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Arduino-based Remotely Accessed Weather Monitoring Station

Rowella Zosima A. Gimena[1], Christine Anne A. Narvadez[1], Ahl G. Balitaon[2]
Alexander C. Abad[1*] and Gerald P. Arada[1*]
[1]Department of Electronics and Communications Engineering, De La Salle University
Manila, Philippines
[2] Integrated School, De La Salle University, Manila, Philippines
*gerald.arada@dlsu.edu.ph

ABSTRACT
A weather station is a device that observes atmospheric conditions using instruments and equipment to supply information for weather forecasts and researches. Commercially available weather stations are stationary and can only be accessed on its location. This study designed and implemented a weather monitoring station that can provide real-time weather conditions to the public, which can be accessed online through different social media platforms. The system is composed of four sensors, Arduino board, transceiver, and ethernet shield, which can work altogether to produce an accurate weather data. A solar panel was utilized for generating electricity to produce enough power source for each of the sensors in the weather station. An alarm was also supplemented to notify when rainfall is detected in the environment and the data will be sent to a web-based database for automatic online broadcast. We have compared our results to the data from AccuWeather and Celestron, and found the data from our system to be precise.

Key words: remote access, online access, weather station, alarm system, weather sensors, solar panel

1. INTRODUCTION

Weather condition is an important factor that affects the daily activities and quality of life of humans. This the reason why weather monitoring is so important. Understanding the surrounding weather conditions could maximize harvests in the agricultural sector [1-4], assist decisions in the operation of different modes of transportation [5], and aid people in planning with their leisure.

While there are existing large and expensive weather stations, sufficient, accurate and comprehensive data can still be achieved using available sensors that are cheaper and yet reliable. Arduino board and Zigbee wireless technology can be used to measure meteorological data such as air temperature, dew point temperature, barometric pressure, relative humidity, wind speed and wind direction [6]. In addition to the above data, the light intensity and rain value can also be measured and monitored [7].

Solar-powered weather monitoring system has also been developed for a sustainable and renewable energy source [8-9]. To generate a renewable power source, the researchers utilized a small solar panel to power each of the sensors in the weather station. The weather station, which has been installed at the De La Salle University-Science and Technology Campus (DLSU-STC), updates measurement readings via the Internet and can be accessible inside and outside the campus.

Our system features ringing an alarm when a heavy rainfall has been detected in the environment, in which this information is sent to a web-based online database for the current weather situation to be automatically broadcast and can also be accessed online.

2. DESIGN CONSIDERATIONS

This section discusses the design of the weather monitoring station's whole system. The hardware and software components and the transmitter's process flow are discussed and presented in this section.

2.1. Hardware

The system is composed of a receiver and a transmitter implemented using the Arduino microcontroller. The transmitter is positioned outside the MRR building of DLSU-STC Campus, while the receiver is placed inside the building. In that way, the receiver will be connected to the Internet through an Ethernet Shield. Figure 1 shows the overall circuit diagram of the system.

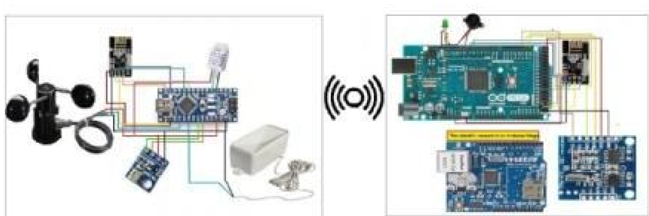

Figure 1: Overall circuit diagram

The transmitter is composed of four sensors for five different weather parameters, such as temperature, wind speed, rainfall rate, humidity, and air pressure.

DHT22 sensor was used for acquiring temperature and humidity data. DHT22, shown in Figure 2, is a temperature and humidity sensor which has thermistor (for temperature) and a capacitive humidity sensor (for relative humidity) used for data gathering [10]. It is connected to an 8-bit-single-chip computer that will enable the sensor to output a calibrated digital signal.

