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Microcontroller based Multifunctional Automated Weather Monitoring and Logging System

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Abstract: This paper describes a microcontroller-based prototype Automated Weather Monitoring and Logging System that can col- lect meteorological data such as air temperature, relative humidity, atmospheric pressure, light intensity, and rain detection from any distant location. The Weather Monitoring and Logging System is entirely automated, and measured weather data is transferred to a public server while showing immediate data on a liquid crystal display (LCD) and stored to a Secure Digital (SD) card. For private viewers, Android-based smart phones may be interfaced with the weather station and operated via the android application. The weather station is supplied by a direct current (DC) source, with a backup rechargeable battery. In the event of an emergency power outage, the system will immediately switch to battery power. Two Atmega 328p and Two ESP 8266 microcontrollers are utilized as the core of the control and coordination of the relative multitude of exercises of the singular modules. All of the sensors in the systems have been calibrated, ensuring that the system's accuracy seems to be exceptional. This system will benefit all users, and it will benefit the meteorological industry because it will allow them to work from a remote location.

Keywords: Automated Weather Station; Microcontroller; Sensor; Meteorological Instrument

I. INTRODUCTION

For the last few decades, gathering meteorological data has become an important activity all over the world. Temperature, pressure, humidity, and other meteorological data are collected using several types of weather monitoring systems. The majority of the systems use traditional technology to collect meteorological data, but they have always required a diligent and dedicated human observer to record readings from manual equipment at a set time, every day, without fail. The National Climatic Data Center, which is part of the National Oceanic and Atmospheric Administration, as well as Regional Climate Centers and State Climatologists, are the primary sources of data in the United States. Other countries' weather services run similar government archives. A variety of local government organizations, colleges, and private companies, in addition to national government sources, store meteorological data and run weather observing stations as part of special monitoring networks [1]. Weather forecasts are more accurate than they have ever been. A 5-day weather prediction now is as dependable as a 2-day forecast was 20 years ago, according to the World Meteorological Organization (WMO). This is because forecasters today collect weather data using modern technologies and the world's most powerful computers. Data and computers work together to create complicated models that more precisely describe atmospheric conditions. These models may be designed to forecast changes in the atmosphere and weather. Despite these advancements, weather forecasts are still frequently inaccurate. Because weather is a complicated and unpredictable system, it is incredibly difficult to anticipate. [2] Collecting meteorological data in a remote area is difficult due to the distance between the collecting station and the place. To overcome this problem, the development of methods for the remote indication of meteorological measuring instruments has received the attention of experimenters for many years. Although many suggestions have been made for developing automated weather stations, the functions of them were going to be limited. This leads to the problem of finding a suitable multi-functional automated low-cost weather station for measuring meteorological data carried out for a long period. There are numerous benefits to using automated weather systems instead of traditional stations, the most important of which are: data monitoring in sparse areas where human observations are impractical, continuous data flux at frequent intervals and for any observation time, increased coverage, elimination of subjectivity in observations, and cost savings. [3]

This Automated Weather Monitoring and Logging System is a collection of previously developed weather stations with the capability of data collection, data indication, data Wi-Fi network, and control via a smart mobile phone. It has advantages such as consistency in data measurement, increased frequency of data acquisitions, operability in all weather conditions throughout the year, and can be installed in any remote location. [4] [5] [6] The following is how the remainder of the paper is organized: The materials and methodology utilized to develop this Automated Weather Monitoring and Logging System, as well as the sensor calibration process, are presented in Section II. In part III, the numerical results, as well as the benefits and drawbacks, are extensively explored. Finally, Section IV brings the paper's work to a close.

II. DESIGN AND METHODOLOGY

The Automated Weather Monitoring and Logging System can be divided into four main sub stations.

1) Sensor Station
2) Microcontroller Station
3) Power Supply Station
4) Graphical User Interface

