SMART WEATHER MONITORING SYSTEM USING IOT

by

Iresha De Silva

Student ID: RD06540

Student name: U. H. Iresha Dilrukshi De Silva

Module name: UNIT 21 - Emerging Technologies

Centre name: Pearson BTEC HND in Digital Technologies

Supervisors name: Mr. R. M. C. Rathnayaka

Centre name: SLT Mobitel Nebula Institute of Technologies Peradeniya

Authenticity declaration form

Student ID: RD06540

Student Name: U. H. Iresha Dilrukshi De Silva.

Document: Smart Weather Monitoring System using Iot

I certify that the work produced in the mentioned document is my own work and all the referred literature have been properly referenced.

	2024.09.09
……………………	…………………………….
Signature	Date

Abstract

The Smart Weather Monitoring System is an Internet of Things (IoT) solution that gives users, especially farmers, access to historical and real-time weather data for effective decision-making. The system is constructed with a NodeMCU ESP8266 microprocessor that is linked to DHT11 temperature and humidity sensors as well as a raindrop sensor to detect rainfall. The meteorological information is sent to the Blynk platform, where a web and mobile application displays it in real time. In order to enable users to react quickly to changing conditions, the system also notifies users via email and the Blynk app when weather conditions exceed specified limits.

The system leverages Power BI to analyze historical weather data in addition to real-time monitoring, giving customers the ability to identify patterns in the weather and make better informed judgments. A thorough understanding of weather patterns is produced by combining historical and real-time data, which can help with planning and forecasting, especially in the agricultural industry.

This project demonstrates how to develop an accessible, user-friendly weather monitoring system that can work well in areas with poor connectivity to the internet. It also shows how LoRa technology can be used to improve the system's dependability and range. The system's easy-to-use visuals and integration of historical and real-time data make it a useful tool for making weather-dependent decisions.

Keywords: IoT, Weather Monitoring, Blynk App, Power BI, Real-Time Data, Historical Data, LoRa Technology.

Acknowledgement

I would like to express my sincere gratitude to all those who have supported me throughout the course of this project.

First and foremost, I am deeply thankful to my supervisor, Mr. R. M. C. Rathnayaka (Engineer/Access Network Planning/SLT), for providing invaluable guidance, continuous support, and constructive feedback during every stage of the project. Their insights have been instrumental in the successful completion of this work.

I would also like to extend my gratitude to the faculty and staff for their assistance, resources, and encouragement. Their support created a positive environment for research and learning.

A special thanks to my family and friends for their unwavering encouragement and patience, which motivated me to complete this project.

Finally, I would like to acknowledge the open-source communities and documentation resources that were essential in developing the Smart Weather Monitoring System. The knowledge and tools provided by the online communities have significantly contributed to the success of this project.

Thank you all for your support and encouragement.

Table of content

List of tables

List of figures

1. Introduction

The goal of the Smart Weather Monitoring System project is to meet the growing need for dependable and easily available meteorological data, especially in light of climate change and its effects on different industries. Through real-time data collecting and analysis, this initiative intends to improve weather monitoring by utilizing new technologies like the Internet of Things (IoT). For remote visualization and management, the system makes use of an ESP8266 microcontroller, a DHT11 temperature and humidity sensor, a raindrop sensor, and the Blynk app. This connection makes it possible to gather environmental data, which is subsequently examined to reveal trends in the weather over time.

1.1 Research Questions

To guide this research, we have established the following key research questions,

1. How can IoT and the Blynk app be used to develop a user-friendly, cost-effective and efficient weather monitoring system?
2. How can the system be designed to function effectively in areas with limited and unreliable internet connectivity?
3. How does the incorporation of historical weather data alongside real-time data enhance the accuracy of weather predictions?

1.2 Objectives

- Gather environmental data, including temperature, humidity, and rainfall, and transmit it to the Blynk platform for real-time visualization.
- Analyze both real-time and historical data to identify trends and make accurate future weather predictions, ultimately supporting informed decision-making.
- Enable users to access and manage their weather monitoring system via the Blynk mobile app, allowing for alerts and notifications based on specific weather conditions.

1.3 Methods

The project uses a combination of hardware and software components to achieve these objectives. Environmental data is collected via the DHT11 and raindrop sensors, and the DHT11 microcontroller functions as the central processing unit. User engagement and data visualization are made easier with the Blynk app. In order to guarantee the precision and dependability of the data gathered, the project will also comprise testing and validation stages.

1.4 Importance of the Research Findings

For the purpose of creating a dependable and easy-to-use weather monitoring system for the aviation, marine transportation, crisis management, and agricultural sectors, this study is essential. It improves resilience to climate problems and decision-making by supplying precise, up-to-date meteorological data. The project's goal is to close gaps in the current systems by providing a complete, easily accessible, and reasonably priced solution for a range of stakeholders.

2. Literature review

2.1 Historical Evolution of Weather Monitoring Systems

Over time, weather monitoring methods have changed dramatically: from manual observations to automated stations and, more recently, to smart systems based on the Internet of Things. Weather monitoring underwent a revolution with the development of electronic sensors in the middle of the 20th century, which made it possible to collect data continuously and more precisely. The 1970s and 1980s saw a further advancement in weather monitoring capabilities with the advent of microprocessors and communication technology, which made it possible to build automated weather stations that could send data to centralized sites.

A new era of weather monitoring has begun with the rise of IoT in the early 21st century, which is marked by the convergence of mobile, cloud, and sensor network technologies. Low-cost, internet-connected sensors are used by IoT-based weather monitoring systems to gather environmental data, which is subsequently processed and examined in the cloud. This method enhances the precision and granularity of weather data by enabling the development of dense sensor networks that can deliver hyperlocal weather information.

2.2 Review of Similar Studies

Several studies have explored the development and implementation of IoT-based weather monitoring systems.

Rana (2022) suggested a smart weather monitoring system that uses a number of sensors and Internet of Things technologies to identify water presence, temperature, humidity, pressure, and dew point. The data is then displayed on a web platform. The study used system development and hardware prototype techniques to show how IoT technologies can be used in real-world weather monitoring scenarios. Nevertheless, the technology did not integrate with mobile apps and was only capable of web-based visualization.

Kumar and Oil (2023) developed an Internet of Things (IoT) device that converts analog sensor data into digital values via a microcontroller and sends them online for remote examination and monitoring. With the use of Internet of Things-based sensor networks, their work created a thorough framework for evaluating environmental conditions. The report demonstrated how IoT technologies might enhance the gathering of meteorological data, however it was devoid of information regarding sensor kinds, data processing techniques, and UI design.

Chauhan and Banara (2022) conducted a comprehensive review of IoT-based weather monitoring systems for smart cities, identifying the major components, sensors, and communication technologies used in these systems. The study emphasized the importance of IoT in enhancing weather monitoring capabilities and the need for future research to improve the performance and cost-effectiveness of such systems. However, the review focused primarily on smart city applications and did not discuss other sectors.

Manoathan Manoj and Weerasinghe (2023) designed an IoT-based weather monitoring system to enhance the socio-economic well-being of farmers in the upcountry area of Sri Lanka. The system employed sensors to detect environmental factors, such as temperature, humidity, and air pressure, and uploaded the data to a website for remote viewing. While the study demonstrated the benefits of real-time data access for agricultural decision-making, it was limited to web-only interface and lacked data analysis features.

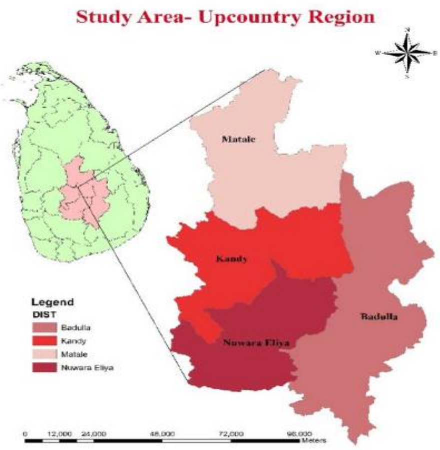

Figure 1: Study area of this study in Manoathan Manoj and Weerasinghe (2023) designed an IoT-based weather monitoring system

Aziz (2018) study reviews various IoT-based weather monitoring systems, analyzing their methodologies and implementations. The author discusses the advantages of using low-cost sensors and cloud-based data processing for real-time weather monitoring. However, the review also highlights common challenges, such as sensor calibration and data accuracy, which are critical for reliable weather forecasting. The lack of a comprehensive framework for integrating these systems into existing infrastructure is noted as a limitation.

Zhang et al. (2021) suggested an Internet of Things (IoT)-based weather monitoring system employing LoRaWAN technology in a recent study. The system was made up of several sensor nodes, a LoRaWAN gateway, and a cloud based server for data analysis and storage. Users may get real-time weather information via a web-based dashboard thanks to the system's collection of temperature, humidity, and atmospheric pressure data.

2.3 Merits and Limitations

Merits: The studies that have been evaluated clearly showcase how IoT may improve weather monitoring, especially when it comes to remote access and real-time data collecting. The use of inexpensive sensors, microcontrollers like the ESP8266, and cloud computing are important developments. These technologies aid in the development of accessible and scalable systems.

