Low Cost – Remote Passive Sensory Based Weather Prediction System with Internet of Things

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ABSTRACT

Climate effects many major daily aspects of the society, from the food sources and transport infrastructure to the choice of fashion and certain daily routines. Due to these reasons, the demand for means to accurately foresee climatic changes have increased. Weather forecasting, especially in Sri Lanka, has been hampered due to numerous reasons and this has resulted in erroneous predictions that has adversely affected many areas of development ranging from agriculture, irrigation, and the tourism industry to certain branches of engineering. Many researchers have analyzed and proposed solutions to these problems. However, the need for accurate predictions prevails due to the hardship of accurate data acquisition, processing, and transmission. To address these problems, in this paper, a system that adheres to the rules and regulations set forth by the World Meteorological Organization (WMO) to carry out well informed and reliably accurate weather predictions based on the data attained from a wireless passive remote sensory medium has been implemented. This task was carried out by means of feeding the relevant climatic parameter readings measured via multiple wireless passive remote sensory nodes placed within the proximity of a considered area to a selected computational model, which in turn was implemented to yield considerably accurate predictions compared to the weather prediction systems currently available in the market. The paper comprises of the implementation of the category, Low-Cost Automatic Weather Station (LC-AWS) specified by the WMO and Internet of Things (IoT), one of the latest technologies, for the transmission of attained data even in the absence of Wi-Fi. The research was further conducted to perform an analytical comparison between highly accurate weather stations and the implemented low-cost weather station when compromising accuracy due to low cost. The hardware and related software implementation yielded an acceptable success rate and was concluded successfully.

KEYWORDS: *Low-Cost Automatic Weather Station, World Meteorological Organization (WMO), Wireless passive remote sensory medium, Internet of Things (IoT)*

1 INTRODUCTION

Abrupt changes of weather patterns may hinder many day-to-day activities of humankind. It not only affects the daily lifestyle of people, but it also adversely affects many daily revenues of development in countries such as transportation, agriculture, irrigation etc. Hence, the importance of accurate weather prediction systems has been identified and implemented. When considering Sri Lanka, accuracy in weather prediction has been hampered due to numerous reasons and has also adversely affected the development of many industries and revenues.

Weather Forecasting has been identified as one of the most important aspects of the society as it plays an important role in any village, city, or country. Since the 19th century, humans have attempted to predict weather informally. However, the accuracy in data acquisition, processing, and transmission and the choice of reliable and accurate sensors plays a major role in this implementation. This research and design focuses on high accuracy and cost efficiency compared to other Automatic Weather Station's (AWS) available in the current market of Sri Lanka.

Inaccurate weather prediction results in many downfalls of development in many revenues and engineering branches of a country. Therefore, it is highly necessary to adhere to suitable World

Meteorological Organization (WMO) guidelines and conquer this situation. Addressing this problem, a stand-alone AWS with facility of remote communication to capture and then transmit meteorological parameters with high accuracy was developed. SDG friendly means of disposal, Minimum possible Power Consumption, Simple User Interface, Durability, and Maintainability were focused on.

1.1 WMO Guidelines

The WMO guidelines were followed thoroughly throughout the design and construction of the AWS for the choice of sensors and placement of nodes. The sensors recommended for AWS by the WMO are the ones most commonly used at traditional manual observation stations that are currently active. Since AWS controls long distance measurements, it is necessary that the sensors used in the design and implementation must be robust, maintenance free, high accuracy, high range, and long-lasting life. Therefore, overall sensors with an electrical output are preferred for this purpose. Furthermore, research also states that the new development is of which sensors are to be considered such as the enhancements in existing sensors and new physical principles. Furthermore, the research also specified that the three types of sensors were also categorized depending on their outputs as follows,

- Analogue - Output in the form of Current, Voltage, Charge, Capacitance or Resistance.
- Digital - Output contains information in a bit or in a group of bits. Also includes sensors with pulse or frequency output.
- Intelligent - Sensors with a microprocessor that performs basic data collecting and processing and provides a serial digital or parallel output.

These factors were considered extremely important to adhere to when deciding on the appropriate sensors to be chosen for the construction and final implementation of the model. Along with these, the necessary factor to be considered while choosing sensors for various measurements were also included as follows,

Considering the objective of the project cost efficient high accuracy sensors were of high preference. The currently existing sensors in the market were known to be of extremely high cost whereas the predictions were not of high accuracy. Multiple sensors met the cause for each dedicated scenario causing multiple comparisons between sensors to be made. The cost efficiency, the accuracy, the range the availability and feasibility of the sensors were discussed in these comparisons. After a considerable amount of research, the sensors for the design were chosen mainly due to their cost efficiency, high accuracy, and availability.