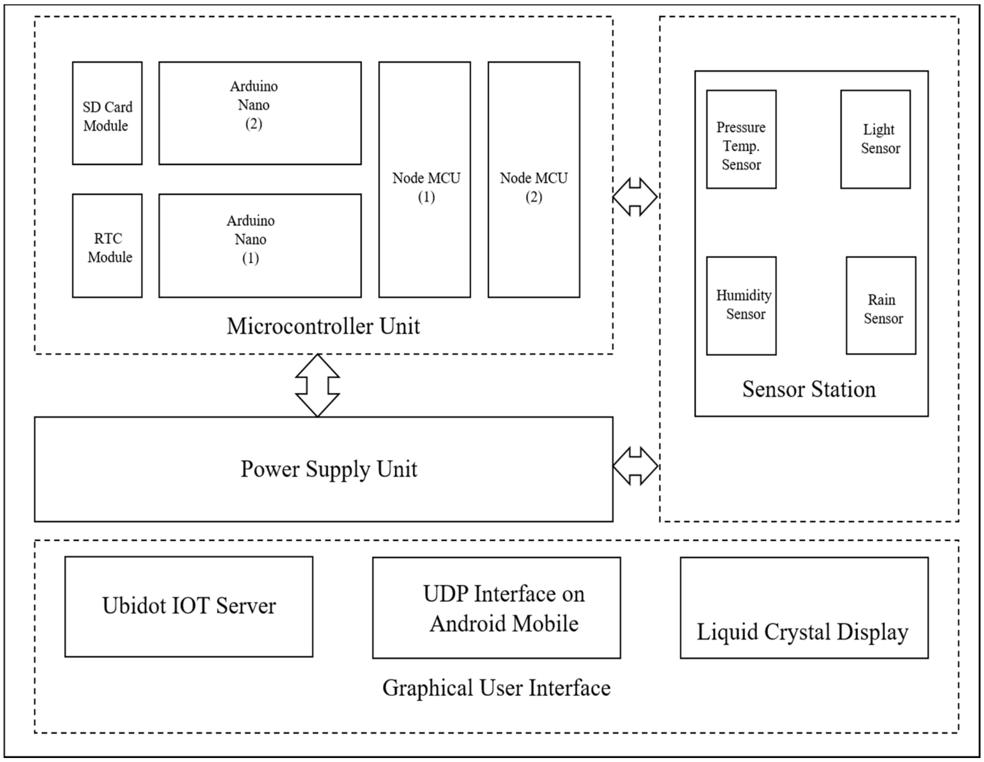

Fig. 1 Basic Block Diagram of the Automated Weather Monitoring and Logging system

A. *Sensor Station*

A sensor station is made up of various sensors that detect meteorological data such as temperature, pressure, humidity, light intensity, and rainfall. The sensor station can be deployed in a remote location, and the data collected is transferred to the microcontroller station via a connected link.

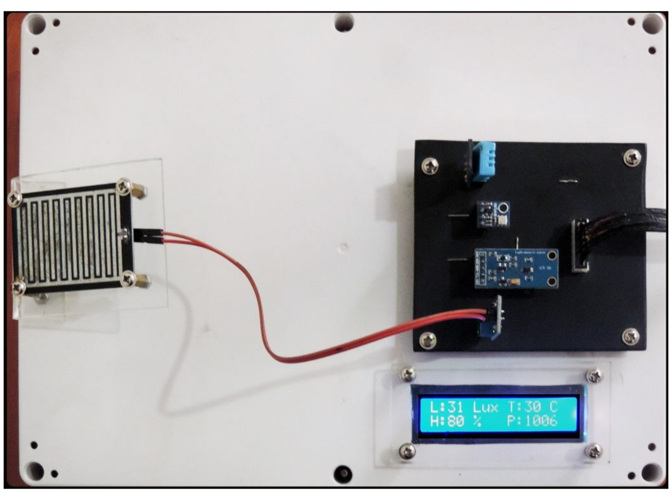

Fig. 2 Sensor Station with LCD Display

1) *The Digital Humidity and Temperature (DHT11) Sensor:* DHT11 is a temperature and humidity sensor that measures the ambient air using a capacitive humidity sensor and thermistor. It offers high dependability and outstanding long-term stability by employing an exclusive digital-signal-acquisition technique as well as temperature and humidity sensing technologies. [7]
2) *Barometric Pressure Sensor (BMP) 180:* BMP 180 is an I2C compliant pressure and temperature sensor that can measure atmospheric pressure, air temperature, and elevation with respect to pressure and temperature. [8]
3) *BH1750FVI Light Intensity Sensor:* BH1750FVI is a digital light sensor, which has a digital ambient light sensor IC for I2C bus interface. It is possible to detect wide range at high resolution.
4) *Rain Sensor Module:* The rain drop sensor module is a sensor that detects the presence of rain or wet weather in the immediate vicinity. The module comprises of a rain board for detecting droplets, a potentiometer for adjusting the sensitivity, and an LED for power indication. It outputs both analog and digital signals.

B. Microcontroller Station

Automated Weather Monitoring and Logging System's microcontroller unit serves as the system's CPU. All sensor data is routed to the unit, where it is processed. The Microcontroller Unit is made up of two Arduino Nanos, two Node MCUs, a Secure Digital card reader module, and a Real Time Clock module [9]. All of these microcontrollers are linked together, and data is transmitted via Universal Synchronous Asynchronous Receiver Transmitter technology. The microcontroller integrated circuits (ICs) utilized in the Arduino Nano and Node MCU are Atmega 328P [10] and ESP 8266 [11], respectively.

