Development of a Scalable Weather Monitoring System Using Two-way Radios

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Abstract – **This paper presents the development and implementation of a weather monitoring system that is both low-cost and not reliant on power from the mains. The researchers made use of two-way radio as the system's means of communication. The system is also scalable, that is, additional stations can be connected to the system to extend the range and more monitoring stations can be added. The weather monitoring system is composed of Remote Stations that collect data from different locations, and a Command Center that collects all data from the remote stations, displays the current data on a Graphical User Interface (GUI) and stores previous data in a data base. The stations communicate with each other over the two-way radio via Dual-tone Multi-frequency (DTMF) signals. Relaying was also employed in this system, meaning a command/data from one station passes the data to the next station, then to the next, until the command/data reaches the intended station. Testing results show that the system was able to transmit weather data accurately within a distance of 1 kilometer between stations using an omnidirectional antenna. Communication over longer distances can be achieved using directional antennas.**

Key Words – Two-way radio, DTMF, Scalable, Relaying.

I. INTRODUCTION

The Philippines is located along the typhoon belt in the Pacific. Because of this, the country is visited by an average of 20 typhoons every year [1]. The effects of these typhoons range from destructive wind, extreme rainfall and floods, significant amount of destroyed infrastructure and agriculture, and loss of lives.

In 2011, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) have started to deploy several Automated Weather Stations (AWS) in various locations in the country [2]. The automated weather station is significant nowadays especially because of the increase in intensity of the weather disturbances experienced in the country due to climate change. AWS is a stand-alone station which monitors weather-related parameters and enables to transmit the data to PAGASA head office in Quezon City on real-time basis [1]. In AWS, the current medium of transmission is through a Short Message Service (SMS) but the station can be fitted by satellite transmitters if the SMS capability fails [3]. However, the cost for the satellite communication equipment is expensive.

This study can be a good alternative to SMS and satellite communications because of its reliability and low cost. Using two-way radios utilizes the radio frequency link that does not rely on cellular sites which are prone to power outages during severe typhoons. It is also ideal in rural and mountainous areas wherein cellular signal coverage and a stable power supply is little to non-existent. However, the radio frequency has certain limitations such as limited range and it requires line-of-sight communication for maximum efficiency. Because of the limitations mentioned, the researchers come up with a solution which is to make the system scalable.

II. METHODOLOGY

The system is made up of three remote stations (referred to as Stations A, B, and C, respectively) and a command center. Each of the three remote stations will consist of a set of sensors, microcontroller, two-way radio, and a modem. The sensors attached, which are anemometer, water level indicator, temperature sensor, and rain gauge, will collect the weather data. The microcontroller will integrate the collected data as well as process the incoming/outgoing data and the commands to/from the remote station. A two-way radio will serve as the transceiver of the system and a modem will be used as an interface between the microcontroller and the transceiver. The command center will also contain a two-way radio to send/receive commands to/from the other stations, and a modem to translate the received analog signal into digital signal to be fed to a computer.

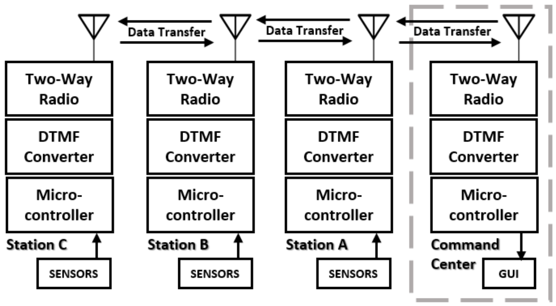


Figure 1. General Block Diagram of the System

To start the data collection process, the command center will send out a command to the rest of the stations. The command will first reach station A. Upon receiving the command, Station A will collect the data from its weather sensors, and then transmit the data back to the command center. The key feature of this system is the relayed communication, in which a data or command is relayed/passed-on to the next node until it reaches its intended recipient. This relayed communication is used in the subsequent stations. After receiving the data from Station A, the command station will once again send the command to collect weather data, which is, this time, addressed to Station B. From the command station, the said command will reach Station A. When Station A receives the command, knowing that Station A is not the intended recipient of the command, Station A will then pass the command to the next station, which is Station B. When Station B receives the command, since Station B is the intended recipient of the command, Station B will then collect data from its sensors, and then send the collected data back to the command center, with Station A relaying the data from station B to command center. When the command center receives the data of Station B, the command center will send another command, this time telling Station C to collect data. When Station A receives the command and sees that it is not intended for Station A, the command will then be relayed to the next station. When Station B sees that the command is not intended for him, either, Station B will pass the command to Station C. Upon receiving the command, upon seeing that the command is intended for that station, Station C will then collect data from its sensors, then send the weather data by passing the data to Station B, which will relay it to Station A, which will then relay the data to the command center. The command to collect data can either occur after one-hour intervals or on demand by pressing a button on the command center.

