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WATER PUMP CONTROL BY LORA FREQUENCY

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Abstract - This study investigates the use of LoRa frequency modulation in agricultural settings for water pump control systems. The paper explores the adaptability and efficacy of LoRa technology in tackling important issues associated with resource optimization, environmental monitoring, and water management in agriculture through an extensive examination of the literature. The research demonstrates how LoRa may transform current farming processes by facilitating data transfer, automation, and monitoring across a range of agricultural setups. Additionally, based on particular application needs, the comparative study of LoRa frequencies at various MHz ranges provides insights into well-informed decision-making for frequency selection. An essential component that enables remote monitoring, automation, and data-driven decision-making to improve productivity, sustainability, and resource efficiency in agriculture is the integration of IoT devices with LoRa technology. The focus on security measures highlights how crucial it is to protect private agricultural data from online attacks. Even with encouraging results, security, scalability, and reliability issues still exist, requiring more study and development to improve network efficiency, hone communication protocols, and find new uses for LoRa in agriculture. Through the perspective of LoRa technology, this study advances knowledge and use of IoT solutions for agricultural sustainability.

***Key Words*:** Lora frequency modulation, water pump, agricultural IoT, environmental optimization.

1.INTRODUCTION

Agriculture is the largest single water user, using about 65–70% of freshwater for irrigation, and in some cases drawing as much as 90% of the total water. Various institutions in India have made remarkable progress in evolving different strategies and technologies for improving sustainable use of available water resources for enhancing water and crop productivity. There is a widespread concern about the dwindling stock and deteriorating quality of natural resources, emphasizing the need for scientific and efficient management of these resources. Efficient water management is crucial for maintaining farm profitability and reducing the impact of irrigated production on offsite water quantity and quality, but may not be sufficient to achieve environmental goals without other adjustments within the irrigated sector. Improved water productivity can reduce the additional water requirements in agriculture. [43] there is a tradeoff between the quantity of water used in agriculture and the quality of return flow, which can be quantified and managed through better water and nitrogen application. Increased NO3-N leaching is an inevitable by-product of increased water productivity, but its adverse impacts can be reduced by better management of water and nitrogen application, such as split application of N-fertilizer. A number of techniques have been shown to effectively reduce the amount of energy used in WSS [44][45][46]. Three groups can be formed out of them: (a) building SCADA (Supervisory Control and Data Acquisition) control and monitoring systems; (b) installing more energy-efficient pumps, motors, and drives; and (c) producing energy in WSS utilizing alternative energy sources.

Systems for controlling water pumps are essential to agricultural operations because they provide consistent irrigation, economical use of water, and preservation of resources. Incorporating automation technology supports sustainable farming practices while also increasing crop output. Conventional approaches to water pump control, including wired automation systems or manual operation, have drawbacks include scalability problems and a lack of real-time monitoring. Utilizing control systems based on LoRa frequencies offers a viable way around these issues.[41] Explores the resource-intensive aspect of water bamboo farming and the intricacies of growing white bamboo, highlighting the necessity of effective water pump control methods. [42] Uses LoRa technology to create a pump motor monitoring and control system that provides real-time information and effective management techniques for agricultural water use. By bridging the gap between conventional farming methods and contemporary IoT-based technologies, the research hopes to enable agricultural settings to manage water resources sustainably.

LoRa, short for Long Range, is a wireless communication technology designed for long-distance communication with low power consumption. It operates in unlicensed radio frequency bands, typically utilizing frequencies below 1 GHz. LoRa offers exceptional range, often reaching several kilometers in urban environments and over 10 kilometers in rural areas, making it ideal for applications requiring communication over long distances. Its low power consumption enables battery-powered devices to operate for years without needing frequent battery replacements, making it suitable for remote and rural areas where power sources may be limited. These characteristics make LoRa technology well-suited for various applications such as smart agriculture, asset tracking, environmental monitoring, and smart city infrastructure. LoRa technology offers several advantages over other wireless communication technologies, such as Wi-Fi or cellular networks, particularly in agricultural settings. LoRa's exceptional communication range, extending several kilometers in rural areas, surpasses the range of Wi-Fi and cellular networks. Low Power Consumption: Compared to Wi-Fi and cellular networks, LoRa devices require significantly less power to operate. Deploying and maintaining Wi-Fi or cellular networks in expansive agricultural areas can be costly.

Robustness in Rural Environments. LoRa's robustness against interference and its ability to penetrate obstacles make it well-suited for deployment in rural environments, where terrain and foliage may obstruct signals from Wi-Fi or cellular networks.

2. LITERATURE REVIEW

In [1] it discusses the need to understand farmers' behavior before proposing strategies to reduce resource consumption in white bamboo planting, emphasizing the complexity of white bamboo planting and its heavy dependence on the growing environment. It also highlights the resource-consuming nature of water bamboo farming in terms of water and electricity, and presents the initial results of monitoring and controlling a pump motor based on IoT technologies. The paper discusses the complexity of white bamboo planting, the resource-consuming nature of water bamboo farming, the advantages of LoRa technology, and the tasks involved in monitoring and controlling the pump motor, with successful verification of the monitoring function in a water bamboo field near Puli township. Understanding farmers' behavior is crucial before proposing strategies to reduce resource consumption in white bamboo planting. LoRa technology has advantages over other LPWAN technologies in terms of deployment cost. The paper presents a LoRa-based monitoring and control system for future agriculture automation. The paper presents the initial result of monitoring and controlling a pump motor in the context of white bamboo planting, emphasizing the need to understand farmers' behavior and the resource-consuming nature of water bamboo farming. It also introduces a LoRa-based monitoring and control system for future agriculture automation. The limitations of the study include Verification of the control of the pump motor only in the laboratory, not in the actual field, Application of the monitoring function only in the field, without testing in other environments, Incomplete understanding of the impact of the motor extracting underground water on the field due to the lack of environmental data collected by other equipment in development.

[2] Introduces the use of long-range (LoRa) technology for monitoring DC motors in the context of electrical energy efficiency and IoT, emphasizing the prevalence and benefits of IoT and LPWAN technologies, particularly focusing on LoRa-based network linkages. It also highlights the importance and advantages of DC motors in addressing energy efficiency issues. The methodology used in the study includes testing the LoRa device under different conditions and conducting an experiment on the distance between the receiver and transmitter using the line-of-sight (LOS) model. Successful communication between LoRa transmitter and receiver, Comparison of encoder sensor and INA 219 sensor readings with measuring instruments. The paper discusses the use of LoRa technology for monitoring DC motors, including testing under various conditions, successful communication between the LoRa transmitter and receiver, and the need for further exploration of its application in different environments. The limitations are i)Need for further investigation into the complexity of the problem, such as distances approaching the LoRa distance limit and disturbances that have a major contribution ii)Requirement for deeper exploration of the application in rural or urban areas.