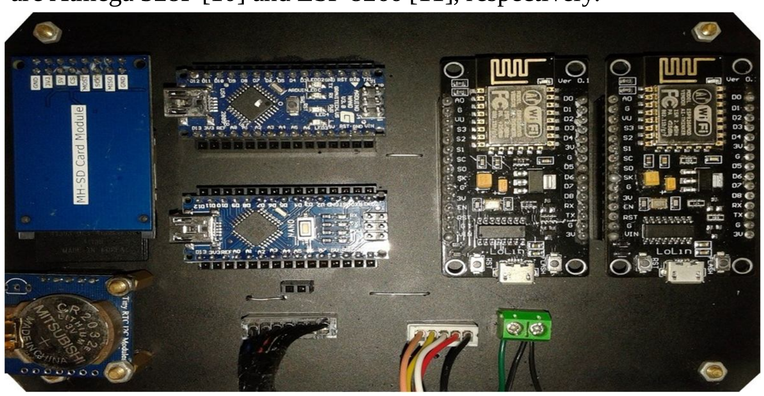

Fig. 3 Microcontroller Unit of the System

C. Power Supply Station

The Automated Weather Monitoring and Logging System's power supply requirements are met by a 7.5 DC power supply and a 6V battery, which is responsible for powering all microcontrollers and modules in the microcontroller unit as well as all sensors in the sensor station. In the event of an Alternating Current (AC) power supply breakdown, a 6V lead acid battery is connected as a backup power source, and if there is no AC supply, the circuit will automatically switch to battery power, and when AC is available again, the circuit will switch back to AC power. Power is supplied to the microcontrollers and sensors through LM 7805 voltage regulators. Battery charging function is controlled using external signal and 5VDC relay is connected for the separation of the charging circuit. A voltage indicator is also connected to the power supply unit for quick measurement of the battery voltage.

Fig. 4 Power Supply Unit of the System

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D. Graphical User Interface

The graphical user interface plays an important part in a weather monitoring system because it allows the end user to visualize the data. Three graphical user interfaces are employed to visualize the data in this Automated Weather Monitoring and Logging System.

1) *Liquid Crystal Display:* 16x2 LCD is mounted on the top of the sensor station unit to display weather data for any user at the sensor station. This display unit is useful for get instant readings whenever if there is any repairing process and especially in calibration.
2) *Ubidot IoT Server Display:* The Internet of Things (IoT) is becoming a prominent factor of our complex Internet infrastructure. In this weather station, all sensor data is sent to the Ubidot IoT server for the public viewers. Ubidots include with Tables, graphs, indicators, sliders and many other visualizers for easy understanding. [12]