III. THEORETICAL CONSIDERATIONS

Temperature Sensor

As a tropical country, the Philippines experiences mostly hot and humid climates. According to Weatherbase.com [4], as of May 2017, the average annual temperature in the Philippines is 26.4◦C, with average highs of 30.2◦C and average lows of 22.6◦C. The month of May logs the highest average annual temperature of 27.8◦C, while January has the lowest average at 25.1◦C. In Manila, the annual average temperature is 27◦C with average highs of 31◦C and 23◦C average low temperatures. Knowing the temperature of a certain location is important. In the field of agriculture, for example, exposing crops to temperature extremities not suitable to them may cause the crops to die, which would result to loss of livelihood to the farmers. Temperature extremities may also cause some health problems like heat stroke or frost bites.

Water Level

The Philippines occasionally experiences floods during this season, which leads to destruction of crops and small houses, possibility of drownings in the case of flash floods, and health risks brought about by the exhuming of corrosive substances from clogged drainages, especially in heavily populated cities like Manila. Monitoring the water level is important to determine if a certain place/environment is in need of/in excess of water. For a weather monitoring system, a considerably high water level indicates the presence of flood.

Rain gauge

The rain gauge is mostly used by meteorologists and hydrologists. From the gathered measurements, the researchers will be able to know if the amount of rain of this day, week, or month is above average from the normal rainfall and a certain precaution or warning can be sent by the authorities to the affected communities which are prone to flash floods and landslides. This scenario happened in Iba, Zambales on October 2015 due to the onslaught of Typhoon Lando. The municipality gets 154.8 mm amount of rainfall in 24 hours which is already the average rainfall in the area in half a month [5].

Anemometer and Wind Vane

The anemometer is used to measure the wind speed while the wind vane is used to determine the wind direction. This is an important tool for meteorologists, who study weather patterns, and physicists, who study the way air moves. The common type of anemometer consists of three or four cups propeller and a reed switch [6]. The reed switch will be activated if it completes 1 revolution. The wind direction is measured by a potentiometer which changes its position with respect to the wind vane. Both the wind speed and the wind direction have fluctuations in measurements in just a period of seconds and this is mainly caused by the different surface or geographical features in the area.

VHF

Very High Frequency or VHF is one of the radio frequency bands which has a range of 30 MHz to 300 MHz. The wavelength of the VHF is small enough to propagate efficiently in small antenna and can be able to use in handheld devices such as two-way radio [19]. VHF radios are usually cheaper than their more advanced counterpart and is supplied with a longer lasting battery. Its limited frequency range makes it more power conservative [7].

DTMF

Dual-Tone Multi-Frequency (DTMF) is a signaling scheme used in touch-tone dialing systems. In DTMF, two tones having different frequencies are multiplexed together to represent a digit. In a DTMF signaling system, there are four different low tones and four different high tones arranged in a 4x4 array, with the low tones taking up the 4 rows and the high tones comprising the 4 columns, making a total of 16 digits addressable by the distinct tone pairs

Two-way Radio

A two-way radio is a radio that can both transmit and receive voice signals [8]. It is a half-duplex which means that only one user can transmit at a time. To enable the transmission, the user must push the push-to-talk or PTT button in the two-way radio to switch from the receive mode to transmit mode [9]. Due to its functionality, the two-way radio is ideal for business and security purposes which needs constant and reliable mode of communication compared to using SMS. The characteristic of two-way radio makes it ideal transceiver in times of emergency or natural disaster because they do not rely on Telco's services which are prone to downtime due to power outages.

IV. System Design

Sensors

LM35

The LM35 is an IC-based temperature sensor which has an output voltage directly proportional to the temperature. The LM35 can measure temperature ranging from -55 ◦ C to 150 ◦ C and it didn't require an external calibration to meet the ± 3/4 ◦ C.

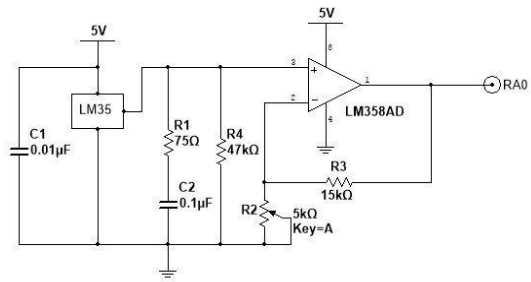


Figure 2. Temperature Sensor Circuit

Float switches

The water level is composed of 6 float switches placed in 6 inches apart inside a rectangular enclosure with a small hole at the bottom to enable the water to have an access in the water level sensor. Also, the distance from the ground to 1st float switch is 6 inches. The float switches are connected to a pull-up resistor via a series of resistors. In order to get the output of the water level, it is configured in a voltage divider to be able to save I/O ports of the microcontroller.

