inthe atmosphere or at a particular place to make an interactive environment through a wireless network. The designed system is more adaptable and distributive to examine the environmental parameters. The architecture design is discussed in a 4-tier model. The working of particular modules developed for weather monitoring . The given model has 4-tiers. Tier 1 consists of the overall environment, Tier 2 contains all sensors, retrieving dataand decision making is held in Tier 3, and acute environment for monitoring is present in Tier 4.

Tier 1 gives information about the parameters and particular places to be monitored for weather parameters. Tier 2 deals with sensor devices having different characteristics, features and each of these sensors' devices are controlled based on their range of sensing and sensitivity. In between Tier 2 and Tier 3, sensing and controlling based upon the conditions, like threshold value fixed by us, periodicity, messages like an alarm or LED, etc. The parameter threshold values in normal working conditions are examined based on the data analysis performed in two layers and past experiences. Tier 3 defines data acquisition from implemented sensor devices and decision-making. (Weather Climate – National Weather Service).

Figure 6 Arduino Interface for the software code

Figure 7 below shows the whole system consists of a microcontroller, the central unit of processing for the entire system, and all other sensors and other devices will be connectedwith the microcontroller. All sensors are operated through a microcontroller to retrieve thedata from the sensors, analyze the sensor data, and update data to the Internet using the Wifi module connected it.

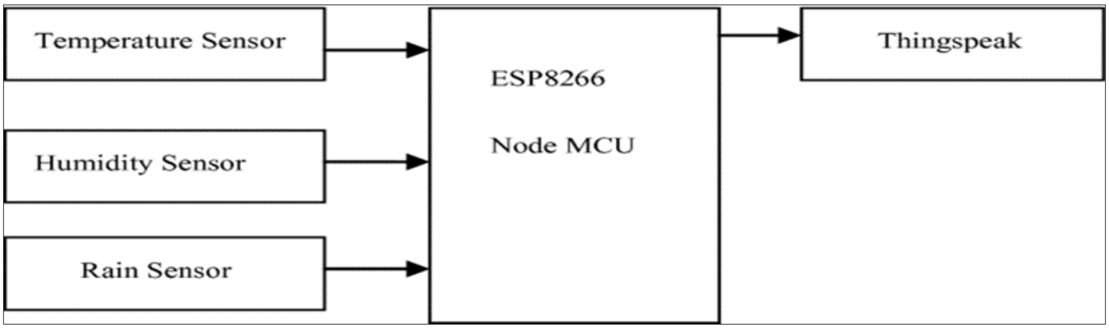

Figure 7 System Architecture (Chaudhari A., 2018)

