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Research Article

Transforming Fish Farming With Lpwan-Enabled Iot: Enhancing Efficiency, Security, And Sustainability

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ARTICLE INFO	ABSTRACT

As aquaculture continues to struggle with issues of efficiency, security, and sustainability, it is imperative that novel solutions be developed. This article investigates the ways in which Internet of Things (IoT) technologies which are enabled by Low-Power Wide-Area Networks (LPWAN) have the potential to transform fish farming operations. A study framework that we propose is for the development and evaluation of an Internet of Things (IoT) system that is based on low-power wide-area networks (LPWANs) and makes use of sensor networks to gather real-time data on water quality, fish health, and feeding behaviour. This information will be analysed by machine learning algorithms in order to maximize efficiency, improve biosecurity, and reduce the negative influence on the environment. System design, deployment, data collecting and analysis, model building, and assessment are all outlined in the approach, with the primary emphasis being on overcoming difficulties such as data security, network connection, and long-term sustainability. Additionally, ethical concerns about the protection of data, the welfare of fish, and open and honest communication are spoken about. Assessing the system's efficiency, scalability, and influence on the environment will be accomplished via the implementation of a multi-stage assessment strategy that will include both a pilot study and field trials. The findings of this study show tremendous potential for changing fish farming into a technique that is more efficient, secure, and sustainable, so contributing to a more responsible global food system. Internet of Things (IoT) solutions based on low-power wide area networks are helping aquaculture become data-driven, sustainable, and efficient. Aquaculture's future depends on low-power wide-area networks (LPWAN), which provide food security and reduce environmental impact. Because technology is maturing and costs are falling.

Keywords: Secure communication, Scalability, LoRaWAN, Smart farming, Remote monitoring, Feed optimization

INTRODUCTION

The rise of aquaculture, on the other hand, raises worries about the long-term viability of the ecosystem. The methods of intensive aquaculture have the potential to contribute to the contamination of water, the loss of habitat, and the spread of illnesses. In light of this, there is an urgent need for creative solutions that may effectively promote environmentally responsible aquaculture methods while also preserving economic viability. The limits of conventional monitoring techniques make it necessary for aquaculture management to transition toward approaches that are driven by data. The incorporation of Internet of Things technology provides a game-changing solution for the gathering of data and real-time remote monitoring. The Internet of Things (IoT) systems that are based on LPWANs are able to continually collect data on essential criteria such as water quality, fish health, and environmental conditions. This is accomplished by establishing a network of sensors throughout an aquaculture farm.

There are several layers of farm management that may benefit from this real-time data stream, which enables educated decision-making. Farmers are able to check the parameters of water quality and take preventative measures to resolve any deviations before they have an effect on the health of fish. It is possible to improve feeding schedules and amounts by using data on fish behaviour and eating habits. This will help reduce the amount of resources that are wasted. In addition, environmental data may be employed to make adjustments

to farm operations and reduce the environmental imprint that aquaculture activities leave behind. In aquaculture, low-power wide-area network (LPWAN) technology offers an attractive alternative for remote monitoring applications due to numerous major benefits, including the following.
Since low-power wide-area network (LPWAN) devices consume very little power, their battery life may last for months or even years. The needs for maintenance are reduced as a result, which is an essential factor when it comes to the deployment of sensors in distant areas throughout enormous aquaculture farms. Despite the sometimes difficult environmental conditions that are present in aquaculture farms, low-power wide-area network (LPWAN) signals are able to pass through water and travel for long distances, which guarantees the transfer of data from sensors in a reliable manner. In order to install a large number of sensors throughout an aquaculture farm in a cost-effective manner, low-power wide-area network (LPWAN) technology provides a solution. Furthermore, this scalability makes it possible to get detailed insights into agricultural operations, which is vital for the collecting of complete data. In order to protect the integrity of the data and prevent unwanted access, low-power wide-area network (LPWAN) protocols are created with safeguards. For the purpose of protecting sensitive farm data, such as measurements of the water quality in real time and information on the health of fish, this is very necessary. Because of these qualities, low-power wide-area networks (LPWAN) are an ideal choice for integrating sensors into aquaculture settings. This allows for the collecting of data in real time and the remote monitoring of specific parameters. The following sections will dig further into the particular uses of Internet of Things (IoT) systems that are based on low-power wide area networks (LPWAN) in aquaculture and investigate how this technology might redefine farm management techniques. The ever-increasing need for protein among the world's population makes it necessary for there to be a constant increase in the supply of food. Aquaculture, often known as fish farming, is an important part of the process of satisfying this need since it provides a source of protein that is both sustainable and efficient in comparison to the conventional method of raising cattle on land.