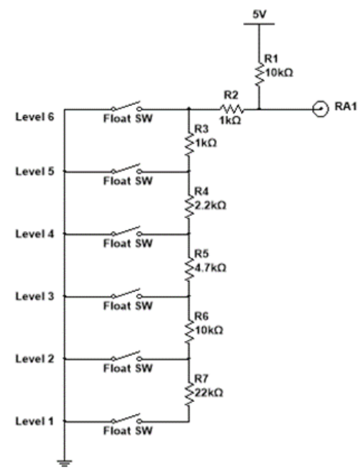


Figure 3. Water Level Circuit

Rain Gauge

The small rain gauge from PRONAMIC is composed of a pull-up resistor of 10k Ω and a reed switch. Every time the reed switch closed, it has a pulse sent to the microcontroller. The sampling period of the rain gauge is set at 1 hour.

Figure 4. Small Pronamic Rain Gauge

Anemometer with Wind Vane

The circuit of anemometer from Davis Instruments is the same to the rain gauge because it composed of a pull-up resistor of 10k Ω and a reed switch. Every time it completes one revolution, the reed switch will close which sends a pulse to the microcontroller. The group sets the sampling period at 2.25 seconds as it was stated in the datasheet and the speed is set at miles per hour (mph).

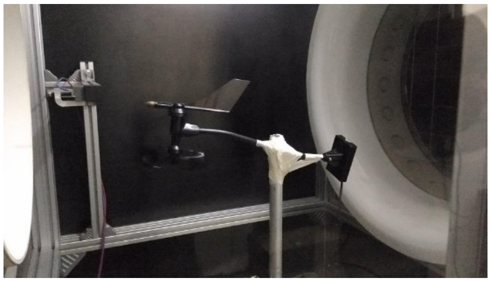


Figure 5. Davis Instruments Anemometer with Wind Vane

UDP

A user-defined protocol was designed to make the scalability of the project possible. Through this protocol, the system could have a maximum of 254 remote stations with 1 command center.

Figure 6. User-Defined Protocol for sending a request

The protocol for sending a request is comprised of origin, next, destination. The origin will show where the data came from. The station ID for command center and each of the remote stations A, B, and, C are 0, 1, 2, and 3; respectively. The next is used to determine what station is supposed to receive the current transmission of data. The destination determines the target/final station the data must be transmitted to.

Figure 7. User-Defined Protocol for sending back the data collected

The data consists of a total of 56 bits from temperature, rainfall, wind speed, wind direction, water level, and the battery voltage reading. The group decided to include the reading of the battery voltage in order to determine if the station already ran out of battery which led to the downtime of the station and affect the whole scalability of the system.

DTMF Module

The encoder and decoder to be used are the W91312 Tone Generator and the CM8870 Integrated DTMF Receiver, respectively. The interface between the radio and the DTMF module is an auxiliary headset to avoid messing with the internal circuitry of the radio. The generated DTMF will go through the microphone terminal of the headset, and the received DTMF signal will pass through the earphone terminal. The microphone part is electrically isolated from the circuit via a transformer to ensure that only AC signals will go through the microphone. An amplifier circuit is implemented at the output of the W91312 DTMF encoder and just before the microphone terminal to ensure that sufficient signal level is fed through the microphone. The Push-to-Talk function of the radio is switched using a relay, and will only activate when the node is ready to transmit and deactivate when the node is done transmitting. To know when the system is transmitting, the group placed an indicator LED at the relay part.

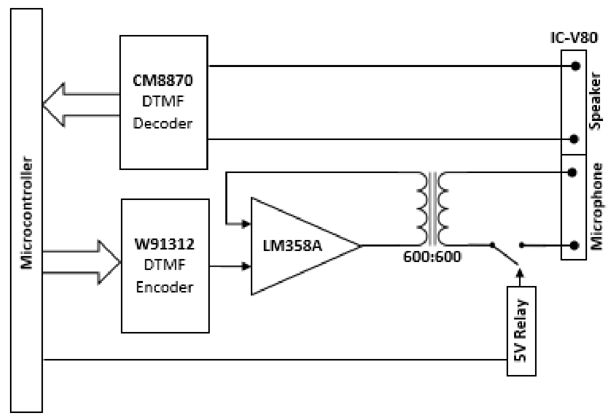


Figure 8. DTMF Module Block Diagram

ICOM V80

The two-way radio used was the ICOM IC-V80 VHF transceiver. This two-way radio is a handheld type of radio which has frequency coverage of 144 to 148 MHz in transmit and 136 to 174 MHz in receive. This two-way radio can last up to 19 hours operating time with the supplied 7.4V 2000 mAh Li-Ion battery. It also has an IP54 rating which offers water resistance and protection against dust and dirt [10].

