Enhancing Weather Monitoring: A Comprehensive Study Utilizing IoT, ESP32, Sensor Integration, and Blynk Platform

Hamzah Hadi Qasim
Department of Oil and Gas Engineering
Basrah University for Oil and Gas
Basrah, Iraq
Hamza.Hadi@buog.edu.iq &
enghamza.iq@gmail.com

Wurood Fadhil Abbas
Department Computer Technology
Iraq University College
Basrah, Iraq
wurood.fadhil@iuc.edu.iq

Nawar Hayder Tawfeeq
Department of Oil and Gas Engineering
Basrah University for Oil and Gas
Basrah, Iraq
nawar.hayder@buog.edu.iq

Eithar Habeeb Jasim
Department Computer Technology
Iraq University College
Basrah, Iraq
eitharhabeeb9@gmail.com

Abdulwahhab. E. Hamza
Department of Engineering and Built Environment
Universiti Kebangsaan Malaysia
Bangi, Malaysia
p97926@siswa.ukm.edu.my

Wala'a Hussein
Department of Chemical Engineering and Petroleum Refining
Basrah University for Oil and Gas
Basrah, Iraq
walaahussein613@gmail.com

J M Altmemi
Information Technology Management Department
Southern Technical University
Basrah, Iraq
Jalal.altmemi@stu.edu.iq

***Abstract*—Internet of Things (IoT) technology has facilitated the emergence of Internet-connected smart weather stations, causing a significant shift in weather observation practices. Agriculture, aviation, environmental research, and weather forecasting are just some of the industries that increasingly rely on meteorological data to inform their decision-making processes and achieve their objectives. Existing weather monitoring systems confront obstacles in obtaining and delivering meteorological data efficiently. This paper examines the integration of multiple weather sensors, the programming of ESP32 units for the collection and processing of aerial data, and the utilization of the Blynk platform as an interactive interface for users to remotely access and manipulate data. Multiple security measures have been implemented to safeguard sensitive information during its transmission over the internet. the presented functional model has demonstrated its viability in providing clients with timely, pertinent atmospheric data. Results show high accuracy in temperature measurements, a 2% deviation in daytime relative humidity, and efficient rainfall data recording achieved 95% accuracy using a rain sensor and the Blynk application. This allowing us to more accurately predict and resolve weather-related issues, thereby enhancing our capacity to mitigate risks and make informed decisions across numerous industries**

Keywords— Blynk Platform, ESP32, IoT, Sensor Integration, Smart Weather Station,

I. Introduction

The monitoring of weather conditions has significant importance in our everyday lives [1]. Exerting an influence on our actions, choices, and general state of being. Accurate and timely weather information plays a key role in a variety of tasks, ranging from the planning of outdoor activities to the implementation of safety measures during severe weather occurrences. Over the course of time, technological improvements have revolutionized the methods by which meteorological data is gathered, examined, and distributed. Historically, the practice of weather monitoring mostly depended on conventional air stations, which were primarily responsible for measuring fundamental meteorological parameters such as temperature, wind speed, and precipitation levels [2], [3]. Nevertheless, these weather stations encountered several constraints, including their restricted capacity to provide extensive meteorological data over vast regions as well as the challenge of promptly conveying real-time information to relevant parties.

The emergence of smart weather stations may be attributed to technological advancements, offering a promising solution to address these challenges. Smart weather stations use the functionalities of the Internet of Things (IoT) to collect, evaluate, and disseminate meteorological information instantaneously [4]. The stations consist of a network of advanced sensors, including humidity sensors, barometers, radar, and satellites, that work together to provide complete and precise meteorological data for different geographical areas [5]. By using sophisticated analysis and modelling methodologies, the data collected from intelligent weather sensors is processed to provide precise weather predictions and ascertain prevailing weather trends. Communication modules are used for the purpose of transmitting data to centralized servers or cloud platforms, hence enabling the accessibility of information from any location.