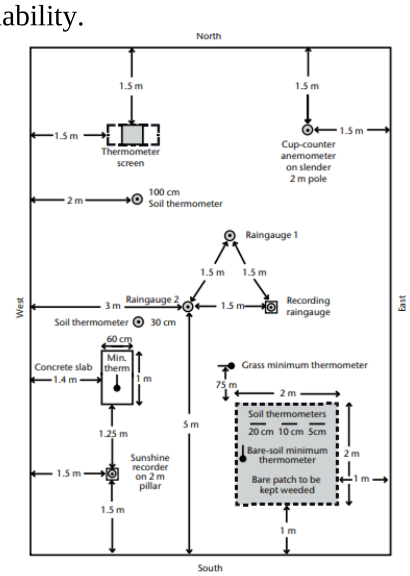


Figure 1.1. Layout of Site for AWS Installation

Outdoor instruments must be put on a flat piece of ground, ideally no smaller than 25m × 25m when there are numerous installations, but in circumstances where there are few installations (as in Figure *1.1*), the space can be much smaller, for example 10m x 7m (the enclosure), according to the

WMO rules. It was also noted that the location must be free of trees, buildings, walls, and other impediments. Sensors inside a screen should be installed at a height set by the meteorological service (between 1.25m to 2m, as per the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8)). The node was put on a rooftop surface away from impediments at a height of 10 meters above ground level, following all standards.

2 CURRENTLY EXISTING AWS

It was necessary that the system consists of separate modules for data acquisition, storage and communication. These modules communicate with each other serially and are controlled by microcontrollers. Data storage and communication are as important as the other sections of the research. As per previous projects and research done on AWS's, there are two options to serve this purpose. The measured (by sensors) and recorded meteorological parameters can be stored in built-in data loggers or it could also be transmitted to a remote location via a communication link. However, it has been considered a failure as with the built-in data logging option, data must be physically downloaded onto a computer for further processing. This is highly inconvenient since the AWS is located in a remote location. Thus, it is understood that a communication system plays a major role in Automatic Weather Systems (AWS).

Previous systems focused solely on collecting temperature data or transmitting it through ZigBee, GSM, Wi-Fi, or some other distant means. Despite these systems measuring the same parameters, they have one flaw: accuracy. And the major goal of this project is to create a freestanding modular weather station with a remote communication facility that can effectively and accurately gather and transmit meteorological information. Many implementations performed without proper observations or patterns tend to be erroneous. There have been multiple implementations of communication with communication devices or through serial and parallel ports to obtain hard copies of weather data. The University of Colombo implemented the built-in data logging facility using a USB communication facility. ("I", 2021). This used a wired communication method for the transmission of data. It transmitted data to the monitoring station through the computer's built-in USB interface.

However, this is not a feasible option as in real situations since this requires physical cables as links between the AWS and the monitoring station. The proposed system will use a communication module will accept incoming serial data and transmit through GSM. An interactive android mobile application interface was implemented to provide the user with the real time data to suite his needs. The lesser known 'ngrok' service, a cross-platform program that allows developers to conviniently expose a local development server to the internet was used to access attained weather parameters from anywhere across the globe.

3 HARDWARE OF PROJECT

3.1 Microcontroller

The ESP32 was chosen to be the microcontroller of this design. The primary reason being that it possesses the ability to transmit data even in the absence of Wi-Fi by utilizing a SIM card with an active data connection for the purpose. The ESP32 is a feature rich MCU with integrated Wi-Fi and Bluetooth connectivity for a wide range of applications. ("I", 2021). It is robust and functions extremely reliably on all industrial environments. It can operate at temperatures ranging from –40 to +125 degrees Celsius. ESP32 can dynamically erase exterior circuit defects and respond to changes in the external environment thanks to improved calibration circuitry. Power consumption is extremely important for an AWS as it needs to operate from remote areas and constantly be up and running to provide real time data. Because the ESP32 is designed for mobile devices, wearable electronics, and IoT applications, it uses a mix of proprietary technology to achieve highly low power consumption. It also incorporates cutting-edge technologies like fine-grained clock gating, several power modes, and dynamic power scaling, all of which contribute to the goal of low power usage.