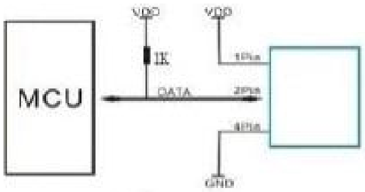

Figure 2: Schematic diagram of DHT22

The BMP180 sensor for air pressure is an Arduino compatible anemometer for wind speed and rain gauge for the rainfall rate. BMP180 is a low-cost barometric pressure and temperature sensor from Bosch which can also be used as an altimeter. BMP180 is soldered onto a PCB with a 3.3V regulator and an I2C level shifter is included to enable the sensor to be safely used with 5V logic and power. An I2C bus consists of two wires: SCL (serial clock) and SDA (serial data). SCL and SDA have open-drain outputs which means that the chip cannot drive its output high. To drive its output high, there must be pull-up resistors (Rp) to the 5V supply as shown in Figure 3.

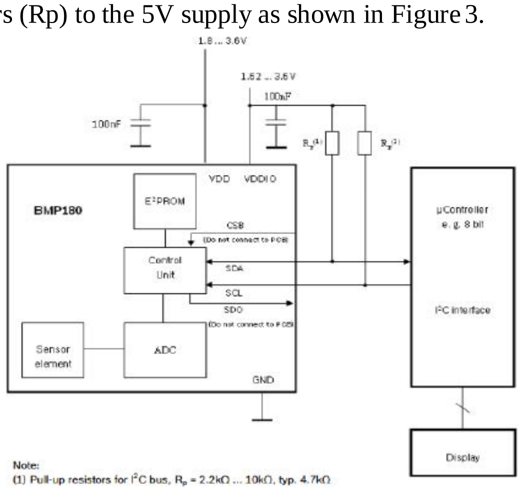

Figure 3: Measurement flow of BMP180

QS-FS wind sensor is an Arduino-compatible anemometer which is used to measure wind speed. It has a three-cup design concept that obtain external environmental information effectively. It has an output of 0.4V to 2V, a testing ranges from 0.5 m/s to 50 m/s, an initial wind speed of 0.2 m/s, a precision of 1 m/s, and a maximum wind speed of 70 m/s. The wind speed is computed as:

$$\text{Wind speed value} = \frac{\text{output voltage} - 0.40}{1.6} \quad (32.4)$$

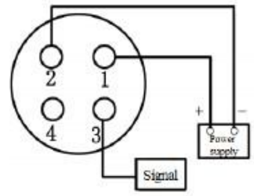

Figure 4: Layout pin configuration of QS-FS wind sensor

The pin layout configuration the QS-FS wind sensor is shown in Figure 4. Pin 1 and Pin 2 corresponds to the power and the ground, respectively. Pin 3 corresponds to the signal or the analog voltage output, while Pin 4 has no connection or null.

The rain gauge is a self-emptying tipping bucket which consists of magnetic reed switch, two buckets, and a pivot. The magnetic reed switch closes when rain is measured to be 0.2794 mm. The tipped down bucket empties itself.

NRF24L01 single chip 2.4 GHz transceiver was also included along with the sensors. The nRF24L01 is a 2.4 GHz transceiver that is designed for ultralow power wireless applications. This is also configured to 2Mbps through a Serial Peripheral Interface (SPI). Figure 5 shows the dimension of the transceiver and its pinout. This device is a solitary chip radio transceiver for 2.4GHz ISM band.

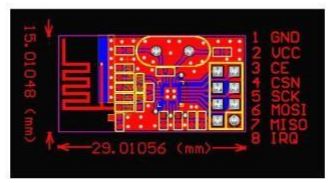

Figure 5: Pin layout configuration of NRF24L01 transceiver module

To collectively process the data, connections were implemented using the Arduino Nano board. In this case, the nRF24L01 transceiver is used as a transmitter.

The transmitter, shown in Figure 6, is designed to be deployed outdoor and expected to be a stand-alone transmitter. To ensure reliability of the weather station, a weather enclosure was made to protect electronic circuit and at the same time to withstand the different weather conditions.

