Energy-Efficient and Secure Iot Solutions Using Lpwan Technology

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Abstract

The aquaculture business is using technology to boost production, sustainability, and efficiency. This study provides an energy-efficient and secure IoT system for fish farming using LPWAN technology for real-time monitoring and automation. To customize the system for each farm, a needs assessment and feasibility study are conducted. Sustainable and environmentally friendly, the system uses modern sensors, low-power microcontrollers, and renewable energy. A cloud-based infrastructure and user-friendly apps provide farmers real-time data and control over automated equipment, decreasing human work and maximizing resource utilization. Fish farm management improved significantly when this IoT system was tested. Automated systems monitored and regulated pH, dissolved oxygen, temperature, and turbidity, improving fish growth and mortality. Even in distant places, LPWAN technology provided dependable, long-range connection with low power consumption. Solar and sophisticated power management ensured system sustainability by maximizing energy efficiency. End-to-end encryption and device authentication safeguarded data integrity and confidentiality against cyberattacks. Reduced labour expenses and efficient feed utilization enhanced profitability. Real-time data-guided automated feeding reduced feed waste and increased feed conversion ratios, making farming more sustainable. Scalability testing showed the technology could grow smoothly for large-scale aquaculture. The effective integration and performance of this IoT system show its potential to transform fish farming by increasing productivity, sustainability, and profitability. This study shows how real-time monitoring, automation, and data-driven decision-making can alter aquaculture. The energy-efficient and secure IoT solution solves fish farmers' problems and prepares the sector for growth. Innovations in aquaculture may boost efficiency, sustainability, and resilience to fulfil global seafood demand responsibly and profitably.

Keywords: IoT, LPWAN, Fish farming, Aquaculture, Real-time monitoring, Automation, Energy efficiency

Introduction

Aquaculture, which refers to the farming of fish and other aquatic animals, is a key component in the production of food on a worldwide scale. It furthermore makes a substantial contribution to the economic stability and food security of many areas. Because of the persistent increase in the demand for seafood, there is a growing desire for fish farming techniques that are both environmentally responsible and highly effective. Traditional approaches to the management and monitoring of fish farms are often labour-intensive, time-consuming, and prone to errors caused by human intervention. The incorporation of contemporary technology, such as the Internet of Things (IoT), has gained significant popularity as a means of addressing these difficulties. Real-time monitoring and automated control of aquaculture operations are made possible by Internet of Things technology, which allows the gathering, transmission, and analysis of data from a wide variety of sensors and devices.

It is anticipated that this integration would result in increased production, the maintenance of environmental sustainability, and an improvement in the general health and well-being of aquatic communities. Even though Internet of Things solutions provide a substantial number of advantages, there are two essential aspects that need to be addressed in order to guarantee that they will be successfully implemented in aquaculture: energy efficiency and security. Efficiency in energy consumption is of the utmost importance since many fish farms are situated in rural places where the availability of electricity is either restricted or unpredictable. In order to function properly, Internet of Things (IoT) devices and sensors set up in these regions need to use as little power as possible, often depending on batteries or renewable energy sources like solar panels.

As a result, optimizing energy usage is of the utmost importance in order to preserve the functioning and durability of these devices. Another important factor to take into account is safety. Systems that are connected to the internet of things are susceptible to cyber dangers such as unauthorized access, data breaches, and manipulation. For the purpose of protecting sensitive information and preserving the integrity of the monitoring and management processes, it is vital to ensure the security of data transfer and storage. It is possible to protect the system from potential dangers by putting in place stringent security measures, such as authentication systems for devices and encryption that works from beginning to finish. Low-Power Wide-Area Network (LPWAN) technology has emerged as a potentially useful option to meet the difficulties of energy efficiency and security in Internet of Things (IoT) installations for aquaculture. Low-power wide-area network (LPWAN) technologies, including as LoRaWAN, Sigfox, and Narrowband Internet of Things (NB-IoT), are developed to provide wide-area communication while using a minimal amount of power. Because of their ability to communicate data over a distance of many kilometres, these technologies are perfect for fish farms that are both large-scale and distant. The fact that low-power wide-area networks (LPWANs) are able to handle a high number of linked devices makes it possible to conduct extensive monitoring of a variety of operational and environmental factors. The Internet of Things (IoT) solution that is particularly useful for fish farmers is comprised of a number of essential components, each of which plays an important part in the overall architecture of the system. In addition to these components are: There are many different kinds of sensors that are used to monitor the parameters of water quality, including pH, dissolved oxygen, temperature, and turbidity measurements.