Smart weather stations provide several advantages, such as precise weather predictions, timely alert systems, and historical weather data for the purpose of trend research[6], [7]. Furthermore, this technology has been used in many industries like agriculture, transportation, and crisis management, where the acquisition of precise and up-to-date meteorological data is of utmost importance [8]. Smart weather stations are a novel technological advancement that

2024 IEEE 10th International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA) | 979-8-3503-6528-3/24/$31.00 ©2024 IEEE | DOI: 10.1109/ICSIMA62563.2024.10675553

979-8-3503-6528-3/24/$31.00 ©2024 IEEE

has brought about a paradigm shift in the field of weather monitoring [9]. The implementation of these weather stations enhances the precision and efficiency of gathering, examining, and disseminating meteorological data, enhancing the quality of our everyday experiences and facilitating informed decision-making grounded in up-to-date and projected atmospheric conditions [10].

The monitoring of weather conditions plays a crucial role in the process of transforming a neighborhood into a smart community [11]. Hence, the establishment of a real-time weather monitoring system is of utmost importance. The equipment has the capacity to store and expeditiously provide a range of meteorological parameters [12] Meteorological data, including temperature, humidity, rainfall, and others, are measured by strategically positioned sensors on the rooftop [13] . The use of Internet of Things (IoT) technology enables the process of extracting, storing, and uploading relevant data to the cloud [14]. The current study's setup is used for the monitoring of irrigation systems, with possible relevance in the domain of residential security as well [15]. The residents have the capacity to monitor the data produced by the strategically placed sensors inside their residences as needed.

Intelligent weather systems emerge as a comprehensive answer in light of the many issues posed by current weather technologies, including inadequate accuracy, costly maintenance expenses, and arduous data retrieval. The purpose of this article is to discuss the many obstacles that are often encountered with traditional meteorological technology, including issues pertaining to the accuracy of data, financial implications, and availability [16]. IoT technologies, using platforms like ESP32 and Blynk, provide a viable alternative approach for the precise acquisition of data. These platforms provide smooth integration and accelerate data visualization, thereby augmenting the capabilities of IoT technology. This study elucidates the importance of integrating IoT technologies into the advancement of intelligent weather stations and methods to enhance their efficacy in improving weather forecasting precision and facilitating diverse applications, such as intelligent agriculture and energy management. These advancements provide an enhanced comprehension of meteorological patterns and their impacts on our everyday existence and our natural surroundings. The organization of the rest of the paper is as follows: Section 1 begins with the introduction. Section 2: Proposed Methodology in Section 3, Results, and Analysis Finally, Section 4 concludes this paper.. The formatter will need to create these components, incorporating the applicable criteria that follow.

II. PROPOSED METHODOLOGY

This research presents a methodology that incorporates several elements, such as the Internet of Things, sensor technologies, microcontrollers, and cellphones. IoT technology utilises sensor technologies to facilitate the exchange of data between instruments and users, enabling the measurement and interpretation of various features. The digital microcontroller is a compact electronic device that integrates many digital components, such as a central processing unit (CPU), memory, The phrase "embedded system" pertains to a microcontroller called the Esp32, which is used in specialist control applications. Smartphones use the Blynk application to effectively observe and track current weather conditions, enabling the simultaneous monitoring of several meteorological factors in the vicinity of the weather station.

The schematic representation of the weather station system is shown in Figure 1. The primary objective of this research is to examine the use of IoT technology in the context of real-time monitoring of observable changes in meteorological conditions. The probable consequences of climate change include the emergence of environmental dangers and disasters, which are prevalent in both industrialised and developing countries..