Figure 6: Transmitter Side of the Weather Station

Moreover, a solar panel was installed and connected to the transmitter through a solar charge controller that prevents the battery to overheat, and from the battery with 12V, it steps down to 5V using the switched - mode power supply to power the microcontroller. The battery serves as the main power supply of the transmitter system. The receiver is composed of the ethernet shield, real-time clock module, piezo-buzzer and the nRF24L01 transceiver module. For data processing, Arduino Mega 2560 is used. In this case, the nRF24L01 transceiver module is used as a receiver. The ethernet shield serves as a medium to transfer data to the database and the social media. Furthermore, the piezo- buzzer serves as an alarm when light rains, moderate rains and heavy rains are detected. The frequency of the alarm depends on the level of the rainfall. A slow beep sound for light rains, fast beep sound for moderate rains, and a continuous siren alarm for heavy rainfall. The duration of the alarm will last for 30 seconds after rain has been detected.

2.2. Software

The system uses Arduino Integrated Development Environment (IDE) to upload the written code for the microcontroller of the transmitter and receiver. The measurement reading of each sensor that is received by the microcontroller of the receiver, Arduino Mega, is now sent to the database. The data is sent on Twitter and Facebook three times a day at exactly 5 am, 1pm, and 9 pm when there is a good weather condition and every hour during bad weather condition. A database is necessary to easily record and monitor the measurement readings on each sensor. The database can also be accessed through the Internet that is updated every 5 minutes. The software used to store the data of the measurement readings is MySQL. Xampp is used to create a web server for the database to be accessed online which is the.

Three things are needed to be able to set-up a web server: a server application (Apache), database (MySQL), and scripting language (PHP). Below are the steps that were performed to create the database: (1) Apache and MySQL are being run using the control panel of Xampp; (2) A table was created with seven columns using the functions of MySQL. These tables include the ID indicating how many data was tested, time and date, temperature in degrees Celsius, relative humidity in percentage, barometric pressure in millibars, wind speed in meters per second, and rainfall rate in millimeters per hour; (3) A code was created using PHP (Hypertext Preprocessor). This program is connected to the database and enables the data to be displayed in an internet browser.

The researchers created Facebook and Twitter accounts for the regular updates of the weather condition and indication of heavy rainfall around the school campus. The accounts of Facebook and Twitter are both named “STC Weather Station”. The weather conditions and heavy rainfall indication are sent through Twitter. With the help of Arduino IDE, the data are sent through Twitter by just indicating the username, password and token. Facebook page automatically posts the same content as the Twitter account every time a tweet is sent to the public.

2.3. Process Flow

Figure 7 shows the transmitter process flow. The accumulated raw data from the sensors are used as receiving inputs for the microcontroller. An nrRF24L01 transmitter now acts as the wireless data link between the microcontroller and the computer that displays the weather parameters from each sensor.

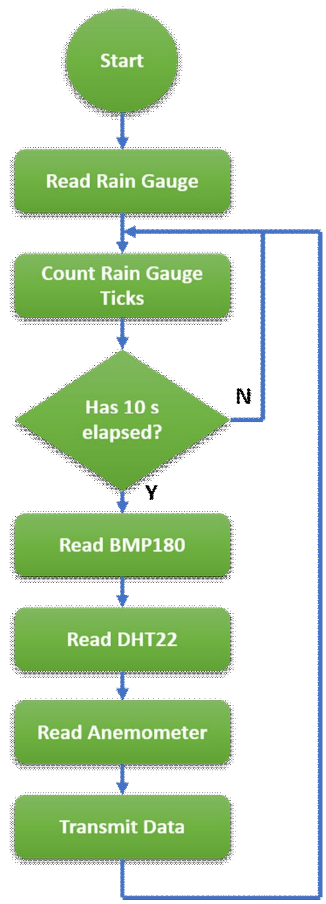

Figure 7: Transmitter Process Flow

When the data is validated, the rainfall count base will be stored. After 20 minutes, the difference of the previous rainfall count and the present rainfall count will be considered to determine the classification of rain.

When the classification of rain is determined, flag for tweet and alarm are set. The calibration for wind speed and humidity are then applied. The conversion from rainfall count to rainfall rate are now displayed and the weather condition is determined. Time and date are then updated, and the flag for tweet and database is set. This enables the receiver to tweet, send its data to the database, and trigger the alarm if rainfall is present. Sensors are expected to transmit new data every 10 seconds to the receiver which is updated by the web server every 5 minutes.