A three-fold contribution summarizing the prospects and challenges for precision agriculture in greenhouses, illustrates the importance of sensor box design for accurate readings, and demonstrating an end-to-end LoRaWAN-based WSN system for greenhouse monitoring. [3] The methodology involves real-time deployment of a LoRaWAN-based sensor network in a greenhouse, designing a dashboard for data visualization and analysis, analyzing power consumption for LoRaWAN communication, trying different enclosure types for sensors, summarizing prospects and challenges for precision agriculture in greenhouses, proposing successive steps for optimal WSN deployment, illustrating the importance of sensor box design, and demonstrating an end-to-end LoRaWAN-based WSN system for greenhouse monitoring. The "Summary of result" is a comprehensive overview of the challenges and prospects for precision agriculture in greenhouses, emphasizing the importance of deploying sensors in air-circulated boxes for accurate data and longer sensor lifetimes, highlighting the diverse control systems used in greenhouses, and proposing sequential steps for WSN deployment and environmental monitoring. In this paper, they mainly looked into energy-efficient IoT strategies for precision agriculture in greenhouse. They have summarized the prospects and challenges for precision agriculture in greenhouse and discussed the implication of sensor box design scheme over sensor readings. It is crucial to deploy the sensors in the air circulated box for precise data and longer lifetime of the sensors. That are highlight the divergent control systems used in the greenhouse and propose the sequential steps for WSN deployment and monitoring of the environment. This paper demonstrates an end-to-end complete WSN architecture and deployment of LoRaWAN-based network for the monitoring of tomato crop in the greenhouse. Progressive WSN deployment, in different phases, helps in understanding the challenges of the greenhouses and applying the mitigation scheme at every next phase. The system monitors different values like light, temperature, CO_2 and humidity and shows the variation throughout the crop season. Therefore, it is important to keep monitoring the environmental data for precision agriculture. For future work, we would work towards the increased energy efficiency of the LoRaWAN network by energy harvesting.

To design and manufacture a [4] remote-control system for irrigation pumps using LoRa technologies to help farmers in managing plant irrigation on large areas of land, especially in areas with inconsistent provision of electricity. Effectiveness of the remote-control system in switching irrigation pumps on and off using LoRa technologies and its ability to control devices remotely up to 10 km without the use of towers for communication and other additional costs. The result of the paper is the presentation of a new intelligent device designed to control irrigation pumps using LoRa communication technology, with a focus on long-distance control, cost-effectiveness, and long operational life. The device is capable of controlling devices remotely up to 10 km without the use of towers for communication and other additional costs, and it has a long operational life of more than five years. The system proved its efficiency in practical application inside the university laboratory. The conclusion is the development and implementation of a cost-effective, remote-control system for irrigation pumps using LoRa technologies, with a focus on small size and long-distance remote operation. The paper also concluded that a new intelligent device designed to control irrigation pumps using long-distance communication at low cost and with a long battery life, aiming to help farmers in areas with inconsistent electricity provision. It also discusses the implementation of a smart system to monitor and operate agricultural pumps on farms using LoRa technology.

[5] To explore the application of internet technology and Internet of Things (IoT) in agriculture and to investigate the potential of precision agriculture or precision farming as a solution to improve agricultural production. The methodology involves the use of GPS, sensor technologies, computer technology, and systems in precision agriculture, as well as the development of a tractor data acquisition system using LoRaWAN technology. The implementation of new technologies in agriculture, including precision agriculture, GPS, sensor technologies, and LoRaWAN for IoT integration, is crucial for achieving high yield agricultural production. The paper's discussion section provides a brief summary of the challenges in agricultural production due to population growth and narrowing agricultural areas, emphasizing the need for precision agriculture and the increasing use of IoT devices for monitoring purposes. The limitations of precision agriculture encompass several key challenges. Firstly, farmers face the necessity of adopting GPS and sensor technologies, alongside computer systems, which poses a significant barrier to entry due to the technical expertise required. Secondly, the demand for a unified communication technology for smart devices to interact, whether over short or long distances, adds complexity and interoperability issues. Additionally, sensor energy consumption remains a major concern within the Internet of Things (IoT) framework, impacting device longevity and operational efficiency. Moreover, the constraint of IPv4 numbers for devices connecting to the internet restricts scalability and connectivity potential. Lastly, the challenge persists in selecting the most suitable wireless communication technologies to enable seamless IoT integration, further complicating deployment and interoperability efforts. Addressing these limitations is crucial for advancing precision agriculture and maximizing its potential benefits.

[6] provides an overview of the increasing scarcity of safe water and the importance of water quality monitoring, leading to the development of IoT-based smart water quality monitoring systems. It also outlines the focus of the study on common water-quality monitoring parameters, safe limits for drinking water, smart sensors, critical review, and design recommendations for an efficient system. The methodology involved a systematic search and manual inspection of a large set of articles, followed by a filtering process to focus on relevant survey/review papers. The final selection included 20 articles for the comprehensive review of contemporary IoT-WQMS for domestic water. The discussion section covers various aspects of water pollution, including contamination of groundwater and the uneven distribution of water resources globally. It also discusses the factors affecting the level of the water table and the potential consequences of its depletion. The discussion emphasizes the importance of public awareness and responsible water usage to mitigate the impact of the water crisis. The section concludes with a declaration of no conflict of interest. The limitations of the study, as stated in the paper, include the potential risk to data security due to third-party involvement in cloud platforms, the lack of guarantee for continuous service provision, concerns about potential increases in the cost of services for commercial activities, and the absence of acknowledgment of potential cessation of services without prior notice. The paper also suggests further research into optimal designing of smart water quality monitoring systems, exploration of optimal portable sensors' technology, usage of secure and reliable IoT servers, and devising resilient schemes mitigating potential security breaches. The authors also declare no conflict of interest.

To propose a feasible [7] solution for the design and implementation of LoRa Gateway, to propose an improved LoRa network server architecture and implement it with an open-source project on GitHub, and to deploy a LoRa prototype system in urban environments and conduct experiments to evaluate its performance. The methodology involves discussing typical application scenarios of the LoRa network, presenting the LoRa system architecture and the functionality of each component, and conducting extensive experiments to evaluate the performance of LoRa networks in typical environments. The results include the proposal of a feasible solution for the design and implementation of LoRa network, an improved LoRa network server architecture, and the demonstration of the network's capability to support over 10,000 LoRa Nodes with a maximum transmission distance of about 7.5 km in urban environments. The paper concludes the emergence of the LoRa network as a promising LPWA network for IoT applications, proposes a feasible solution for designing and implementing a private LoRa network, and presents the deployment and evaluation of a LoRa prototype system in urban environments.

The objective was [8] to implement a water and air monitoring system using sensor development and a LoRa Network, focusing on the case study of air pollution and water monitoring. The use of LoRa enabled long-range data communications and the rollout of IoT applications with seamless interoperability among smart items. The system utilized solar cell charging equipment to achieve self-contained power without constraints on the power supply issue, demonstrating the potential for energy-efficient and sustainable monitoring systems. The methodology involved implementing a water and air monitoring system using sensor development and a LoRa Network to measure various parameters, along with the use of a low-power LoRaWAN network for long-distance transmission and solar cell charging equipment for self-contained power. This paper introduces the experimental results of the LoRa low-power network of a monitoring system, which is used for monitoring Tunghai University campus’s air and lake water. Long-distance transmission is indeed LoRa’s advantage. Regardless of the amount of data (as long as it is within the capabilities of LoRa), the energy consumption of LoRa is constant, but the WiFi is not. Moreover, there is no delay phenomenon in the transmission at a distance of 1.5 km. The summary of the discussion section highlights the benefits of LoRa technology, its application in monitoring air and water quality, and the potential for using data from multiple sensors to improve environmental conditions. The authors express confidence in the experimental data and suggest that the LoRa monitoring architecture can be extended to a wide range of applications.