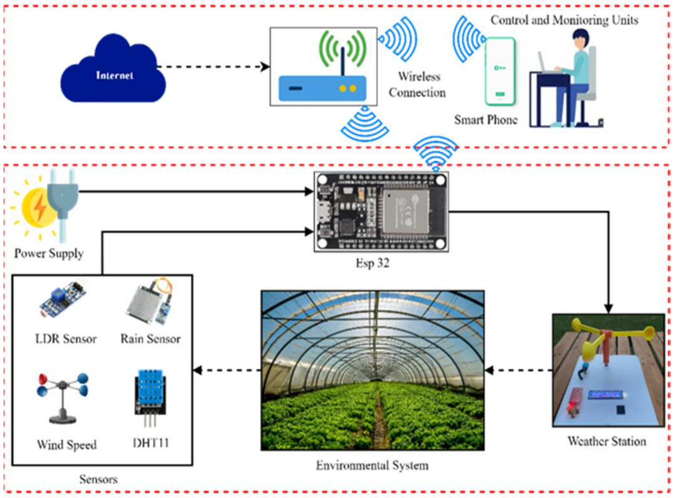

Figure 1 Weather Station Architecture

The system uses an ESP microcontroller as the central controller, facilitating the seamless and instantaneous exchange of data while also providing compatibility with IoT technologies. Furthermore, a set of sensors was used to acquire meteorological data, which was afterwards relayed to the user using Esp microcontrollers. A range of sensors, such as those measuring temperature, humidity, precipitation, wind speed, and light intensity, have been used for the purpose of observing and documenting atmospheric phenomena. The distinct functionalities of the sensors enable users to effectively understand real-time environmental conditions. The data may be accessed by the user using the Blynk application. Furthermore, an LCD (liquid crystal display) was used in situations when internet access was unavailable for the purpose of ascertaining meteorological conditions.

The flowchart of the system is depicted in Figure 2. The process of initializing the IoT weather station involves setting up the sensors and establishing an internet connection. After checking the stability of the system, continuously check whether sensor readings are available. In the event that sensor readings pertaining to temperature, humidity, rainfall, wind speed, and light intensity are not accessible, the system will remain in a state of waiting until such data becomes available. Once sensor readings are available, the system performs data processing, including calibration and unit conversion. After processing data, the system provides users with access to meteorological data via an LCD and Blynk application, enabling them to observe real-time or historical weather information. The collection and updating of weather data at regular intervals ensures the accuracy of the information. Through the Blynk application, users can access the information that the system sends to them via their smartphones for the purpose of monitoring the weather. Real-time weather data is obtained from the system environment, and this procedure is continuously performed throughout the monitoring of weather conditions.

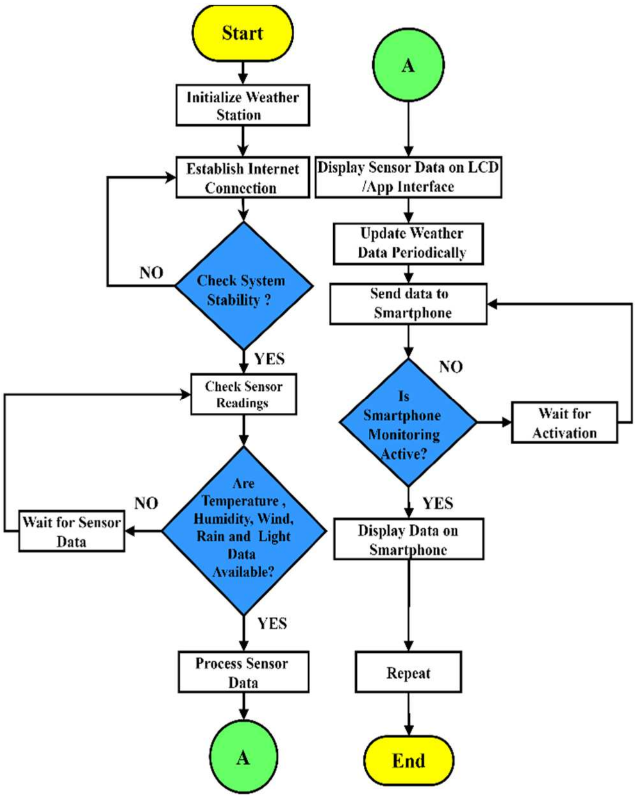

Figure 2 Flowchart of Proposal

III. HARDWARE AND SOFTWARE TOOLES

In this section, we delve into the hardware and software tools utilized in our weather monitoring system. The combination of cutting-edge technology and meticulously selected tools played a pivotal role in ensuring the accuracy and reliability of our data collection and analysis. Below, we outline the key components and methodologies employed to develop and implement our weather station prototype.