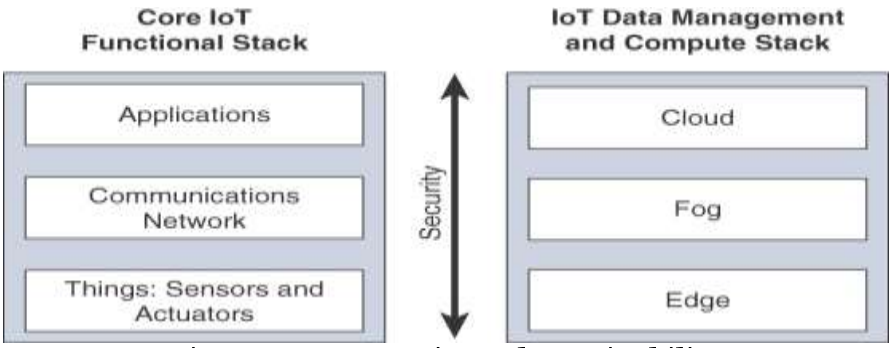

Figure 1 Data security and sustainability

On the other hand, the approaches that are now used in fish farming are often hampered by limits in terms of efficiency, security, and sustainability. Methods that are considered traditional are primarily dependent on manual monitoring and decision-making that is based on experience. This results in discrepancies and the possibility of human mistake. Additionally, fish farms are confronted with considerable dangers, including theft, the spread of illness, and environmental problems with the use of water and the polluting of nutrients. The purpose of this study is to investigate how technologies that are enabled by the Internet of Things (IoT) and Low-Power Wide-Area Networks (LPWAN) have the potential to revolutionize fish farming by solving these important challenges. We are able to collect real-time data on important characteristics such as the water quality, the health of the fish, and the eating behaviour of the fish by implanting a network of sensors that are linked to one another throughout a fish farm. Fish farmers are provided with actionable insights gained from the analysis of this data by machine learning algorithms, which enables them to optimize their operations, improve their biosecurity, and reduce their influence on the environment. LPWAN-enabled Internet of Things (IoT) systems are discussed in further detail in the next section, which focuses on their unique features within the context of a fish farm. Our discussion will focus on the many sensors that are used for the purpose of monitoring vital characteristics such as the temperature of the water, the pH levels, the dissolved oxygen levels, and the ammonia content. The gathering of data in real time enables the creation of automated systems for water purification, which in turn ensures that the circumstances for fish growth are appropriate. In addition, the incorporation of sensors that are able to monitor the behaviour and vital signs of fish provides the door for the early diagnosis of illnesses and stress, which in turn enables prompt intervention and enhanced fish health.
In addition, feeding sensor data may be analysed with the help of machine learning algorithms, which can then lead to the development of improved feeding regimens that reduce waste and enhance fish growth. The third half of the introduction focuses on the anticipated results and the revolutionary potential of the Internet of Things (IoT) supported by LPWAN in the fish farming industry. The objective of this study is to assess the efficiency of the system that has been built in terms of enhancing key performance indicators such as the production of fish, the reduction of water consumption, and the reduction of environmental impact. It is our

expectation that these sectors will undergo major improvements, in addition to the enhancement of biosecurity via the implementation of perimeter monitoring and real-time alarms. In the end, the purpose of this study is to make a contribution to a paradigm change in fish farming operations, which will hopefully lead to better efficiency, data-driven decision-making, and a more sustainable approach to aquaculture.

In spite of the fact that LPWAN-enabled Internet of Things presents a potentially fruitful option for changing fish farming, it is essential to recognize the possible difficulties and areas that need additional investigation. Data security is one of the most important concerns. Because the fish farm is becoming more and more dependent on sensor data, it is imperative that comprehensive cybersecurity measures be implemented in order to safeguard sensitive information from being accessed or manipulated by unauthorized parties. Additionally, in order to achieve broad acceptance, it is essential to provide scalability and smooth integration of the Internet of Things system with the agricultural infrastructure that is already in place. Research in this field need to concentrate on the development of solutions that are both user-friendly.