Limitations: These investigations do, however, also show some limits. One of the most prevalent problems is the absence of mobile app integration, which restricts accessibility and user interaction. Furthermore, data analysis capabilities are restricted, especially when it comes to utilizing previous data to enhance forecasts. Along with a reliance on dependable internet access, issues with sensor accuracy and calibration are also mentioned, which reduces the usefulness of these systems in rural or isolated areas.

2.4 Identification of Gaps

Mobile App Integration: While IoT-based weather systems have been successfully implemented in a number of studies, many do not include mobile applications such as Blynk. Both user engagement and system accessibility are hampered by this lack.

Data Analysis and Prediction: The majority of current systems focus primarily on data gathering and visualization, neglecting to examine historical data in addition to real-time data. This deficiency restricts the usefulness of these systems for predicting and lowers the accuracy of weather forecasts.

Connectivity Issues: The requirement for solutions that can function well in places with spotty or nonexistent internet connectivity was noted as a major gap in the examined studies. This problem is still mostly unsolved, which limits the use of existing systems in a variety of geographical contexts.

2.5 Addressing the Gaps

By integrating the Blynk app, this project will close the integration gap for mobile apps. In order to improve accessibility and user engagement, the app will offer an intuitive interface for notifications, remote system administration, and real-time data visualization.

The initiative will integrate historical and real-time meteorological data to increase prediction accuracy. The objective of this technique is to improve the overall utility of the weather monitoring system by offering more precise and knowledgeable information.

The research will investigate ways to guarantee that the system continues to operate in places with inadequate internet access. To guarantee data integrity and system performance even in demanding contexts, this involves establishing delayed synchronization with cloud services and adding local data storage.

3. Methodology

The methodology for the Smart Weather Monitoring System project is structured to seamlessly integrate both hardware and software components using Internet of Things (IoT) technologies and mobile app frameworks. The goal of this strategy is to methodically create and put into place an all-inclusive system that facilitates the acquisition, processing, and analysis of environmental data in real time. The project aims to efficiently monitor weather conditions by utilizing IoT technology, guaranteeing precise and prompt data transmission to consumers via an intuitive mobile application. This project uses Power BI to improve weather forecasting by analyzing historical weather data in addition to current weather conditions and real-time weather monitoring. The system helps users make well-informed decisions based on predictive analysis by offering insights into future weather patterns through the comparison of previous trends with present data. The final objective is to develop a working prototype that illustrates IoT's potential for weather monitoring.

3.1 Research Design

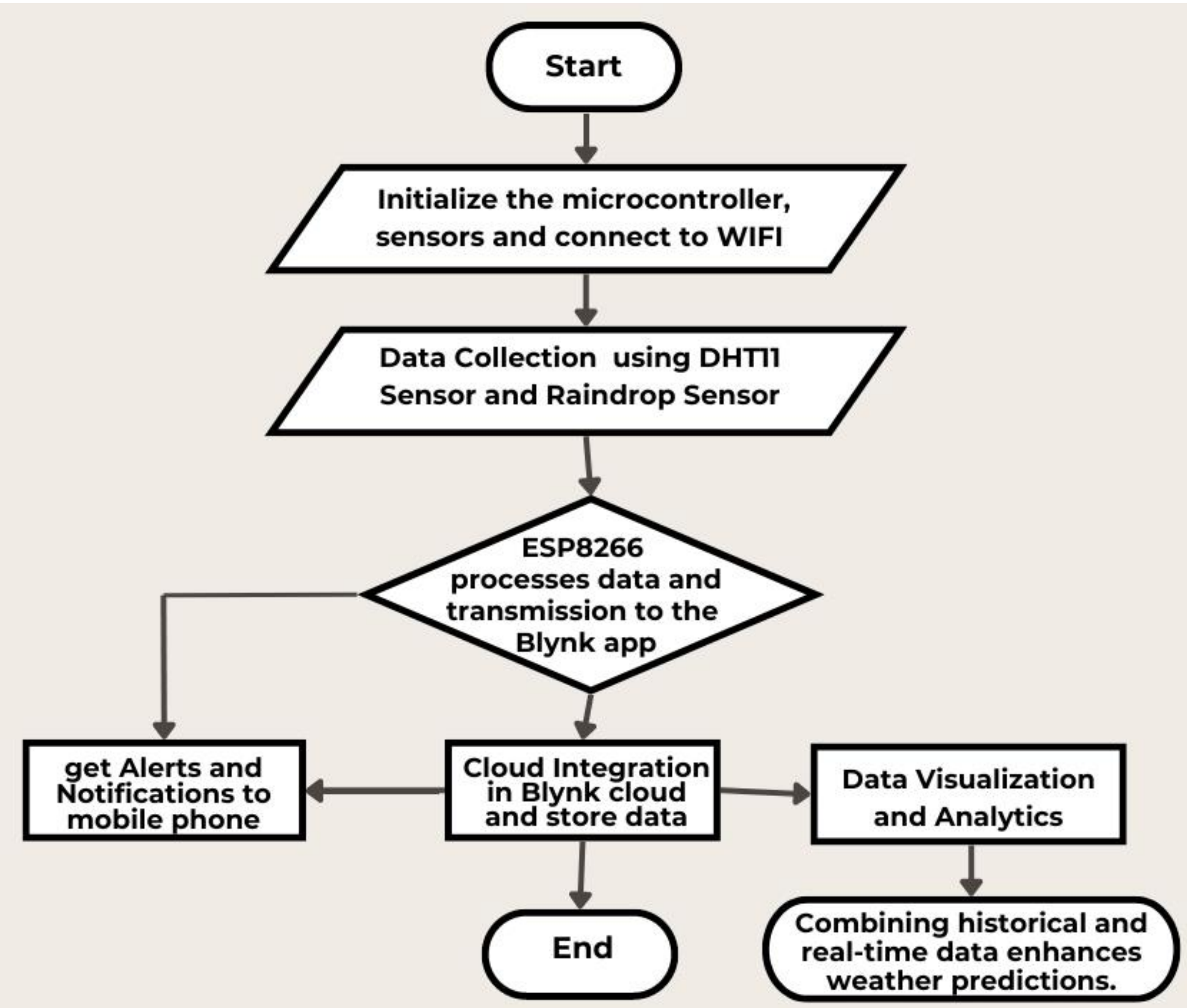

figure 2 System Flowchart Smart Weather Monitoring System

A flowchart illustrates a system's operation. The microcontroller and sensor initialization and WiFi connection establishment are the first steps in the flowchart. Completing this step is essential to allow remote data transfer and cloud-based Blynk app interaction. Incorporating cloud computing into the research design guarantees that the data gathered by the sensors is efficiently processed and saved, as well as readily available for real-time display, mobile alerts and notifications, and additional analysis.

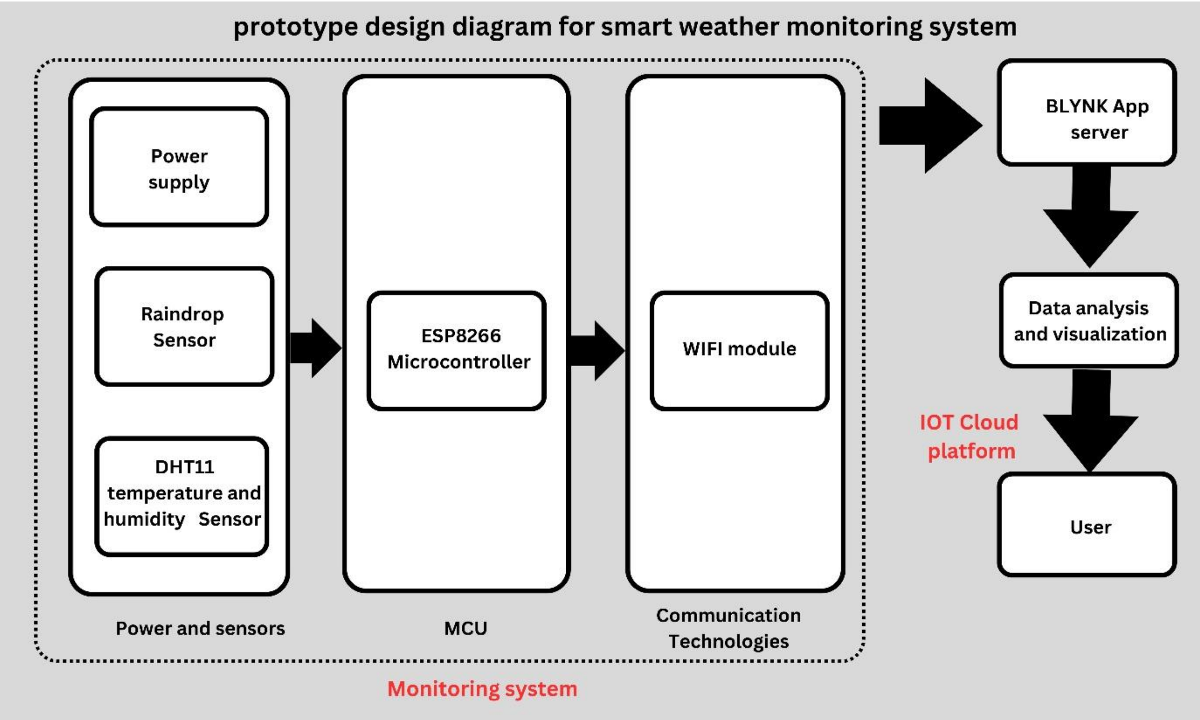

Figure 3 block diagram of the weather monitoring system

The weather monitoring system's block diagram is displayed in Figure 2. The flowchart functionality insights into the system are shown in Figure 1. To start, the system needs a power supply to be initialized. In order for the NodeMCU ESP8266 microcontroller to receive sensor data, the attached sensors must be in active mode. The microcontroller is programmed using the Arduino IDE. Via a Wi-Fi network, all sensor data is sent to the Blynk server. One of the most recent systems is called Blynk, which allows users to create interfaces that primarily track and monitor preferred programs from Android computers and the iPhone operating system (iOS). The gathered information is examined and used in data visualization so that end users can get updates on the weather conditions.