3.2 Sensor Compliance with the WMO

It was mandatory that the sensors used in the construction of the AWS was in comply with the requirements and specifications of the WMO standard. The following comparison was performed between the WMO specifications and high level sensors to prove accuracy of selected sensors:

Temperature Sensors

① DS18B20 Temperature Sensor Module KY-001
② NTC Temperature Sensor Module (MD0410)
③ LM35 Temperature Sensor (IC0140)
④ DHT22

Table 1. Comparison of Temperature Sensors

	WMO Requirement	①	②	③	④
Measurement Range	-20°C to +60°C	-10°C to +85°C	-20°C to +105°C	-55°C to +150°C	-40°C to +80°C
Resolution	0.1°C	0.5°C, 0.25°C, 0.125°C	0.125°C	0.01°C	0.1°C
Accuracy	±0.1°C	±0.5°C	±0.5°C	±0.5°C	±0.5°C

Humidity Sensors

Table 2. Comparison of Humidity Sensors

	WMO Requirement	HR202L Humidity Sensor Module	DHT22 Humidity Sensor
Measurement Range	0-100% RH	20-95% RH	20-95% RH
Accuracy	+1% RH	+5% RH	+4% RH
Operating Temp. Range	-40°C to +60°C	0°C to +60°C	0°C to +50°C

Pressure Sensors

① Digital Barometric Pressure Sensor Module 0-40KPa 3.3-5V Liquid/Air (MD0535)
② GY-65 BMP085 6-pin 3.3V Digital Barometric Pressure Sensor (MD0616)
③ MS554 MS5540-CM 10-1100mbar Digital Pressure Sensor Module 16bit DC
④ BMP/E 280

Table 3. Comparison of Pressure Sensors

	WMO Requirement	①	②	③	④
Measurement Range	500-1100hPa	0-40KPa	300-1100hPa	10-1100hPa	300-1100hPa
Operating Temp. Range	-40°C to +60°C		-40°C to +85°C	-40°C to +85°C	-40°C to +85°C
Total Accuracy	±0.25hPa		±1.0hPa	±0.5hPa	±0.12hPa
Resolution	0.10hPa		0.01hPa	0.01hPa	0.18hPa
Long Term Stability	±0.10hPa		±1.0hPa	±1.0hPa	±1.0hPa

According to the above comparisons, it was evident that with all the available sensors in the market, the chosen sensors were the best choice for the construction of the AWS of Node 1. The following are the chosen sensors in brief:

Temperature/Humidity Sensor - DHT22

Pressure/Altitude Sensor - BMP/E280

Furthermore, research papers were found to further prove the fact that the sensors chosen complied with the WMO standards and hence, is appropriate for the construction of the AWS. According to (Ioannou et al., 2021), after extensive research of WMO requirements, it was evident that The World Meteorological Organization (WMO) publishes papers that detail how to set up, install, and use various AWS stations. There are four (4) types of AWS, according to the WMO:

- AWS for a limited number of variables (air temperature and/or precipitation).
- Basic AWS for the collection of basic meteorological data (air temperature, precipitation, relative humidity, atmospheric pressure, wind speed and direction).
- AWS with extra solar radiation, sunshine duration, soil temperature, and evaporation measurements.
- AWS with visual observation automation (present weather and cloud base height)

All of the categories allow for the logging of data using a proprietary data logger as well as the transmission of data via a number of means. WMO also acknowledges another kind of weather station, dubbed Automatic Weather Station—Low Cost, in addition to the AWS classifications (AWS-LC). This sort of station is distinguished by its inexpensive cost of operation and procurement, as well as its low power consumption, real-time data transmission capabilities (with or without logging), and ultimately, its miniature and compact size. This was the type of weather station that was chosen to be implemented. Other than traditional stations, the AWS-LC offers a range of benefits. These benefits include the capacity to monitor data in sparse and rural regions, cost savings, reduced random mistakes, greater dependability, and measurement precision, among others.