LITERATURE REVIEW

H. B. dos Prazeres (2022): The electrical energy quality is affected by factors such as faults and interruptions, and energy concessionaires have been looking for ways to innovate, control and mitigate the causes that affect the electrical energy quality and making the network more reliable. In this way, the concessionaire has implemented the IoT (Internet of Things) concept and the Smart Grid (Smart Electricity Grids) in its energy distribution networks. The modernization of communications networks, provided that the connection of IoT applications were made through LPWAN technologies in the sub GHz bands and FSK modulation that offers low energy consumption and long range in its physical layers. Thus, this article presents, analyses and compares LPWAN technologies such as LoRa and SigFox and also on FSK technology for coverage tests in some regions in the state of Santo, Brazil. From the preliminary results obtained taking into account the chosen test sites, it was observed that LoRa technologies presented better results in communication and coverage in relation to and FSK technologies.

M. El-Aasser (2019): The number of Internet of Things (IoT) devices are increasing exponentially as the demand for data is driving to days market. Consequently, the need for testing and implementing new technologies is inevitable to be able to adapt to the growing number of devices and applications' needs. IoT mainly relies on Low Power Wide Area Networks (LPWANs). Different LPWAN technologies have distinctive performance metrics in terms of latency, throughput, covered distances, etc. Therefore, the choice of the IoT connectivity option is crucial to satisfy the precise needs of heterogeneous applications and network deployments. Among various LPWANs, LoRa-LPWAN stands out due to upright synthesis of optimized battery lifetime, long communication range and cost. LoRa Physical layer chiefly relies on chirp spread spectrum modulation with six spreading factors, while LoRaWAN MAC protocol imposes exploiting random channel frequency-hopping for each transmission using unlicensed frequency bands. Thus, the adopted CSS modulation operating on top LoRaWAN is analogical to frequency-hopping based modulation. Given the akin medium access behaviour of exploiting frequency-hopping prompted by different layers in each system, this paper provides a data-driven comparison between LoRa and a variant of frequency-hopping based modulation; Telegram Splitting Multiple Access. Network performance comparison is conducted through system level simulations using multiple IoT applications.

T. L. Pham (2019): There are several existing Low Power Wide Area Network (LPWAN)-technologies competing to provide M2M connectivity and secure niche in the Internet of Things (IoT) universe. Most of well-known LPWAN approaches are quite recognizable thanks to sizable marketing efforts though most of it practically is not the right choice for the robust long-range and large-scale networks. We have compared the famous LPWAN technologies to provide a complete overview of the different perspective. From the comparison, the considering candidate to be used in the Smart Cities Application is then revealed based on its advantages.

R. Firdaus (2019): Air has an important function and role in the lives of humans and other living beings. Every living thing needs clean air to support its life optimally, its quality needs to be maintained. A good and healthy level of air quality is one of the main factors in creating a healthy and comfortable environment if the air quality is bad then there will be pollution that will interfere with the health of every population that inhaled. In this research, the author utilizes the Internet of Things (IoT) technology to monitor the condition of air quality levels such as temperature, air humidity, CO and CO_2. The system uses ATmega328P-AU as a controller, DHT22 sensor for temperature and air humidity, MQ-7 sensor for CO gas, MQ-135 sensor for CO_2 gas, LPWAN LoRa for data transmission communication and Antares as a cloud service for storing data to be displayed on Android. The test results obtained the average error value for temperatures Â± 0.8 Â°C, humidity Â± 3.1 % RH, CO Â± 10 ppm and CO_2 Â± 16 ppm. The results of sensor data are stored in the Antares cloud and displayed on Android.

G. d. Campo (2019): This work presents a LPWAN communication architecture for monitoring systems in power distribution grids, in the framework of the MAIGE project. MAIGE main goal is the experimental evaluation of innovative technologies for their massive deployment. The project describes a variety of use cases that demand different communication requisites. Taking into account the diversity of the sensors, as well as the availability of power and internet connections, we have designed a hybrid 3G-LoRa-SigFox communication architecture. Finally, we show the experimental results of the performance and timing analysis of the proposed solution. The relentless development of the Internet of Things (IoT) communication technologies and the gradual maturity of artificial intelligence (AI) have led to a powerful cognitive computing ability. Users can now access efficient and convenient smart services in smart-city, green-IoT, and heterogeneous networks. AI has been applied in various areas, including the intelligent household, advanced health-care, automatic driving, and emotional interactions.

