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# A Study on Building Cost-Effective Solutions Utilizing Automatic Weather Stations (AWS) Data to Investigate Smart Irrigation System Design Issues with Iot

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**ABSTRACT**

**People have been able to see the weather change since ancient times. But modern weather devices weren't made until the 1400s. Automated observational systems are becoming more and more significant in the age of the Internet of Things because they provide researchers the real-time data they need to create and carry out good environmental policies. This project aims to create affordable solutions by using AWS data to solve design problems in smart irrigation systems. The suggested system uses inexpensive sensors, an Arduino Uno microcontroller, and GSM communication modules to keep an eye on real-time environmental factors including temperature, humidity, rainfall, wind speed, and air pressure. The data that was gathered is analysed and sent to users, which lets them make quick decisions about irrigation and crop management. The system uses solar energy and cheap hardware parts to make sure that it is both energy-efficient and cost-effective, especially in areas that are rural or have limited resources. AWS systems that use the Internet of Things (IoT) may boost farming output, lower the hazards to crops, and use less water, all while keeping prices low.**

**Keywords: Smart weather station, Sensor, Cost, Agricultural,**

## INTRODUCTION

Ancient Greeks were the first to examine weather phenomena in an effort to foretell future weather patterns. Meteorologica was an effort by Aristotle to provide a philosophical and speculative explanation for meteorological occurrences. Nonetheless, the earliest thermometer, barometer, and hygrometer (for measuring humidity) were all developed at the close of the seventeenth century.

These devices were introduced in 1643 and 1670, respectively. Accurate and trustworthy weather prediction became possible with the proliferation of measuring devices. The transmission of weather observations became possible with the introduction of the telegraph in 1843. In 1950, we made even more progress when we used computers to solve complicated mathematical equations that described the behaviour of the atmosphere. We also used Doppler radars, which allowed us to see what was happening within intense thunderstorms.

Instructions for the collection of meteorological data, including measurements and data transmission between Meteorological Services, were published at a series of International Meteorological Conferences that began in 1873. Further instructions for using this data for research, forecasting, and mapping purposes were published. With the primary objective of enhancing cooperation between national meteorological agencies, the International Meteorological Organization was established in 1878. By 1950, it had changed its name to the World Meteorological Organization.

Over the years, the research community and agencies have had access to a variety of methods and observing systems, including aeronautical, marine, aircraft-based, and terrestrial ones. The World Meteorological Organization (WMO) is responsible for both the usage and the guidelines for collecting these measured data. Automatic Weather Stations (AWS) and data collection from networks through different communication routes are also of interest to the World Meteorological Organization (WMO). The World Meteorological Organization has published guidelines and publications that analytically define the work of installing and operating AWS.

In the eyes of the World Meteorological Organization, an automated weather station (AWS) is one that automatically records and transmits weather data. An AWS is utilised to augment the quantity and accuracy of surface observations. There are four distinct types of AWS, according per WMO:

- In order to measure a small number of variables, such as air temperature and precipitation, a light AWS is required.
- The most fundamental AWS for measuring air temperature, humidity, wind speed and direction, precipitation, and atmospheric pressure.
- Additional solar radiation, sunshine duration, soil temperature, and evaporation metrics are measured by the extended AWS.
- Visual observations (such as cloud base height and current weather) can be automated by using AWS.

Data logging using a proprietary logger and data transmission via a number of techniques are capabilities provided by all the categories. In addition to the automatic weather stations listed above, the World Meteorological Organization also recognises a subset of these stations known as Automatic Weather Station—Low Cost (AWS-LC). Among the many distinguishing features of this sort of station are its tiny and compact form, its capacity for real-time data transmission (with or without logging), its low power consumption, and its cheap usage and purchase costs. Unfortunately, the data quality becomes uncertain due to their consumer market emphasis and the use of electronics and sensors made by suppliers without considerable expertise in meteorological observations. What's more, AWS-LC stations are not currently standardised.