Figure 9. ICOM IC-V80 Two-way Radio

Graphical User Interface (GUI)

The group used the Visual Basic program for the implementation of the GUI to display the values collected from the sensors of all the stations. The output of the Command Center Module is then connected to the COM1 port of the computer. . Since Visual Basic is an event-driven programming language, the group designed a program wherein it will check every 2 milliseconds if there is a data sent through the COM1 port. It will then read the received data and display it. After it displays the data, it will then save the received data onto the database, which is an Excel file. The database has the Date, Time received, and the values of every data from the sensors.

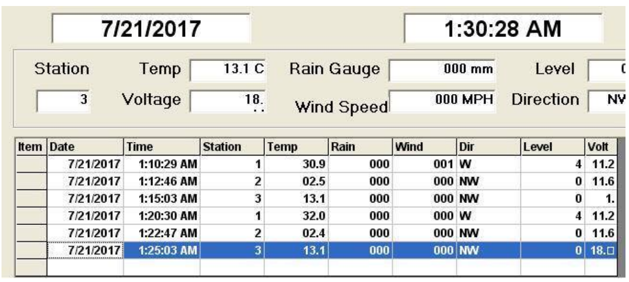
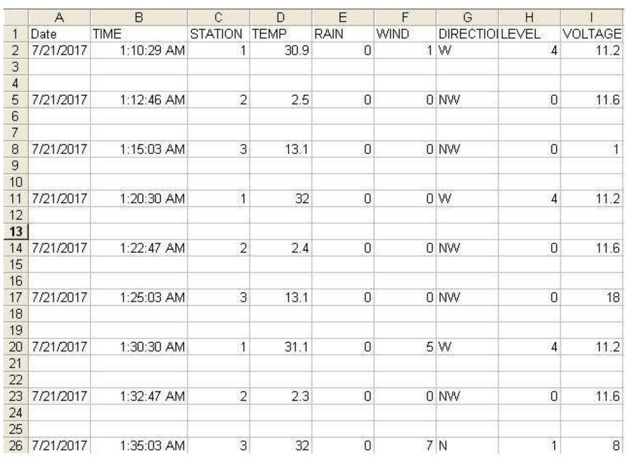


Figure 10. Relay of data via Automatic Request Sensors Connected only to Station A



	A	B	C	D	E	F	G	H	I
1	Date	TIME	STATION	TEMP	RAIN	WIND	DIRECTIOI	LEVEL	VOLTAGE
2	7/21/2017	1:10:29 AM	1	30.9	0	1	W	4	11.2
3									
4									
5	7/21/2017	1:12:46 AM	2	2.5	0	0	NW	0	11.6
6									
7									
8	7/21/2017	1:15:03 AM	3	13.1	0	0	NW	0	1
9									
10									
11	7/21/2017	1:20:30 AM	1	32	0	0	W	4	11.2
12									
13									
14	7/21/2017	1:22:47 AM	2	2.4	0	0	NW	0	11.6
15									
16									
17	7/21/2017	1:25:03 AM	3	13.1	0	0	NW	0	18
18									
19									
20	7/21/2017	1:30:30 AM	1	31.1	0	5	W	4	11.2
21									
22									
23	7/21/2017	1:32:47 AM	2	2.3	0	0	NW	0	11.6
24									
25									
26	7/21/2017	1:35:03 AM	3	32	0	7	N	1	8

Figure 11. Excel Output of Station A with Sensors

An indicator on the GUI was also developed that will alert or inform the user whether it received the requested data from the remote station(s) or not. The PIC of the Command Center is programmed to have a timer in which if it failed to receive the requested data at the amount of time given, the Command Center will then send 0s to the GUI. The GUI, on the other hand, is programmed such that when it receives a 0.0 data from the voltage reading, it will then turn the background color of the station number to red to notify that the user needs to retransmit the request to the remote station(s).

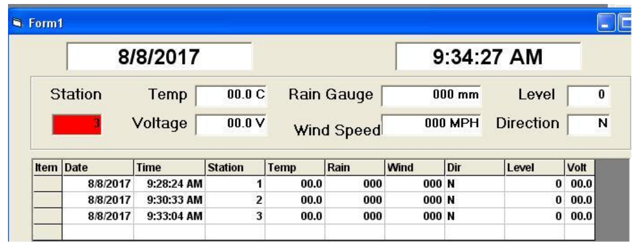


Figure 12. Station 3 with no reading or TURNED OFF

Command Center Program Flow

After initialization, the Command Center will start a countdown timer that will initiate the data collection process. When the timer reaches the 5 minute mark, the Command Center will send a command to the first station telling it to collect weather data. After receiving the weather data from the first station and displaying it to the GUI, the Command Center will wait until the timer hits the 3-minute mark. When it does, the Command Center will send a command to the second station to collect weather data. After receiving the data and displaying it to the GUI, the Command Center will wait until the timer reaches the 1-minute mark, afterwhich the Command Center will send a command to the third station. After receiving the data from the third station and displaying the weather data at the GUI, the Command Center will wait until the 0-minute mark before resetting the timer. The Command Center will only collect data outside of the given time is through the intervention of a push-button. The push-button will indicate the desired station to collect data, send a command to that station, receive the data from that station.