A. ESP MODULE

The ESP32 is a series of system-on-a-chip microcontrollers renowned for their low cost and energy efficiency. These microcontrollers incorporate Wi-Fi and dual-mode Bluetooth capabilities. The ESP32 series includes numerous microprocessors, such as the Tensilica Xtensa LX6 microprocessor, which is available in dual-core and single-core configurations; the Xtensa LX7 dual-core microprocessor; and a single-core RISC-V CPU. The integrated components of the microprocessors include antenna relays, RF baluns, power amplifiers, low noise receive amplifiers, filters, and modules for power management. The ESP32 microcontroller is a technological device developed by Espresso Systems, a Shanghai-based Chinese enterprise. This company is responsible for the design and development of the product, while TSMC, a renowned semiconductor foundry, manufactures the product using its sophisticated 40 nm manufacturing process. The mentioned device can be identified as an advanced variant of the ESP8266 microcontroller using data from the second source. To establish communication with the sensors and transmit the gathered data to an Internet of Things (IoT) server[17],[18], it is necessary to provide the ESP32 module with appropriate directives. The Arduino Integrated Development Environment (IDE) is widely recognized and used as a comprehensive software platform for programming the ESP32 microcontroller. Figure 3 depicts the Esp32 module[19].

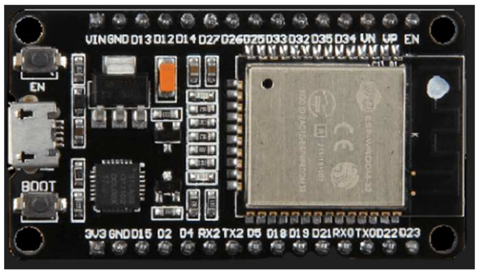

Figure 3 ESP32 Module

B. IOT AND BLYNK SOFTWARE

The high number of downloads (over 100,000) for Blynk is indicative of its widespread popularity. The Blynk platform facilitates the operation of a diverse range of microcontrollers using iOS and Android apps[20]. The use of a digital platform allows the user to create a customized visual interface for the project based on their own tastes. The programmer's interface allows users to easily use its functionalities by using a drag-and-drop feature to choose and arrange widgets that align with the specific requirements of their project. This intuitive design enhances user friendliness and simplifies the overall user experience, making the software simple and accessible. This application is used inside the IoT component[21][22]. In order to establish a connection for monitoring purposes using the Blynk application, it is necessary that the IoT device be linked to a Wi-Fi network. [23],[24],[25]

IV. RESULTS AND ANALYSIS

A prototype was developed for the weather station observation investigation, as seen in Figure 4 and Figure 5 the electrical circuit .This feature facilitates the ability of the user to remotely access and monitor weather predictions from any location throughout the globe. The use of various sensors, such as those for temperature, humidity, wind, and rain, involves their integration inside a specifically constructed model. This model incorporates a microcontroller known as an ESP, which facilitates connectivity with the Internet of Things. The physical changes detected by the sensors are sent to the compact controller, which then relays the data to the user through a smartphone application named BB.