The researchers tested and measured five different weather parameters: temperature, humidity, air pressure, wind speed, and rainfall rate. Different methods for calibration are used for different weather parameters. The temperature is the only weather parameter that does not need calibration based on the measurements gathered.

3. RESULTS AND DISCUSSION

In Table 1, the 15 data points acquired during the implementation of the weather station has 97% average accuracy, in terms of temperature, compared to the output of the AccuWeather. An average accuracy of 98% is obtained compared to the Celestron Weather Station.

Table 1: Data Comparison for Temperature

DHT22	AccuWeather	Accuracy Percentage	DHT22	Celestron	Accuracy Percentage
30.2	30	99.33	29.6	29.8	99.33
30.1	30	99.67	31.3	31.6	99.05
29.5	30	98.33	36.2	36	99.44
28.8	29	99.31	30	29.9	99.67
28.3	28	98.93	37.8	38	99.47
27.2	27	99.26	37.4	37.1	99.19
26.9	27	99.63	30	29.4	97.96
26.3	26	98.85	30	29.4	97.96
27.1	27	99.63	29	29.88	97.05
28.1	28	99.64	30.7	31.1	98.71
28.8	28	97.14	31.2	31.7	98.42
29.2	29	99.31	30	30.7	97.72
29.5	30	98.33	28.4	28.9	98.27
30.6	31	98.71	24	24.3	98.77
32	32	100.00	27.1	27.3	99.27

Table 2 shows that the lowest and highest accuracy level acquired by the humidity sensor when compared to the AccuWeather is 94.25% and 99.99%, respectively. On the other hand, the lowest and highest accuracy level acquired by the humidity sensor when compared to the Celestron Weather Station is 94.84% and 99.69%, respectively.

Table 2: Data Comparison for Humidity

DHT22 Humidity	AccuWeather	Accuracy Percentage	DHT22 Humidity	Celestron	Accuracy Percentage
72.97	69	94.25	66.91	67	99.87
77.24	78	99.03	73.56	73	99.23
77.51	78	99.37	64.2	64	99.69
79.13	78	98.55	65.5	67	97.76
80.6	78	96.67	66.2	66	99.70
80.51	78	96.78	63.21	65	97.25
80.85	85	95.12	67.9	67	98.66
81.35	86	94.59	68.4	67	97.91
82.33	83	99.19	67.45	67	99.33
83.67	83	99.19	61.38	63	97.43
64.4	62	96.13	59.62	62	96.16
83.01	83	99.99	69.23	67	96.67
61.42	62	99.06	67.3	64	94.84
56.28	58	97.03	80.65	80	99.19
61.18	62	98.68	58.54	58	99.07

The air pressure values acquired by the BMP180 sensor are also compared from the data of AccuWeather and the Celestron Weather Station. It can be seen in Table 3 that the accuracy level of the sensor does not go below 99% which can be assessed to be stable.

Table 3: Data Comparison for Barometric Pressure

BMP180	AccuWeather	Accuracy Percentage	BMP180	Celestron	Accuracy Percentage
1010.13	1010	99.99	1012.7	1012	99.93
1009.57	1009	99.94	1010.11	1010	99.99
1009.68	1009	99.93	1013.16	1013	99.98
1009.59	1009	99.94	1013.71	1013	99.93
1009.84	1009	99.92	1010.16	1010	99.98
1009.85	1009	99.92	1011.47	1011	99.95
1009.81	1009	99.92	1012.65	1012	99.94
1010.17	1009	99.88	1012.78	1012	99.92
1010.26	1009	99.88	1011.85	1011	99.92
1010.4	1009	99.86	1010.94	1010	99.91
1012.48	1011	99.85	1012.82	1012	99.92
1011.23	1010	99.88	1012.83	1012	99.92
1011.73	1010	99.83	1010.83	1010	99.92
1013.18	1012	99.88	1009.16	1009	99.98
1012.24	1012	99.98	1007.95	1007	99.91

The data for the rainfall height is not compared on a one to one output data since the glass tube and the rain gauge do not have the same features. Shown in Table 4 is the rainfall height, tube height and the volume for each equipment. Looking at the volume, the accuracy percentage value is lower when there is more volume of water.