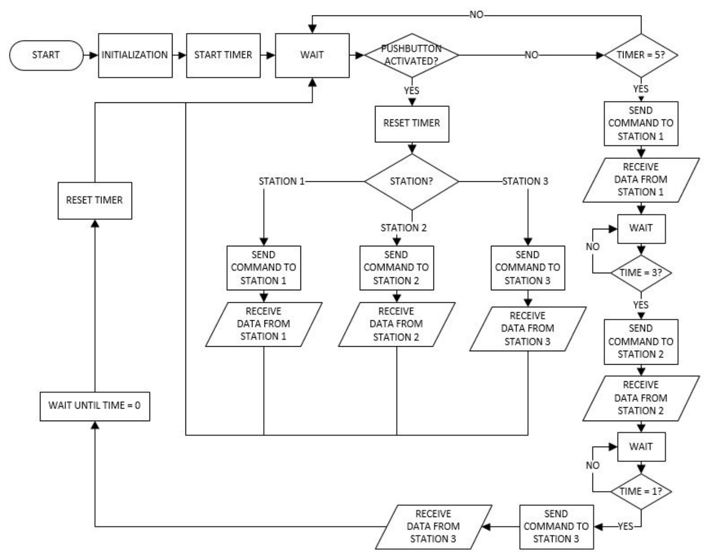


Figure 13. General Flowchart for Command Center

Remote Station Program Flow

The Remote Station essentially waits for a command from the Command Center. When a command is received, the Remote Station determines if the command or data is intended for that station. If not, the Command Center passes the data to the other Remote Stations. If the command is intended for that Remote Station, the station will collect weather from the weather sensors and send the collected data back to the Command Center.

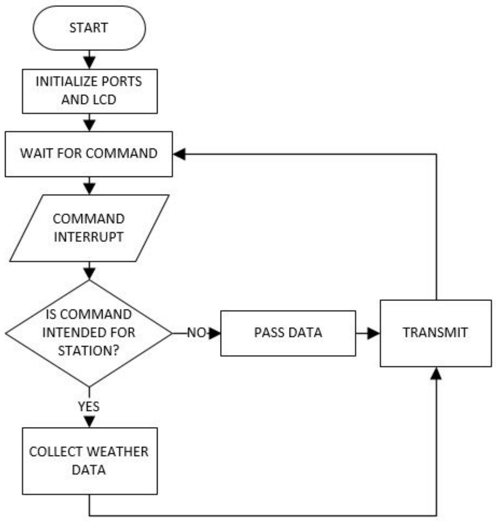


Figure 14. General Flowchart for Remote Station

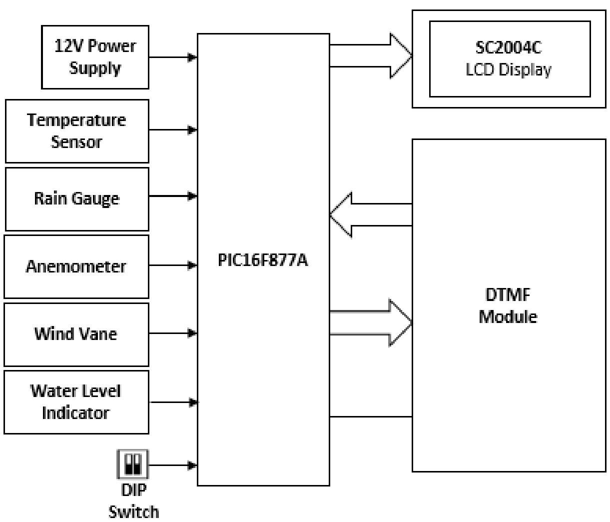


Figure 15. Overall Block Diagram of the System

V. DATA AND RESULTS

Individual Testing of Sensors Temperature Sensor

The LM35 was placed inside the climatic chamber to ensure a controlled environment. The comparison was done with three temperature values namely 20ºC, 30ºC and 40ºC for four trials each which will be set at the climatic chamber however the reference temperature will be read at the logger which is separate equipment from the climatic chamber. The first two trials are set up by decreasing temperature while the other two trials are at increasing temperature. This procedure is standard for checking the temperature sensor. The sensor was checked at each remote station to ensure that the sensor was properly functioning at all remote stations.