3.2 Hardware Design

The hardware design of the system includes the following components,

NodeMCU ESP8266

In this project, NodeMCU ESP8266 is utilized for internet communication. It is an inexpensive, very user-friendly gadget. The NodeMCU ESP8266 has dual functionality as a station (it can establish a Wi-Fi connection) and an access

Figure 4: NodeMCU

point (it can generate hotspots). It can therefore gather and send data to the internet with ease, enabling the Internet of Things.

DHT11

Figure 5 : DHT11

A affordable digital sensor for measuring temperature and humidity is the DHT11. In order to monitor temperature and humidity at the same time, this sensor can also be linked to a microcontroller. The humidity and temperature sensor DHT11 is included as a sensor module. There is no power-on LED or pull-up resistor on this sensor. Relative humidity sensor Its DHT11 sensor combines a capacitive humidity sensor with a thermistor. With a precision of 2 degrees, the DHT11's temperature range is 0.0 to 50.0 °C. With a 5% accuracy, the humidity range is 20.00 % to 95.00 %. But the DHT11 reacts more slowly, taking up to 5 seconds to react to changes in humidity and up to 10 seconds to react to changes in temperature. The polling interval used in the system design takes this constraint into consideration by striking a balance between the sensor's response capabilities and the requirement for updated data.

Rain Drop Sensor

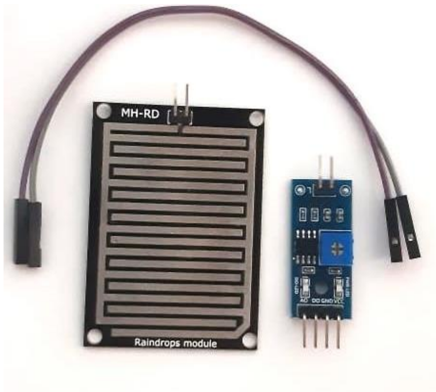

Figure 6 : Rain Drop Sensor

Rain is detected by means of this raindrop sensor module. There are two components in the sensor as well. The Sensing Pad, also known as the PCB, is the first part and is printed with a network of copper wires. Raindrops will be able to touch down on this copper channel, reducing resistance. The sensor notifies the NodeMCU, which subsequently forwards the information to the Blynk app, when rain is observed. Users can now receive real-time updates regarding rainfall thanks to this feature, which is crucial for outside agricultural operations that could be impacted by erratic weather patterns.

The system uses the cloud-based Blynk platform for remote monitoring, giving users instant access to vital meteorological data. The project offers an efficient way to monitor and react to changing weather conditions, which improves decision-making processes in agricultural settings. It does this by connecting these sensors with the NodeMCU ESP8266 and using the Blynk app for data display.

3.3 Software Design

Software Development	Description
Arduino IDE	To utilize the ESP8266 library to program the NodeMCU ESP8266. and yet another sensor as well.
Blynk Application	to make it easier for users to manage and stay up to speed on their hardware projects by creating interfaces on their iOS and Android smartphones. Blynk app users can create a project dashboard by arranging buttons, sliders, graphs, and other widgets on the screen.

Table 1: Software List

3.3.1 Circuit Diagram

The circuit diagram of our proposed system is given below. The diagram represents the connection of the sensor and how the connection will be done.

The illustration circuit of the project

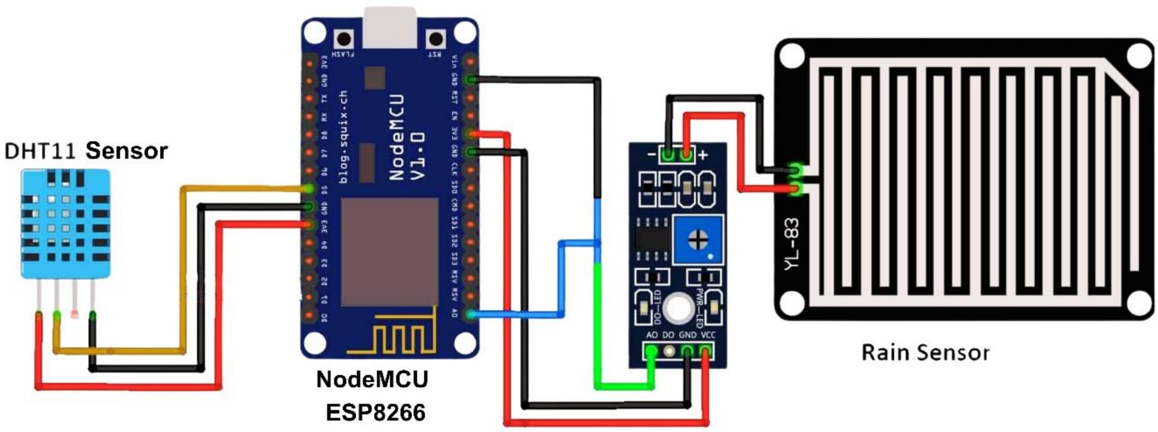

Figure 7 : Circuit Diagram of the project

The Dht11 sensor and rain sensor connected with the node MCU pins and the power supply is done by USB cable to connect the hardware to the system. The prototype model is represented in the above images. All the connections should be done in the same manner then will get a proper result. The below tables show the pin connection for each sensor.

VCC	3V3
DATA	D2
GND	GND

Table 2 : Pin Configuration between node MCU and Rain

A0	GND
GND	GND
VCC	3V3

Table 3 Pin configuration between node MCU and

3.3.2 Software Interface Development

The Blynk platform was selected for the development of the software interface for the smart weather monitoring system due to its versatility and ease of integration. Real-time viewing of data obtained from DHT11 and raindrop sensors linked to the NodeMCU ESP8266 microcontroller is made possible by the interface. Using simple widgets, users can keep an eye on temperature, humidity, and rainfall conditions right on the Blynk web dashboard or mobile app.

The system is set up to deliver notifications over a number of channels in order to guarantee timely alerts. While SMS and email notifications make sure users are aware of important weather changes even when they are not actively using the app, Blynk app notifications offer instant alerts on the mobile interface.

The Blynk platform also makes it possible to monitor historical data, giving customers the ability to identify trends and base decisions on prior weather patterns. The complete data management strategy and multi-platform compatibility improve the weather monitoring system's usability and efficacy.

3.4 Data Collection and Analysis

Primary Data: Using DHT11 and raindrop sensors, real-time temperature, humidity, and rainfall measurements are the main sources of data for this project. Continuous data collection results in an extensive dataset that may be used for monitoring and analysis. This data is processed by the ESP8266 microcontroller and sent to the Blynk cloud platform for visualization and monitoring.

Secondary Data: A review of previous research on sensor technology, data visualization methods, and Internet of Things-based weather monitoring systems constitutes secondary data. These studies offer a contextual basis for comprehending the state of technology today and pinpointing areas where this project might advance.

Data Analysis: The Blynk app, which offers capabilities for analyzing trends and patterns in meteorological conditions, is used to examine the data that have been collected. With real-time monitoring and alarms, the app provides insights into changes in the surrounding environment. To close a significant gap in the literature, data analysis also incorporates historical data to improve the precision of weather forecasts.

3.5 Gantt Chart

The project timetable is shown in a Gantt chart that covers every stage, from testing and analysis to design and development. By monitoring progress, the chart makes sure that all jobs are finished within the allotted time.

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Literature review and background research								
Report Writing								
System design and prototyping								
System implementation and testing								
User assessment and feedback collecting								
Final report and project completion								

Table 4: Gantt Chart

3.6 Cost, Access, and Ethical Considerations

The project includes expenses for purchasing hardware, such as the ESP8266 microcontroller, raindrop sensor, DHT11 sensors, and other required electronics. Most of these parts are easily obtained through online retailers or electronics stores, making access to them relatively simple.

Hardware	Quantity	Price
NodeMCU ESP8266	1	RS 1400
Rain Drop Sensor	1	RS 300
DHT11 Sensor	1	RS 380
Breadboard	1	RS 450
Jumper Wires (Female to Male)	1 set	RS 120
Jumper Wires (Male to Male)	1 set	RS 120
Total		RS 2770

Table 5 : Lists of Equipment

Data security and privacy are the main ethical concerns. The system's architecture guarantees that all gathered data is safely transferred, kept, and only accessible by those who are permitted. The project also follows the ethical standards for Internet of Things systems, making sure that the technology is deployed and used in a way that respects user privacy and complies with any data protection laws.

4. Results and Discussion

4.1 Data Analysis

By analyzing historical and real-time weather data gathered from the prototype weather monitoring system, the data analysis aims to address the research questions and meet the project's objectives. This analysis gives users (like farmers) who depend on precise data for decision-making insights into how well the system performs under various circumstances and its capacity to generate accurate weather forecasts.