Table 5 shows the data comparison acquired by the QS-FS wind sensor and the Accuweather. It is very evident that the values from the Accuweather are very far from the values acquired by the QS-FS wind sensor since Accuweather results are dependent on the satellite's position.

Table 4: Data Comparison for Rainfall Height

Rain Gauge	Tube Height	Rain Gauge Volume	Tube Volume	Accuracy Percentage
0.3091	7	17.0005	16.84	99.05%
0.6182	14	34.001	33.67	99.02%
0.9273	21	51.0015	50.51	99.02%
1.2364	28	68.002	67.35	99.03%
1.5455	37	85.0025	89	95.51%
1.8546	44	102.003	105.83	96.38%
2.1637	51	119.0035	122.67	97.01%
2.4728	56	136.004	134.7	99.03%
2.7819	67	153.0045	161.15	99.49%
3.091	74	170.005	177.99	95.51%
3.091	74	17.0005	177.99	95.51%
3.091	73	170.005	175.59	96.82%
3.091	74	170.005	177.99	95.51%
3.4001	81	187.0055	194.83	95.98%
3.7092	88	204.006	211.66	96.38%

Table 5: Data Comparison for Windspeed

Anemometer Wind Speed	Accuweather Wind Speed	Accuracy Percentage
2.02 m/s	6 m/s	33.67%
2.21 m/s	6 m/s	36.83%
1.56 m/s	7 m/s	22.28%
1.38 m/s	6 m/s	23%
2.21 m/s	5 m/s	44.2%
3.5 m/s	6 m/s	58.33%
1.29 m/s	4 m/s	32.25%
1.2 m/s	3 m/s	40%
1.84 m/s	3 m/s	61.33%
1.66 m/s	4 m/s	41.5%
2.12 m/s	4 m/s	53%
1.2 m/s	4 m/s	30%
1.1 m/s	4 m/s	27.5%
0.64 m/s	4 m/s	16%
0.74 m/s	3 m/s	24.67%
0.18 m/s	3 m/s	6%
1.38 m/s	4 m/s	34.5%
2.21 m/s	3 m/s	73.67%
3.5 m/s	4 m/s	87.5%
1.29 m/s	3 m/s	43%
1.2 m/s	3 m/s	44%
1.84 m/s	3 m/s	61.33%
1.66 m/s	3 m/s	55.33%
1.47 m/s	4 m/s	36.75%
Average Percentage		45.44%

Table 6 shows the data comparison of the analog and digital anemometers. Although the measurements are close to each other, the accuracy level goes down as the wind speed decreases. Figures 8 and 9 show the data transmission through Twitter and Facebook, respectively.

Table 6: Data Comparison for Windspeed

Anemometer Wind Speed	Digital Anemometer Wind Speed	Accuracy Percentage
6.81 m/s	6.5 m/s	95.23%
1.47 m/s	1.4 m/s	95%
3.86 m/s	3.7 m/s	95.68%
1.47 m/s	1.5 m/s	98%
1.1 m/s	1.1 m/s	100%
4.14 m/s	4 m/s	96.50%
2.02 m/s	2.1 m/s	96.19%
2.21 m/s	2.1 m/s	94.76%
1.56 m/s	1.5 m/s	96%
1.38 m/s	1.4 m/s	98.57%
2.21 m/s	2.1 m/s	94.76%
3.5 m/s	3.4 m/s	97.06%
1.29 m/s	1.3 m/s	99.23%
1.2 m/s	1.2 m/s	100%
1.84 m/s	1.8 m/s	97.78%
1.66 m/s	1.6 m/s	96.25%
2.12 m/s	2.2 m/s	96.36%
1.2 m/s	1.2 m/s	100%
1.1 m/s	1.1 m/s	100%
0.64 m/s	0.6 m/s	93.33%
0.74 m/s	0.7 m/s	94.29%
0.18 m/s	0.2 m/s	90%
1.38 m/s	1.4 m/s	98.57%