The research also determined the most efficient sensor with the most accurate measurements), MCP9808 and BMP180, MCP9808 and DHT22, and BMP180 and DHT22 were separated into pairs, and the correlation between their measured levels and the regression between measured data were computed. Additionally, two-sided t-tests were used to see if there was a distinction between the 2 populations' means. Finally, the sensors' responses to maximum and lowest values, and the average measurement each day, were studied. In order to determine whether the measurements acquired from the BMP180, MCP9808, and DHT22 are quantitatively equal to the distribution of real values, it was determined whether the sensor readings were normally distributed (Oneway ANOVA); otherwise, a Kruskal–Wallis H-test was performed whenever the sensor values were not normally distributed. In addition, regression analysis was performed on each sensor to assess the association with the mercury thermometer. The results obtained depicted that the BMP180 and DHT22 sensor measures as compared to the values supplied by the MCP9808 sensor, values whose distribution more closely resembles the distribution of the real values (Ioannou et al., 2021). Therefore, it was concluded that the choice of BMP280 and DHT22 sensors were appropriate for the construction of the Node. The prototype was constructed using the selected sensors to test accuracies as follows:

Figure 3.1. Prototype Testing

3.3 Construction of Anemometer and Wind Vane

Due to the Anemometers and Wind Vanes available in the market being of extremely high cost, it was necessary that this was DIY constructed and tested to troubleshoot. Extensive research was carried out to implement the best Anemometer and Wind Vane as there is a wide range of types to choose from. The following is the research carried out:

The WMO does not specify any strict parameters and requirements for the construction of the Wind speed and direction sensors and further mentions that it may be able to supply some extremely low-cost, simple equipment that assist the observer in taking measurements at locations where traditional anemometers cannot be installed. Therefore, parameters were chosen using research that has already been done for reliable measurements. However, some guidelines mentioned in the WMO requirements,

- Arm connecting the cup to the rotation axis must not be longer than the diameter of the cup.
  This is due to the reason that near the starting threshold, for wind speeds of less than 4ms^{-1}, the calibration of cup anemometers can deviate substantially from linearity and therefore, it was necessary to avoid this occurrence.
- Multiple vane fins should preferably be parallel to the vane axis.
  This is because a vane with two fins at angles > 10° - This is to maintain an equilibrium position to obtain a satisfactory measurement.
- Height – 10m above ground level
  To avoid obstacles and, especially over rugged terrain (rough patch of land), wind speed increases dramatically with height.

3.3.1 Wind Vanes

According to the research performed, there were three types of Wind Vanes identified. Namely,

I. Vanes with a Potentiometer
II. Vanes with a Selsyn Motor System
III. Vanes with an Optical Pulse Encoder

Vanes with potentiometers offer disadvantages such as Sliding contactors wear quite rapidly, Torque of the receiver to move the indicator pointer is miniature, the distance between the vane and the indicating device greatly affects the electrical resistance of the cables between the potentiometer and the receiver, and in case the connection of the three cable leads is not tight, large wind-direction errors may appear.

If the position of the transmitter's rotor does not correspond to that of the receiver, the voltage induced in each of the transmitter's three windings does not correspond to that in each of the receiver's three windings. Consequently, a current flow's, producing torque, causing the receiver's angle to match the transmitter's spin. The transmitter is also subjected to the same torque, but it is restricted by wind pressure. As a result, the receiver's axis, which has a very light pointer, spins until it matches the angle of the transmitter. According to all the above, it was concluded that the Vane with an Optical Pulse Encoder was the best choice for the implementation due to the following advantages it offers:

- Zero contacting parts and therefore, Free of mechanical friction
- It is possible to attain superior reaction characteristics by making the unit tiny and light.
  Because the output may be handled as digital signals, it's better for data processing using a computer.

the Wind Vane was designed using the 3D AUTOCAD software and the following design was used:

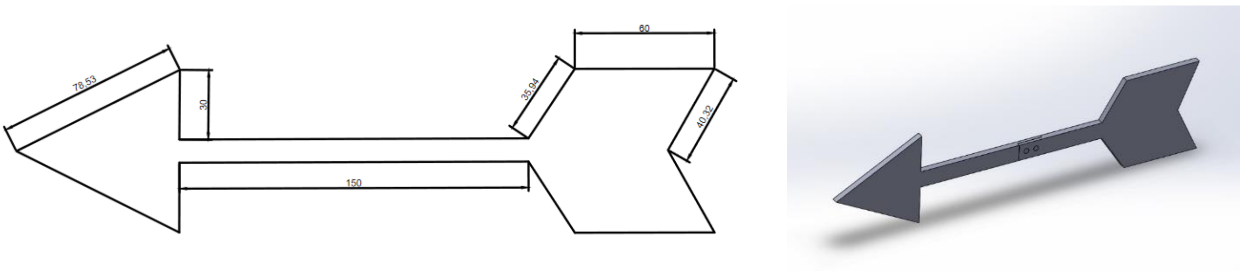


Figure 3.2. 3D Design of Implemented Wind Vane

The Wind Vane was printed in 2 parts so that mounting and locating the center of gravity would be much easier. The 3D printed Wind Vane is as follows,