Research Question 1: How can IoT and the Blynk app, along with Power BI, be used to develop a user-friendly, efficient, and cost-effective weather monitoring system?

We developed a low-cost prototype utilizing a NodeMCU microcontroller, DHT11 temperature and humidity sensors, and a raindrop sensor in order to answer the question. The Blynk platform receives the data gathered by these sensors and uses it to visualize the weather in real time via the Blynk web platform and Blynk mobile app. With this configuration, users can easily monitor the system from any location, get alerts, and get real-time weather information.

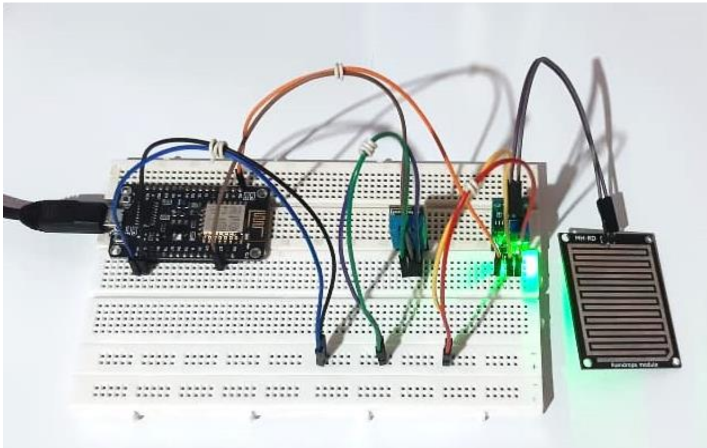

Figure 9 : Real-time prototype model Testing

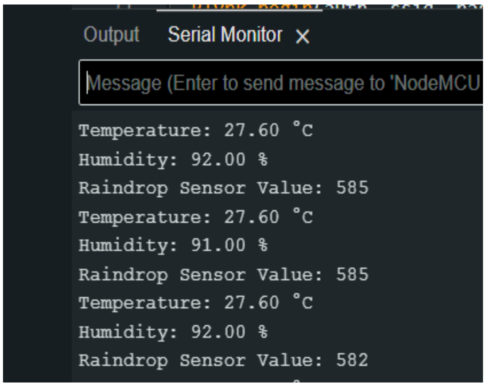

Figure 10: Real time weather prediction in Serial Monitor

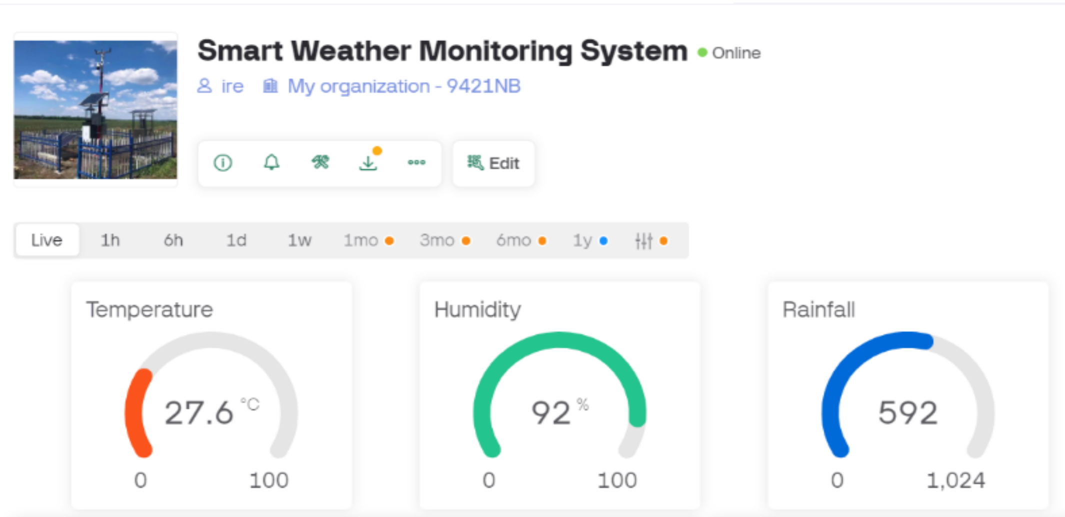

Figure 8 : Overview of the Real-time prototype model in Blynk web platform

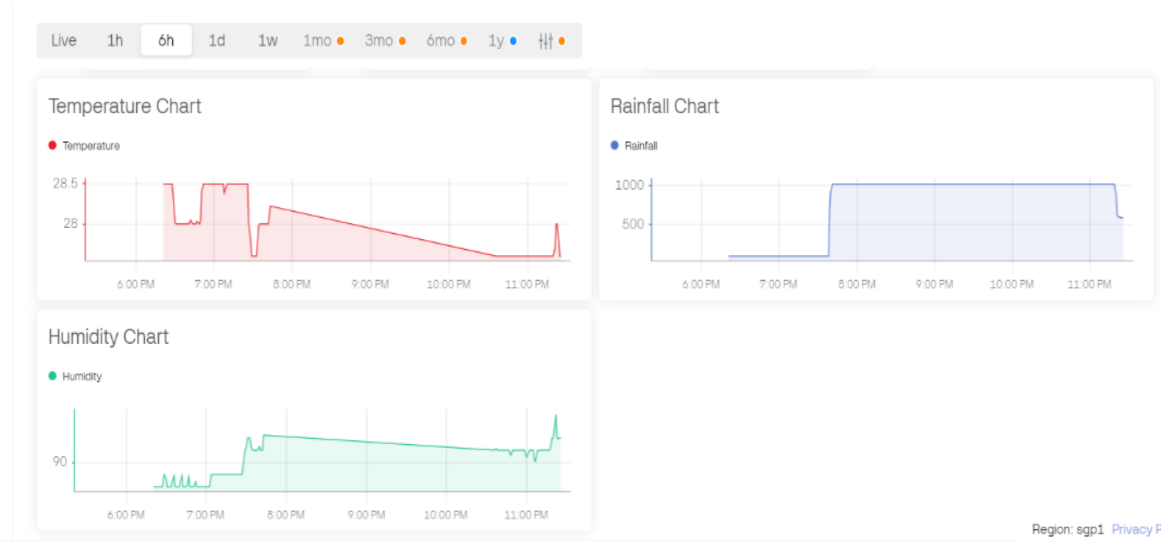

Figure 12 : weather condition chart in Blynk web

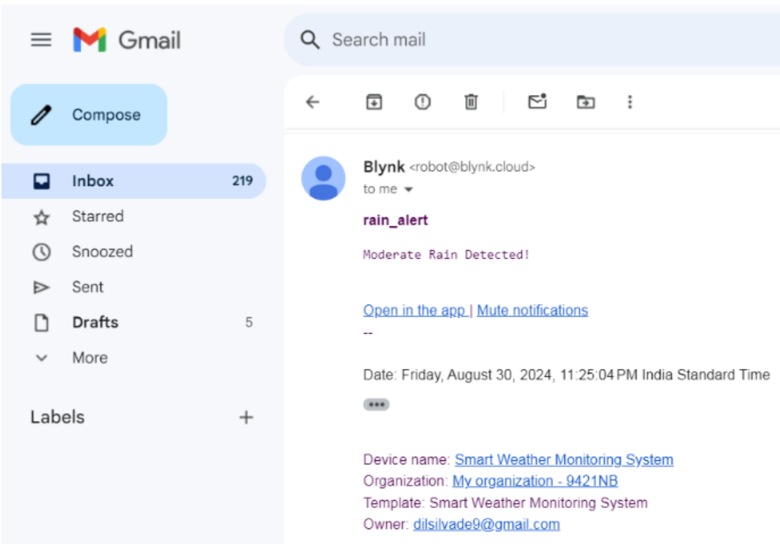

Figure 11 : notifications based on specific weather conditions via email

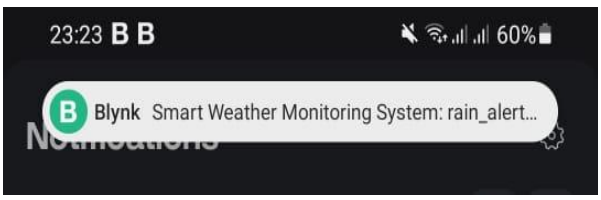

Figure 13: notifications via Blynk mobile app

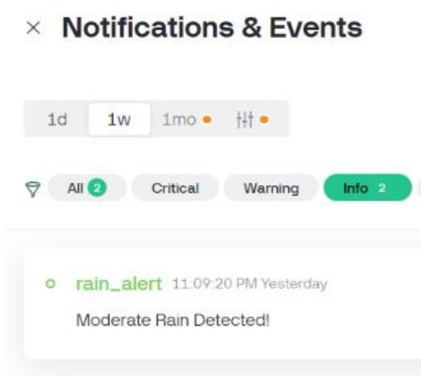

Figure 14 : notifications via Blynk web

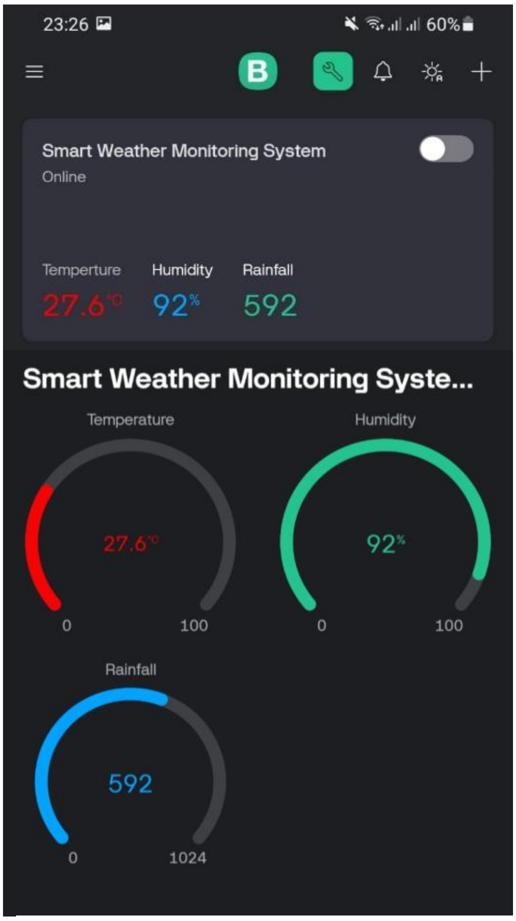

Figure 15 : Blynk mobile app interface

Figure 16 : weather condition chart in Blynk mobile app

Even customers with little technical experience can utilize the Blynk app because of its easy to use design. Its visualizations make it simple for users to understand the data, which promotes better decision-making.