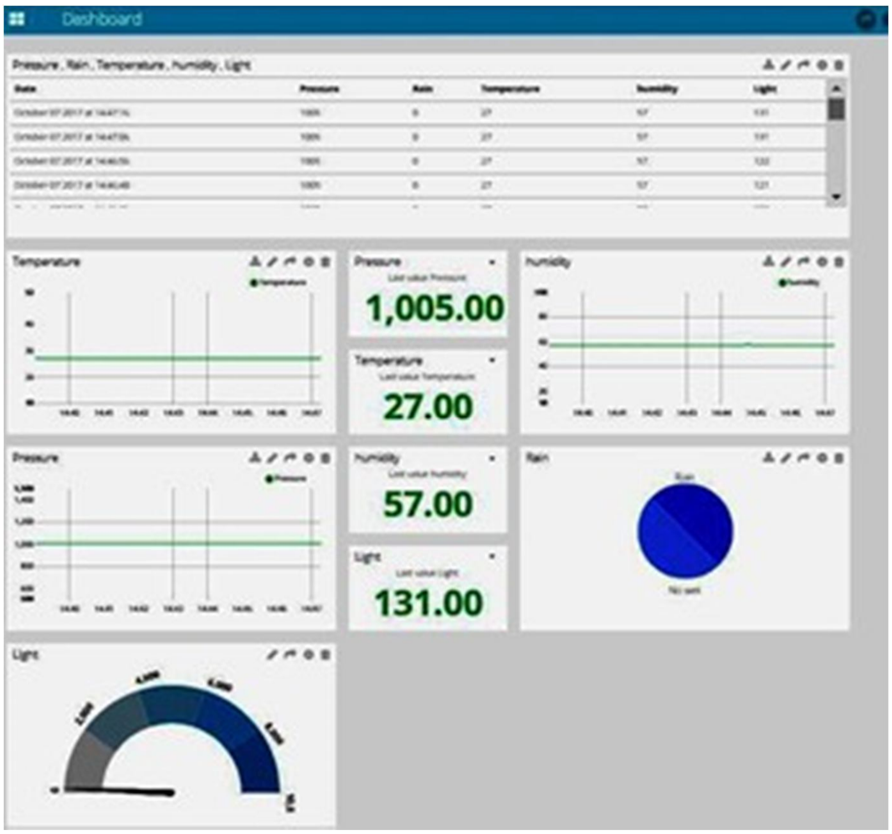

Fig. 5 Ubidot IoT Server Display

3) *UDP Android Smart Mobile Display:* The User Datagram Protocol (UDP) is designed to provide a datagram mode of packet-switched computer communication in the context of a networked environment. In this case, UDP communication is facilitated via a Wi-Fi network. Both the smart phone and the ESP 8266 are linked to the same Wi-Fi network. UDP messages are delivered via mobile, and the data that is returned is also presented in the graphical userinterface.
4) *Working Principle:* As previously stated, the Automated Weather Monitoring and Logging System was developed as a stand-alone system, with the various functional circuits and modules assembled as standalone detachable units connected by wire connections. Each unit is responsible for a specific purpose. The sensor station is gathering all meteorological data. All sensors are linked to the Atmega 328P, and data processing takes place here. This microcontroller is linked to a single liquid crystal display, and all-weather data is presented on the LCD every 10 seconds. To reduce the amount of data and control wire lines, the LCD is also connected via the I2C bus interface. After that, via Universal Synchronous Asynchronous Receiving and Transmitting (USART), the sensor data is sent to other microcontrollers. Sensor data is transformed to a string format before being sent to other devices, as demonstrated below.

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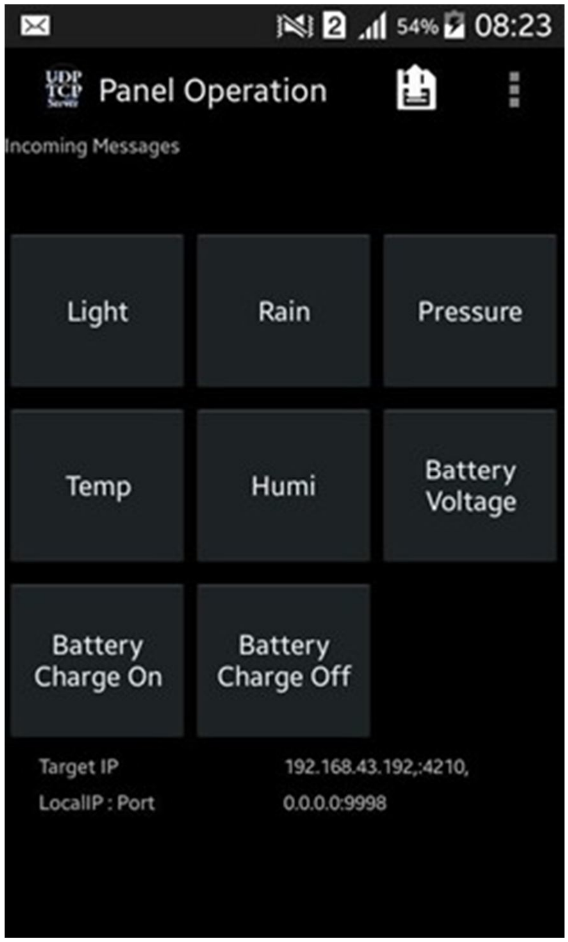

Fig. 6 Android Application for Smart Mobile Viewers

$$1008, 0, 105, 66, 33* \tag{1}$$

The data for pressure, rain, light intensity, temperature, and humidity are sent with a comma separation, and a star symbol is sent at the conclusion to signal the end. Three microcontrollers are waiting for the string, which will be separated using a string separation method and stored in five variables after it is received.

Another Atmega 328P is connected with the SD card module and the real time clock module. This microcontroller is used to store the received weather data in the SD card with date and time which is given by RTC Module. It is necessary to adjust date and the time of the RTC module before interfacing with the microcontroller.

Because this system is based on Wi-Fi communication, a Node MCU with an integrated ESP 8266 Wi-Fi module is utilized to connect to a Wi-Fi network. One ESP 8266 was set up to obtain an IP address from a known Wi-Fi network by providing the network's SSID and password. it will wait for data transmitted from Atmega 328P after assigning an IP address. The data is then transferred to an IoT server for public viewing.

Other ESP 8266 is configured with the static IP address which is in same Wi-Fi range and both the ESP 8266 and the mobile is connected with that Wi-Fi network. The smart phone can transmit UDP messages, and each message will request specific data from the ESP 8266, which will respond to each message. The weather data is updated every 10 seconds, according to the system's programming.

5) *Calibration:* The calibration process must be completed at the end of the project in order to retain acceptable accuracy. All sensors, with the exception of the pressure sensor, were calibrated here using various methods. The calibration coefficients for each sensor were computed after graphs were plotted using Mat Lab.

a) *Calibration of Temperature Sensor:* Calibration of the Temperature Sensor was done using standard thermometer.

