Implementation of a Weather Station and Forecasting Weather using IOT: A Review

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***Abstract*— Since ancient times, humans have witnessed the weather's ebb and flow. However, it wasn't until the 1400s that modern meteorological instruments were developed. Automated observational systems are becoming increasingly important in the modern Internet of Things age because they give researchers with the real-time information they need to formulate and implement effective environmental policies. In this article, we take a deep dive into the state of the art when it comes to the hardware and software that power automatic weather stations. In addition, we detail how we've put to use cutting-edge innovations like IoT, Edge Computing, and Deep Learning.**

Keywords*— artificial intelligence, privacy, confidentiality, sensitive information, protection, Internet of Things; artificial intelligence; data mining; weather station; meteorology

I. Introduction

The study of weather and atmospheric conditions is called meteorology. meteorological events like rainbows and pollution, and the study of day-to-day weather, are all a part of meteorology. A weather station is a collection of devices used to monitor the weather on a regular basis. Whether it's for aviation, agriculture, construction, or shipping, you can always count on accurate weather forecasts from your local weather station because of the instruments and equipment housed there. [1]

Weather stations are able to a modernized version of the standard weather station, an automated weather station employs sensors to measure its many characteristics instead of human observers, use cases include reducing the need for manual work and allowing for off-site measurement. Additionally, a manual weather station is a more conventional option, as it requires human knowledge, ability, power, and energy to provide results. A sensor network is a distributed system of microcontroller-equipped, self-aware electronic nodes that collect and relay data. To keep tabs on things like temperature, humidity, wind speed, wind direction, barometric pressure, and rainfall amount in the actual world, sensors are an indispensable part of any network. [2]

Networks of weather stations in out-of-the-way places are known as "remote stations," and these stations typically rely on solar power and batteries rather than the traditional power grid. Information from this decentralized network is sent to a centralized repository. The ideas of the internet of things and cloud computing are what binding these decentralized networks together. In computing, the term "Internet of Things" (IoT) refers to a hypothetical future in which commonplace physical things are networked with computers and can uniquely identify themselves. [3]

Instead of having a local computer link directly to a server, users of cloud computing systems instead access their data and programs over the internet and other web-based tools and apps [4].

Servers are used to store information and computer programs. In contrast, the design of cloud computing makes it possible to access data online, enabling remote work. Here are some of the most common categories of weather stations: The first is a Synoptic Weather Station, which provides local weather observations at predetermined periods and includes the standard equipment found on most weather stations, such as a thermometer, barometer, wind speed and direction indicator, and rain gauge. The second type of weather station is a climatic weather station used in different eras; it shares the same basic characteristics as the first type, without the rain gauge. The third type of weather station is one used by farmers for crop planning, and it requires a unique set of parameters based on the specifics of each application it serves (such as soil temperature and sunshine). [5]

Various methods and observing systems (Aeronautical, Marine, Aircraft-based, and Terrestrial) have become available to the research community and agencies over the years, and the World Meteorological Organization (WMO) is responsible for the utilization of the measured data and the guidelines for collecting them. Automatic Weather Stations (AWS) that can automatically retrieve meteorological data and environmental observations from a network over multiple communications channels are of particular importance to the World Meteorological Organization (WMO). The World Meteorological Organization's publications and standards provide an analytical description of the process of implementing, installing, and operating AWS. [6]

II. Previous Studies

A framework for predicting Internet of Things weather stations is introduced in [7]. In order to predict whether or not frost will form on a given day, a number of machine learning algorithms have been integrated into an online frost forecasting service. This technology can significantly aid in increasing agricultural output by giving farmers with more precise frost forecasts and so lowering the likelihood of frost damage.

In [8], a method for weather forecasting is provided that makes use of past data from various weather stations to train basic machine learning models that, in a short amount of time, may produce usable forecasts regarding particular weather conditions in the near future. All of the models can be executed on far less powerful hardware. The assessment findings confirm that the models are accurate enough to be employed in conjunction with the state-of-the-art methods currently available. We also demonstrate the value of using weather station data from various nearby locations rather than just the data from the area for which forecasting is being done.

Linear regression and decision trees are only two of the machine learning algorithms used by the author of [9] to make weather forecasting predictions. As a result, they have settled on linear regression as the method of choice for predicting weather forecasts that rely on dependent datasets, as linear data is already available for linear regression while decision trees require manual labeling.