Research Question 2: How can the system be designed to function effectively in areas with limited or unreliable internet connectivity?

A LoRa-based connection between sensors and the NodeMCU microcontroller can improve the system's functionality in areas with poor or unavailable internet connections. Because of its long-range connection and low power consumption, LoRa technology is well-suited for rural and remote areas where regular internet connectivity may be spotty or nonexistent. Through the use of LoRa, the system can continue to gather and send data over long distances without using a lot of power, guaranteeing ongoing monitoring even in difficult circumstances.

The current configuration of the system, which makes use of the Blynk platform and mobile app, requires an internet connection in order to transmit and visualize data in real-time. However, data integrity and continuity can be preserved by incorporating LoRa, which allows data to be sent to a local gateway or momentarily saved until connectivity is restored.

Research Question 3: How does the incorporation of historical weather data alongside real-time data enhance the accuracy of weather predictions?

To improve the precision of weather forecasts, historical and current meteorological data must be included. A reference framework for recognizing patterns and trends, such as seasonal fluctuations in temperature, humidity, and rainfall, is provided by historical data. Through this data analysis combined with real-time observations, the system is able to provide more accurate alarms and projections.

This project uses Power BI to improve weather predictions by analyzing historical weather data in addition to current conditions and real-time weather monitoring. The system gives customers insights into future weather patterns by comparing historical trends with current data, allowing them to make well-informed decisions based on predictive analysis. Users can quickly select particular dates and view weather predictions on a daily, monthly, or annual basis in a style that is easy to understand thanks to Power BI's strong data visualization features. This feature makes sure that users, including farmers, can accurately predict the weather, which facilitates improved planning and decision-making.

For instance, a farmer using the technology can determine the ideal planting time based on past weather trends by using Power BI's historical rainfall data. Then, by monitoring current weather conditions and receiving notifications if any major changes occur, farmers may make timely adjustments to their farming techniques using real-time data from the Blynk app. Furthermore, by evaluating past and current rainfall data, the system anticipates the amount of rain that will fall in the future, enabling farmers to plan their operations appropriately. By using a complete strategy, users may maximize their farming results by staying informed and responding proactively to weather changes.

The user-friendly interfaces of the Power BI dashboards listed below make it simple for users to examine historical weather data. Users may obtain insights and produce accurate weather forecasts with ease if they have access to both historical and current data.