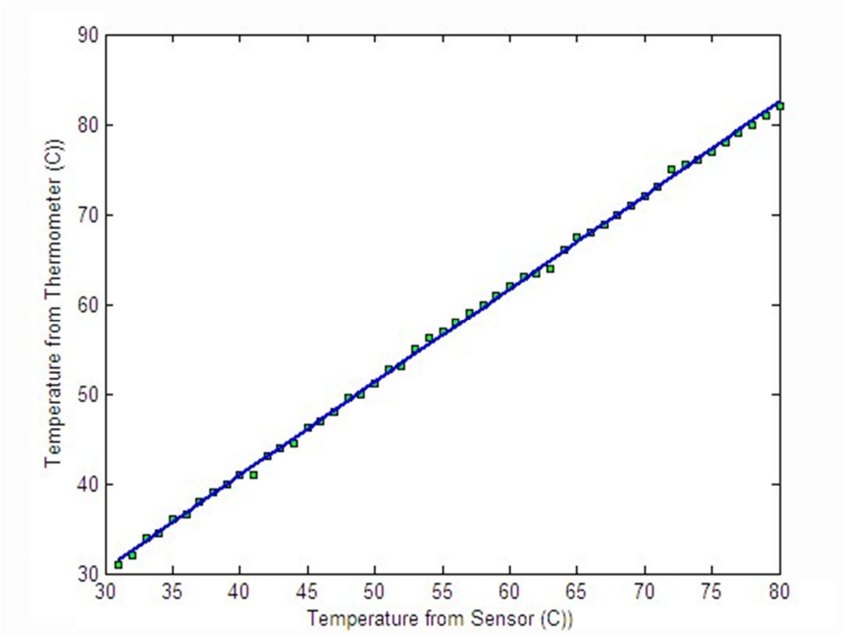

Fig. 7 Sensor Temperature vs Thermometer Temperature

$$CT = (CC \ * ST) \pm Offset \quad (2)$$

Where, CT = Calibrated Temperature, CC = Calibration Coefficient, ST = Sensor Temperature
Calibration Coefficient = 1.0387
Offset = - 0.6333*C*

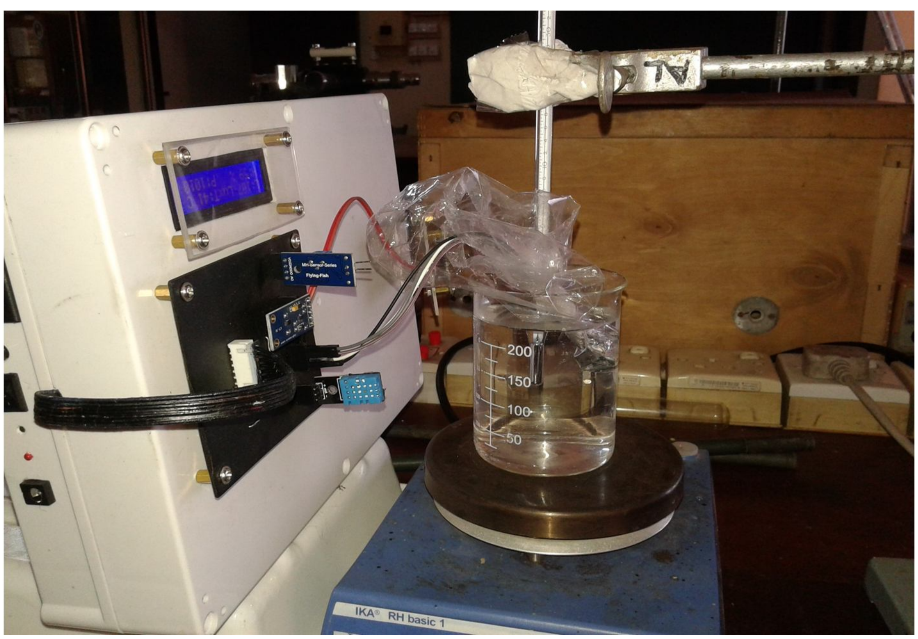

Fig. 8 Calibration Process of the Temperature Sensor

b) *Calibration of Humidity Sensor:* Calibration of the humidity sensor is rather different than the other calibration processes. Relative humidity can be kept constant under different types of saturated salt samples and this method was implemented to calibrate the humidity sensor. Six types of different chemicals were taken and put each of them into small bottle and dissolved with small amount of water and kept constant for approximately 12 hours to become saturated. After 10-12 hours, relative humidity of the sensor was observed and compare it with actual relative humidity value according to the data sheet. Finally, values were plotted using Mat Lab and calibration coefficient was calculated. [13]