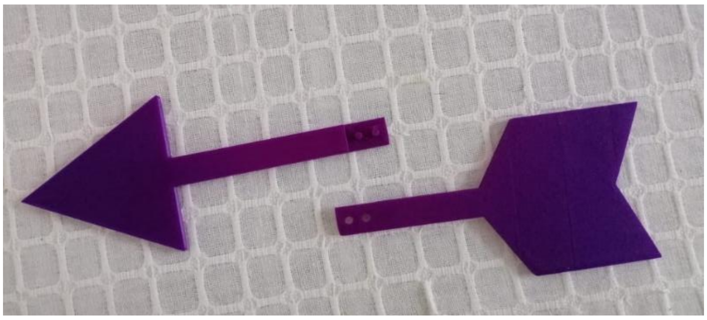


Figure 3.3. Implemented Wind Vane

3.3.2 Anemometers

Just as Wind Vanes, there exists two types of Anemometers namely the 3-Cup Anemometer and the Propeller Anemometer. However, the 3-Cup Anemometer is the better choice for the construction of the AWS for the following reasons:

- Propeller anemometers are unable to respond to rapid changes in wind direction.
- Such delayed response to these changes significantly makes wind speed observation erroneous.
- The propeller axis faced the airflow directly faster as the wind speed increased. The response will be delayed, and wind speed cannot be measured accurately if the wind direction changes within the time the propeller axis takes to face the wind direction directly. (This can be avoided by reducing the amplitude and having a short oscillation period).

The 3-cup Anemometer works on the concept that the cup's revolution speed is proportionate to the wind speed. Three cups are symmetrically positioned around a freewheeling vertical axis in the cup anemometer. The cup turns in the direction of the concave side to the concave side of the following cup due to the difference in wind pressure between the concave and convex sides. Regardless of wind direction, the revolution speed is always proportional to the wind speed. According to the principles used, the types of 3-Cup Anemometers are as follows:

- Generator Type Cup Anemometer
- Pulse Generator Type Cup Anemometer
- Mechanical Type Cup Anemometer

Counting the number of cup rotations is a much simpler way for measuring wind speed using a cup anemometer utilizing the Mechanical Type cup. Through gears attached to the sensor axis, a mechanical-type cup anemometer indicates the number of cup revolutions. This kind has the advantages of not requiring a power source, having a simple design and construction, and not requiring a power supply. The necessity to travel outdoors to acquire readings can be removed, as opposed to alternative choices with a reed-relay immediately attached to the counter. Therefore, considering all the above conditions and requirements the parameters and design of the Anemometer was decided to be of type 3-Cup Anemometer and the dimensions according to the analysis and requirements with a Diameter of 8cm, Radius 4cm, and Axis length of 10cm.

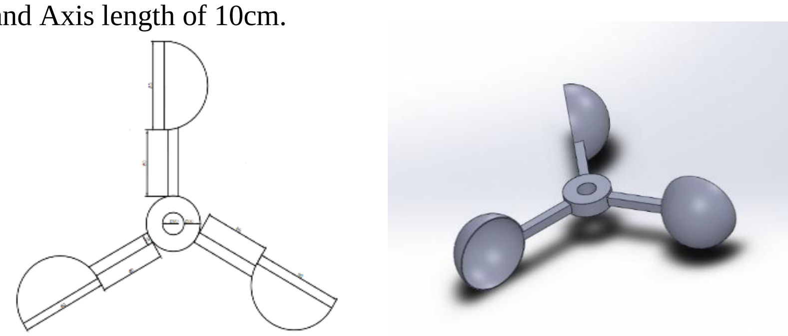


Figure 3.4. 3D designed Anemometer

Therefore, the following 3-Cup Anemometer was printed as 3D as follows:

Figure 3.5. Implemented Anemometer

3.3.3 Construction of Node

The body of the node was designed to be made of Aluminum due to it being an extremely versatile material with numerous advantages such as,

- Light in weight and highly robust therefore, installation, inspection and replacing will be easy and convenient.
- Strong therefore, ability to endure rough weathers.
- Corrosion Resistant to avoid corrosion during adverse weather conditions and during constant exposure to air and rain.
- Durability and longevity.
- Infinitely Recyclability and therefore, eco-friendly.
- Lower Energy costs and carbon emissions also eco-friendly.
- Reflects up to 95% of sunlight which protects the hardware, sensors and does not cause erroneous predictions.