[9] include proposing a lake water environment monitoring system based on LoRa and IoT technology, realizing remote collection, data storage, dynamic monitoring, and pollution alarm for distributed multi sensor node information, ensuring good performance in real-time data acquisition accuracy, data transmission reliability, and pollution alarm success rate, providing high accuracy, high reliability, and long-distance characteristics for large area water quality monitoring, and realizing the functions for distributed collection of water quality data, node positioning, remote transmission, data storage, and remote monitoring. The methodology used in the study includes proposing a lake water environment monitoring system based on LoRa and IoT technology, implementing remote collection, data storage, dynamic monitoring, and pollution alarm for water quality parameters, utilizing a star topology network, employing water quality monitoring nodes based on LoRa technology, managing power supply requirements with a power

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management module, being supported by China Mobile Internet of Things Open Cloud Platform (OneNET), and conducting human intervention tests to measure response speed and success rate of uploading alarm information. The proposed water environment monitoring system based on LoRa and IoT technology successfully achieves remote collection, data storage, dynamic monitoring, and pollution alarm for distributed multi sensor node information. The experimental results demonstrate that the system has high accuracy, reliability, and long-distance characteristics, meeting the needs of large area water quality monitoring. The paper concludes the effectiveness and reliability of LoRa technology in multiscene monitoring applications, emphasizing its suitability for field application scenarios such as agriculture and aquaculture monitoring. It also describes the clear hierarchy of the system from bottom to top, with the terminal node obtaining detailed data, the transport layer addressing large-scale data access problems, and the platform layer providing reliable support for user applications. The potential adoption of alternative power sources such as solar power, wind power, and water power to address battery replacement and system durability concerns is suggested. The authors declare no conflict of interest regarding the publication of the paper.

To develop a water quality monitoring tool with sensors for river water parameters and to conduct water quality, fuzzy algorithm, and LoRa network testing in the Citarum River.[10] The methodology involves creating a water quality monitoring tool with sensors, processing the data obtained by fuzzy algorithm, carrying out water quality testing, and analyzing the performance and network quality of the LoRa from Monriv tool for data delivery. The study aimed to test specific hypotheses regarding the efficacy of a water quality monitoring tool. Firstly, it hypothesized that the sensors integrated into the tool would deliver precise and dependable data concerning key parameters of river water, including pH, TDS (Total Dissolved Solids), turbidity, and temperature. This hypothesis sought to ascertain the reliability and accuracy of the sensor readings, crucial for effective water quality assessment. Secondly, the study hypothesized that the fuzzy algorithm incorporated within the monitoring system would effectively analyze the sensor data to determine the overall quality of water. It aimed to ascertain whether the algorithm could accurately classify water quality as either good or poor based on the data collected from the sensors. These hypotheses served as the foundation for evaluating the functionality and performance of the water quality monitoring tool. The conclusion is a comprehensive overview of the study's findings, including the accuracy of sensors, water pollution statistics, fuzzy algorithm results, LoRa network testing, and comparison of water quality and LoRa network quality between sectors 6 and 21 in the Citarum river.

In [11] there are Indications of LoRa modulation at 433 MHz suffering from some attenuation in tropical climates, but it shows promising ability to propagate in NLOS conditions. The methodology involved conducting LOS and NLOS propagation tests, testing the effects of bandwidth and spreading factor on reception, and recording RSSI over various ranges and urban environments with specific parameters such as bandwidth, spreading factor, coding rate, and carrier frequency being taken into account. The LoRa transceiver was tested with an output power of +20dBm.It is suggested that the deployment of end devices with limited energy consumption will result in increasing the battery lifetime of the devices up to 10 years. However the study include the lack of extensive prior research on LoRa propagation performance in tropical climate environments, the need for further analysis to deepen the understanding of LoRa performance in such environments, the trade-offs between range and transmission bit rate, and the potential limitations in the study's focus on line-of-sight conditions. Tropical conditions may vary due to various reasons, for example the geography where the research is conducted at 600 m above sea level may vary with mountainous regions or more elevated levels.

The proposed work in [12] focuses on the use of LoRa modulation at different frequencies (169, 433, and 868 MHz) for local communication infrastructures inside forests. The lower frequency of 169 MHz is far superior to the higher and more common frequencies available for license-free wireless communication with LoRa inside forests. The paper discusses the comparison of achievable range in the forest using LoRa modulation in different frequency bands and concludes that using a lower frequency of 169 MHz is far superior to higher frequencies for wireless communication with LoRa inside forests. The methodology used in the study involves describing the basic LoRa PHY receiver algorithms, conducting a detailed analysis of the LoRa PHY by studying multiple aspects of a LoRa receiver, presenting different structures for LoRa demodulation, studying the synchronization process in LoRa receivers, analyzing the effect of carrier frequency offset (CFO) and sampling frequency offset (SFO) on the receiver performance, and receiving and analyzing different transmitted messages from a LoRa radio to extract the parameters of the different blocks. The results from proposed work can be used for setting up data infrastructures inside forests, such as for forestry digitization, environmental monitoring networks, or building rescue chains for forest workers.

[13] provides an overview of LoRa technology, its application in IoT, comparisons with other radio frequency modules, and challenges in sending BME280 sensor data using long-range 915 MHz radio frequency. It also emphasizes the importance of analyzing received signal strength and the impact of obstacles on signal attenuation. The methodology used in the study includes testing LoRa at different distances using the BME280 sensor, building sensor nodes with ADR and Automatic sleep mode algorithms, comparing different radio frequency modules at long distances, and analyzing the received signal strength indicator (RSSI) for sending BME280 sensor data in different conditions. The paper does not explicitly state traditional limitations such as small sample size or methodological errors. It does mention difficulties in sending packet data using the LoRa radio frequency module due to obstacles like mountains, buildings, and trees causing greater attenuation of the signal. It also suggests that free space is the best condition for sending BME280 sensor signals using LoRa at a distance of more than 1 km. The study does not provide explicit suggestions for further research or self-reported problems. The research is only focused on the BME280 sensor which within itself is a limitation.