In [10], we see an implementation of IoT and ML techniques like Decision Tree and Time Series Analysis. It was shown through Machine Learning findings that the time series technique provides more reliable weather forecasts over longer periods of time. Recently, in [11].

III. WEATHER MONITORING STATION

The weather is crucial to our survival. Weather monitoring has many important and useful applications, from the agricultural field to the factory floor. By monitoring the weather, we can maintain tabs on variables like temperature, humidity, atmospheric pressure, rainfall amount, wind speed, and wind direction. Maintaining stability in the agricultural sector and in industrial operations requires a whole range of weather conditions. All sorts of the man's endeavors are impacted by the climate. For a reasonable price, today's weather monitoring devices and networks can produce the measurements required to follow these changes. Both interior and outdoor conditions, including temperature and humidity, are displayed. The monitoring system also has customizable alerts in the event of a value being outside of a predefined tolerance. [12]

There are two main parts to the satellite-based weather observation system described in [13]. The satellite complete with its array of sensors and data processing machinery. The data processing system is in charge of making data collection requests to the satellite and planning when those requests will be fulfilled. The ability to keep tabs on the weather conditions at one's farm is a huge benefit to any farmer. Because of this, industrial operations benefit as well, making weather monitoring a very important and socially beneficial activity.

A. *Predictive Weather Station Concept*

Every economy relies on agriculture. Progress in agriculture is essential in a country like Sudan, where the growing population is driving up food demand. The current economic climate and government regulations in Sudan also make the implementation of precision farming, sometimes known as "smart farming," a must. The model will help farmers increase crop yields while minimizing losses due to factors including erratic rainfall, drought, and other environmental stresses. Extreme weather conditions have a negative impact on agricultural output. IoT solutions that are useful across a wide range of industries have proliferated in recent years. As a result of its systematic complexity, weather forecasting has long been recognized as an important role in the field of meteorology. Any electronics enthusiast should be able to follow the steps outlined in this plan and put up a weather display system. Instead of relying on sensors to gather weather data, the new system will access reports from weather stations all across the world via a centralized data provider [14].

Extreme weather occurrences provide a test to the state of the art in weather forecasting, which relies only on a partial explanation. Many of the variables that contribute to weather occurrences are too complex to fully describe or calculate. Hybrid systems have arisen as a result of the proliferation of communication channels, which has allowed weather prediction specialists to pool their resources. Even with these climatic prediction enhancements, these expert systems can't be completely trustworthy so long as weather forecasting remains a major issue. The microclimate data around crops, together with crop photos and worldwide weather data from the web, are gathered via the predictive weather station platform. Minutely readings from all sensors are sent to a central database for hourly averaging. The daily average luminosity of the sun is used to determine solar radiation. Recent investigations have demonstrated that temperature inversion is a major factor in what clouds get wet with rain or snow. It's likely that frost will form because convection, caused Because of the heating of the air from below, it will be limited to layers that are below the inversion. [15]

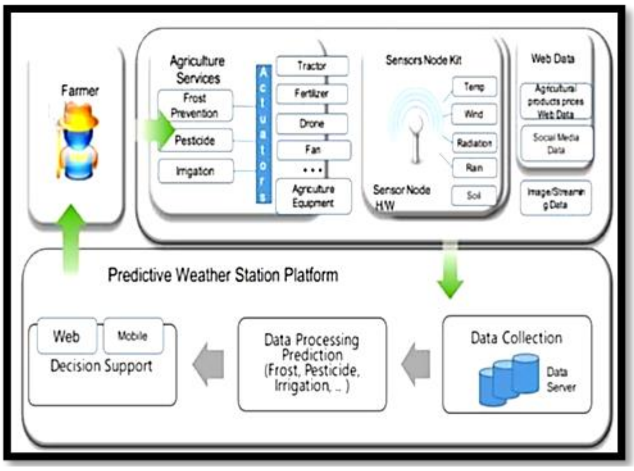

Fig. 1. Concept of Predictive Weather Station Platform [5]

B. *Parameters of Weather Station [16]*

- Humidity: Humidity refers to the concentration of water vapor in the atmosphere. Gaseous water vapor is the intangible form of water that exists in the atmosphere. The percentage of relative humidity is the standard measurement.