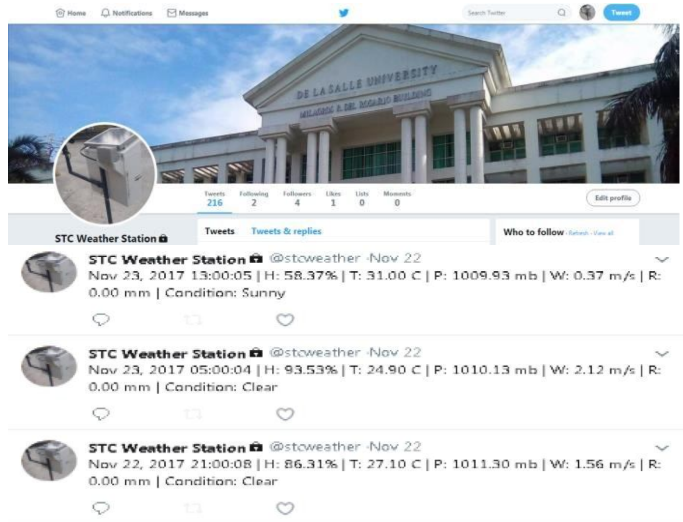

Figure 8: Data transmission on Twitter

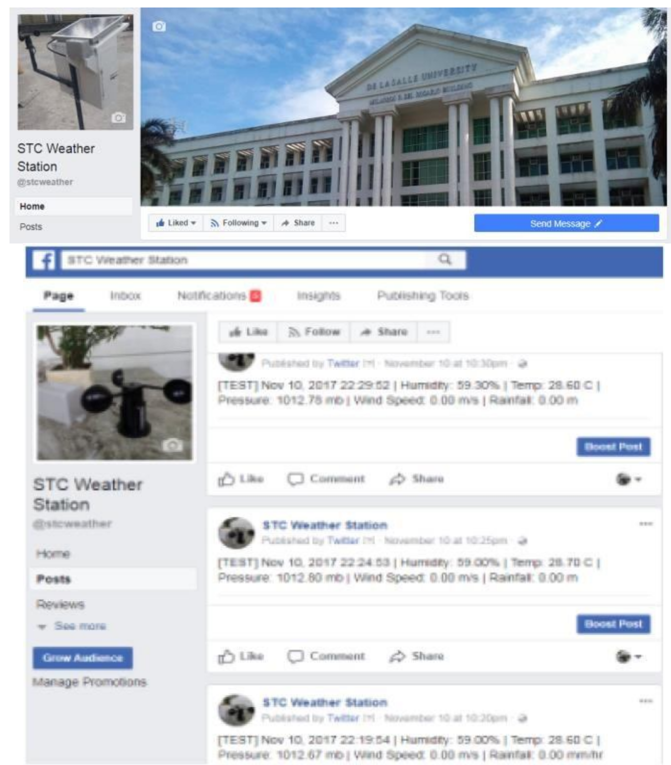

Figure 9: Data transmission on Facebook

4. CONCLUSION

There are many factors affecting the data gathered that is why it is necessary to calibrate of each sensor. The weather parameters cannot also be compared immediately without considering other factors such as location and transmission time. The AccuWeather updates its information every 30 minutes to 1 hour, while the STC weather station updates every 5 minutes on the database.

The data from each sensor is compared individually to AccuWeather and Celestron in order to get their accuracy. It is important to note that AccuWeather provides general information for a given location. This is the reason why we obtained low accuracy level for the windspeed when compared to the AccuWeather. The Celestron Weather Station provides more reliable information since it is mounted specifically on a selected place inside the campus.

This study was able to integrate 5 sensor parameters to build a cheaper and reliable weather station. The weather parameters acquired by the sensors are sent to the database and sent for posting on social media. Posts on Twitter and Facebook are updated 3 times during good weather and updates every hour when rainfall has been detected or more frequently during bad weather.

The overall integration of the weather station, including its hardware and software, was implemented successfully in this study to deploy a remotely accessed weather monitoring station.

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