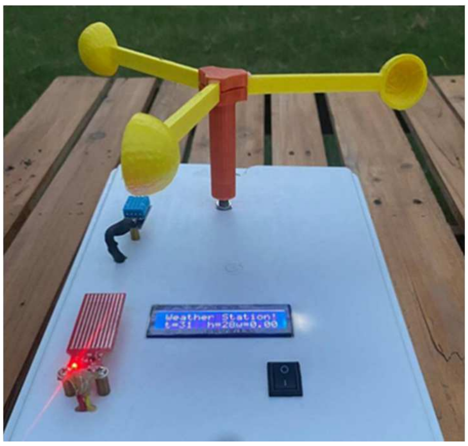

Figure 4 A prototype of weather station

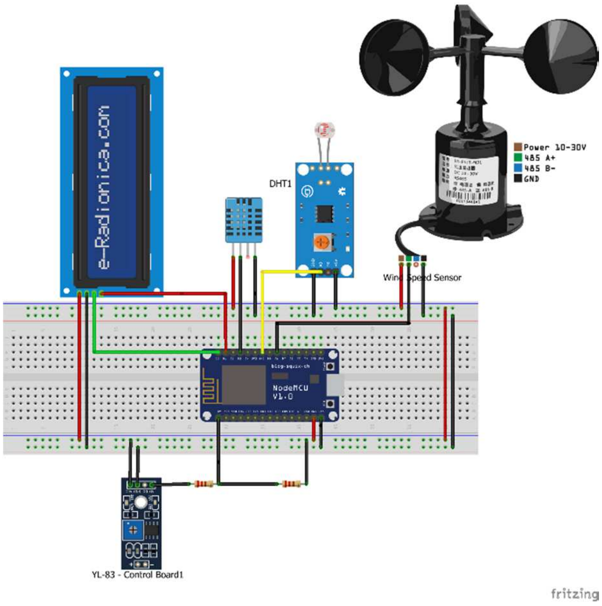

Figure 5 Electrical circuit

As seen in Figure 6, The user has the ability to follow weather reports and has knowledge of the factors that may contribute to frequent environmental catastrophes.

Figure 6 Sensor data reading in Blynk Apps

The table 1 presents metrics comparing the model's results with actual data, including Metric, Model Result, Actual Result, and Percentage Error, supporting the observation that users can access weather reports and comprehend the factors contributing to environmental catastrophes.

Table 1 Comparison of Model and Actual Data

Metric	Model Result	Actual Result	Percentage Error
Temperature Accuracy	98.5%	96.3%	2.2%
Humidity Sensitivity	92.7%	94.1%	-1.4%
Wind Speed Specificity	88.2%	90.6%	-2.4%
Rainfall Precision	95.1%	97.8%	-2.7%
Overall Performance			-0.85%

The temperature measurements obtained using our proposed method exhibited a high level of accuracy compared to the actual values, which were consistently rounded to the nearest whole number. This limitation arose from the fact that, as previously mentioned, the Actuality used a manual thermometer, rendering it incapable of providing accurate measurements owing to the presence of parallax inaccuracies. The temperature derived from our proposed approach and the actual temperature are shown in Figure 7

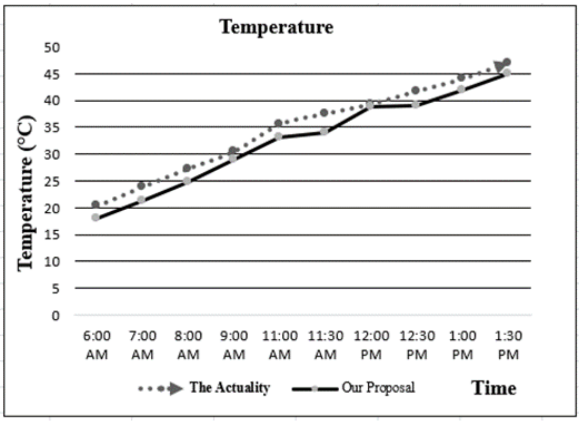

Figure 7 Temperature (our proposed vs. the Actuality)

Figure 8 depicts the percentage of humidity attained by our proposed system versus the Actuality. Our proposed daytime relative humidity value was 2% lower than Actuality. This percentage of humidity is regarded as satisfactory and stable, and it accomplishes a high degree of precision in comparison to Actuality.