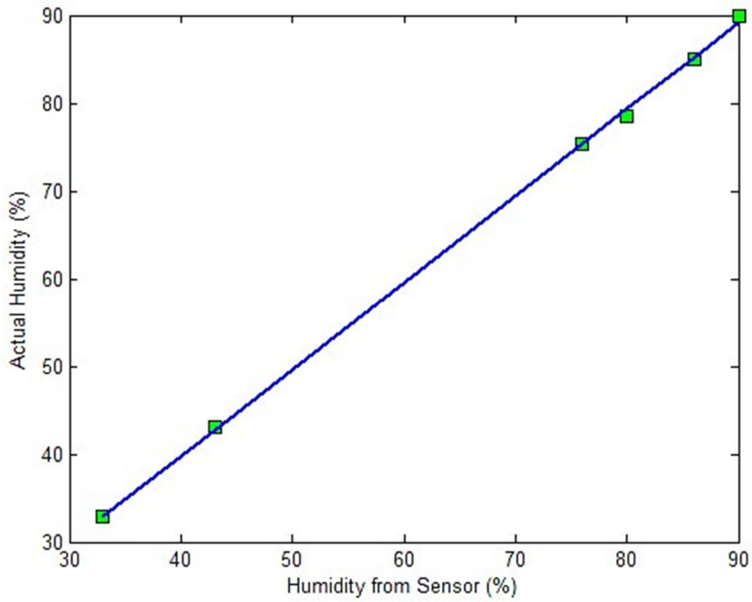

Fig. 9 Sensor Humidity vs Actual Humidity

$$C.H = (C.C * S.H) \pm Offset \tag{3}$$

Where, CH = Calibrated Humidity, CC = Calibration Coefficient, ST = Sensor Humidity

Calibration Coefficient = 0.9877
Offset = 0.3004

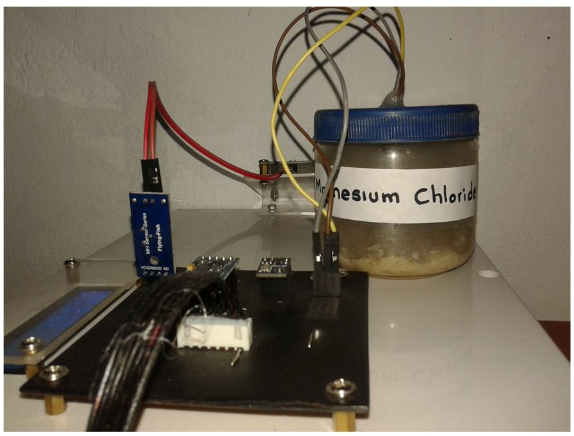

Fig. 10 Calibration Process of the Humidity Sensor with Magnesium Chloride

c) *Calibration of Light Intensity Sensor:* Calibration of light intensity is somewhat difficult than the others, because the light intensity is change rapidly in less time. DT 1309 Commercial Lux Meter was used to calibrate the light intensity of BH1750 Light intensity sensor. Readings were taken by keeping both sensor and the lux meter at same light level and experiment was done in several times. Observed vales were averaged and plotted in Mat lab.