Typically, WMO acknowledges three distinct kinds of AWS-LC: Compact, All in One, and Stand-Alone. The most basic models, the Compact and the All in One, are designed for amateurs who just wish to collect local meteorological data. Both of these kinds can transfer little amounts of data locally on occasion, but they can't usually record anything. The third category, "Stand-Alone instruments," makes use of a network of standalone smart devices that communicate with one another and with central processing servers using Wi-Fi and Bluetooth, despite the devices' relatively modest power consumption and bandwidth requirements. Optimal placement and equipment selection are hallmarks of this category of weather stations. When deploying several instruments, star topology is the most typical pattern to employ. Here, a central hub connects all hosts (or, in the case of AWS-LC, all measurement devices). There is a central point that stores and transmits the communications.

The use of AWS and AWS-LC systems has several benefits over the more conventional manned stations. These include, but are not limited to, the following: reduced costs, higher dependability, improved measurement precision, less random mistakes, and the ability to monitor data in sparse and rural regions. It is important to weigh the benefits of these kinds of weather stations against their potential drawbacks before installing them. Installing the system can be a challenge, and there have been instances when expert meteorologists have disagreed on how to automatically interpret the data (particularly when it comes to precipitation, cloud cover, and cloud base), in addition to transmission costs and other issues.

**KEY COMPONENTS OF AN AUTOMATIC WEATHER MONITORING SYSTEM**

Automated weather stations, at its most fundamental, collect data on the weather and send it to a computer, forecaster, or screen. To measure the surface weather measurements that were discussed before, they employ specialised devices. A barometer and a thermometer are two components of a weather station that work together to provide accurate readings of the surrounding air pressure and temperature. In the weather sensor section below, we detail all the components and their functions, so be sure to read on!

The components of a station might vary in number and kind depending on the manufacturer and model. The weather station can collect and relay a variety of atmospheric data thanks to each of its components. The following items are often seen in automated weather stations:

**1. Weather Sensor**

"Weather sensor" may seem vague, but in reality, the vast majority of these devices only detect the direction and speed of the wind. The anemometer is the component of a weather station that records the rate of wind. It is the wind vane's job to determine which way the wind is blowing. Our weather stations monitor both pressure and wind speed and direction using the same device, a vane anemometer. An integral component of every weather station is the wind speed and direction sensor, which provides valuable insight into the path and timing of impending weather systems.

**2. Lightning Sensor**

An automated weather station's lightning sensor is the next component. Any good weather station will have a lightning sensor; however, they aren't required. This is because one of the most important safety tools are lightning sensors. To avoid missing a lightning strike, equip your automated weather station with a complete lightning sensor. To gauge the severity of a storm, you need total lightning, which is defined as lightning that hits both within and outside the cloud. Tornadoes, hail, and downbursts are only some of the extreme weathers that may be predicted by looking for storm cells that exhibit high frequencies of in-cloud lightning.

The lightning detectors are really cylindrical devices with a circuit board inside. Total lightning sensors connected to a wider lightning network provide the most accurate lightning warnings. Reduced occurrences of false alarms and missed triggers are observed when these sensors are linked to a whole lightning network. In order to assess the intensity of a storm, send out potentially life-saving lightning notifications, and pinpoint specific lightning strikes, we employ network-based lightning detection.

**3. Sensor Shelter**

The sensor shelter is an additional part of the weather sensor. Surprisingly, there are a lot of instruments used in this piece, even though it seems like it's only protecting automated weather stations. The following pieces of hardware are housed in the sensor shelter, which is used by automated weather stations:

- Temperature with thermometers
- Relative humidity with hygrometers
- Dew point with hygrometers
- Barometric pressure with barometers
- Heat index with thermometers and hygrometers (Heat index = temperature + humidity)
- Wind chill with thermometers and anemometers (Wind chill is the cooling wind velocity brings to a given temperature)
- Wet bulb globe temperature with hygrometers, thermometers, pyranometers, and anemometers (WBGT = humidity + temperature + solar radiation + wind speed + sun angle)

**4. Rain Gauge**

After the sun sensor, a rain gauge is an essential and straightforward component of every automated weather station. The liquid-equivalent precipitation is measured by rain gauges. A rain gauge resembles a broad, upright cylinder or a bucket in appearance. You may find out how much precipitation has fallen in a specific time frame from weather stations that feature rain gauges. At Earth Networks, our automated weather stations have rain gauges that can inform you:

- Daily rainfall total
- Daily rainfall average
- Weekly rainfall total
- Weekly rainfall average
- Yearly rainfall total
- Yearly rainfall average

**5. Data-Logger/Network Appliance**

Information recorders and networking devices are two complementary parts of automated weather stations. There is an automatic, sequential procedure that these systems follow together. It all starts with them taking readings from your sensors. They proceed to store and process the data. At last, the data is sent to various devices and services via the network appliance, such as your weather display, applications, and warnings. In the event of a power outage, it is wise to seek for weather stations that include network equipment with long-lasting batteries. To make sure you never lose the data you pay for, our network appliances have a backup battery life of 72 hours and reboot themselves automatically when necessary.

**6. Weather Display**

A display is a standard feature on most weather stations. Many weather stations, even those that weather aficionados keep in their homes, have some kind of digital display. Automated weather stations designed for professionals usually have even more powerful screens. For instance, our commercial-grade weather station may be linked to an HD screen that provides a comprehensive view of the weather, including both the present and the prediction for the next seven days. With online weather centers, you may get the latest forecasts from any location. The integration of real-time video, historical data, predictions, and observations makes these extremely useful.

**7. Weather Camera**

A weather camera is the final piece of equipment needed for a weather station. You won't find a weather camera at every weather station. On the other hand, weather cameras are a great asset since they provide real-time footage and bring people together. Some individuals choose to keep their camera feeds private, while others choose to share them with local news outlets.

## REVIEW OF LITERATURE

Gamal, Yomna et al., (2023) A number of nations are banding together to streamline agricultural processes by integrating cutting-edge technological tools. Therefore, the future of sustainable agricultural output depends on making irrigation more efficient. With the advent of wireless communication systems, monitoring devices, and improved control techniques for optimal irrigation scheduling, smart irrigation approaches have the potential to significantly improve irrigation efficiency. In order to examine scientific methods for smart irrigation, the study contrasted on several study subjects. Therefore, this project covered a lot of ground in terms of irrigation techniques, decisionmaking, and technology. A number of scholarly articles were used for this data set. As a result, we drew on a number of published papers for our study; these documents were mostly written by writers from around the globe and published during the previous four years. During this time, we focused on a number of irrigation projects. Smart sensing, energy harvesting, internet connectivity, real-time irrigation scheduling, and the internet of things (IoT) are the next main points of the review.

Vieira Rocha, Jampierre et al., (2022) The practice of irrigation allows agricultural borders to be expanded and production to be increased. In order to keep plants from wasting water, this approach needs careful supervision, which in turn raises operational expenses due to the need for specialised labour. Consequently, this study's primary goal is to develop and test an automated irrigation system that takes into account variables such as water consumption and performance. A simple, inexpensive weather station was created to collect data every day as crop evapotranspiration is the main factor that determines the water demand. Using the FAO's Penman-Monteith model, this data may be utilised to determine the reference evapotranspiration (ET0). Soil and irrigation system hydraulic characteristics, together with crop water needs, allowed us to calculate the number of days and hours the system needed to run in order to supply enough water to the crop without stressing it out due to a lack or surplus of water. A web-based application was developed and deployed as part of the management/monitoring system to enable users' remote access to data. Without the user having to physically be present at the crop site, this program allows for the real-time transfer of data connected to irrigation, including weather station data and system logs. This enables the cost-effective observation of several locations at once.

Hippargi, Miss & Patkar, Uday. (2022) The constituents of the observational system and the uses of the widely inaugurated AWS and PGMIS in the meteorological system are covered in this study. Our quick review of the current technologies for automatic lookouts and grid meteorological information systems concludes with a focus on the technical levels and control issues. The automated lookout is directed by a computer or other electronic gadget to monitor the weather and send back data. A sensor, a transmitter, a processing device, a data transmission device, and a power source are the components that make up AWS. A processing device takes the electrical signals received from the transmitter and turns them into the correct meteorological elements based on the weather parameters measured by the sensors. The term "Grid Meteorological Information System" (PGMIS) is short for "Grid Meteorological Comprehensive Platform," which is a system that combines weather data with grid production and operation and is used by grid corporations at the lowest level. For grid operations such as monitoring, tracing, forecasting, and warning of catastrophic weather, as well as for load forecasting, the system delivers complete and up-to-date meteorological data.