$$Absolute\ humidity\ \Delta H = mH2O\ /V\ net$$
$$mH2O = mass\ of\ water\ vapor.$$

- Temperature: In order to objectively compare how hot or cold something is, we need a thermometer. A thermometer is the typical tool for taking the temperature of a given environment. Temperature can be expressed on a number of different scales and units, including Celsius (^{0}C), Fahrenheit (^{0}F), and Kelvin (^{0}K)

$$1K = 273 + {}^0C\ and\ 1F = 32 + 9/5\,{}^0C.$$
$$V\ net = Volume\ of\ air\ and\ water\ vapor\ mixture$$

- Light intensity: Light intensity may be measured in a variety of ways. The term "luminous intensity" refers to a photometric quantity expressed in either lumens per steradian (lm/sr) or candela. The lux is the SI unit for illuminance, which is defined as the amount of light per area.

$$1\ Lux = 1\ Lumen\ per\ square\ meter$$

- Atmospheric pressure: Weight of air pressing down on the surface of the Earth. A pressure of 10.1 N/m^2 is exerted across a distance of one centimeter.

$$1\ milli\ bar = 1 hecto\ Pascal$$

$$At\ sea\ level = 101325\ Pascal\ or\ 101.325\ hecto\ Pascal$$

- •Wind: Wind is the motion of the gaseous in a large-scale pattern on the planet's surface. Wind is the movement of the air in bulk. The average wind speed is typically expressed in meters or kilometers per hour.

Wind is the global movement of gases at Earth's surface. Wind is made up of large-scale air currents. The standard units for measuring wind speed are meters per second or kilometers per hour.

$$1\ m/sec = 2.237\ miles/hour = 3.60\ km/\ hour.$$

- Rainfall: Rain is the precipitation of liquid water from clouds because the particles of water vapor in the atmosphere have grown thick enough to fall to the ground.

Above a certain size, raindrops begin to break apart. This size occurs between 0.1 and 9 mm. In this context, a 24-hour period of rainfall is expressed in millimeters.

IV. Monitoring Approaches

A. Traditional Approach/ Manual Approach

The weather parameters can be calculated in a number of ways. For accurate results, readings must be taken manually at the station location. There is truth in the conventional approach, and the values that are taken from it are relative to the individual. To begin any strategy, we must first have a firm grasp on the definitions and standard units of the meteorological factors at play. A manual inventory system places a premium on human action, which might introduce inaccuracies. A Failure Due to Human Factors Sometimes people make mistakes while writing down values or they neglect to note the meteorological conditions. The security of the system may be compromised. Analog instruments take a long time to sense, which contributes to the mistake. The precision of this method is inferior to that of modern digital systems. [16]

Traditional Approach/ Manual Approach

TABLE I. Traditional Approach/Manual Approach [16]

Visited places	**Hydrology Project, Godavari Pathbandhare Vikas Mahananda, Aurangabad MS India**		
Parameters	Instrument used	Range	Difficulties
Temperature	Thermometer 1	-35 C to +55 C	Reading needs to take manually
	Thermometer 2	-40 C to +50 C	
Humidity	Dry bulb Wet bulb	10 % to 80 %	Reading are not accurate
Rainfall	Conical flask of 25 cm fixed itself cylindrical jar	10 mm to 25 mm for 12 hour	Reading is taken after 12 hours
Wind Velocity	Anemometer Cups	Max 74 m/sec	
Wind Direction	Arrow-like structure		Direction decide by observing

TABLE II. Traditional Approach [16]

Visited Places	**Department of Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani MS India**		
Parameters	Instrument used	Range	Difficulties
Temperature	Thermometer 1	-35 C to +55 C	Need to take readings manually
	Thermometer 2	-40 C to +50 C	
Humidity	Dry Bulb Wet bulb	10 % to 80 %	Reading is not accurate
Rainfall	Cylindrical jar and conical flask	10 mm to 250 mm	Need to calculate value manually
Wind Velocity	Anemometer Cups	Max 74 m/sec	
Wind Direction	Arrow-like structure		Direction decide by observing