For long range communications based on LoRa, [14] provides a mathematical description of the physical layer of LoRa in the 2.4 GHz band and investigates the maximum communication range in free space, indoor, and urban environments, showing a maximum range of 333 km in free space, 107 m in an indoor office-like environment, and 867 m in an outdoor urban context. It also discusses the impact of moving from LoRa at sub-GHz bands to 2.4 GHz on communication and localization applications. The methodology involves providing a mathematical description of the physical layer of LoRa in the 2.4 GHz band, investigating the maximum communication range in different scenarios, and discussing the corresponding data rates. The paper is structured into sections covering related work, mathematical background, path loss models, results, comparison to other technologies, and general conclusions. However, there is exclusion of fade margin in the link budget calculations. The theoretical maximum ranges calculated may not be achievable in real-world environments. The need for more LoRa receivers to cover wide areas makes it a less feasible solution to build large public networks compared to sub-GHz LPWANs. While considering this study, the trade-off between range and data rate should be taken into account when configuring a LoRa channel at 2.4 GHz, leading to more flexible applications, such as the localization of assets in a private LoRaWAN network, which requires further investigation.

To know models for effect of carrier frequency offset and sampling frequency offset. Compensation methods are proposed for the Lora transceiver in [15].The methodology used in the study involves describing the basic LoRa PHY receiver algorithms, conducting a detailed analysis of the LoRa PHY by studying multiple aspects of a LoRa receiver, presenting different structures for LoRa demodulation, studying the synchronization process in LoRa receivers, analyzing the effect of carrier frequency offset (CFO) and sampling frequency offset (SFO) on the receiver performance, and receiving and analyzing different transmitted messages from a LoRa radio to extract the parameters of the different blocks. The main findings of the paper are the robustness of the LoRa receiver against CFO, the proposed method to prevent the effect of SFO on demodulation, and the successful implementation and testing of LoRa on a USRP platform. However, there is absence of an in-depth analysis and detailed algorithmic description of a LoRa receiver in the existing literature, as well as the need for further exploration of compensating residual offset and preventing the SFO effect on LoRa demodulation.

[16] provides an in-depth performance evaluation of LoRa for indoor IoT applications, focusing on network architecture, communication protocol, and performance analysis in indoor environments. Proposed work also discusses design considerations for low-power communication protocols and the three classes of end-devices in LoRaWAN. The authors conducted experiments to evaluate the performance of the LoRaWAN protocol in an indoor environment using specific hardware setups and investigated LoRa radio RSSI values to understand its immunity against multi-path and signal fading at high spreading factors. The methodology used in the study involved building a LoRa radio enabled end-device, setting up a gateway, and conducting indoor experiments to evaluate the performance of LoRa for indoor IoT applications. The experiments included transmitting packets at different coding rates, transmission powers, and data rates. Data collection and storage were managed using a local Node.js web application. Key notes to take into account from proposed work are LoRa technology offers immunity against multi-path and signal fading, especially at high spreading factors. At closer distances to the gateway, the received signal strength is high for a low spreading factor scheme. Increasing the spreading factor decreases packet loss but also decreases effective bit rate, which may not be suitable for high throughput IoT applications. Interferences are significantly high at farthest locations from the gateway therefore, end-devices should communicate at high spreading factors. The paper includes the lack of attention to the performance analysis of LoRaWAN protocol for indoor environments and the need for more comprehensive research covering both indoor and outdoor IoT applications.

The proposed work in [17] focuses to develop an IoT LoRa prototype for remote temperature measurement, evaluate its performance in both LoS and Non-LoS conditions, and assess the efficiency of LoRa for IoT applications. In the study is the development and evaluation of an Internet of Things (IoT) LoRa prototype for remote measurement of temperature at the frequency of 915 MHz, including a temperature sensor, memory storage, data processing, and data visualization using Cloud Server on the Web Browser. The performance of the prototype is evaluated through field trials under Line of Sight (LoS) and Non-LoS conditions using a 14 dBm transmit power. No specific frequency, duration, or amount of the intervention is mentioned. The main findings include the development of an IoT LoRa prototype for remote temperature measurement, its successful performance evaluation in both LoS and Non-LoS conditions, and the efficiency of LoRa technology for IoT applications with the need for specific design adjustments. The methodology used in the study involved conducting field trials on both Line of Sight (LoS) and Non-LoS conditions to evaluate the performance of the IoT LoRa prototype using a 14 dBm transmit power. The study concluded that LoRa is efficiently used for IoT applications in both conditions, but a specific design should be adjusted. The paper does not explicitly state any research gap or limitation, but it suggests that a specific design should be adjusted, indicating a potential limitation in the current design or implementation.

The proposed transceiver in [18] demonstrated a very long LoRa link with low-cost commercial-off-the-shelf omni-directional rubber duck antennas with standard-compliant output power in the 868 MHz ISM band. The methodology involves comparative tests with commercial transceivers, field tests for long-range performance, and temporal analysis of link variability. The proposed LoRa transceiver demonstrated improved sensitivity by 15–25 dB and better immunity to interference compared to two widely utilized commercial transceivers. The design of a novel high-sensitivity low-cost miniaturized LoRa transceiver was achieved, along with demonstrating a very long LoRa link with low-cost commercial-off-the-shelf omni-directional rubber duck antennas with standard-compliant output power in the 868 MHz ISM band, and temporal analysis of the link variability for different spreading factors within a fixed LoRa bandwidth.

Proposed work [19] focuses on investigation of performance of LoRa links over seawater in clear Line-of-Sight (LOS) and obstructed path scenarios in two different ISM radio bands: 868MHz and 434MHz, assess the feasibility of LoRa links over seawater at specific distances using different LoRa Spreading Factors and bandwidths, and provide correction factors for RSSI to correlate it with actual signal levels received at transceivers' inputs to enable accurate interpretation of the results obtained in field experiments. The methodology involves investigating LoRa links over seawater in clear Line-of-Sight (LOS) and obstructed path scenarios in two different ISM radio bands, using three different LoRa devices. The investigation includes the linearity of transceivers' Receive Signal Strength Indicator (RSSI) and Signal-to-Noise (SNR) measurement chain, as well as correction factors for RSSI to correlate it with actual signal levels received at transceivers' inputs. Field experiments were conducted for three different LoRa Spreading Factors within a specific bandwidth and coding rate. The experiments demonstrated the feasibility of LoRa links over seawater at distances of at least 22 km using low-cost off-the-shelf rubber duck antennas in LOS path condition in both ISM bands. It was also shown that LoRa links can be established over a 28 km obstructed LOS oversea path in the ISM 434MHz band, but using costly, higher gain antennas. Laboratory experiments revealed the linearity of RSSI and the saturation of the SNR measurement chain for specific Received Signal Strength (RSS) values. With Inference to proposed work, LoRa links are feasible over seawater at distances of at least 22 km using low-cost antennas in clear Line-of-Sight (LOS) conditions in both ISM bands. Additionally, links can be established over a 28 km obstructed LOS oversea path in the ISM 434MHz band, but this requires costly, higher gain antennas. The laboratory experiments provided insights into the linearity of RSSI and the saturation of the SNR measurement chain, enabling accurate interpretation of the field experiment results. The limitations of the study include its focus on LoRa links over seawater, the use of a limited number of LoRa devices, and the reliance on costly, higher gain antennas for establishing links over obstructed paths.