Ioannou, Konstantinos et al., (2021) Gathering data on weather and climate is a common task for Automatic Weather Stations (AWS). Publications from the World Meteorological Organization (WMO) include instructions for setting up and using these stations. More and more, in this age of the Internet of Things, scientists require real-time data from automated observation systems in order to formulate and execute effective environmental policies. The present technologies utilised to establish Automatic Weather Stations are thoroughly examined in this article. We also detail how future AWS-based observation systems will make use of cutting-edge developing technologies like the IoT, edge computing, deep learning, LPWAN, and more. Lastly, we showcase a case study and findings from our research team's AWS testbed, project AgroComp. Included in the findings are forecasts given by locally running Deep Learning algorithms as well as test readings from inexpensive sensors that were mounted on the device.

Dunaieva, Ielizaveta et al., (2021) The purpose and operation of automated weather stations as they pertain to farming are discussed in this article. Through the acquisition and accumulation of data on the continuing technical processes and the development of suitable management choices, digitalisation in agriculture has the potential to greatly enhance production efficiency while decreasing product manufacturing costs. Operational data on soil moisture reserves, current weather, etc., may be obtained in real time, which plays a significant role. Data useful for controlling and monitoring activities can be obtained through the use of automated meteorological stations. This article takes a look at the Meteobot® Pro, Davis Vantage Pro 2, and Sokol-M weather stations in the Krasnogvardeisky, Belogorsky, and Saky districts, as well as their applications and operations in agriculture. Weather station setups, sensor installation techniques, measurement precision, and other factors are examined. The data collected from the weather stations in the WMO network was used to compare with the measured data. We take into account the potential for automated weather stations to be used more often for agricultural monitoring.

Abdul-Niby, Mohammed et al., (2017) This study introduces an embedded system-based automated weather station that continually observes a number of meteorological variables, including humidity, temperature, barometric pressure, wind speed, wind direction, and rainfall, enabling both real-time and localised readings. There are two wirelessly linked sections to this weather station: one inside and one outside. Weather conditions such as present temperature, humidity, wind speed and direction, barometric pressure, and amount of precipitation in the past few hours are recorded by the outside weather station. A graphical liquid crystal display shows the outdoor reading in addition to the room's temperature and humidity at the inside station. Blynk, an app for both iOS and Android, also makes it possible to obtain this weather data from anywhere.

Kuśmierek-Tomaszewska, Renata et al., (2012) The best way to regulate plant water needs is to take continuous, standardised readings of the weather from as many locations as feasible. A rise in both the quantity and convenience of access to records made available by automated measures makes this a reality. Automatic stations collect a lot of data, yet they deviate from the established norms more than regular stations. Particularly relevant here are issues of instrument comparability and, to a lesser degree, measurement time. Similarly, there are additional variations, such as data processing processes, which increases the possibility of non-standard findings. The findings of agrometeorological indices, mostly derived from precipitation measurements, provide the basis of the observations of plant water requirements. During the growing season (April to September), this research compared the selected agrometeorological indices (precipitation, reference evapotranspiration, climatic water balance, and standardised precipitation index) measured or calculated at standard and automatic weather stations. It also aimed to verify whether the data from the automated stations could be used without any changes. Information gathered in the Kuyavia area of central Poland between the years 2000 and 2004 was used in the study. Investigations centred on how the two sets of data interacted with one another. An integral part of the research was looking for methods to modify the system to use typical 10-day growing season data. In spite of the fact that the two stations' measured outcomes were different from one another, the high correlation coefficients between them made it possible to create mathematical formulae that would eventually lead to the replacement of manual records with automated data series.

## MATERIALS AND METHODS

A low-cost, smart weather monitoring and real-time alarm system that can be automated, controlled, and monitored from anywhere in the globe with cellular connection was the purpose of this project's design prototype. The smart weather station communicated measurements of several meteorological parameters to a user over a GSM network in real-time. Hardware and software were the two primary necessities for this system. The hardware required was a GSM900A module, sensors, an I2C liquid crystal display, and an Arduino Uno microcontroller. The software requirements included Altium Designer and Arduino Uno.