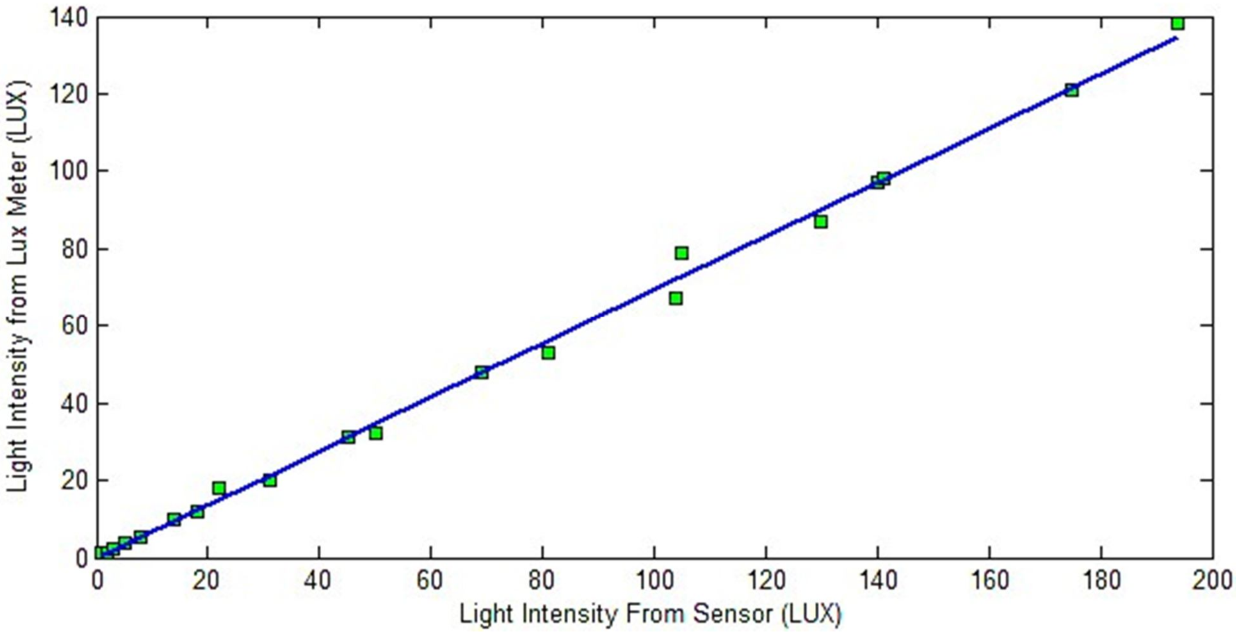

Fig. 11 Light Intensity from Sensor vs DT1309 LUX meter

$$C.L.I = (C.C * S.I) \pm Offset \quad (4)$$

Where, CT = Calibrated Light Intensity, CC = Calibration Coefficient, ST = Sensor Intensity

Calibration Coefficient = 0.6954
Offset = - 0.2656 Lx

III. RESULTS AND DISCUSSION

It was taken at least 2 months to design the Automated Weather Monitoring and Logging System and those results were observed for nearly one month time. All-weather data were saved in the Ubidot IoT server and the saved data can be exported to an Excel sheet for further analysis. The following table shows the results that were taken from the Ubidots IoT server after calibration.
Finally, observed that there is no huge difference in the results by comparing with other weather monitoring equipment and online weather channels. The error of the results was calculated for each sensor using the standard deviation formula.

1) The error of the Temperature Sensor: 0.6902 *C*
2) Error of the Humidity Sensor: 0.5886 % RH
3) Error of the Light Intensity Sensor: 19.2806 Lx

In the designing period, some problems were raised in the hardware part and even in the software part. As explained earlier two ESP 8266 have to connect to the same Wi-Fi network. The ESP 8266 which connects to the IoT server will get a dynamic IP address from the network and the ESP 8266 which connects to the UDP server will assign to a static IP address. But if both sensors connect at the same time an error has occurred in the UDP server. To overcome this problem the ESP 8266 which connects to the IoT server was configured to power on after the ESP 8266 which connects to the UDP Server. This was done by giving a software-based input signal from the ESP 8266 which connects to the IoT server to the other one.

Date	Pressure	Rain	Temperature	humidity	Light
October 07 2017 at 14:47:16	1005	0	27	57	131
October 07 2017 at 14:47:06	1005	0	27	57	131
October 07 2017 at 14:46:56	1005	0	27	57	122
October 07 2017 at 14:46:48	1005	0	27	57	121
October 07 2017 at 14:46:36	1005	0	27	57	122
October 07 2017 at 14:46:26	1005	0	27	57	121
October 07 2017 at 14:46:15	1005	0	27	57	120
October 07 2017 at 14:46:06	1005	0	27	57	121

Fig. 12 Saved Data in Ubidot IOT Server

During the calibration process, some limitations of sensors were observed. Calibration of the temperature was only done for the values above room temperature. It was difficult to calibrate the values below room temperature. The same calibration method was taken place by putting the both thermometer and the sensor into Ice. But the sensitivity of the BMP 180 was too slow concerning the thermometer. Because of the high sensitivity, the thermometer value becomes zero in less time than the sensor. Time for the calibration of the humidity was taken more than one week time. For sodium chloride minimum time for saturation is 96 hours and the enclosure must be sealed. After calibration, it was observed that the range of the sensor is limited to 10-90 % in relative humidity.

By analyzing the graph of the light intensity, the deviation of the values that were taken from the commercial lux meter and the weather station sensor were increased for higher light intensity. calibration was only done for a limited range and the range of the sensor was varied from 0 to 54000. The sensitivity of the rain sensor was decreased over time because of the corrosion effect of the conductor plate. sensitivity potentiometer had to adjust at least once a week. The time that was given by the real-time clock module also shifted from nearly five minutes to real-time after one-month observations. it is essential to adjust the time of the RTC module at least once a month. Fault finding and the repairing process which carried out in case of any emergency failure is not a difficult task, since the weather station was assembled as separate detachable units. A person who takes the repairing action can be observed the weather station is functioning correctly or not using the LCD. Battery voltage was not given for the public viewers and the rain detection is also not showing in LCD, because it was useless. There is a voltage indicator that connects to the remote station and the accuracy of the voltage sensor is +/- 0.2 V by comparing with a commercial. The weather station can be operated for approximately 6 hours using a 6V lead-acid battery. By connecting a wind power station or a solar power station, it is possible to increase the battery, and the weather station can be operated without AC power for a long period.