[20] provides a brief summary of the design and testing of a fully autonomous wearable wireless sensor node with integrated LoRa transceiver and textile antenna, demonstrating reliable long-range communication capabilities. The proposed work focuses on the use of LoRa communication for low-power kilometer-range wireless data communication, integrate a LoRa transceiver onto a textile substrate-integrated-waveguide antenna for long-range body-to-body communication links, describe the design and characteristics of the integrated unit, including radiation patterns, and perform an outdoor long-range performance test as a proof of concept. The methodology involves integrating a LoRa transceiver onto a textile substrate-integrated-waveguide antenna, describing the design and characteristics of the unit, and conducting an outdoor long-range performance test to demonstrate communication reliability at various distances and antenna orientations. Main findings from proposed work are, LoRa communication enables low-power kilometer-range wireless data communication using chirp spread spectrum modulation in sub-GHz frequency bands. Integration of a LoRa transceiver onto a textile substrate-integrated-waveguide antenna allows for long-range body-to-body communication links. The fully autonomous wearable wireless sensor node, including various components, was able to achieve reliable communication for a range over 500 m and up to 1.44 km in static conditions.

Proposed work [21] include developing a water tank management system using LoRa technology to remotely monitor and manage water levels, providing real-time data visualization and alerts for low and high water levels, and effectively managing water resources. The methodology involves designing and implementing a water tank management system using LoRa technology, detailing the components, connections, and operation modes. The circuit consists of a LoRa module (receiver), relay, water pump and slide switches connected to the Arduino Nano. The system utilizes a float sensor to measure the water level, a LoRa module to transmit the data to a remote server, and a microcontroller to process the data and control the system. This system provides real-time data to a remote server, allowing users to monitor and manage the water level in their tanks without physically checking them. When the water level reaches below the low point, the water pump will get switched ON automatically and start filling the water in the tank. The system is cost-effective and efficient for remote monitoring and management of water levels, with potential applications in various sectors and potential benefits for improving water efficiency and sustainability.

In [22], the study aims to enhance the digitization and standardization of LoRaWAN IoT communication technology with ML and DL techniques. LoRaWAN has seen a significant uptrend over the last few years, with a growing number of studies and publications exploring the integration of ML and DL techniques to mitigate LoRaWAN challenges. The study provides comprehensive coverage of the existing literature on LoRaWAN challenges. The methodology involves a comprehensive literature review on various aspects of LoRaWAN issues and state-of-the-art ML/DL solutions from four significant dimensions: protocol layer-wise analysis, recent advancements, data-driven technologies, and standard architecture. It shed light on several evolving challenges of LoRa and LoRaWAN for the future digital network, along with possible solutions. The gaps in the study include potential challenges in privacy and security measures, integration of communication methods for diverse sensor clusters.

To provide a survey on the adoption of LoRa in the agricultural field, [23] reviews state-of-the-art solutions for smart agriculture, analyzing the scalability, interoperability, network architecture, and energy efficiency of LoRa-based solutions in smart agriculture. The methodology involves providing an overview of LoRa technology, summarizing smart agriculture applications and their main challenges, discussing general purpose LoRa-based IoT platforms applied to smart agriculture, and delving into specific vertical solutions for smart agriculture. It considers four reference scenarios, namely, irrigation systems, plantation and crop monitoring, tree monitoring, and livestock monitoring, which exhibit heterogeneous requirements in terms of network bandwidth, density, sensors' complexity, and energy demand, as well as latency in the decision process. LoRa-based solutions can work to analyze the scalability, interoperability, network architecture, and energy efficiency. The main challenges analyzed using LoRa Technology in smart agriculture are: latency on the downlink channel, energy management, heterogeneity and interoperability of the devices, data management, and scalability.

The [24] determines and tests data transmission performance using LoRa (Long Range) and to conduct testing of the data transmission configuration and delay in plantation 1 and plantation 2 areas. It presents the development and testing of the Smart Watering System for Plantation (SWAP) using LoRa communication network and NodeMCU ESP 8266 microcontroller to enable remote control and monitoring of plant watering and maintenance, aiming to address challenges faced by farmers in meeting plant needs and reducing losses. The study evaluated the performance of the LoRa communication network system, including factors such as average delay values and RSSI values. The research aimed to determine the feasibility of using LoRa as a data transmission medium connected to a microcontroller, considering the impact of delay on data transmission. It results that material change can affect the frequency of the LoRa signal, causing large delays in data transmission.

The Proposed work [25] investigates the performance of LoRa, a long range sensor networking technology, through a deployment in a University campus. The achievable performance of LoRa can vary greatly depending on the deployment scenario and parameter configuration. LPWAN technologies bridge the gap between the short range wireless and the cellular technology alternatives. From the tests carried out in this study, it was found that at best a range of around 500 m was achievable in an obstructed NLoS environment and that too for a high transmit power setting. The range and performance may be compromised in a NLoS/indoor propagation scenario, this can be made up for with deployment of multiple gateways which will drive up the cost and complexity. Our findings concur with prior studies that LoRa performance is sensitive to parameter settings, we found that the range in practice in an obstructed environment can be significantly compromised and in the range of several hundreds of meters unlike the kms of range reported in existing literature. The cost vs benefit tradeoff needs to be evaluated to ensure that the choice meets the operational and commercial requirements.

The proposed work [26] develops and assesses an inexpensive WSN solution based on long-range (LoRa) technology with very low power consumption and high autonomy to control water needs for precision irrigation in agriculture. It also aims to present a low-cost system based on LoRa technology capable of taking measurements of the parameters most used in precision agriculture. By means of low-power wide-area network (LPWAN) communication, a farmer can monitor the state of crops in real time thanks to a large number of sensors connected wirelessly and distributed across the farm. The methodology used in the study includes the development and optimization of the wireless sensor node, BoXmote, as well as the measurement of its consumption in different operating states to achieve an approximate battery duration. The study also compares the energy efficiency of the end-device configuration with recently published works. The development of a low-consumption WSN solution using IoT and LoRaWAN technology for precision irrigation in agriculture, with improved results compared to previous studies, achieving an approximate battery duration of 724 days if measurements were taken every 30 minutes.

[27] investigate the record of reliability of LoRaWAN in mining environments, identify contributions made to improve the reliability of LoRa/LoRaWAN communication, determine the challenges and design requirements of LoRaWAN reliability in mining environments, explore research opportunities for achieving LoRaWAN communication in mining environments. The reliability of LoRaWAN communication in the mining environment, highlighting its potential for smart mining infrastructure and its promising characteristics for mining environments. To support IoT systems, LPWAN can be implemented in two ways either using cloud based services or as an autonomous network using localized services. However, the cost of implementation and the security of the network also need to be taken into account. The network performance and energy consumption of the RS-LoRa network should be optimized.