In order to detect humidity and temperature, traditional weather monitoring systems rely on hydrometers and thermometers. A DHT11 sensor was utilised to ascertain the relative humidity and temperature in this setup. Since just one sensor could have measured both parameters, it was economical. The FC37 rain drop sensor was employed to ascertain the presence or absence of precipitation. This rain sensor eliminates the need to use a tipping bucket. This device made use of a low-cost anemometer and wind vane that were created utilising cheaper materials, as opposed to the commercially available, extremely expensive alternatives.

An intelligent weather monitoring and alarm system, the Arduino Uno was its central component. All the weather parameters sensors namely temperature and humidity sensor, pressure sensor, rain sensor, real time and clock sensor, light sensor, CO2 sensor, anemometer and Wind direction detector were connected to arduino uno and programme was created using Arduino IDE. In Fig. 1, you can see the sensors attached to the Arduino Uno board. In order to show weather data in the field, sensors collected data according to the software and delivered it to an I2C liquid crystal display. It was transmitted to GSM-900A at the same time. One can receive weather updates on their mobile phone by sending a "STATE" message to a GSM module, should the need arise. Figure 2 displays the system's block diagram. This approach of monitoring meteorological data was entirely automated, so there is no room for human error.

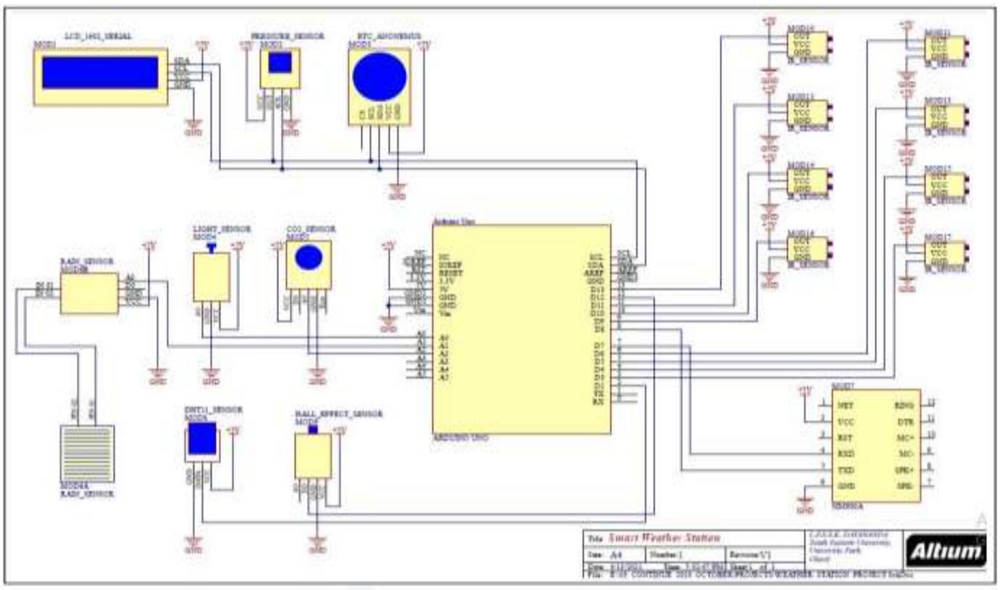


**Figure 1: Circuit diagram of the system**

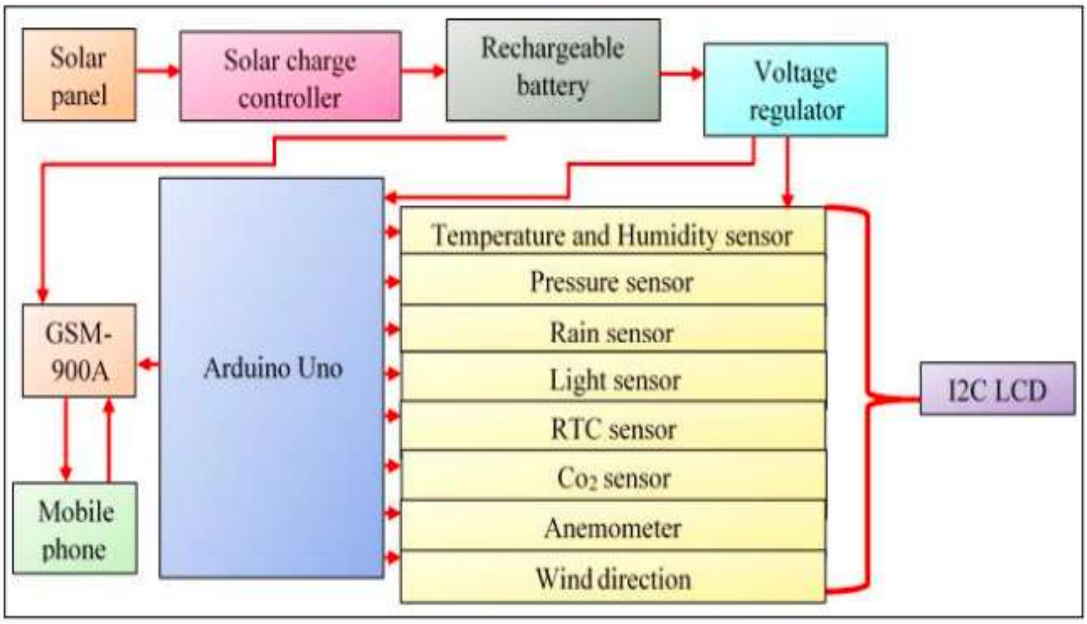


**Figure 2: Block diagram of the system**

## RESULTS AND DISCUSSION

Environmental factors like temperature, humidity, light intensity, precipitation, pressure, carbon dioxide level, wind speed, and direction can be tracked by this system. The developed system analyses environmental parameters more adaptively and distributively. The power unit, the sensing unit, and the output unit were the three primary components of this system.

In this setup, a 10W solar panel was utilised. Under intense light, it captured 21.2 volts. The solar charge management unit in the system received this 21.2V. The solar charge controller reduced the voltage from 21.2V to 14V. A voltage regulator was utilised to convert the 12V rechargeable battery into 5V from the 14V utilised to charge it. Figure 3 is a schematic of the power unit. The Arduino Uno microcontroller, every sensor (with the exception of the BMP180), the LCD, and the GSM-900A all received 5V power. The microcontroller known as an Arduino Uno was the central element of this setup. All of the sensors were connected to the Arduino microcontroller, which required 5V to operate. The Arduino Uno was programmed using the Arduino software. In order to detect the humidity and temperature, a DHT11 sensor was used. The DHT11 sensor received 5V via a voltage regulator.