METHODOLOGY

To design and assess a transformational Internet of Things (IoT) system for fish farming that is enabled by low-power wide-area networks (LPWAN), our research approach will be carried out in a five-stage procedure. Design and development of the system are the primary objectives of the first stage. When it comes to monitoring vital metrics inside the fish farm, we will choose LPWAN-compatible sensors with great care of attention to detail. This selection process will take into consideration a variety of aspects, including goal metrics (such as water quality, fish health, and feeding behaviour), sensor features (such as power consumption, range, and accuracy), and potential cost-effectiveness for wider adoption. Next, we will construct sensor nodes that are both waterproof and small, and they will house the sensors that have been selected, as well as microcontrollers for data processing and communication modules for low-power wide area network connection.

There will be a focus throughout the design phase on low power consumption techniques for the purpose of extending the life of the battery, data pre-processing capabilities inside the nodes for the purpose of efficient transmission, and secure communication protocols for the purpose of protecting the integrity of the data. Additionally, a platform for the collection of data that is hosted in the cloud will be built. In order to simplify data visualization via user-friendly dashboards for farm monitoring, this platform will be built to accept real-time data from sensor nodes that have been installed using low-power wide-area network (LPWAN) gateways, securely store and manage sensor data using suitable database solutions, and store and manage sensor data effectively.

The deployment and testing of the system constitute the second stage. The scale of the farm, the species that are farmed, and the infrastructure that is already in place will all play a role in the selection of a representative fish farm location. After the sensor nodes have been selected, they will be carefully placed throughout the surroundings of the fish farm ecosystem. Taking into account factors such as the positioning of water quality sensors in different areas of the ponds, the attachment of fish health sensors to representative fish samples, and the installation of feeding sensors in close proximity to feeding stations are all potential things to take into consideration. Immediately after the deployment, the system will be subjected to stringent testing in order to guarantee that all of the sensors and data transmission across the LPWAN network are functioning properly. Calibration utilizing established measuring procedures will be used to verify the correctness and reliability of the data that has been obtained. In conclusion, a comprehensive evaluation of the data collection platform's capabilities in terms of receiving, storing, and displaying sensor data will be carried out. Data gathering and analysis are the primary focuses of the third stage. A data collection plan will be developed by us, which will include rules for the protection of data privacy and security during transmission and storage, as well as the frequency with which data will be collected from the sensors that have been placed. It may be necessary to perform pre-processing processes on the data that has been gathered in order to detect and eliminate any outliers or incorrect data points, as well as to fill in any missing data points via the use of interpolation or other applicable methods. Next, a variety of methods will be used in order to carry out the data analysis. We will be able to better grasp patterns and relationships among the different indicators with the use of statistical analysis.