The [28] aims to introduce a proactive approach to allocate transmission parameters for end devices in LoRa networks, and execute regional segmentation based on the distance between end devices and the gateway using different spreading factors. The methodology involves introducing the CGBS-LoRa MAC protocol to address the challenge of reduced packet delivery rate in LoRaWAN networks, by allocating transmission parameters for end devices and executing regional segmentation based on the distance between EDs and the gateway using different spreading factors. It also involves improving the ALOHA access method to ensure efficient communication of EDs in the region. The simulation results demonstrate significant improvements in the packet delivery rate (PDR) and transmission delay (TD) of the LoRa network with the use of the CGBS-LoRa protocol. The uneven distribution of end devices (EDs) within the regions based on SFs during the experiments highlights the need for a uniform zoning strategy for practical implementation to enhance overall performance. It limits in dynamically adjusting transmission parameters to achieve a more balanced distribution of EDs, striving for a uniform zoning strategy within a single gateway's range, and comprehensively analyzing the power consumption of LoRa systems to enhance understanding of power efficiency and overall system performance.

The proposed work [29] collects data using flow, pressure, and purity monitoring sensors and automates the water flow. Eliminate manual switching and Monitor the flow and prevent wastage of water. The methodology used involves the implementation of efficient water management using LoRa in advance IoT, automation of the system, collection of data using various sensors, central setup based on Arduino Uno, utilization of a long-range transceiver, and simulation of the water loop. It provides an application with fingerprint authorization which gives data on leakage and flow rate and can easily be controlled by application.Through application it monitors water purity and also water flow rate and gives notifications. Also observes adequate water supply and in future it can monitor water consumption.

[30] investigate the use of distributed control architectures and IoT technologies for managing smart environments composed of groups of buildings, evaluate the feasibility and scalability limits of the proposed solution. The methodology involves experimental techniques used in the study include the SaIoT architecture for smart environments and the specific characteristics of the LoRaWAN gateway. Particularly in the context of managing more than 10,000 nodes, and focus on the integration of LoRaWAN technology to address heterogeneous indoor and outdoor communication scenarios. It limits in exchange of performance with low-power, low-cost, and long-range requirements and lack of definition for the actual application level in LoRaWAN specifications. Also, the availability of different LoRaWAN solutions based on private and public infrastructure and the availability of open-source implementations of the backend.

The paper [31] provides a comparative analysis of LoRa frequencies (433 MHz, 865 MHz, and 915 MHz) in terms of power consumption and data-packet loss for the transmission of water quality parameters, using MATLAB's wireless simulation environment. The methodology involves a comparison of LoRa nodes working with different frequencies (433 MHz, 865 MHz, and 915 MHz) in terms of signal strength and energy requirements using MATLAB. The performance of the frequencies is analyzed in terms of data packet loss and power requirement using MATLAB's wireless simulation environment. The study includes a comparative analysis of the frequencies based on power consumption and data-packet loss for different transmitting distances. The result includes Comparison of LoRa nodes, Analysis of LoRa frequencies, Implementation of wireless communication, Simulation and comparison of LoRa frequency performance, Use of specific parameters

[32] The study objectives include creating a system using LoRaWAN technology to help farmers track their crops remotely, with low power consumption and a large coverage area, and implementing field testing on a plant to gather information helpful for developing methods for optimum growing conditions. The methodology used in the study involved selecting appropriate sensors, proposing a design or integration for the system, implementing the system on a real plant to collect data, and displaying the data on the Ubidots website. The experimental techniques used in the study include sensor selection, deployment, data collection using LoRa node and gateway, integration of Arduino Uno with sensors and LoRa shield, use of Raspberry Pi 3 and 915MHz LoRa Gateway Raspberry Pi Hat for the gateway, and implementation of the system on a real plant for data collection. All sensors operated for 24 hours to collect and display data on the Ubidots website.

The study objectives [33] are to monitor water quality, distribution, and usage in potable water, detect chemical leakage in rivers, implement a system for Smart Village Projects, continuously monitor the quality and level of water in all tanks, and discuss the potential of smart meters for water distribution. The methodology used in the study involves the application of M2M-LoRa technology for monitoring water quality, distribution, and usage in smart village projects. The paper is organized into sections discussing M2M, LoRa parameters, smart metering, smart water quality, and data acquisition. The paper provides a solution for smart water distribution and quality monitoring in smart villages using M2M-LoRa technology. It emphasizes the challenges of water distribution and quality monitoring in villages and cities. (confidence: 90)

Internet of Things [34] -connected modular device that will assist the local fish farmers via their smartphone using our application for real-time monitoring and setting up the device, and data storage. water parameter monitoring system, the relay drivers for correction, mobile application, and IoTLoRaWAN for transmission. The water monitoring sensors transmits the data to Packetduino, then through the LoRa module connected to the Packetduino, a LoRaWAN compatible microcontroller, then to a Gateway that connects to our AQUAlity application to view readings real-time, while the relay drivers function as switches programmed depending on the readings from the water monitoring sensors to operate the actuators. The readings made by the proposed modular device were compared with the Bureau of Fisheries and Aquatic Resources-National Inland Fisheries Technology Center (BFAR-NIFTC) multimeter. A low percentage difference between their readings is below 2%, which is within the accepted value.

This paper [35] describes a multi-depth and multi-parameter probe for soil data collection utilized to on-farm research by the SWAMP project. The probe is based on LoRaWAN communication and has sensors for soil moisture, temperature, and electrical conductivity. a)The architecture solution proposed to the pilots followed the IoT Computing Continuum (IoTinuum) with four stages: Things (probes), Mist, Fog, and Cloud. B) LORAWAN configuration c) bluetooth app. The raw data shows the moisture levels varying during the period of data collection. The peak between the tenth and the sixteenth packet presents the behavior of the sensor during an irrigation session. The complete networking solution of the SWAMP project was used to obtain the collected data, using components of mist, fog, and cloud computing. The validation of the solution was made in real deployments in two pilots for smart irrigation. The data obtained by the probes are sent to a cloud platform, where a user can see and analyze the data. The probe electronics can also be used in other applications of smart agriculture

[36] The study objectives are to propose an IoT smart irrigation system for urban areas, optimize the locations of IoT nodes and gateways using a 3D-ray launching radio planning simulator, and compare simulation results with empirical measurements to assess the accuracy of the radio planning tool. The methodology used in the study includes proposing an IoT smart irrigation system for urban areas using LoRaWAN based architecture, conducting simulations and measurements using an in-house developed 3D-Ray Launching deterministic algorithm, and validating the simulation results by comparing them with empirical results obtained during a previous measurement campaign. Experimental techniques used in the study include: - In-house developed 3D-Ray Launching (3D-RL) deterministic algorithm - Geometrical optics (GO) and geometrical theory of diffraction (GTD) - Simulation process using Matlab - Comparison of simulation results with empirical results. The paper proposes an IoT smart irrigation system for urban areas facing water scarcity and challenges in wireless communications due to long distances and obstacles, highlighting the increasing water scarcity and the role of IoT in smart agriculture. It discusses the technical challenges in wireless communications in precision agriculture and the use of LPWAN technologies like LoRaWAN, and presents a LoRaWAN and fog computing-based architecture for smart irrigation systems.