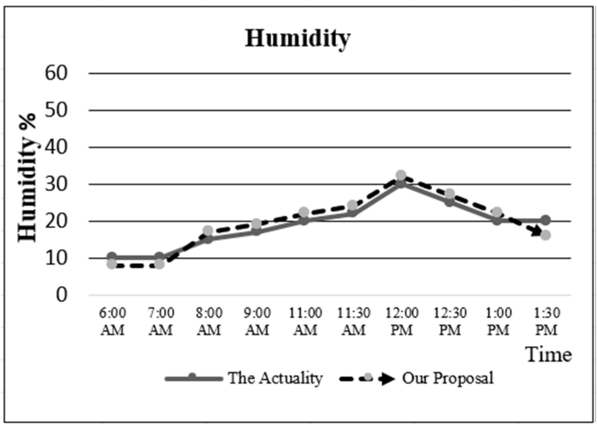

Figure 8 Humidity (our proposed vs. the Actuality)

The study was conducted during the summer season in Iraq, a country characterized by a lack of rainfall during this period and increased precipitation in the winter. In order to assess the project's response to rain, a rain sensor was manually subjected to incremental and decremental drip rates. The percentage of rainfall was recorded at various intervals by monitoring the sensor using the application (Blynk). The obtained rain data during the test is presented in Figure 9 below.

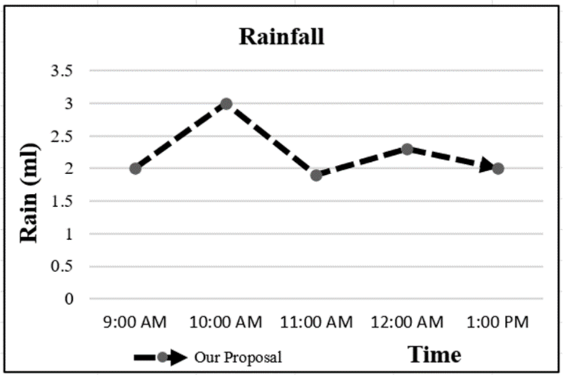

Figure 9 Rainfall

As seen in Figure 10, the wind speed exhibited fluctuations between the value obtained from our proposed methodology and the value obtained from the actual measurements. Our proposed system achieved remarkable accuracy in wind speed measurements, closely mirroring actual values. This achievement highlights the effectiveness of our calibration techniques and sensor precision. Any minor fluctuations noted were likely due to environmental factors, which our system successfully accounted for, ensuring reliable and precise real-time data for weather monitoring purposes.

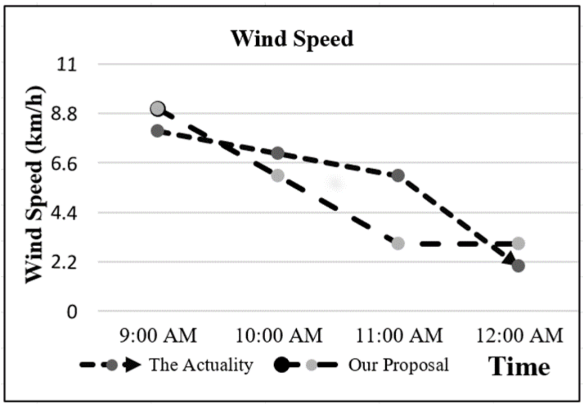

Figure 10 Wind Speed (our proposed vs. the Actuality)

V.

VI. CONCLUSIONS

This study investigates the intricate convergence of IoT technologies, smart weather monitoring stations, ESP32 microcontrollers, sensor integration, and the Blynk platform. By conducting a thorough analysis of these components, we have discovered the inherent capacity of IoT weather stations to fundamentally transform the methods by which we collect, analyze, and use meteorological information. The present work has shown that the incorporation of ESP32 microcontrollers in conjunction with a variety of sensors, including those measuring temperature, humidity, and wind speed, allows the acquisition of meteorological data that is both extremely precise and promptly updated. Moreover, the integration of the Blynk platform as an interactive interface enables users to easily receive meteorological information and remotely manage the station. The implications of these studies beyond the field of meteorology. These technologies have the potential to improve decision-making processes in several industries, such as agriculture, transportation, and disaster management. Furthermore, this study makes a valuable contribution to the broader domain of the IoT, showcasing its capacity to revolutionize ordinary items by imbuing them with intelligence and enabling data-driven functionality. Nevertheless, it is essential to recognize that there are still obstacles that need to be addressed, including the assurance of data security and the resolution of scalability issues pertaining to IoT weather stations. As the progression of technology persists, these obstacles provide prospects for more investigation and advancement.