Table 1. Station A: Reference Temperature at 40ºC

Trials (°C)	Reference Value (°C)	LM35 (°C)	% Error
1	39.90	40.08	0.45
2	39.91	40.12	0.53
3	39.88	40.05	0.43
4	39.87	40.03	0.40

Average % Error = 0.45

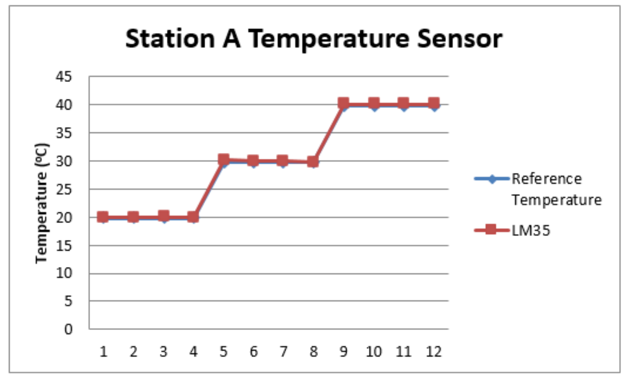


Figure 16. Graph of temperature readings at station A compared from the reference

Table 2. Station B: Reference Temperature at 40ºC

Trials (°C)	Reference Value (°C)	LM35 (°C)	% Error
1	39.89	38.74	2.88
2	39.9	39.89	0.03
3	39.88	40.29	1.03
4	39.91	40.29	0.95

Average % Error = 1.22

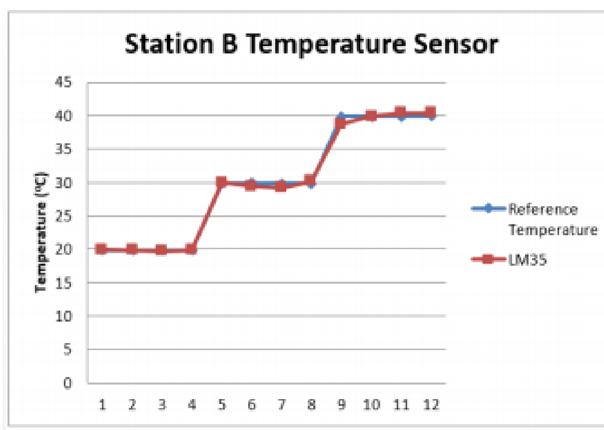


Figure 17. Graph of temperature readings at station B compared from the reference

Table 3. Station C: Reference Temperature at 40ºC

Trials (°C)	Reference Value (°C)	LM35 (°C)	% Error
1	39.87	40	0.33
2	39.91	40.54	1.58
3	39.91	39.84	0.18
4	39.89	39.5	0.98

Average % Error = 0.77

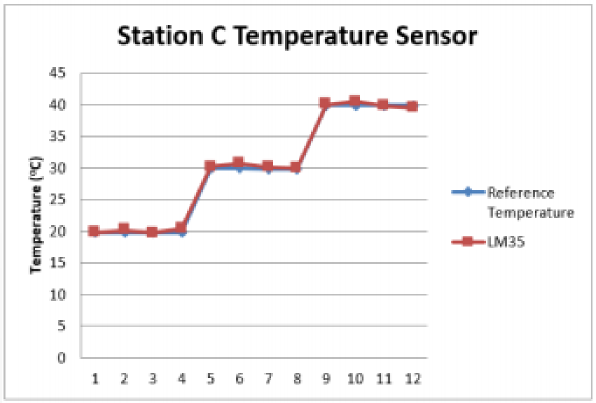


Figure 18. Graph of temperature readings at station C compared from the reference

From the tables and graphs above, it can be seen that most of the readings gathered by the LM35 are relatively close to the reference temperature. The most efficient station in terms of the temperature displayed is Station A, while both stations B and C relatively have a slight significance in percentage error. The difference in the temperature readings as shown in the results has several factors such as the climatic chamber, the logger used, the temperature sensor and the modules remote station. This test has shown that the LM35 is accurate while producing on average of 0.35% - 1.32% error.

Water Level Sensor

The water level sensor was tested at the swimming pool located inside the Enrique M. Razon Sports Center of De La Salle University. One of the members of the group lower the water level sensor to be able to activate the float switches while the others in the group were monitoring the LCD to check if the reading from the sensor is correct. If the actual level and the reading from the water level sensor is the same, an OK will be indicated in the table below.

Table 4. Water Level Sensor Testing

Actual Level	Water Level Sensor at Station A	Water Level Sensor at Station B	Water Level Sensor at Station C
0	OK	OK	OK
1	OK	OK	OK
2	OK	OK	OK
3	OK	OK	OK
4	OK	OK	OK
5	OK	OK	OK
6	OK	OK	OK

The group has shown that the water level sensor can accurately measure water level. On a side note, the water level reading returned at the station is determined by the topmost float switch activated, meaning that if the float switch for the sixth level is activated, the LCD will display L6, and will basically ignore the state of the lower switches because it is automatically assumed that, in a real flood, the topmost activated switch will determine the water level and all others below it are pressumably activated.