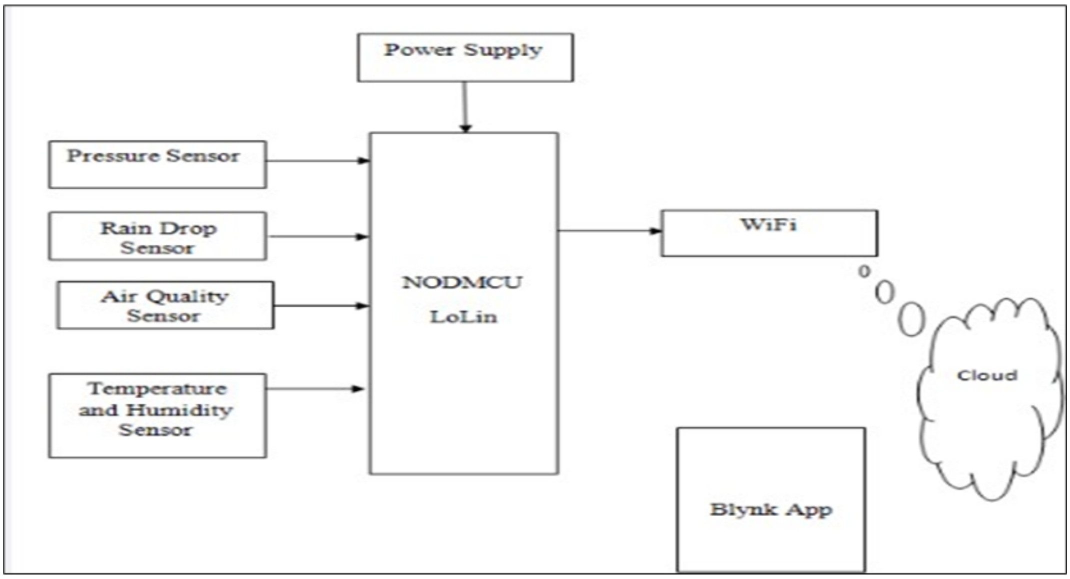

Figure 8 Block Diagram of the Construction of the Weather Monitoring System (Sarkar 2020)

The implemented system consists of a microcontroller (ESP8266) as a central processing unit for the entire system, and all the sensors and devices can be connected with the microcontroller. The microcontroller can operate the sensors to retrieve the data from them. It processes the analysis with the sensor data and updates it to be the Internet througha Wi-fi module connected with it. The microprocessor is programmed using Arduino programming language to have a Wi-Fi-SSID “Things” and password “123456789” which connected a hotspot having the sameSSID and password as the one programmed on the microprocessor. Once the online stationhardware is on, a led light will be blinking , and once it is connected to the hostspot, it stopsblinking and shows a stable Greenlight. Once connected, you can get connected to *thingspeak.com/channels/1645292,* where all the requirements will be seen, which includes: temperature, humidity, pressure, location, and altitude.

NB: There must be an online connection to access data on thingspeak.

3.1.1 ESP8266 WI-FI MODULE

Here we used the ESP8266 Wi-Fi module, which has a TCP/IP protocol stack integrated on the chip. So that it can provide any microcontroller to get connected with a Wi-Fi network, ESP8266 is a pre-programed SOC, and any microcontroller has to communicatewith it through the UART interface. It works with a supply voltage of 3.3v. The module isconfigured with AT commands, and the microcontroller should be programmed to send theAT commands in a required sequence to con configure the module in client mode. The module can be used in both client and server modes (Bhagat et al., 2019).

After carrying out all the paper design and analysis, the project was implemented, constructed, and tested to ensure its working ability. The construction of this project was done in three different stages. The implementation of the whole project on a solder-less experiment board(breadboard), The soldering of the circuits on a printed circuit board and The coupling of the entire project to the casing.

3.2 Implementation

The implementation of this project was done by supplying a power supply that was first derived from a power supply in the laboratory to confirm the workability of the circuits before the power supply stage was soldered. The implementation of the project was successful, and it met the desired aims, with each stage performing as designed.

3.3 Testing

Stage-by-stage testing was done according to the board's block representation before the soldering of the circuit commenced on the printed circuit board.

As stated below, the testing and implementation process involved testing and using measuring equipment.

3.3.1 Power Supply

This was used to supply voltage to the various circuit stages during the breadboard test before the power supply in the project was soldered; also, during the soldering of the project, the powersupply was still used to test various stages before they were finally soldered.

3.3.2 *Digital Multi-Mete*

The digital multimeter measures voltage, resistance, continuity, current, frequency, temperature, and transistor. The implementation of the design on the board required the measurement of parameters like voltage, continuity, current, and resistance vale of the components and, in some cases, frequency measurement. The digital multimeter was used to check the output of the voltage regulators used in this project.

3.4 Soldering

The various circuits and stages of this project were soldered to meet the desired workabilityof the project. The soldering of the project was done on a printed circuit board.