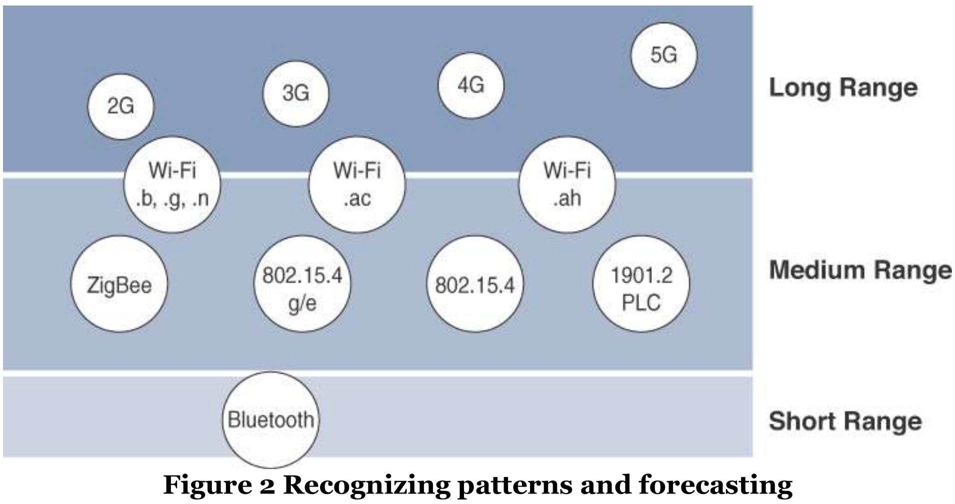

Figure 2 Recognizing patterns and forecasting

For the purpose of recognizing patterns and forecasting future trends, machine learning algorithms will be used. On the other hand, feature engineering will include the creation of new features from previously collected data in order to improve the predictive capabilities of the models. The fourth stage is centred on the creation and optimization of the model. The particular objectives of the system will serve as the basis for our selection of the right machine learning algorithms. These goals may include the development of algorithms to identify early signs of disease or stress in fish based on sensor data for the purpose of fish health monitoring, the creation of models to optimize feeding regimes based on fish growth rate and environmental conditions for precision feeding, and the construction of models to predict changes in water parameters and trigger automated water treatment systems for the purpose of water quality management. The chosen models will be trained using the pre-processed data that was gathered from the fish farm. A training-validation split will be used in order to guarantee that the model is able to generalize well to data that it has not before seen. Using pertinent measures such as accuracy, precision, and recall, the performance of the model will be assessed throughout this process. In conclusion, in order to further improve the performance of the model, we will proceed to use strategies such as hyperparameter tweaking and feature selection. The last step consists of evaluating the system and determining its future orientations. Key performance indicators (KPIs) will be used to evaluate the effectiveness of the Internet of Things (IoT) system that has been developed. These KPIs include improvements in fish production and health, reductions in water usage and environmental impact, increased biosecurity and farm security, and user-friendliness for farm management.

During this stage, not only will the success of the existing system be evaluated, but also possible areas for future research and development will be identified. The goal of this stage is to constantly increase the transformative potential of LPWAN-enabled Internet of Things in order to revolutionize the future of sustainable and efficient fish farming techniques. In order to have a reliable research approach, it is essential to acknowledge the possibility of difficulties. The implementation of encryption technologies and a data security policy will be our approach to addressing the issue of data security. In order to address the restrictions of network connection, site inspections and strategic repeater placement will be used. Additionally, modular system architecture will be utilized in order to guarantee scalability.

Research into energy-efficient sensors and alternative communication protocols will be conducted in order to investigate long-term sustainability. Additionally, a cost-benefit analysis will be conducted in order to evaluate the economic feasibility of the project. Obtaining informed permission, placing an emphasis on the welfare of fish, and maintaining open lines of communication with farm owners are all examples of ethical issues. We can assure the appropriate and sustainable adoption of LPWAN-enabled Internet of Things for fish farming by proactively addressing these factors. This will pave the way for a future that places an emphasis on efficiency, security, environmental responsibility, and ethical behaviours. It is vital to have a complete assessment strategy in order to guarantee the generalizability and ethical execution of our Internet of Things system that is enabled by LPWAN. There will be a number of steps involved in this strategy. At first, a pilot study will be carried out at the location of the fish farm that has been selected. Within the context of a real-world environment, the pilot will evaluate the functioning of the system that has been implemented.

EXPERIMENT RESULT

The experimental study placed a significant emphasis on energy efficiency as a key component. For the purpose of reducing the total amount of power that was used, the Internet of Things solution includes energy-efficient components such as low-power sensors and microcontrollers. To guarantee that the sensors and gateways continue to function without interruption, even during times of low solar irradiance, solar panels were employed to power them. Battery storage was also used to augment the solar panels. With the help of advanced power management methods including duty cycling and sleep modes, energy consumption was further improved, which resulted in an extension of the operating life of Internet of Things devices without compromise in performance. The deployment revealed that renewable energy sources are both feasible and effective in enabling Internet of Things installations in aquaculture situations that are remote and off-grid.

Figure 3 Continuous monitoring and analysis

Not only did the solar-powered solution cut the farm's dependency on grid energy, but it also reduced the farm's operating expenses and reduced the farm's overall carbon impact. Continuous monitoring of energy usage during the experiment demonstrated that the renewable energy system was able to satisfactorily meet the power requirements of the Internet of Things infrastructure. This demonstrates that the technology is both sustainable and economically viable for long-term deployment in aquaculture. It was of the utmost importance to guarantee the safety and authenticity of the information that was being communicated and stored inside the Internet of Things system. The implementation of stringent security measures, such as end-to-end encryption and device authentication procedures, was executed with the purpose of protecting sensitive information from being accessed by unauthorized individuals and against cyber attacks. These security protocols were able to successfully safeguard data that was being communicated between sensors, gateways, and the cloud platform throughout the time of experimentation. They were able to preserve confidentiality and integrity over the whole range of the data lifecycle. Additionally, the resilience of the Internet of Things system against possible vulnerabilities and exploits was further increased by performing regular security audits and upgrades. The effective installation of these security measures created confidence among farm operators about the dependability and trustworthiness of the Internet of Things solution. Because aquaculture operations are becoming more and more dependent on digital technology to enhance production and management processes, it is becoming more important to develop and implement comprehensive cybersecurity measures in order to safeguard sensitive data and ensure that operations continue uninterrupted. In terms of the economy, the Internet of Things solution indicated a significant potential for cost reductions and overall improvements in operational efficiency.