Rain Gauge

The rain gauge was tested by monitoring the actual number of tips of the rain gauge and compares it to the LCD of the remote station. The rain gauge was checked at each remote station to ensure that the rain gauge was properly functioning at all remote stations. An OK will be indicated if the actual number of tips and the data received by the remote station from the rain gauge is the same.

Table 5. Rain Gauge Testing

Actual Number of Tips	Rain Gauge at Station A	Rain Gauge at Station B	Rain Gauge at Station C
1	OK	OK	OK
2	OK	OK	OK
3	OK	OK	OK
4	OK	OK	OK
5	OK	OK	OK
6	OK	OK	OK
7	OK	OK	OK
8	OK	OK	OK
9	OK	OK	OK
10	OK	OK	OK

From the test above, the group was able to show here that each RPT was able to properly respond to the tip of the bucket. Since the rain gauge was already calibrated at PAGASA, the group has shown that the system can accurately measure the amount of rainfall.

Anemometer with Wind Vane

The anemometer was tested in the wind tunnel at the IRDU of the PAGASA. It was checked at each of the remote station to ensure that the anemometer was properly functioning in all remote stations. The same process during the calibration was just repeated to other remote stations. The 1st trial starts in increasing wind speed while the 2nd trial starts in decreasing wind speed. The reference wind speed will be indicated by the wind tunnel and the group monitors the LCD of the remote station for the reading of the anemometer. The wind direction was tested by comparing the LCD of the remote station with respect to a compass. An ok will be indicated if the wind direction displayed at the LCD is the same with the compass.

Table 6. Anemometer Testing (same in all stations) (in mph)

Reference Wind Speed	Trial 1	Trial 2	Average Wind Speed	Correction
4.47	4	4	4	+0.47
22.37	22	22	22	+0.37
44.74	43	43	43	+1.74
67.11	67	67	67	+0.11

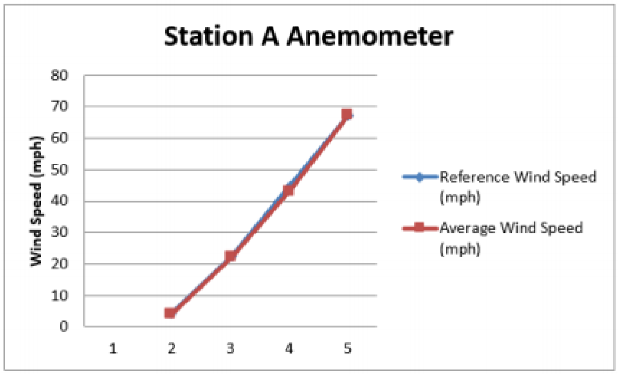


Figure 19. Graph of anemometer readings at station A

For the wind speed, the group observed a very small difference between the reference wind speed and the wind-speed reading at each station. It was also seen that the wind speed displayed for each station is consistent with each other. The highest observed difference between the reference data and the displayed data at the stations is at 1.74mph when the reference wind speed is set to 44.74mph.

Table 7. Wind Direction Testing

Actual Wind Direction	Wind Direction at Station A	Wind Direction at Station B	Wind Direction at Station C
North	OK	OK	OK
North East	OK	OK	OK
East	OK	OK	OK
South East	OK	OK	OK
South	OK	OK	OK
South West	OK	OK	OK
West	OK	OK	OK
North West	OK	OK	OK

As for the wind vane, the group pointed the stem of the whole anemometer (the true north of the sensor) to the geographical north, as pointed at by the compass. The group was able to see that the wind direction data pointed by the groups wind vane is consistent with the direction at the compass, with some variations at the mid-way directions (NE, SE, SW, NW).

Range Test

Received data at Command Center vs. Remote Data

Testing was done from Quirino grandstand to Rizal Park under good weather conditions and with line of sight. The system was tested with different distances between the stations. Sensors are connected to 1 station. The accuracy of data transmitted and received are also tested at various distances. The reading at the LCD of the station with sensors was compared with the reading of the LCD of the Command Center. The transmission is considered to be successful if there are no differences between the transmitted data and received data.