B. Disadvantages

- High installation cost.
- Hard to replace any elements
- Complex installation.
- Readings are needed to take manually by human cause's human error. [16]

C. Modern Approach

There has been a recent surge in the usage of wireless technologies for remote weather monitoring. Now we may utilize digital equipment that are already calibrated inside instead of older, more inaccurate analog ones. Moreover, the sensing time is quite short with the aforementioned capabilities, therefore the digital approach is beneficial. The system architecture includes both a transmitter and a receiver. The several sensor devices that make up the transmitter portion measure things like temperature, humidity, atmospheric pressure, air quality, rainfall, wind speed, and wind direction. LCD or computer monitor display options are available for the output. While the LCD is often used to display data in a wired system, a computer monitor may be used to display data in a wireless system. [16]

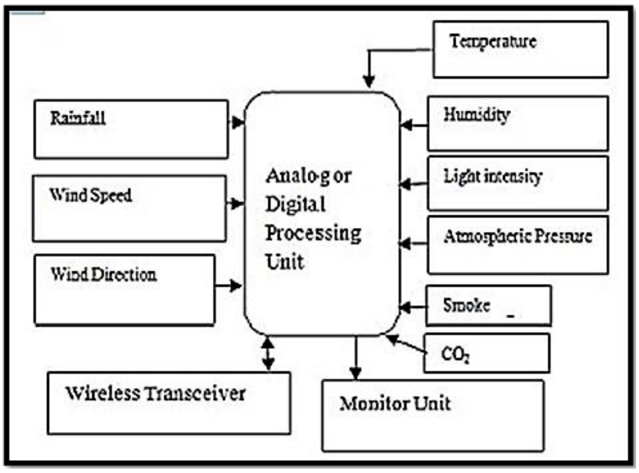

Fig. 2. Typical Block Diagram of Weather Monitoring Station [16]

V. Internet of Things IOT

The goal of computers has always been to make people's lives easier and better in some way (for example, look at the ideas behind "The Computer for the 21st Century" [17] and "Computing for Human Experience" [18].

When attempting to achieve this goal effectively, IoT necessitates data that either improves the services offered to consumers or increases the efficiency of the IoT platform. This facilitates the gathering of raw data from multiple networked sources and processing it to provide information. Data science will have a significant impact on making IOT applications more intelligent, as it will be the most important source of fresh information. Data scientists utilize data mining, machine learning, and other methods to decipher large amounts of data in the pursuit of meaningful patterns and unexpected findings. One method of this type is the utilization of multiple different algorithms that can be applied in different situations. Data analytics is the process of recognizing data types like volume, variety, and velocity, using models of data like neurons, classes, clusters, and employing efficient algorithms that correspond to the properties of the data being scrutinized. [19]

In light of these advances, a plethora of new avenues for progress have opened up. In order to get more insight, make better decisions, and automate more processes, businesses must be able to analyze Big Data, which is described as "large amounts of varied data being generated at a high rate," [19] at a reasonable cost.

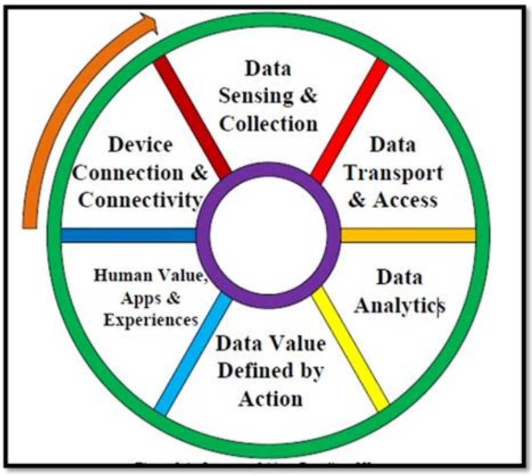

Fig. 3. Internet of things Paradigm [21]

The advent of the Internet enabled a level of global communication never before possible. The next big thing will be when everyday things become connected to one another to form a "smart" environment. The GSMA estimates that mobile network operators in vertical markets including healthcare, transportation, utilities, and consumer electronics stand to gain $1.3 trillion in income from these prospects. In Figure 3 we can see how the extent of the influence of the data created guides the selection of application domains

Fig. 4. IOT Schematic showing the end users and application areas based on data [17]

A. Technologies that made (IOT) a possibility

1. Connectedness: the internet has numerous protocols that facilitated the connection of sensors to clouds. [20].

2. Access to cheap, power efficient sensor technology [22].

3. Machine learning and analytics: Advances in machine learning and analytics, as well as having access to a variety of large, diverse data stores on the cloud, has facilitated the rapid and efficient acquisition of information for businesses. Additionally, the IoT data is a catalyst for the creation of these supplemental technologies. [20].