With having considered all the above-mentioned advantages, an Aluminum body was designed consisting of a tripod at the bottom to hold up and balance the node. Furthermore, an Aluminum plate was used to keep the body straight and a Damping mat composite to make the surface even when fixing the Wind Vane and Anemometer to the horizontal plane of the body.

The following is the body of the node designed (Apart from the radiation box),

Figure 3.6. Implemented Body of Node 1

The implementation of the Final Hardware was decided to consist of the body of the node along with an enclosed project box to contain the sensors and microcontroller to protect them from radiation and rainwater. All sections of the electronic and data processing unit must be encased in a sealed sturdy container with simple access to all components and mounting options at least to a mast or a wall, according to WMO regulations. The following items must be included in the enclosure:

- All connections must be through waterproof connectors, one connector for each sensor or device.
- All connectors must be clearly labelled as to their function.
- To decrease the chance of water or humidity penetration, the connections must be positioned on the enclosure's bottom side.
- The enclosure should be thoroughly ventilated using a system that prevents dampness from entering.

4 DATA TRANSMISSION

The Web server was able to be viewed through the web server by simply copying the IP address displayed on the serial monitor onto the URL of any web browser. However, the issue with this implementation was that clients around the world did not have the ability to access the web server other than a client accessing it through the local network (Wi-Fi) having the same IP address as the host. Therefore, this issue needed to be resolved as well.

However, it was vital to be able to connect to the web server from anywhere on the planet. The web server may be accessed using a third-party service that will transport the ESP32 IP address from the local area network to the internet. This way, anybody from any location will have the ability to access the sensor readings obtained. To serve this purpose, 'ngrok' service was used. ngrok is a cross-platform program that allows developers to conveniently expose a local development server to the Internet. The program lets the locally hosted web server seem to be hosted on a ngrok.com subdomain, removing the need for a public IP address or domain name on the local system ("ngrok and Cross-Platform Development", 2022). It allows to expose a web server running on one's local machine, to the internet. ngrok provides a real-time web UI where one can introspect all HTTP traffic running over tunnels. However, ngrok only works using any port number other than port 80. Due to this reason, port number 8888 was used in the code. Next, it was necessary to create a ngrok account and obtain an 'Authtoken' to access the tunnel.

The following Authtoken was obtained after the registration to the service, *1wnpCCNUNBemSGaRZ2VWTN7CYD2_48eFgzGwkukxKvz1EE9Lv*

This tunnel authtoken was necessary for the next step of the procedure. The downloaded ngrok software was run on windows and the following command was necessary to be entered, (This included the IP Address of the local network and the authtoken)

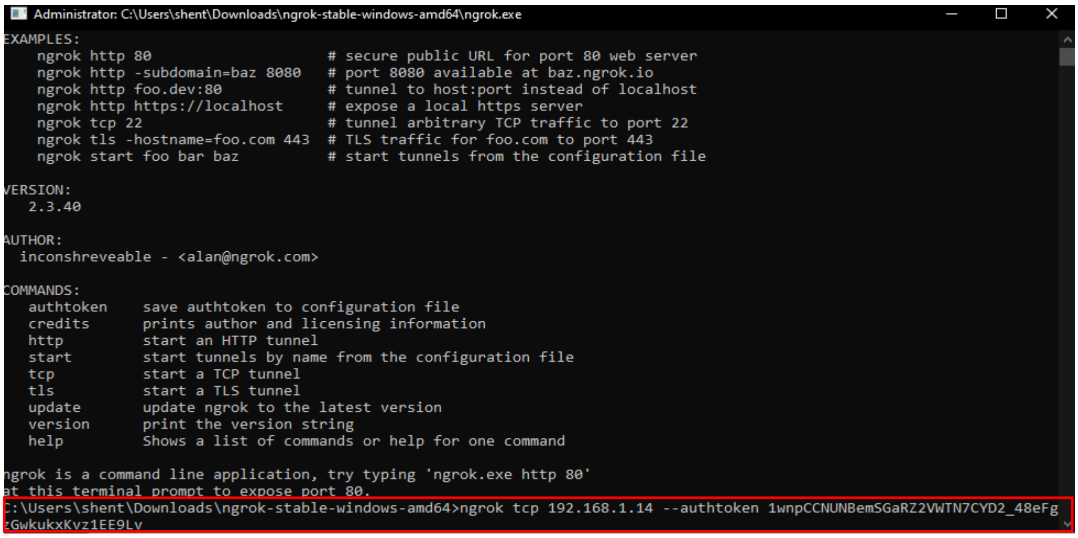
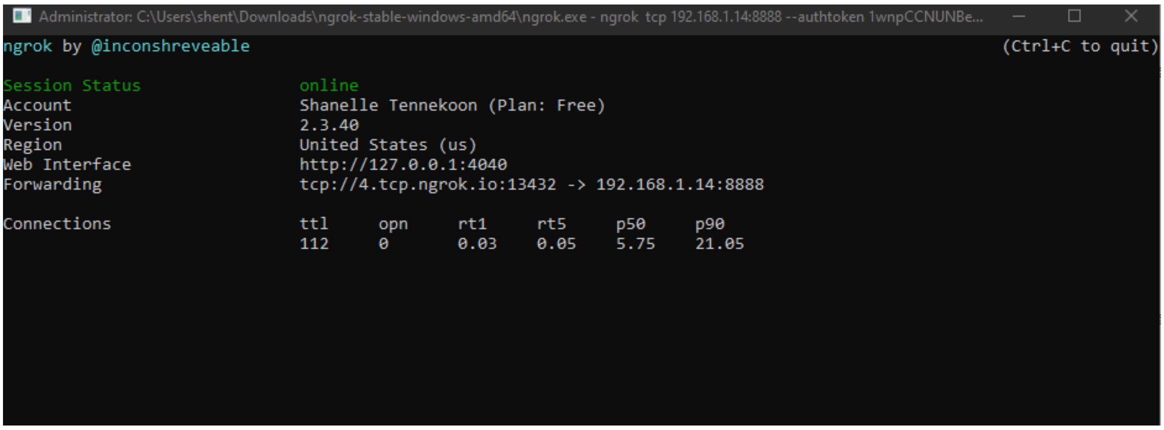