Table 8. Station A - Distance from GUI: 200 M

Sensor	Data at GUI	Data at Station A	% Error
Temperature [C]	33.3	33.3	0
Rain Gauge (mm)	8	8	0
Wind Speed (mph)	5	5	0
Wind Direction	3	3	0
Water Level	6	6	0

Table 9. Station B - Distance from Station A: 200 M

Sensor	Data at GUI	Data at Station B	% Error
Temperature [C]	33.5	33.5	0
Rain Gauge (mm)	5	5	0
Wind Speed (mph)	0	0	0
Wind Direction	6	6	0
Water Level	0	0	0

Table 10. Station C - Distance from Station B: 200 M

Sensor	Data at GUI	Data at Station C	% Error
Temperature [C]	33.3	33.3	0
Rain Gauge (mm)	4	4	0
Wind Speed (mph)	0	0	0
Wind Direction	2	2	0
Water Level	0	0	0

The errors in transmission are caused by the obstructions in the line of sight and the orientation of the two-way radio. These are some of the factors the group observed why some of the digit/s are missing in the command center. The high percentage error was caused because the error is when a missing digit/s is missing which the caused the other digits to shift to the left. The line of sight is really important and it shows in this test. The location where there is an error have a slight challenge in line of sight and the two-way radio must keep in an upright position to send the signal without error to the command center. The electromagnetic signal coming from the two-way radio affects its station especially if it's close to each other and this is the reason why the LCD display is sometimes being corrupted. It is also the reason why the temperature reading was fluctuating at some point.

Overall Test of the System

Rizal Park Location

In this testing the 900m overall distance is located from Quirino grandstand up to Rizal Park near Taft Avenue. The group can conclude if the transmission is successful when all the digits of the source, next, destination, sensors, and battery voltage of the station are complete and received by the command center.

Table 11. Overall Testing along Quirino Grandstand to Rizal Park (in meters)

Overall	Command Center to A	Station A to B	Station B to C	from Station A	from Station B	from Station C
60	20	20	20	OK	OK	OK
150	50	50	50	OK	OK	OK
300	100	100	100	OK	OK	OK
600	200	200	200	OK	OK	OK
900	300	300	300	OK	OK	Incomplete

From the results, it got mostly okay to all the measurements in the table and got only 1 error. It is mainly because from the overall distance of 900m which is at from Quirino grandstand to Rizal Park near Taft Avenue, it has some obstructions which have an effect to the transmission. Also, when the two-way radio is not properly held at the correct position which must be upright, the signal was not properly received by the next station due to the lack of line of sight. This is one the causes of the missing bits received by the command center. However, the system still shows a reliable transmission.

Seaside-Mall of Asia (MOA) Location

The testing was conducted along the seaside at the Mall of Asia complex. One of the members of the group will carry the modules of both the command center and the station B while at the other end or at 0m will be the location of both station A and station C. This setup shows the overall effective distance of the system because the group send a request to station C which means it still shows the relaying ability of the system. It also maximized the whole length of the seaside at the MOA complex. Through the LCD screen, the group cross-checked the transmitted data by station C with the received data at the command center. In this testing, the radio position which is at upright position.

Table 12. Overall Testing along Seaside at the SM-MOA Complex having the Radio in Upright Position (n meters)

Overall Distance	Command Center to A	Station A to B	Station B to C	Trial 1	Trial 2	Trial 3
300	100	100	100	OK	OK	OK
600	200	200	200	OK	OK	OK
900	300	300	300	OK	OK	OK
1200	400	400	400	OK	OK	OK
1500	500	500	500	OK	OK	OK
1800	600	600	600	OK	Incomplete	OK
2100	700	700	700	OK	OK	OK
2400	800	800	800	OK	OK	OK
2700	900	900	900	Incomplete	OK	OK
3000	1000	1000	1000	OK	Incomplete	Incomplete
3300	1100	1100	1100	Incomplete	-	Incomplete
3600	1200	1200	1200	-	-	-

VI. Conclusion

In this thesis, the researchers have found out that data transmission using two way radio is possible. They also found a way in making the interface between the radios and the microcontroller and transmitting them in analog and later on converting them into digital codes so that the computer will be able to read it and be displayed in their GUI. The PIC16F877A has been a vital part of this subject for this is where all the interfacing and communication takes place. With this microcontroller having a multiple digital and analog inputs really made the job quite easier and it also contains a built in ADC for the researchers to maximize. Using the DTMF module as the interface between the microcontroller and the radio is successful based on series of tests. The line of sight is really important to make an efficient data transmission. The GUI in the system is functioning its task to make it a friendlier system that can be used by any person without any technical expertise regarding weather monitoring system.

From the results gathered, the group can conclude that, as it stands, the system can be deployed on a barangay level, as the scalable weather monitoring system can provide data when each node was subjected to a separation of up to 1 km., making the effective range of the system up to 3 km. This is in the condition that the radios were equipped with the stock antenna and that the radios are placed in an upright position. It can also be concluded that the effective range of up to 3 km could deteriorate when obstructions come between any of the nodes, causing those nodes to lose the line-of-sight connectivity they have. This loss of line-of-sight, along with the presence of metallic objects near the transmitter and electromagnetic interference, causes the error of the data-gathering process to increase.

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