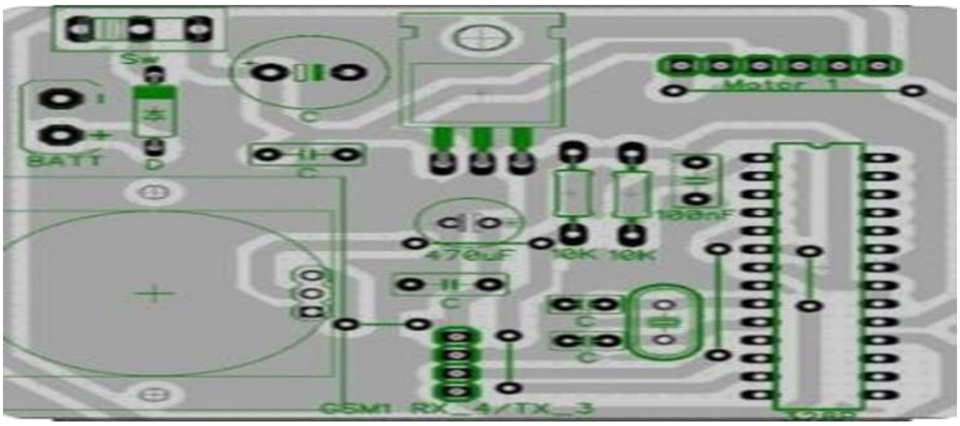

Figure 9 A components layout on printed circuit board (Smith j., 2021)

The printed circuit board has the DC power supply stage, including the polarity inversion protection stage, filtering stage, and voltage regulation stage. It also has the microcontroller stage.

3.5 Casing and Boxing

The third phase of the project construction is the casing of the project. This project was coupled to a plastic casing. The plastic casing material was designed with special perforation and vents and well labeled to give ecstatic value.

4 Result

After implementing and designing the weather monitoring system using the ESP8266 microprocessor and the BME280 sensor, a web page is designed using the Arduino programming designing, which helps in refreshing the web page created and displays temperature, pressure, altitude, and humidity of that location which is being showed in figure 4.3.