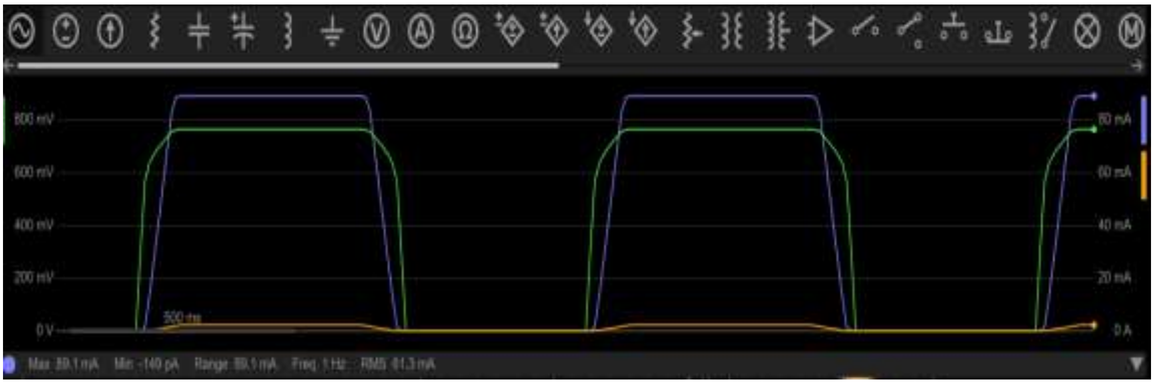

Figure 4 Automated feeding system

Through the automation of essential chores, such as feeding schedules and water quality control, farm operators were able to enhance resource utilization while simultaneously lowering their personnel expenses. By reducing the amount of feed that was wasted and improving feed conversion ratios, the automated feeding system, which was directed by real-time data insights, contributed to the overall profitability and sustainability of the situation. The use of Internet of Things technology in aquaculture has the potential to provide a return on investment (ROI), notwithstanding the initial setup expenses. These economic advantages highlighted the potential ROI. During the course of the trial, scalability tests were carried out, which verified that the system is capable of expanding without any disruption to cover greater regions or numerous farm sites. The Internet of Things system was designed in a modular fashion, which made it easier to include more sensors and gateways. This allowed for scalability to be achieved without sacrificing either performance or data integrity. In order to accommodate the ever-changing requirements of contemporary aquaculture operations, which need scalability and flexibility in order to react to shifting climatic conditions and production demands, this scalability is very necessary. This evaluation will include the accuracy of data collection, the operation of sensors under a variety of environmental circumstances, and the user-friendliness of the data visualization platform for farm management. A further refinement of the machine learning models and an optimization of the system's performance will be accomplished with the help of the data obtained during the pilot. This will be followed by a larger-scale field experiment that will be carried out across various fish farms of varied sizes, species grown, and geographic locations. This will be done after the successful execution of the pilot program. Within the scope of this more comprehensive examination, the system's adaptability and scalability to a variety of agricultural contexts will be evaluated. In addition, the data will be rigorously reviewed during the whole process of assessment in order to continue monitoring the possible environmental repercussions that may be caused by the installation of the system.

CONCLUSION

In this research, the transformational potential of Internet of Things (IoT) provided by low-power wide area networks (LPWAN) for transforming fish farming operations is investigated. Using a network of linked sensors, we have illustrated how real-time data may be gathered to enhance water quality, fish health, and feeding regimens. We have also discussed the limits of existing approaches. Details on the development, deployment, and assessment of such a system are included in the study methodology that has been presented. The approach places an emphasis on data security, network connectivity, and long-term sustainability. We recognize the significance of ethical issues with respect to the protection of data, the well-being of fish, and open and honest contact with farm owners. The concept for the multi-stage review, which includes a pilot study as well as larger-scale field testing, promises to guarantee that the system is successful, scalable, and adaptable across a variety of fish farm situations. Additionally, in order to ensure a responsible and sustainable adoption of the system, it is essential to undertake careful monitoring of the environmental effect of the system during its implementation. As a conclusion, the Internet of Things that is enabled with LPWAN is a tremendous instrument for revolutionizing fish farming. Through the use of real-time data and machine learning, this technology has the potential to dramatically increase efficiency, hence enhancing biosecurity and reducing the effect on the environment. As this study continues to advance, we will be able to pave the way for a future of fish farming that is not just productive and secure, but also contributes to a global food system that is more sustainable and morally sound.

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