Figure 4.1. Accessing ngrok Service

Next the preceding step, the following window displays the tunnel URL, as seen in the image. Instead of using an IP address, this URL was utilized to reach the web server. The URL obtained in the next window had to be taken note of to access the web server. Anyone could access the web server from anywhere in the world using this URL. If the URL is of TCP type tcp://0.tcp.ngrok.io:**** the tcp can be replaced with HTTP and enter the URL in any web browser and be able to access the web server



from anywhere across the globe. The following was the URL obtained at a certain instance,

Figure 4.2: Obtaining URL from ngrok

The URL was of type TCP. Therefore, the following URL was used to access the web server from any location without using the IP Address directly, http://4.tcp.ngrok.io.13432

However, it was necessary that the ESP32 was active, up and running during the time of obtaining the URL. And it was necessary that this procedure was followed every time the microcontroller was turned off and restarted. Thereafter, a few changes to the code were made in order to change the structure and design of the web server and the following web server was observed from different locations of the country using the URL obtained via ngrok. The following are a few instances as such,

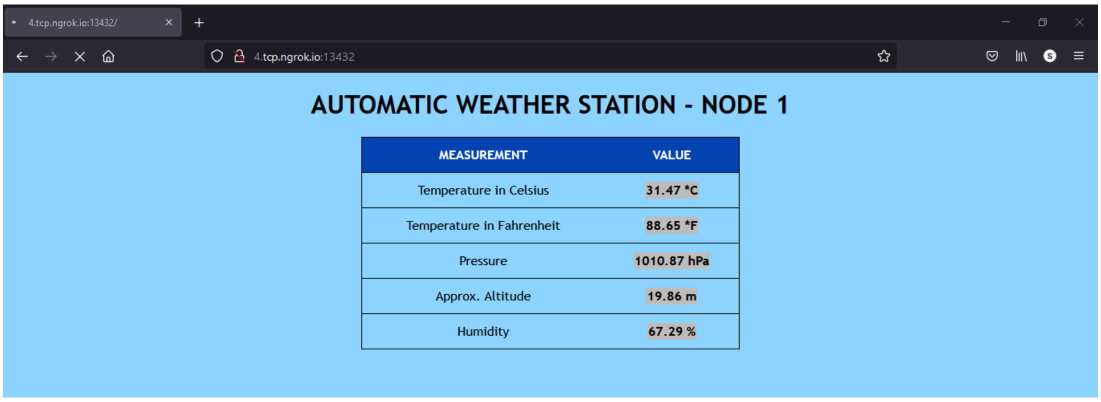


Figure 4.3. Web Server Desktop View

The above figure depicts the web server that was observed when accessing through the desktop. In both instances, the URL used to access the web server was now not just the IP address of the local network but of type, http://4.tcp.ngrok.io.13432

In the setup(), a serial communication must be started at a baud rate of 115200 for debugging purposes. (Any other baud rate would not satisfy the purpose). The Wi-Fi connection was established with WiFi.begin(ssid, password) with the SSID and the Password of the local network provided. It was necessary to wait for a successful connection and print the ESP IP address in the Serial Monitor.