IV. CONCLUSION

The purpose of this work was to produce a simple, cost-effective, and multi-functional Automatic Weather Monitoring and Logging System considering the importance of the availability of weather-related data. From the results obtained in the last two months, it can be concluded that the work achieved its aims and objectives. The sensors which have been used for this weather station were low-cost type and the accuracy of the data can be improved by using industrial sensors.

In a further improvement, it is desired to be interfaced with the local area network (LAN) and then data can be easily viewed by the users within this LAN. One of the future scopes of it is to save the weather data in a local database and visualize it in the local graphical user interface. Again, it is willing to use GSM technology to send an instant message to the user group when the weather becomes critical.

V. ACKNOWLEDGMENT

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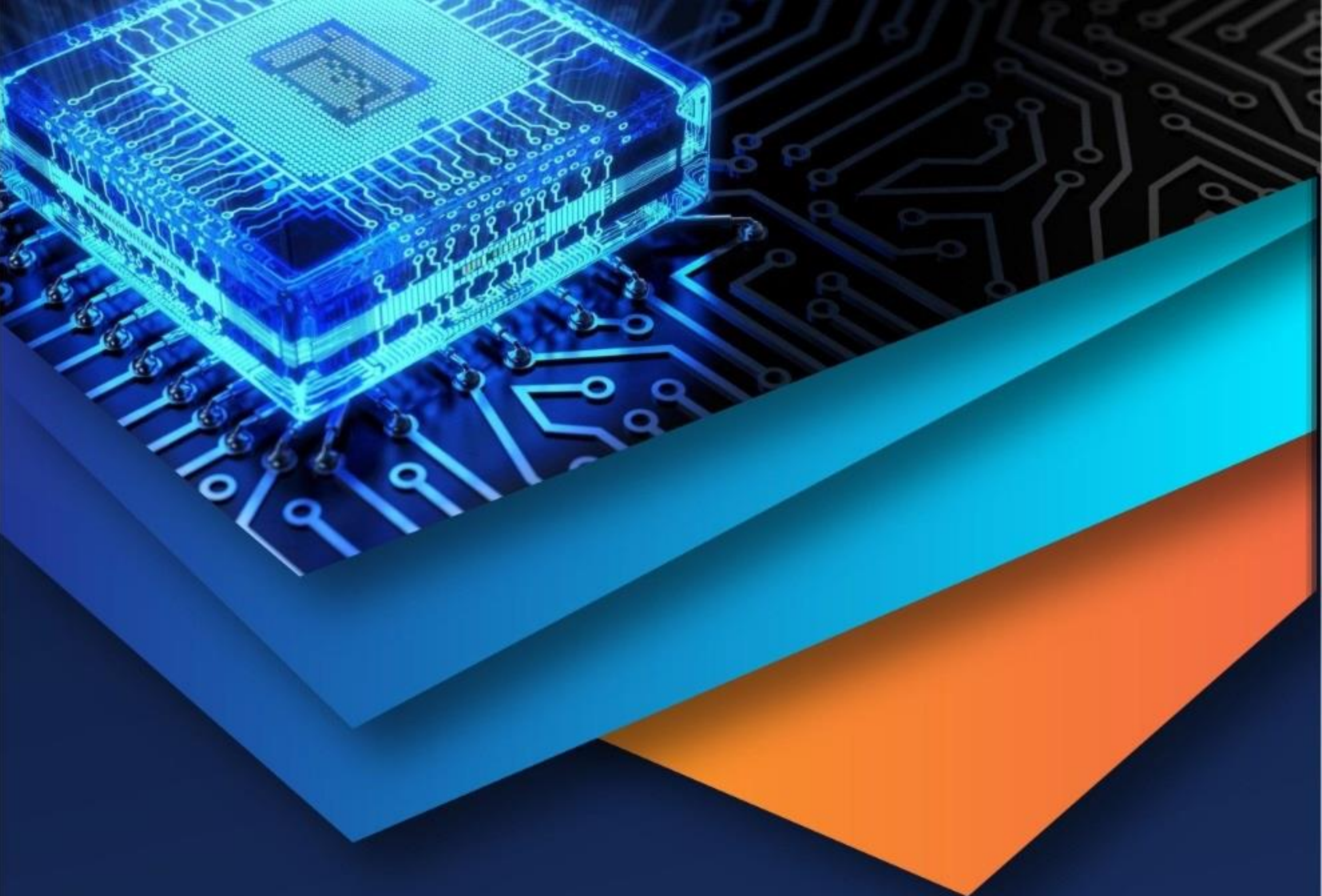

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