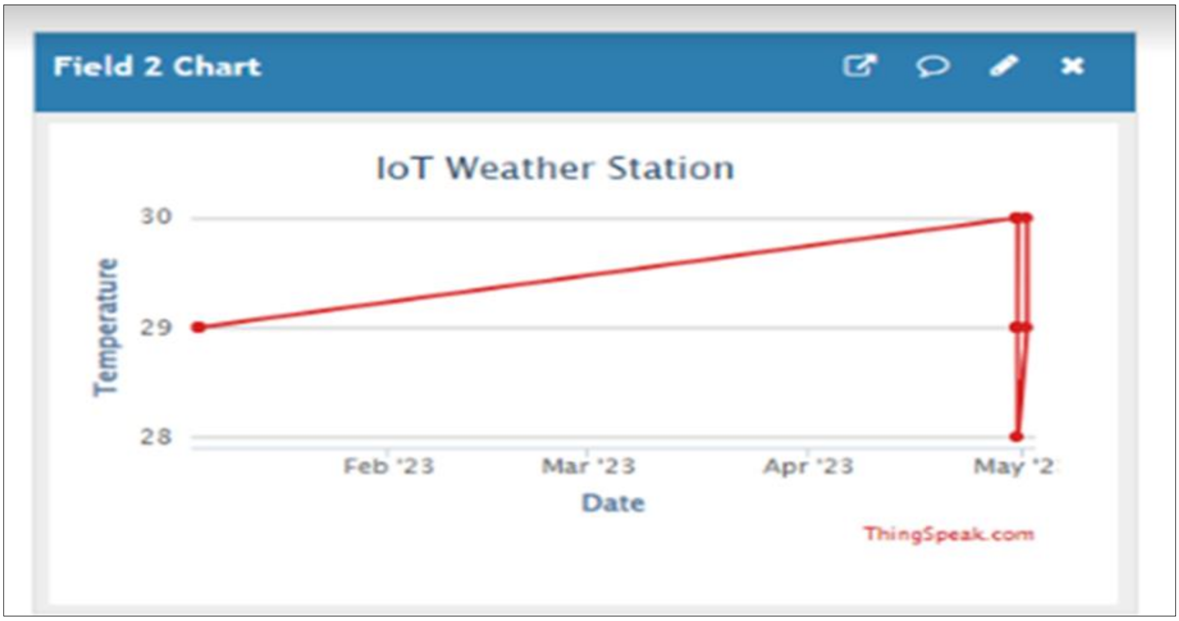

Figure 10 Online Weather monitoring Interface for the Temperature Data

Figure 11 Online Weather monitoring Interface for the Relative Humidity

Figure 12 Online Weather monitoring Interface for the Co2 Level

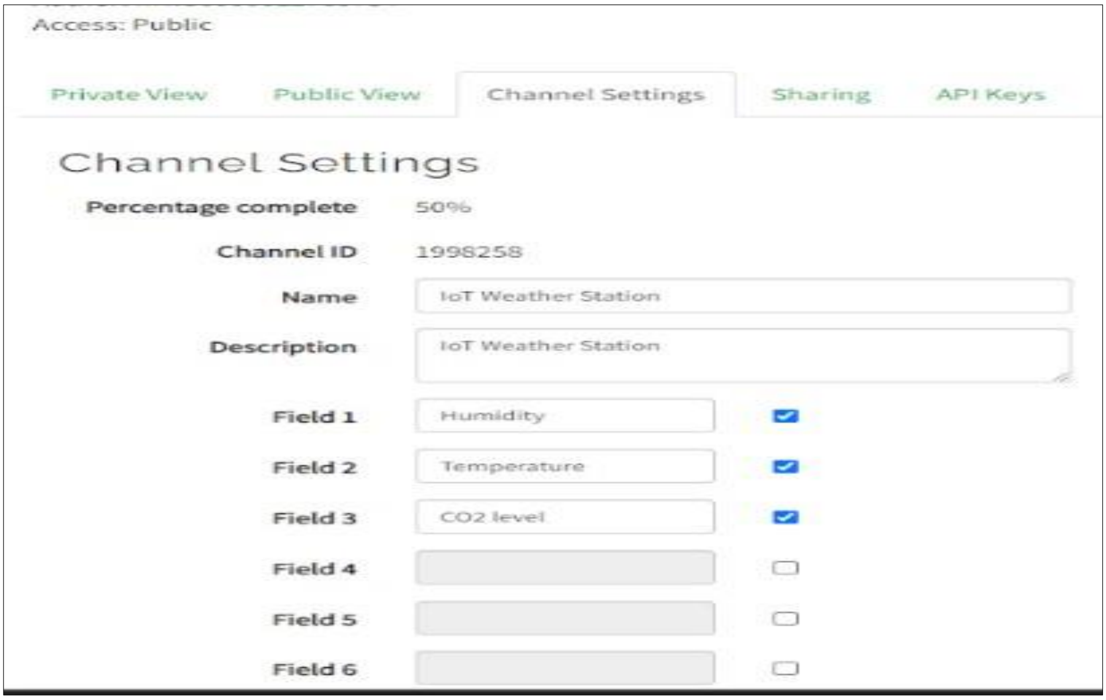

Figure 13 Channel Connection Interface for Thingspeak(Cloud Computing)

Like every research and practical engineering work, diverse problems are often encountered. The problems encountered in this project solved and maneuvered are listed below:

At the implementation stage of this project, the communication between the microcontroller and the BME280 module used in this project was found to fail. Theproblem was traced to both not sharing the same ground. Both ground pins of the modules were connected, and the problem was resolved. At the testing stage of the project, the BME280 could not measure the humidity, making it a demerit of using a BME280 over BMP280.

5 Conclusion

The project, which entails designing and installing an online weather monitoring system, was planned with weather conditions, component and research availability of materials, efficiency, compatibility and mobility, and durability in mind. The project's performance following the test was in line with design parameters.

The operation is also dependent on how effectively the soldering is done and how well the components are positioned. If substandard soldering lead is used, the circuit may produce a dry joint too soon, causing the project to fail Packaging, component quality, handling, and usage are all factors that could affect performance.

For future research, the project work can be improved upon. The following areas were highlighted for this purpose. The whole circuitry can be reduced by using integrated circuits with a larger scale of integration.

A larger-scale integrated circuit can be used so that other means of authentication could be used to cut across to he less privileged in the society (e.g, visually impairedindividuals)). Moreover, it is recommended that students be enlightened on new areas of technology that are yet to be addressed to solve the various problems man faces in his day-to-day activities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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