4. Conversational artificial intelligence (AI): Improved neural network technology has made it possible for IoT devices, such as the digital personal assistant Alexa, Cortana, or the like, are also supported., and Siri) to do natural-language processing (NLP) [20].

5. Cloud computing platforms: With the increasing number of cloud platforms, businesses and individuals can access the necessary growth infrastructure without having to deal with the administrative responsibilities of taking care of it themselves. [20]

B. Potential Application Domains of IOT

The IoT's potential uses are vast and varied, touching on nearly every facet of people's lives, businesses, and organizations. According to [21], IoT may be used in a variety of contexts, from the medical to the industrial to the municipal to the emergency management.

1. Smart Cities: At least according to [22], the IoT is crucial in making cities smarter and in fostering better infrastructure in general. Intelligent transportation systems [23], smart buildings, traffic congestion [24], waste management [25], Smart lighting, smart parking, and urban mapping are all examples of the areas of IoT that contribute to the development of smart cities. This may necessitate the implementation of multiple features, including monitoring the number of open parking spaces, monitoring the structural and material health of the city's bridges and buildings, installing sound detection devices in areas with noise, and keeping track of the volume of traffic. Congestion in Smart Cities can be observed, managed, and decreased with the utilization of AI-powered IoT. [26].

2. HealthCare: Medical systems in many nations are notoriously ineffective, sluggish, and error-prone. The healthcare industry's reliance on multiple tasks and technologies that may be automated and improved through technology makes this a straightforward adjustment. A significant amount of change might occur in the healthcare industry with the introduction of further technology that can facilitate numerous activities, such as report sharing to many persons and places, record keeping, and prescription distribution [27]. Tracking patients, workers, and items; identifying and authenticating persons; and automatically gathering data and sensing are just some of the ways in which IoT technology might improve health care. Patient tracking has the potential to greatly enhance hospital efficiency. As an added bonus, patient safety is improved, records are easier to keep, and there are fewer instances of mismatched newborns thanks to verification and identification. Furthermore, process automation, reducing form processing times, automated procedure auditing, and medical inventory management all benefit greatly from

automatic data collection and transfer. Patients can benefit from sensor devices because of their ability to provide real-time information about their health indicators and facilitate diagnosis.

3. Smart Agriculture and Water Management: When it comes to agriculture, the IoT may be used to improve operations by measuring soil moisture and, in the case of vineyards, checking the trunk diameter [30].

4. Implementing the IoT in retail and logistics management has multiple benefits. Some instances include monitoring the inventory level at every phase of the supply chain, or keeping track of the supply chain's progress. on where and when products were purchased and sold, and processing payments in places like public transit, amusement parks, fitness centers, and similar establishments based on the user's current location and current activity. Inside the store, IoT can be employed for a variety of purposes, including but not limited to: directing customers based on a pre-curated list, speeding up payment processes like automatically checking out with the help of biometrics, recognizing potentially allergenic products, and automating the restocking process by controlling the rotation of products on shelves and in storage. [30].

5. Smart Living: The Internet of Things (IoT) may be used to implement remote control devices in this sphere, allowing people to safely and efficiently turn appliances on and off from a distance [31]. There are also smart refrigerators that include LCD (Liquid Crystal Display) panels so you can see what's in there, when it's going to expire, and what needs to be refilled. Also, this data may be synced with a mobile app, so it can be accessed even while you're not at home and used to make purchases. Also, modern washers include a feature that lets you check on your loads from afar. Also, many appliances in the kitchen may be interfaced with a smartphone, allowing for remote control of functions like the oven's temperature. Even self-cleaning ovens may be tracked and supervised. Security alarms and cameras installed to watch for unlocked doors and windows can make homes safer [32].IOT Architecture