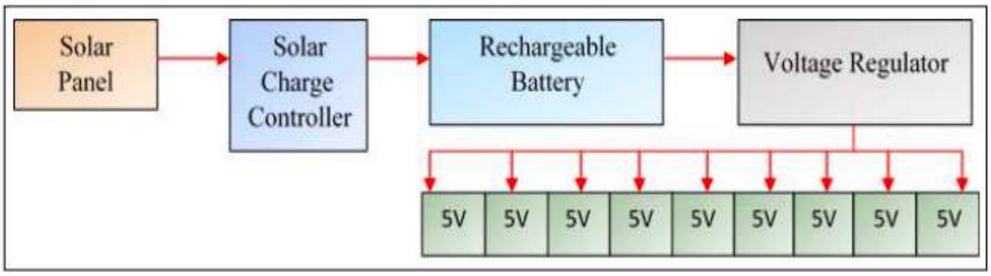


**Figure 3: Power unit of the system**

Since the BMP 180 sensor's working voltage is 3.3V, it was utilised to measure atmospheric pressure and fed with 3.3V via Arduino. Rain was detected using the FC37 sensor. In the program, three different circumstances were utilised for rain sensors. There were three requirements: "RAIN," "RAIN WARNING," and "NOT RAIN." Data on rainfall was detected by a rain sensor using values encoded in the code. Within that range, a value of 0 indicated that the rain was falling, a value of 1 meant that a rain warning was being shown, and a value of 3 meant that it was not raining. The level of illumination was measured using a light sensor. In it was a resistor that depended on sunlight. The light's intensity was detected by that LDR. A voltage regulator provided 5V as the operating voltage. A total of five states—"VERY BRIGHT," "BRIGHT," "LIGHT," and "DARK"—were input into the LDR sensor software. Under these circumstances, five analogue values were provided, and the LDR sensor's output was determined by these values. The MG811 CO2 sensor was used to measure atmospheric CO2 levels, and it was powered by a voltage regulator that delivered 5V to the sensor. We employed a real-time clock sensor to get weather reports as they happened. A voltage regulator supplied 5V for this.

The wind speed was measured using an anemometer. A combination of a cup anemometer and a Hall Effect sensor allowed for the detection of wind speed in this system. An anemometer measures wind speed by sensing the rotation of three cups, which are then translated to kilometres per hour. The direction of the wind was determined using a wind vane. The eight-direction Wind vane was equipped with eight infrared sensors. Due to the use of less expensive materials, both the anemometer and the wind direction sensor are incredibly inexpensive. The code created in the Arduino IDE was used to control all of these sensors.

The output unit was equipped with a GSM-900A and an I2C liquid crystal display. The system's output unit is seen in Figure 4. The weather data was shown on an LCD in the field. The system made use of a 16x2 LCD, however connecting the board to the Arduino proved to be a challenge. The I2C module was utilised to decrease the number of pins from 16 to 4. It was installed close to the weather station, so anyone visiting the field can quickly see the current weather conditions. In this system, GSM was utilised to provide weather data to the user. Transmitting mobile voice and data services is made possible using the open-source Global System for Mobile Communications (GSM) wireless cellular infrastructure. Due of its low power consumption, GSM 900A was utilised in this system. 5V was supplied to the Arduino board by a voltage regulator, and a regular Mobitel SIM card was placed into the GSM. It is possible to obtain meteorological data without physically visiting the field if the user requires such information. Through GSM, weather data may be sent to a mobile phone at anytime, anywhere. Users can get weather alerts by sending messages with the format "STATE". A Stevenson screen with louvres holds the microcontroller, LCD, and GSM.


**Figure 4: Output Unit of the system**

Farmers may better care for their land and crops, as well as mitigate weather-related risks, with the use of up-to-the-minute meteorological data according to the present area and season. Agricultural IoT uses are domain-specific. Automated weather monitoring is a common use case for internet of things (IoT) sensors. In order to monitor the weather for agriculture, IoT sensors lay the framework for a more extensive connected system. The foundation of these systems is a series of interconnected sensors that gather information from the field. After collecting the data, cloud computing systems analyse it and send out notifications and alerts about any weather threats to crops. Internet of Things (IoT) technologies provide farmers with soil and environmental data in real-time, letting them prepare for weather changes. The use of an Internet of Things (IoT) based weather monitoring system in agriculture has several benefits, such as reducing crop hazards through the monitoring of severe weather patterns, helping farmers optimise resource usage and crop protection, improving product quality through the advice on when to harvest, sending real-time alerts to numerous devices and platforms, and collecting accurate data relevant to the farm's location and season in the field.

## CONCLUSION

Autonomous weather stations may take readings at any time of day or night without any help from a human operator, as the name suggests. This eliminates the potential for human mistake in data collection. As a result, several researchers may make use of them to efficiently and accurately gather data. From what we can tell, there have been many different AWS implementations throughout the years. What distinguishes these implementations is the data transmission technique. The use of wired methods was the norm in the beginning. In the years that followed, leased lines—which made use of modems and PSTN/ISDN networks—became an effective method of data transmission; however, their high cost was a big drawback in situations where no prior installations were available, making it impossible to take advantage of existing infrastructure. Nevertheless, a number of wireless communication protocols have recently emerged, enabling the creation of AWS and End Nodes that can communicate from faraway places. These protocols include Wi-Fi, High-Speed GSM networks in 4G and 5G, LoRa, Bluetooth, and the soon-to-be-released StarLink network.

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