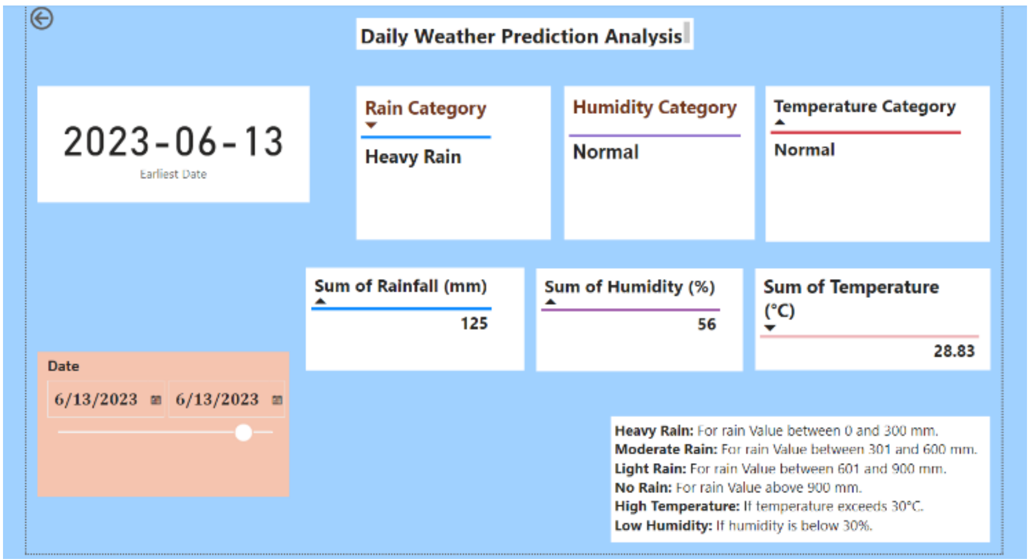

Figure 17: Daily Weather Analysis in Power BI

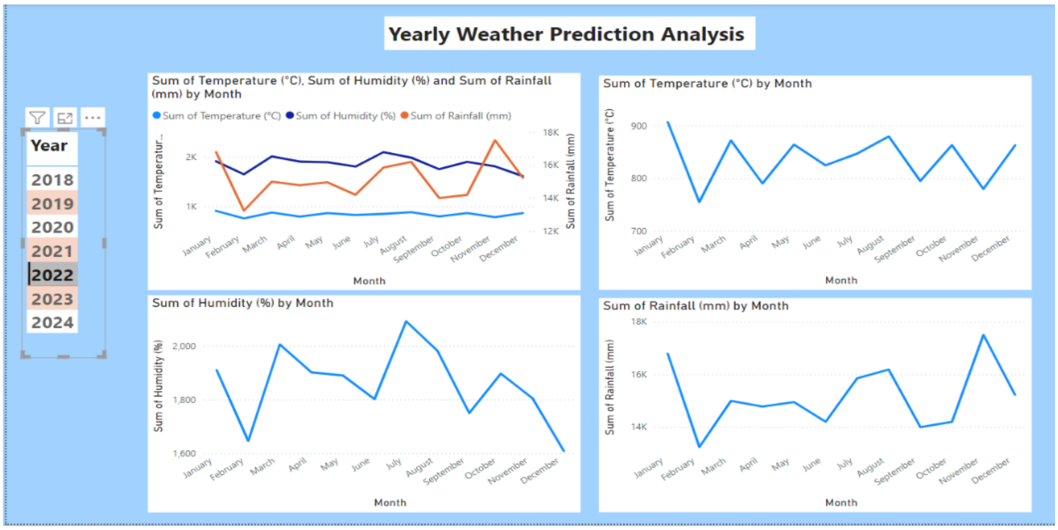

Figure 18: Yearly Weather Analysis in Power BI

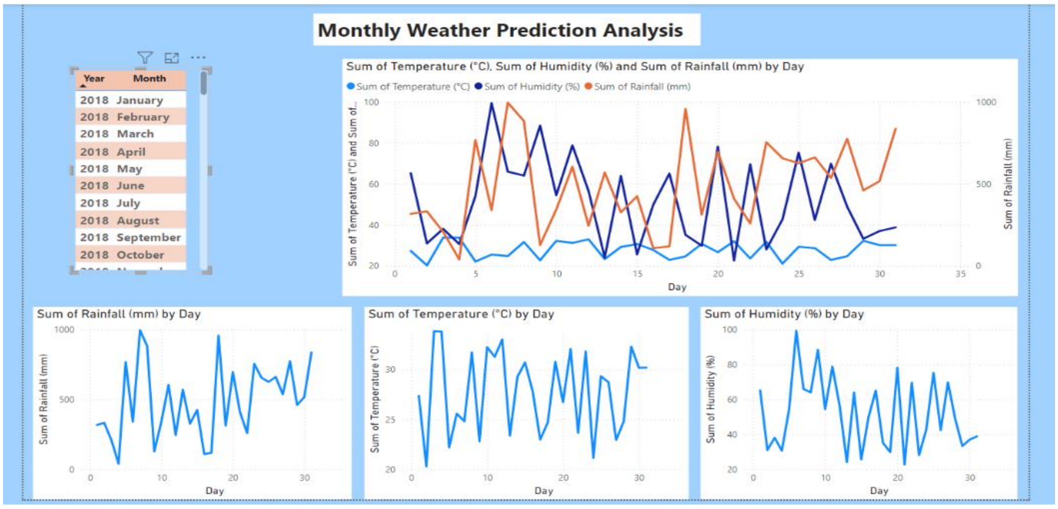

Figure 19: Monthly Weather Analysis in Power BI

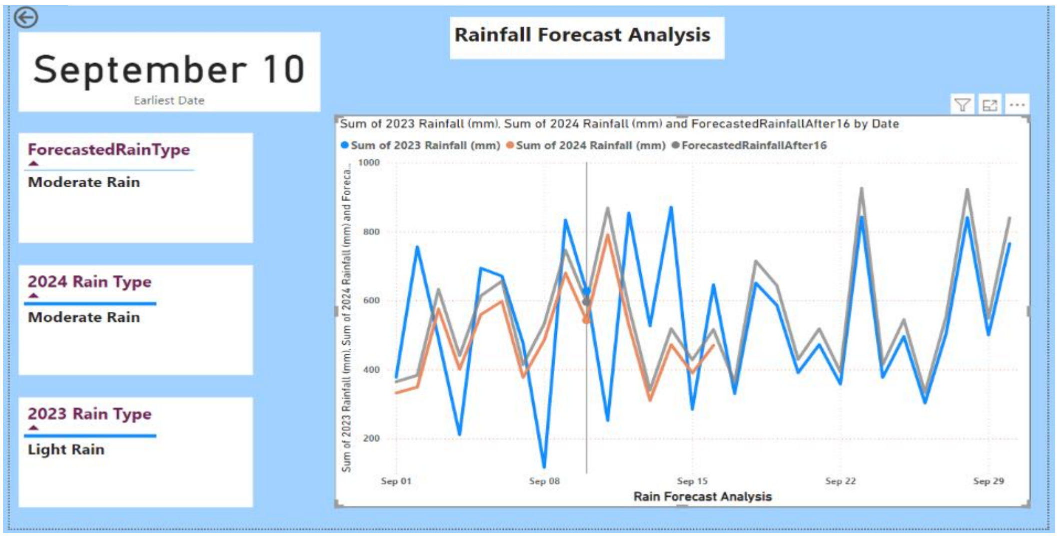

Figure 20: Rainfall Forecast Analysis in Power BI

4.2 Critical Evaluations

4.2.1 Evaluation of the System's Performance, Accuracy, and Reliability

The ability of the prototype system to reliably and accurately gather, transmit, and visualize weather information was used to assess its performance. With response times of up to 10 seconds for humidity and 15 seconds for temperature, the DHT11 sensor offered reasonable accuracy for temperature and humidity readings. However, a more accurate sensor might be recommended for applications which ask for a higher level of precision.

The Blynk app and Power BI connection combined to give historical and real-time data analysis for data visualization. Users found it easy to anticipate weather, evaluate trends, receive alerts, and obtain meteorological information because to an intuitive design. It was proposed that LoRa technology be utilized to enhance data transfer in places with inadequate connectivity, therefore boosting the system's overall dependability and guaranteeing precise weather predictions.

4.2.2 Discussion on Findings in Relation to Research Objectives and Literature Review

The results are consistent with the goals of the study and the body of knowledge regarding the application of IoT and data visualization platforms in weather monitoring systems. The research successfully demonstrated a low-cost method of creating a weather monitoring system that makes use of both historical and real-time data to improve decision-making. The integration of Power BI for data analysis and the Blynk app for real-time monitoring provides a holistic solution that caters to the needs of users, especially those in the agriculture industry.

Maintaining system functionality in places with inadequate internet access is a major difficulty that has been noted in the literature and is addressed by the suggested inclusion of LoRa technology. The system's robustness and dependability would be further increased by this improvement, making it a useful tool for users in rural or remote areas.

5. Conclusions and Recommendations

5.1 Conclusions

The aim of this project was to create an affordable, effective, and user-friendly weather monitoring system by combining Power BI, the Blynk app, and IoT technology to analyze historical and real-time data. The main conclusions of this study successfully answered the research questions and achieved the project's objectives;

1. **Development of a User-Friendly Weather Monitoring System**: The Blynk app's integration of IoT devices, such as raindrop sensors, DHT11 sensors, and NodeMCU microcontroller, proved it was possible to build an affordable and user-friendly weather monitoring system. The technology allowed for real-time data visualization and notifications, providing users - particularly those in agriculture - a useful tool for keeping an eye on the weather and making defensible judgments.

2. **Functionality in Areas with Limited Connectivity**: The project highlighted the possible difficulties of conducting business in places with spotty or insufficient internet access. For the purpose of sending real-time data to the Blynk platform, the existing system depends on internet access. Nonetheless, the recommendation to use LoRa technology for long-range, low-power communication offers a workable way to guarantee uninterrupted data transfer in distant locations, boosting the dependability of the system.

3. **Enhancement of Weather Predictions Using Historical Data**: The accuracy of weather forecasts was greatly improved with the addition of both historical and real-time weather data. More accurate weather forecasts were made possible by combining real-time measurements with trend analysis from historical data. It was discovered that farmers could plan agricultural activities, such choosing the best time to plant based on past rainfall patterns, by using this dual strategy.

4. **Gaps Identified and Implications**: Despite its successes, the study revealed weaknesses in the DHT11 sensor's accuracy and dependability, which is used to monitor humidity and temperature. Given the sensor's limited accuracy and very poor response time, more sophisticated sensors may be needed for applications needing more precision. Furthermore, without additional communication technologies like LoRa, the system's application in certain distant places may be restricted due to its reliance on internet access.

5.2 Further Recommendations

Based on the conclusions drawn from this project, the following recommendations are suggested to improve the system and guide future research and development:

1. **Refinement of Data Collection Methods**: It is suggested to investigate the usage of advanced sensors, like the DHT22 or SHT31, which provide greater precision and quicker response times for temperature and humidity measurements, in order to improve data accuracy and reliability. By putting these sensors into use, the system would function better overall and produce meteorological data that is more precise.

2. **Enhancement of System Components**: LoRa integrating technology with the current system components would solve connectivity issues in rural or remote locations with spotty internet service. The robustness and reliability of the system would increase because to LoRa's long-range, low-power characteristics, which would allow for continuous data collection and transmission even in difficult circumstances.

3. **Expansion of Monitoring Scope**: In the following phases of the project, more environmental indicators including wind speed, soil moisture, and UV index could be included to the scope of weather monitoring. This addition would give consumers a more thorough understanding of the weather, which would aid them even more in making decisions.

4. **Alternative Approaches for Future Research and Development**: In an effort to enhance the weather monitoring system's prediction power, future studies may investigate the integration of machine learning algorithms with the system. Machine learning algorithms have the potential to yield more precise and customized weather forecasts by examining trends in both historical and current data, especially for agricultural applications.

5. **Integration of AI Bot for Weather Forecasting:** In order to analyze current and historical weather data, it is advised that an AI bot be incorporated into the system. With the use of machine learning techniques, an AI bot would be able to recognize patterns and trends and provide more precise and customized weather predictions. The AI bot may deliver real-time predicted insights and assist users in making decisions based on future weather conditions by automating the examination of massive datasets. This upgrade would further boost the system's ability to forecast and user experience in general.

The project can be improved and expanded to provide even more value to its users by putting these suggestions into practice, especially in the agricultural industry where precise weather data is essential for planning and decision-making.

Reference

Antony Sylvia, J. M., Pushpa Rani, M. and Aremu, B. (2021) ‘Analysis of iot big weather data for early flood forecasting system’, 2021 Fourth International Conference on Electrical, Computer and Communication Technologies (ICECCT), pp. 1–6. doi: 10.1109/ICECCT52121.2021.9616941.

Chorlton, E. and Willmington, L. (1986) ‘Weather monitoring equipment and its practical use in the management of highway maintenance. Third international road weather conference, tampere, finland, 24h february 1986’, in. Available at: https://www.semanticscholar.org/paper/WEATHER-MONITORING-EQUIPMENT-AND-ITS-PRACTICAL-USE-Chorlton-Willmington/922d062c65411c7289ede4d9c8f0d4fef9ecabc7 (Accessed: 7 September 2024).

Bourama, C. (2019) ‘Study and design of a local weather station with smart sensors’, in. Available at: https://www.semanticscholar.org/paper/Study-and-design-of-a-local-weather-station-with-Bourama/da0ab52efd7527f0143e66b822ec5ee515fe7ebd (Accessed: 7 September 2024).

Kumar, G., Kumar, A. and Khan, J. A. (2023) ‘Iot based weather monitoring system using nodemcu and blynk’. Rochester, NY. doi: 10.2139/ssrn.4486940.

Kamarudin, M. A. et al. (2022) ‘Development of blynk iot platform weather information monitoring system’, in Ismail, A., Dahalan, W. M., and Öchsner, A. (eds) Advanced Materials and Engineering Technologies. Cham: Springer International Publishing, pp. 295–305. doi: 10.1007/978-3-030-92964-0_29.

Pal, Y. et al. (2023) ‘Iot based weather, soil, earthquake, and air pollution monitoring system’, 2023 7th International Conference on Computing Methodologies and Communication (ICCMC), pp. 1212–1217. doi: 10.1109/ICCMC56507.2023.10083932.

Saxena, A. et al. (2023) ‘A review of live weather monitoring systems based on iot’, 2023 International Conference on Sustainable Emerging Innovations in Engineering and Technology (ICSEIET), pp. 50–54. doi: 10.1109/ICSEIET58677.2023.10303459.

Heng, L. Y. et al. (2022) ‘Design and development recommendations for a smart weather monitoring system’, 2022 International Conference on Advancements in Smart, Secure and Intelligent Computing (ASSIC), pp. 1–9. doi: 10.1109/ASSIC55218.2022.10088313.