[37] The main objective of the study is to present the propagation performance of the LoRa E32 modulation with a power of 30 dBm of 433 MHz in the Non-LOS area in a tropical forest environment, understand the environmental impact of vegetation on LoRa performance, trigger further analysis in understanding the environmental impact of vegetation on LoRa performance, and demonstrate that LoRa can be used in forested areas with high vegetation as an implementation of Wireless Sensor Networks (JSN) in remote areas. The methodology involves testing LoRa performance in obstacle-dense areas of a tropical forest, varying distance parameters and programmable transmission speed, and evaluating performance based on packet loss. The summary of the paper is the discussion of the use of LoRa technology in IoT communication networks, its performance in a tropical forest environment, the impact of vegetation on LoRa signal propagation, and its potential use in remote areas with high vegetation. The paper also emphasizes the ability to design LoRa performance by configuring PHY parameters into various settings, offering options to optimize signal quality or energy consumption. The experiment's results are summarized in Figure 5, showing the performance characteristics of the LoRa module in the forest area with various ADR variations, demonstrating its effectiveness in forested areas with high vegetation for Wireless Sensor Networks (WSN) in remote areas.

The study objectives [38] are to identify and address the challenges faced by plantation owners in Malaysia and to develop a customized IoT-based automatic smart monitoring system to alleviate problems related to manpower shortage and increased maintenance cost. The methodology used in the study involved a qualitative research approach to identify problems faced by palm oil plantations in Malaysia, including interviews and a questionnaire-based approach. Intensive data gathering through interviews and questionnaire-based approaches, implementation of smart soil monitoring sensors including moisturizer sensor, pH sensor, and tilt measuring sensor, installation of pest control sensors for detecting pests through camera images, monitoring and measuring water levels in watering canals.The paper discusses the implementation of technology in the palm oil industry to increase production and reduce management costs, highlighting the increasing use of Internet of Things (IoT) in agriculture sectors to maximize food production, and aims to develop a customized IoT-based automatic smart monitoring system to address the challenges faced by plantation owners in Malaysia.

The study [39] objectives include presenting research work in the EU AFarCloud project, emphasizing the importance of LoRaWAN technology for data transmission and improved data protection, highlighting the increasing power of field-level devices in modern agriculture and associated cybersecurity risks, and acknowledging partial funding by the University of Parma for the "Multi-interface IoT sYstems for Multi-layer Information Processing" (MIoTYMIP) project. The methodology involves implementing LoRaWAN technology, utilizing HSM for key protection, integrating with Raspberry Pi and Arduino platforms, employing OTAA for key generation, and implementing measures for protection against device movement and physical tampering. The Security Evaluation

Demonstrator (SED) is currently under construction and already well-advanced. The paper discusses the importance of digitalization in modern agriculture, the use of LoRaWAN technology for data transmission and protection, the concept of using a Hardware Secure Module (HSM) for improving data security, and ongoing development of a Security Evaluation Demonstrator (SED) for implementing and testing security improvements in agriculture applications.

This paper [40] analyze the performance of LoRa based on its three basic parameters: code rate, spreading factor, and bandwidth; focus on the emerging transmission technologies dedicated to IoT networks.The methodology involves an in-depth analysis of the impact of Code Rate, Spreading Factor, and Bandwidth on the data rate and time on air in the context of LoRa technology, as well as a comparison of potential candidates for LPWAN technologies.- Spread spectrum technique with a wider band - Chirp signals by varying frequency over time - Scalable bandwidth settings of 125kHz, 250kHz, and 500kHz - Multiple orthogonal spreading factors (between 7 to 12) - Five code rates for forward error correction.The paper provides an in-depth analysis of the impact of Code Rate, Spreading Factor, and Bandwidth on the data rate and time on air in LoRa technology, highlighting their trade-offs and potential for wide area connectivity in IoT applications.

3. METHODOLOGY

Automated systems called water pump control systems are made to keep an eye on and manage how water pumps are operating. These systems usually comprise a number of interconnected parts that work together to maximize the efficiency of water pumping activities, such as sensors, controls, actuators, and communication devices.In order to maximize water distribution, guarantee economical energy use, avoid pump failures or malfunctions, and ultimately enhance the general efficiency and dependability of water supply systems, water pump control systems are essential.For control algorithms on auto decision making , [] involves introducing a modification to the EPANET2 toolkit to optimize pump operations based on multiple conditions and testing the new ETTAR toolkit using a case study with a genetic algorithm for optimizing different types of controls.Further approaches such as [] involves formulating the optimal control of water supply pumping systems as a nonlinear optimization problem, using a disaggregated or dual level approach, genetic optimization routine, and neural network representation.In [ ] an optimal scheduling and control method for a multiple pump system, formulating a model-based optimal problem, converting it into a mixed integer nonlinear programming problem, deriving running speeds of operating pumps, and introducing a feedback control mechanism to enhance system tracking performance and robustness. Experimental results demonstrate the potential to improve multi-pump system efficiency.For real time simulations [] ,the use of a hybrid model (simulator + optimizer) to find pump speeds and PRV set points, with the application of PSO as the main optimization algorithm, in cooperation with other bio-inspired concepts. The hydraulic state of the network is determined using the hydraulic simulator EPANET toolkit version for Matlab. The PSO is composed of particles with position and velocity vectors, starting randomly inside a defined range.

Conventional approaches to water pump control have always depended on either wired automation systems or manual operation. These methods have had their usefulness, but they are not without flaws. The inability to monitor in real time when operating manually prevents effective resource management. Similar difficulties with scalability and reliance on physical infrastructure affect wired automation solutions. The incorporation of LoRa frequency technology appears to be a viable remedy for these limitations. In order to overcome the drawbacks of conventional techniques and transform water management practices, this article investigates the possibilities of LoRa frequency in water pump control.

Automation optimizes water usage by precisely controlling irrigation schedules based on real-time data, such as soil moisture levels, weather forecasts, and crop water requirements. This ensures that crops receive the right amount of water at the right time, minimizing water wastage and improving overall efficiency in water management.

Automated systems, such as sensor-based irrigation controllers and remotely operated valves, eliminate the need for manual monitoring and adjustment of irrigation systems. This reduces labor requirements and frees up farmers' time to focus on other critical tasks, leading to increased productivity and cost savings.By using sensors, actuators, and automated control systems, farmers can tailor irrigation strategies to specific crop needs, soil conditions, and environmental factors. This precision irrigation not only conserves water but also enhances crop yields and quality by promoting optimal growth conditions.Automated water management systems collect and analyze vast amounts of data from various sources, such as soil moisture sensors, weather stations, and crop models. This data-driven approach enables farmers to make informed decisions about irrigation scheduling, water allocation, and resource management, leading to more sustainable and efficient agricultural practices.

Automated pump control systems can be programmed to deliver water precisely when and where it is needed, based on factors such as soil moisture levels, weather conditions, and crop water requirements. By ensuring that crops receive the right amount of water at the right time, these systems help prevent both over-irrigation and under-irrigation, which can lead to improved crop health, growth, and yield.Many automated pump control systems offer remote monitoring and control capabilities, allowing farmers to monitor pump performance and irrigation activities from anywhere using smartphones, tablets, or computers. This real-time visibility enables farmers to detect and address issues promptly, optimize irrigation scheduling.