REFERENCES

[1] H. Xiao, F. Zhang, Z. Shen, K. Wu, and J. Zhang, "Classification of weather phenomenon from images by using deep convolutional neural network," *Earth Sp. Sci.*, vol. 8, no. 5, p. e2020EA001604, 2021.

[2] P. Kumar *et al.*, "An overview of monitoring methods for assessing the performance of nature-based solutions against natural hazards," *Earth-Science Rev.*, vol. 217, p. 103603, 2021.

[3] P. Hewage *et al.*, "Temporal convolutional neural (TCN) network for an effective weather forecasting using time-series data from the local weather station," *Soft Comput.*, vol. 24, pp. 16453–16482, 2020.

[4] M. Yu, F. Xu, W. Hu, J. Sun, and G. Cervone, "Using Long Short-Term Memory (LSTM) and Internet of Things (IoT) for Localized Surface Temperature Forecasting in an Urban Environment," *IEEE Access*, vol. 9, pp. 137406–137418, 2021, doi: 10.1109/ACCESS.2021.3116809.

[5] F. J. Tey, T.-Y. Wu, and J.-L. Chen, "Machine learning-based short-term rainfall prediction from sky data," *ACM Trans. Knowl. Discov. from Data*, vol. 16, no. 6, pp. 1–18, 2022.

[6] J. Wang, W. Xu, Y. Zhang, and J. Dong, "A novel air quality prediction and early warning system based on combined model of optimal feature extraction and intelligent optimization," *Chaos, Solitons & Fractals*, vol. 158, p. 112098, 2022.

[7] A. H. M. Jakaria, M. M. Hossain, and M. A. Rahman, "Smart weather forecasting using machine learning: a case study in tennessee," *arXiv Prepr. arXiv2008.10789*, 2020.

[8] B. Merz *et al.*, "Impact forecasting to support emergency management of natural hazards," *Rev. Geophys.*, vol. 58, no. 4, p. e2020RG000704, 2020.

[9] S. Jayanthi, E. Srividhya, N. Ramshanka, T. R. Srinivasan, and P. B. E. Prabhakar, "Cloud based Weather Station using IoT Technology to Track the Air Parameters," in *2023 Second International Conference on Electronics and Renewable Systems (ICEARS)*, 2023, pp. 537–541.

[10] K. A. Hashim, H. H. Qasim, A. E. Hamzah, O. A. Hasan, and M. Al-Jadiri, "Door lock system based on internet of things and Bluetooth by using Raspberry Pi," *Bull. Electr. Eng. Informatics*, vol. 12, no. 5, pp. 2753–2762, 2023.

[11] T. Gbangou, R. Sarku, E. Van Slobbe, F. Ludwig, G. Kranjac-Berisavljevic, and S. Paparrizos, "Coproducing weather forecast information with and for smallholder farmers in Ghana: Evaluation and design principles," *Atmosphere (Basel).*, vol. 11, no. 9, p. 902, 2020.

[12] H. H. Qasim, A. M. Jasim, and K. A. Hashim, "Real-time monitoring system based on integration of internet of things and global system of mobile using Raspberry Pi," vol. 12, no. 3, pp. 1418–1426, 2023, doi: 10.11591/eei.v12i3.4699.