In addition to this a mobile app was developed to showcase the data obtained from the sensors. The 'Blynk' app on the app store and the Blynk Library is an add-on that runs on top of the hardware application that has been installed. This is where the data exchange and connection routines between the implemented hardware, Blynk Cloud, and the developed app project are handled. An authtoken was obtained to connect to the Blynk cloud. The Blynk software is an extremely simple software that allows app designing extremely convenient. The ESP32 was connected to the PC via USB cable. The code implemented was uploaded and thereafter, was connected to the Blynk software.

Figure 4.4. Weather App on Phone using Blynk

5 DISCUSSION

It was identified that the design was implemented successfully adhering to the WMO guidelines and accuracies of sensors. The prototype results proved accuracies of sensors and the extensive research performed prior to the construction of the Anemometer and Wind Vane were of success. Another primary objective of the design was adhering to a low cost. To achieve this, the Budget was planned accordingly from initial stages and the budget of the design is as follows:

Table 4. Budget of Design

COMPONENT		NO OF UNITS	COST (LKR)
Sensors	Temperature – DHT11	1	375.00
	Pressure – BMP/E280	1	180.00
	Raindrop Module – YL-83 FC-37	1	160.00
	Light Intensity – BH1750	1	325.00
16*2 LCD Screen		1	440.00
Wind Anemometer		1	2100.00
Wind Vane		1	550.00
ESP32 Microcontroller		1	3250.00
Wires & Others		-	1000.00
Station Body		1	12,000.00
		TOTAL	**20,380.00**

A total of Rs. 20,380/= has been spent for the construction of node 1 of the AWS. The design has suited the category of weather stations specified by the WMO as an AWS-LC which is a Low-Cost weather station. The goal of this is to spend a lesser amount than the currently available weather stations in the market and achieve a higher accuracy of predictions. A high accuracy weather station available in the market would approximately cost around LKR 150,000.00/= which is an extremely costly price. However, with the Low-cost AWS, compromising only ±0.5 accuracy of sensors, it was able to achieve a better market value of just Rs. 20,380.00/= proving that it is possible to perform accurate predictions with low-cost weather stations deployed.

6 CONCLUSION

The primary constraint and requirement of this design is high accuracy and cost efficiency. Furthermore, adhering strictly to WMO guidelines to design an accepted product with the ability to be put up for the market was also looked into comprehensively. The WMO mentioned that the construction of the AWS had several types and therefore, according to the scope and Budget of this project the Automatic Weather Station Low-Cost type (AWS-LC) was chosen and implemented successfully.

Another important aspect was that since Sri Lanka is still a developing country, the need for data transmission using wireless means in the absence of wi-fi was necessary and therefore, was proposed to achieve by utilizing an active SIM card with an active data plan so that this design project would be a product that can be used extensively in all areas of Sri Lanka. The mobile app to be developed is also designed to be accessed by anyone with any level of technology knowledge and therefore, can be used by farmers, fishermen, etc. The ESP32 was used to successfully achieve this task as well. Furthermore, ngrok service was used to tunnel network traffic, thereby allowing anyone from around the world to access the data read from the sensors and depicted on the web server. Furthermore, the android app 'Blynk' was utilized to implement a Mobile Interface to access real time data read from the sensors. The results were observed and compared with already existing weather apps such as AcuWeather. It was observed that the weather parameters measured were in accordance with the weather platform readings.

Next, the implementation of the completed AWS (The Body), mobile app, research on pushing and thereafter accessing data from the cloud, central processing device and the predictions were completed. It was tested using equipment if the sensors depicted accurate data. For example, when a hairdryer was held onto the sensors with known temperature, the Web Server depicted a high temperature value that was in accordance with the temperature value set on the hairdryer. Furthermore, known values were used to compare with the obtained values form the sensors used in the Node.

In conclusion it can be stated that the project was of success and every objective that was planned at the initial stage of the project was completed and therefore, is a success. When considering the implemented AWS in terms of accuracy and cost efficiency, it can be stated that the product is extremely reliable, cost efficient in comparison to the already existing products in the market and was successfully completed adhering to all requirements and specifications set forth by the WMO and the MET Department.

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