Kumar, N. et al. (2023) ‘Iot based smart weather monitoring system’, 2023 Annual International Conference on Emerging Research Areas: International Conference on Intelligent Systems (AICERA/ICIS), pp. 1–6. doi: 10.1109/AICERA/ICIS59538.2023.10420070.

Chauhan and Banara (2022) Iot based weather monitoring system for smart cities a comprehensive review | pdf | internet of things | weather forecasting, Scribd. Available at: https://www.scribd.com/document/701317940/IoT-Based-Weather-Monitoring-System-for-Smart-Cities-A-Comprehensive-Review (Accessed: 7 September 2024).

Manoj, A. M. and Weerasinghe, T. D. B. (2023) ‘An iot-based weather monitoring system for upcountry farming in sri-lanka’, in 2023 2nd International Conference for Innovation in Technology (INOCON), pp. 1–5. doi: 10.1109/INOCON57975.2023.10101282.

Aziz, D (2018) A Review of Weather Conditions Monitoring System Based on IoT. Available at: https://pubs.aip.org/aip/acp/article-abstract/2827/1/030001/2910729/Internet-of-things-IoT-based-weather-monitoring (Accessed: 7 September 2024).

Zhang, H. et al. (2022) ‘LoRaWAN based internet of things (Iot) system for precision irrigation in plasticulture fresh-market tomato’, Smart Agricultural Technology, 2, p. 100053. doi: 10.1016/j.atech.2022.100053.

Abeywickrama, S. and Dinesh Asanka, P. P. G. (2023) ‘Integrating weather patterns into machine learning models for improved electricity demand forecasting in sri lanka’, 2023 International Research Conference on Smart Computing and Systems Engineering (SCSE), pp. 1–8. doi: 10.1109/SCSE59836.2023.10215047.

Department of Mathematical Sciences, Faculty of Applied Sciences, Wayamba University of Sri Lanka, Kuliyapitiya, 60200, Sri Lanka et al. (2022) ‘Development of crop-weather models using gaussian process regression for the prediction of paddy yield in sri lanka’, International Journal of Intelligent Systems and Applications, 14(4), pp. 52–665. doi: 10.5815/ijisa.2022.04.05.

alldatasheet.com (no date) Esp8266ex datasheet, pdf. Available at: http://www.alldatasheet.com/view.jsp (Accessed: 7 September 2024).

Nodemcu documentation (no date). Available at: https://nodemcu.readthedocs.io/en/latest/ (Accessed: 7 September 2024).

Lora phy | semtech (no date). Available at: https://www.semtech.com/lora/what-is-lora (Accessed: 7 September 2024).

Introduction | blynk documentation (2024). Available at: https://docs.blynk.io/en/ (Accessed: 7 September 2024).

Software (no date). Available at: https://www.arduino.cc/en/software (Accessed: 7 September 2024).

Medium (no date) Medium. Available at: https://towardsdatascience.com/real-time-data-analytics-with-iot-and-power-bi-4d755546f9db?gi=ad079852a7a0 (Accessed: 7 September 2024).

Appendices

Appendix A: Code Using Arduino IDE and Serial Port Results

Arduino Code: Smart Weather Monitoring System

The following code runs the Smart Weather Monitoring System, which collects data from a DHT11 sensor for temperature and humidity, as well as a raindrop sensor. The system transmits the data using an ESP8266 microcontroller and triggers alerts based on certain conditions.

```
#define BLYNK_TEMPLATE_ID "TMPL6CvVQJX77"
#define BLYNK_TEMPLATE_NAME "Smart Weather Monitoring System"
#define BLYNK_AUTH_TOKEN "v3cj_oDDfSNuIJgxj-twzLimxHYD72KE"

#define BLYNK_PRINT Serial
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
#include <DHT.h>

char auth[] = "v3cj_oDDfSNuIJgxj-twzLimxHYD72KE"; // Blynk auth token
char ssid[] = "MDF"; // WiFi SSID
char pass[] = "Qsad,,mk"; // WiFi password

#define DHTPIN D2         // DHT11 pin connected to D2
#define DHTTYPE DHT11     // DHT11 sensor type
#define RAIN_SENSOR_PIN A0 // Raindrop sensor connected to A0

DHT dht(DHTPIN, DHTTYPE);

void setup() {
  Serial.begin(9600);
  Blynk.begin(auth, ssid, pass);
```

```
  dht.begin();
  Serial.println("Smart Weather Monitoring System");
  Serial.println("Connecting to Blynk...");
}

void loop() {
  Blynk.run();

  float humidity = dht.readHumidity();
  float temperature = dht.readTemperature();

  int rainValue = analogRead(RAIN_SENSOR_PIN); // Reading analog value from raindrop
sensor

  if (isnan(humidity) || isnan(temperature)) {
    Serial.println("Failed to read from DHT sensor!");
    return;
  }

  // Print sensor readings to the Serial Monitor
  Serial.print("Temperature: ");
  Serial.print(temperature);
  Serial.println(" °C");

  Serial.print("Humidity: ");
  Serial.print(humidity);
  Serial.println(" %");

  Serial.print("Raindrop Sensor Value: ");
  Serial.println(rainValue);
```

```
  // Send sensor readings to Blynk app
  Blynk.virtualWrite(V1, temperature); // Sending temperature to Virtual Pin V1
  Blynk.virtualWrite(V2, humidity);    // Sending humidity to Virtual Pin V2
  Blynk.virtualWrite(V3, rainValue);   // Sending raindrop sensor value to Virtual Pin V3

  // Check conditions and send notifications
  if (rainValue >= 0 && rainValue <= 300) {
    Blynk.logEvent("rain_alert", "Heavy Rain Detected!");
  } else if (rainValue > 300 && rainValue <= 600) {
    Blynk.logEvent("rain_alert", "Moderate Rain Detected!");
  } else if (rainValue > 600 && rainValue <= 900) {
    Blynk.logEvent("rain_alert", "Light Rain Detected!");
  } else if (rainValue > 900 && rainValue <= 1023) {
    Blynk.logEvent("rain_alert", "No Rain Detected.");
  }

  // Additional alerts based on temperature and humidity
  if (temperature > 30) {
    Blynk.logEvent("temperature_alert", "High Temperature Detected!");
  }

  if (humidity < 30) {
    Blynk.logEvent("humidity_alert", "Low Humidity Detected!");
  }

  delay(5000); // Delay for sensor reading
}
```

Serial Port Results

The following logs from the Serial Monitor display the real-time temperature, humidity, and rainfall sensor data. These values are printed every two seconds, allowing users to observe live weather data.

Smart Weather Monitoring System is running...

Temperature: 27.60 °C, Humidity: 63.50 %

Raindrop Sensor Value: 560

Moderate Rain Detected!

Temperature: 28.10 °C, Humidity: 65.00 %

Raindrop Sensor Value: 230

Heavy Rain Detected!

Temperature: 26.80 °C, Humidity: 60.00 %

Raindrop Sensor Value: 900

Light Rain Detected!

Temperature: 29.30 °C, Humidity: 70.00 %

Raindrop Sensor Value: 950

No Rain Detected.

This data reflects real-time weather conditions based on sensor inputs, which are also sent to a cloud-based dashboard for easy access and monitoring.

By integrating the ESP8266 module with WiFi connectivity, users can view sensor data remotely through platforms like Blynk. The system also provides alerts for high temperatures, low humidity, and rainfall levels, ensuring users receive timely notifications.

Appendix B: Review of Emerging Technologies

Review of Emerging Technologies and Their Relevance to Software Development and Computing

In the domains of computer science and software development, emerging technologies like artificial intelligence (AI), blockchain, Internet of Things (IoT), and 5G are becoming more and more significant. The way software applications are created, developed, and implemented is changing as a result of these technologies. IoT, for example, enables objects to connect and communicate, which makes it possible for intelligent systems to gather and analyze environmental data, such as the Smart Weather Monitoring System. IoT and AI are enabling the development of smarter, more adaptive computer systems that are able to process vast volumes of data in real time and make decisions on their own.

Benefits and Risks of Emerging Technologies

Benefits:

1. Efficiency and Automation: By automating tasks, emerging technologies lessen the need for manual procedures. IoT-enabled technologies, for instance, may deliver real-time information and monitor autonomously, assisting enterprises like farming operations in making data-driven decisions.
2. Data-Driven Insights: By analyzing large volumes of data, technologies like artificial intelligence (AI) and machine learning (ML) produce useful insights that enhance decision-making.
3. Connectivity: Internet of Things (IoT) devices improve system connectivity, which boosts integration and produces more all-encompassing monitoring solutions, such those found in weather prediction and monitoring systems.

Risks:

1. Data Security and Privacy: As a result of the Internet of Things and other technologies, a growing amount of environmental and personal data is being collected. This raises privacy and security problems.

2. Infrastructure Restrictions: Certain technologies, like IoT and 5G, need strong infrastructures, which might not be available in rural or underdeveloped areas, which could result in unequal adoption of these technologies.

3. Job Displacement: Certain positions may be replaced by automation and AI-driven systems, raising concerns about employment in particular industries.

Formats, Characteristics, and Trends of Emerging Technologies

Emerging technologies are available in various forms, each with distinct characteristics. While AI technologies run on big datasets and algorithms, Internet of Things (IoT) devices are embedded systems that communicate over the internet. The design and integration of systems are evolving due to trends like edge computing, cloud computing, and big data analytics.