VI. Prediction Method for IOT Data

As can be seen in Fig. 7, our data prediction model is carried out in four stages: data collection, pre-processing (which includes outlier identification and missing value filling), the actual prediction, and evaluation. Pre-processed data is then utilized for model forecasting. LSTM and ARIMA are employed as models in this project. At last, assessment indices are compared between the two models based on the results. [5]

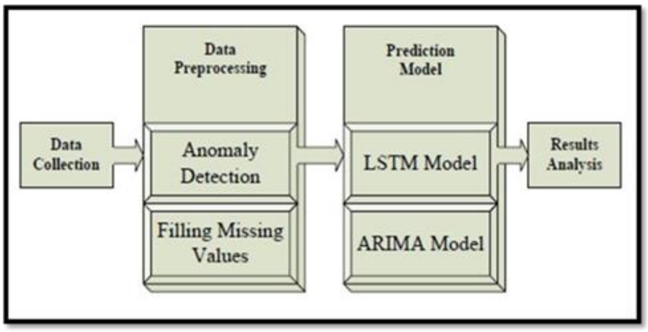

Fig. 5. Model prediction flow chart [5]

A. Data Acquisition Process

To begin, data capture is required to gather information about detection in real time. The sensor in the commercial hotels' kitchen cold storage 15 collects data in real time, which It's then routed to the gateway, the server that codes the data, the data center, and finally the independent database, from there, it can be accessed and analyzed.

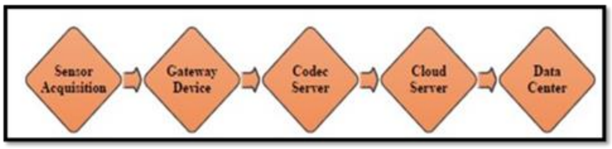

Fig. 6. Data collection flow chart [5]

B. Anomaly Detection

Cold storage areas in commercial hotel kitchens often have two distinct types of network topology for the gateway that connects to the temperature and humidity sensors.

- One-to-one structure: A sensor only communicates with another sensor via a gateway, as illustrated in Fig. 9.
- One-to-many structure: A passage must transmit data from multiple sensors, as illustrated in Fig. 9.

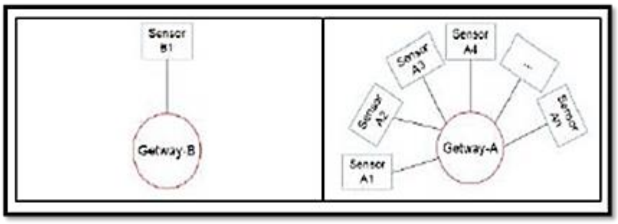

Fig. 7. Gateway sensor topology

Thus, for a gateway with a single sensor, it is sufficient to monitor for packet loss in the gateway's outgoing traffic. Gateway packet loss must be detected before sending out packets to a large number of sensors. The gateway's related sensors experience no packet loss if there is no loss of packets, and if there is loss of packets, pinning must be continued. Sensor's report noticing the packet loss. Only missing data were used in this paper's analysis. [5]

C. Missing Values Filling

Common approaches to filling in missing data include the mean, median, mode, random number generation, etc. Because the temperature in a cold storage room is typically quite consistent, it is not very affected by environmental fluctuations. The average filling method is employed because the data transmission protocol for this project is very limited in its data transmission. The typical value of the previous day's data that is needed to be filled in at time T is called aveX, and if the cold storage temperature sensor回報ed the data every T minutes, the missing value would be replaced with aveTX. [5]

VII. Conclusion

A weather station is a technological installation for monitoring and forecasting local weather conditions. In order to know and predict local weather, the weather station is built to collect quantitative data about the state of the weather in the area. The weather has a significant impact on human activities. Since weather is a transient atmospheric condition, it's important that short-term weather forecasts be made as promptly and precisely as possible.

It's common knowledge that modern science relies heavily on a steady stream of measurements. Using real-time measurements can greatly improve the outcomes of fields such as precision agriculture, forest management, ecophysiology, and others. The need to compute risk indices for the purpose of alerting the public and local authorities to extreme phenomena has also increased as a result of climate change.

In this study, we explore the published literature regarding the various methods currently used to combine IoT with weather stations. The utilization of cutting-edge technologies like IoT, Edge Computing, and others, is also important.

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