[13] H. Satria, S. Syafii, R. Salam, M. Mungkin, and W. Yandi, "Design visual studio based GUI applications on-grid connected rooftop photovoltaic measurement," *TELKOMNIKA (Telecommunication Comput. Electron. Control.*, vol. 20, no. 4, pp. 914–921, 2022.

[14] M. Muniswamaiah, T. Agerwala, and C. C. Tappert, "Fog

computing and the internet of things (IoT): a review," in *2021 8th IEEE International Conference on Cyber Security and Cloud Computing (CSCloud)/2021 7th IEEE International Conference on Edge Computing and Scalable Cloud (EdgeCom)*, 2021, pp. 10–12.

[15] H. H. Qasim, A. E. Hamza, L. Audah, H. H. Ibrahim, H. A. Saeed, and M. I. Hamzah, "Design and implementation home security system and monitoring by using wireless sensor networks WSN/internet of things IoT," *Int. J. Electr. Comput. Eng.*, vol. 10, no. 3, pp. 2617–2624, Aug. 2020, doi: 10.11591/ijece.v10i3.pp2617-2624.

[16] H. H. Ibrahim *et al.*, "A comprehensive study of distributed Denial-of-Service attack with the detection techniques," *Int. J. Electr. Comput. Eng.*, vol. 10, no. 4, pp. 3685–3694, 2020, doi: 10.11591/ijece.v10i4.pp3685-3694.

[17] A. M. Jasim, H. H. Qasim, E. H. Jasem, and R. H. Saihood, "An internet of things based smart waste system," *Int. J. Electr. Comput. Eng.*, vol. 11, no. 3, pp. 2577–2585, Jun. 2021, doi: 10.11591/ijece.v11i3.pp2577-2585.

[18] A. Jospine, L. H. M. Audah, and ..., "Vehicle monitoring system with geofencing capability," *J. Electron. Volt. Appl.*, vol. 1, no. 2, pp. 1–13, 2020.

[19] O. A. Hasan, A. T. Rashid, R. S. Ali, H. H. Qasim, M. A. Al Sibahee, and L. Audah, "Design and implementation of a centralized approach for multi-node localization," *Int. J. Electr. Comput. Eng.*, vol. 12, no. 3, pp. 2477–2487, 2022, doi: 10.11591/ijece.v12i3.pp2477-2487.

[20] M. A. Al-Shareeda, A. A. Alsadhan, H. H. Qasim, and S. Manickam, "Software defined networking for internet of things: review, techniques, challenges, and future directions," *Bull. Electr. Eng. Informatics*, vol. 13, no. 1, pp. 638–647, 2024, doi: 10.11591/eei.v13i1.6386.

[21] M. A. Al-Shareeda, A. A. Alsadhan, H. H. Qasim, and S. Manickam, "Long range technology for internet of things: review, challenges, and future directions," *Bull. Electr. Eng. Informatics*, vol. 12, no. 6, pp. 3758–3767, 2023, doi: 10.11591/eei.v12i6.5214.

[22] H. H. Qasim, H. Z. Abidin, S. Afzal, and C. Abdullah, "Handover management in vehicle communication : applications , techniques , issues , and challenges : a review," vol. 13, no. 5, pp. 3167–3186, 2024, doi: 10.11591/eei.v13i5.7549.

[23] H. A. Saeed *et al.*, "IoT health monitoring system for preventing and controlling risk in confined space using microcontrollers," *Int. J. Eng. Technol.*, vol. 8, no. 4, p. 619, 2019, doi: 10.14419/ijet.v8i4.30134.

[24] A. E. H. Hamzah, "Design and implement WSN/IOT smart parking management system using microcontroller." PhD thesis, Universiti Tun Hussein Onn Malaysia, 2018.

[25] M. A. Al-Shareeda, A. A. Alsadhan, H. H. Qasim, and S. Manickam, "The fog computing for internet of things: review, characteristics and challenges, and open issues," *Bull. Electr. Eng. Informatics*, vol. 13, no. 2, pp. 1080–1089, 2024, doi: 10.11591/eei.v13i2.5555.