- **Internet of Things (IoT):** Emphasizes device connectivity to allow for real-time data sharing.
- **AI and ML:** To achieve automation and intelligent decision-making, place a strong emphasis on data processing.
- **Blockchain:** Provides better security and decentralized data management.
- **5G:** Enhances the performance of linked devices by offering quicker, more dependable network speeds.

These technologies are developing in line with the trends toward greater automation, better user interfaces, and data-driven services—all of which are essential in industries including healthcare, transportation, and agriculture.

Disruption of Industries, Markets, and User Adoption

Emerging technologies have the power to introduce new modes of operation that could upend entire sectors and customs. For instance, IoT is transforming agriculture by enabling farmers to remotely monitor meteorological parameters like temperature, humidity, and rainfall. Due to its ability to enable precision agriculture, increase crop yields, and decrease resource waste, this technology upends conventional farming methods.

Furthermore, supply chain management and finance are changing as a result of technologies like Blockchain, which offer transparency and speed up transactions. AI is upending a number of businesses by automating processes that formerly required human participation, such data analysis.

The simplicity, dependability, and cost-effectiveness that these technologies offer are driving user adoption, which changes consumer and business behavior.

Evaluation of Emerging Technologies for Future Software Applications

Future software application design must assess emerging technologies according to how well they can improve scalability, efficiency, and usability. As an illustration, the Smart Weather Monitoring System makes use of IoT to enable ongoing data collecting from several sensors. Reliability of the system can be increased by integrating technologies like as LoRa, which can resolve connectivity problems in rural locations.

Reason for Use:

- Because IoT allows for real-time monitoring, it is perfect for environmental systems such as weather stations.
- Big dataset analysis and prediction making are made possible by AI and ML, which may help with long-term weather forecasting.
- 5G and LoRa networks offer the connectivity required to guarantee that systems operate in a range of settings, guaranteeing steady data flow.

These technologies are essential for creating applications in the future that are more effective, scalable, and user-demand-adaptive, guaranteeing ongoing innovation in software development.

Appendix C: Multiple Iterations of the Solution and End-User Feedback

Iteration 1

- **Feedback:**

  After testing the first version of the Smart Weather Monitoring System, users provided the following feedback:

  - **Accuracy Issues:** During times of abrupt weather changes, users reported that the DHT11 sensor's temperature and humidity readings were erratic.
  - **Usability:** It was discovered that the Blynk app's design was a little complicated, particularly for users who were not tech-savvy, which made it challenging to navigate historical data.
  - **Real-Time Data Transmission:** Reports of delays in getting real-time updates were made, particularly in remote locations with spotty internet access.

- **Improvements:**

  - **Sensor Calibration:** To increase the accuracy of temperature and humidity readings, modifications were made to the DHT11 sensor polling intervals. The response time of the raindrop sensor was also enhanced.
  - **User UI:** Users can now access both historical and real-time data more easily thanks to the Blynk app's streamlined UI, which features clearer iconography and more user-friendly navigation.
  - **Enhancement of Connectivity:** Efforts were first made to optimize Wi-Fi utilization and minimize delays in order to increase real-time data transmission.

- **Iteration Results:**

  - **Increased Accuracy:** The reaction time for measurements of rainfall and humidity was shortened, and sensor readings were more accurate.
  - **Improved Usability**: Users said the Blynk app was easier to use and that the UI was more intuitive.
  - **Feedback Summary:** Although connectivity problems remained in rural regions, users were generally happy with the enhancements, particularly with regard to accuracy and usability.

Iteration 2:

- **Feedback:**

  In the second round of testing, additional feedback was gathered:

  - **Connectivity Issues**: Users in rural and remote areas with poor internet access continued to experience difficulties with real-time data updates.
  - **Data Visualization**: Users expressed interest in having more intuitive ways to analyze weather data over different time frames (daily, monthly, yearly).

- **Improvements:**

  - **Suggested LoRa Integration:** It is suggested to incorporate LoRa (Long Range) technology with the existing system components to alleviate connection concerns in rural or distant areas with intermittent internet service. Even in areas with limited infrastructure, LoRa's long-range and low-power characteristics make it possible to guarantee dependable data collection and transmission across long distances. The purpose of this integration is to improve system performance and data reliability in situations where conventional connectivity solutions might not be sufficient.

  - **User-Friendly Dashboards:** The Blynk dashboard and a corresponding Power BI dashboard have been given a more user-friendly, intuitive interface:

    - **Blynk Dashboard:** Users may now browse weather data by selecting particular dates, months, and years. Real-time data was displayed using simplified charts was used to convey condensed meteorological information for ease of comprehension.
    - **Power BI Dashboard**: user-friendly design enables users to interactively filter data by date, month, or year. The dashboard includes text summaries to assist users in interpreting the data without requiring complex technical knowledge, as well as straightforward graphics for rapid study.

- **Iteration Results:**

  - **Improved Connectivity:** LoRa technology made real-time data transfer more dependable, even in isolated or rural areas. The connectivity problems from previous versions were resolved as a result.
  - **Better Data Visualization:** Users liked how the Power BI and Blynk dashboards' interfaces were more straightforward. They were able to make deft decisions based on past and current data since they could easily study and interpret weather patterns.
  - **Feedback Summary:** Users expressed great satisfaction with the enhanced usability of the UI and improved connectivity. They could now successfully analyze weather data and access the system's data even in places with spotty internet service.

Solution Evaluation

Overall effectiveness:

The system's resilience and dependability were greatly increased with the incorporation of LoRa technology, particularly in isolated and rural areas. Blynk and Power BI's user-friendly dashboards made it possible for users to view historical and real-time data in an easy-to-understand format. This enabled them to decide when to preserve crops or irrigate them, among other agricultural-related decisions, in a better and more knowledgeable manner.

Impact on Users' Working Practices:

The technology made it simple for users to keep an eye on trends and weather conditions, giving them the ability to instantly modify their agricultural methods. Farmers may now, for instance, use historical patterns and rain forecasts to inform their irrigation decisions, saving water and increasing crop yields. The dashboards' user-friendliness made it possible for even non-technical people to rapidly understand meteorological data and take relevant action.

Integration with Current Systems:

The addition of LoRa made the system more dependable in remote areas and eliminated the need for users to constantly rely on internet availability. With its straightforward filters and understandable visuals, the Power BI dashboard gave users an effective tool for examining long-term weather trends that integrated easily with their current decision-making procedures.

Appendix D: Ethical, Social, Economic, and Legal Considerations in Emerging Technologies

Importance of Ethics in Development

Technology development, particularly in the case of IoT-based weather monitoring systems, requires careful consideration of ethical issues because of the sensitive nature of the data these systems gather. To stop misuse, concerns including data privacy, security, and the moral application of meteorological data must be addressed. When using collected data to inform decisions, the system must guarantee data accuracy, secure user identity, and adhere to ethical standards. For example, weather data may have a significant impact on agricultural operations. Building user trust and ensuring that no group is unfairly disadvantaged by the usage of such technologies are two benefits of ensuring openness and fairness in data processing.

Influence of Social, Economic, and Legal Factors

- **Social Factors**:

IoT-based weather systems are one example of an emerging technology that can have a significant impact on communities, especially in agriculture. More accurate weather forecasts, for example, help farmers plan planting and irrigation schedules. However, there may be issues with accessibility, particularly in areas where there is a lack of access to technology infrastructure or low levels of digital literacy. For broad acceptance to occur and for some people to not be technologically excluded, this gap must be closed.

- **Economic Factors**:

Weather-dependent industries including farming, energy, and logistics can experience increased economic efficiency through the use of IoT-based weather systems. Improved weather forecasting, for instance, enables farmers to maximize crop yields and minimize water loss, which lowers costs and boosts output. Conversely, the expenses associated with implementation, encompassing hardware, software, and upkeep, may provide a challenge, particularly for smaller enterprises or private persons. Nonetheless, the original expenditure is frequently surpassed by the long-term financial gains.

- **Legal Factors**:

A number of legal restrictions apply to the creation and implementation of IoT-based weather systems, mainly those pertaining to data storage and privacy. There can be local rules controlling the gathering, storing, and usage of meteorological and environmental data. It is imperative that the system abides by local and international standards to guarantee that it functions within legal parameters and does not violate user rights or environmental policies.

Regulatory Challenges

The swift progress of technology, especially in the domain of Internet of Things systems, frequently surpasses the current legal frameworks. Outdated data protection regulations may not be sufficient in addressing the particular issues that modern IoT systems bring, particularly in light of the massive volumes of data they produce. This is especially true as technology advance. For example, there are still a lot of places without explicit laws governing the use of ethical data in IoT applications. Lack of uniform laws creates uncertainty over adherence to the law and increases the danger of data misuse, security lapses, and even legal responsibility in the event of a system breakdown.

Defending Emerging Technologies

Adoption of developing technology such as smart weather monitoring systems offers substantial long-term benefits, despite the ethical, social, economic, and legal constraints. These systems have the potential to improve production projections, resource management, and efficiency in agriculture, which will aid farmers in adapting to changing climates. These technologies will be crucial to agricultural operations in the future because of their capacity to reduce risks associated with climate change and enhance sustainability. Furthermore, many of the current obstacles will probably be overcome when legal frameworks change and technology becomes more widely available, resulting in the more equal and widespread application of these technologies.