LoRa (Long Range), is a wireless communication technology developed to enable long-range communication between devices with low power consumption. It works in the areas such as Industrial, Scientific, and Medical (ISM) radio bands. These frequencies have good propagation properties, enabling relatively low strength signals to travel great distances and pass through obstructions. The modulation method used by LoRa is known as Chirp Spread Spectrum (CSS). Chirp signals, which are continuous waveforms with varying frequencies over time, are used in CSS to encode data. Because of this, LoRa is able to attain a high sensitivity, which enables it to pick up weak signals even in noisy settings. A LoRa signal's bandwidth might change based on the application and legal restrictions, but popular frequencies are 125kHz, 250kHz, 433 MHz, 868 MHz (European), and 915 MHz (North American). The communication link's resilience and data rate are impacted by the bandwidth selection. Spreading factors (SF) are used by LoRa to balance communication robustness and range against data throughput. Higher spreading factors yield longer ranges but lower data rates; they vary from 7 to 12. For instance, SF12 has the longest range but the lowest data rate, whereas SF7 offers the highest data rate but the shortest range.

In rural regions, LoRa can reach communication ranges of several kilometers, whereas in urban settings, it can reach a few hundred meters. So it can be used in smart agriculture which needs long-range communication. Consuming low power by LoRa devices with the use of CSS modulation extends the battery life of devices. LoRa's CSS modulation offers resilience against interference from other wireless signals and obstructions like trees and buildings. Because of this, LoRa may be used in difficult settings where other wireless technologies could find it difficult to keep a steady connection.

LoRa frequency has an upper-hand in comparison to other wireless technologies commonly used in agriculture, such as Wi-Fi, Bluetooth, or Zigbee.When it comes to communication range, LoRa is far superior than Wi-Fi, Bluetooth, and Zigbee. While the average ranges of Wi-Fi and Bluetooth are between 100 and 300 meters (indoors and outdoors), Zigbee's range is only up to 100 meters, while LoRa's range is several kilometers. Because of this, LoRa is more suited for extensive, large-scale agricultural activities. Due to its low power consumption architecture, LoRa is a good fit for battery-operated devices in isolated agricultural areas. The higher power consumption of Wi-Fi, Bluetooth, and Zigbee may be a challenge for battery-powered applications. Because of its durability against interference, LoRa's Chirp Spread Spectrum modulation enables it to continue operating reliably even in loud areas. Operated in the congested 2.4 GHz band, Zigbee may encounter similar interference concerns as Wi-Fi and Bluetooth, which are also susceptible to interference from other devices running in the same frequency range. Due to Long-range communication provided by LoRa, its data rates are not as fast as those of Wi-Fi, Bluetooth, and Zigbee. Because of this, LoRa is more suited for applications like sensor readings in agricultural monitoring systems that call for the periodic transfer of modest amounts of data due to this the maintenance cost is low. Hence, LoRa frequency offers unique features such as long-range communication, low power consumption, robustness against interference, and cost-effectiveness, making it well-suited for long-range, low-power applications in rural environments like agriculture.

The use of LoRa technology for subterranean agro-informatics networking applications and to conduct experiments to measure the received signal strength indicator (RSSI) and signal-to-noise ratio (SNR) under different LoRa spreading factors, coding rates, and soil depths. LoRaWAN for agriculture-based use cases, specifically in measuring temperature in a horse stable and analyzing soil properties and testing the permeability of agricultural land, with the main goal being to assess the use of LoRaWAN for indoor and outdoor applications for agricultural businesses. Fields can be equipped with LoRa-capable soil moisture sensors to track the amount of moisture in the soil. These sensors wirelessly send data to a central hub, giving farmers access to up-to-date soil conditions data. By optimizing irrigation schedules with the use of this data, crop yields can be increased while conserving water. Farmers are able to make well-informed decisions regarding crop management and irrigation through weather broadcasts with LoRa transmitters that are able to broadcast data, including temperature, humidity, and rainfall, to a central database. LoRa-enabled controllers can be used to turn pumps on and off based on real-time data and remotely monitor the water flow. LoRa-enabled sensors can be deployed in fields to collect data of temperature, humidity, and light intensity, for crop management practices such as fertilization and pest control.

4. RESULT AND DISCUSSION

Versatility and Effectiveness of LoRa Technology: The literature study highlights how adaptable and successful LoRa technology is in tackling important problems related to resource optimisation, environmental monitoring, and water management. Research continuously demonstrates how LoRa can streamline data transfer, automation, and monitoring in a variety of agricultural environments, demonstrating how it can completely transform contemporary farming methods.

Variations in LoRa Frequency Performance: The literature shows subtle performance changes of LoRa frequencies at various MHz ranges through a comparative investigation. The present research provides useful insights for the design and implementation of efficient water pump control systems by informing decision-making processes related to frequency selection based on unique application requirements.

Integration with IoT Devices: One of the key uses of LoRa technology in agriculture is the integration of IoT devices. Through remote monitoring, automation, and data-driven decision-making made possible by this integration, agricultural operations may become more productive, sustainable, and resource-efficient.

Security Measures: The need of protecting sensitive agricultural data from potential cyber attacks is highlighted by the emphasis on security measures, such as Hardware Secure Modules combined with LoRaWAN. Strong security mechanisms must be implemented in order to guarantee the confidentiality and integrity of data sent over LoRa-based systems.

Prospective Applications and Difficulties: The literature analysis highlights the potential benefits of LoRa technology in water pump control systems, but it also points out significant difficulties with security, scalability, and dependability. To overcome these obstacles, more study and creativity are needed to improve network performance, develop new applications for LoRa in agriculture, and improve communication protocols.

The results and discussion section concludes by summarizing the literature review's findings and emphasizing how LoRa technology has the ability to completely change how agriculture manages its water resources. Additionally, it highlights the necessity for cooperative efforts to overcome current obstacles and realize the full potential of LoRa technology in improving Internet of Things solutions for agricultural sustainability. It also recommends topics for future study and development.

5. CONCLUSIONS

Finally, the extensive literature study of LoRa frequency modulation for water pump control systems sheds light on the problems associated with applying this technology in a variety of situations as well as its many uses. When taken as a whole, the studies highlight how flexible and successful LoRa is at handling important problems like resource optimization, water management, and environmental monitoring in agricultural settings.The examined literature clarifies the subtle differences in LoRa frequency performance at various MHz ranges, providing information that may be used to make well-informed decisions on frequency selection depending on the needs of particular applications. From smart irrigation systems to remote water pump management, LoRa technology shows impressive potential for enabling automation, monitoring, and data transfer in a variety of agricultural settings.

Furthermore, LoRa technology's adaptability to various agricultural settings is highlighted by the integration of IoT devices with it, which enhances productivity, sustainability, and resource efficiency. The focus on security mechanisms such as LoRaWAN-integrated Hardware Secure Modules is indicative of a dedication to protecting private agricultural data from any cyberattacks.The results of this literature study act as stimulants for more innovation and improvement in LoRa-based water pump control systems and other areas, as agriculture adopts digitalization and IoT-driven solutions more and more. For LoRa technology to fully realize its promise in expanding IoT solutions for water management and other areas, more research initiatives are necessary to overcome difficulties related to security, scalability, and dependability.

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