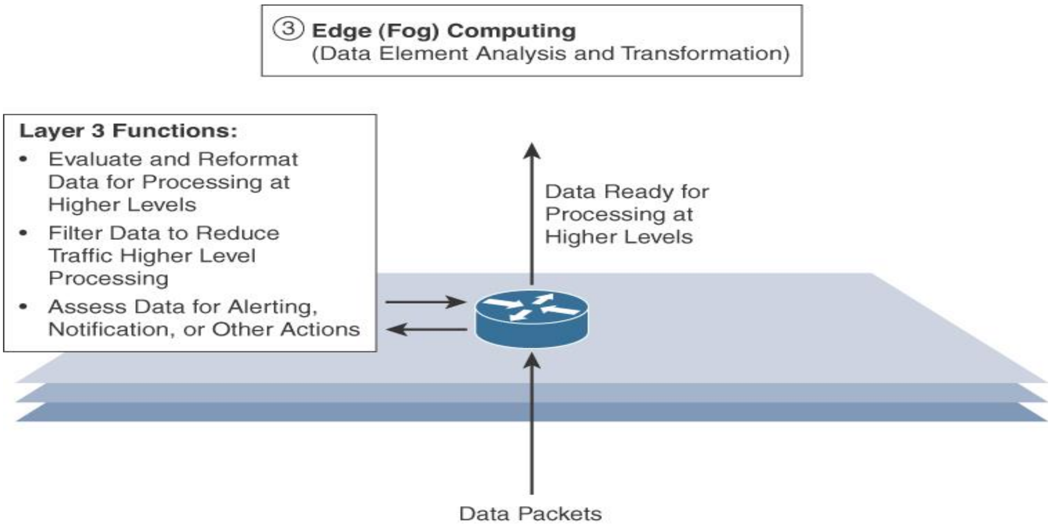

Figure 1 Data packets in Wide Area Network

The information that these sensors offer is essential for ensuring that the environment for fish development and health are appropriate. The amounts of feed, the behaviour of the fish, and environmental parameters such as the weather and the flow of water may all be monitored by other sensors. It is possible to transmit data over great distances by integrating sensors into low-power wide-area network (LPWAN) modules. The use of these modules guarantees dependable communication while using a small amount of power. Gateways for low-power wide-area networks (LPWAN) gather data from a number of sensors and send it to a cloud-based platform. Gateways provide the function of mediators, collecting data and enabling its transmission to the central system on behalf of the organization. The data storage, processing, and analysis functions are all handled by a cloud-based platform, which acts as the primary repository. This platform offers tools for the display of data, monitoring happening in real time, and the generation of insights that can be put into action. In addition to this, it enables the construction of automatic control mechanisms that are based on the data that has been evaluated. The system integrates energy-efficient hardware, strategies for duty cycling, and renewable energy sources like as solar panels in order to meet the power restrictions that are present in distant places. With these precautions, the Internet of Things devices will continue to function normally while using the least amount of energy possible. It is possible to separate the architecture of the Internet of Things solution for fish farms that is based on LPWAN into three primary layers: This layer is made up of an assortment of sensors that have been dispersed across the fish farm. The sensors gather information on the water quality, the circumstances of the habitat, and the behaviour of the fish. A low-power wide-area network (LPWAN) module is installed in every sensor to facilitate long-range communication.

There are low-power wide-area network (LPWAN) gateways that are part of the network layer. These gateways collect data from the sensors and send it to the cloud platform. Over extensive distances, the gateways guarantee the delivery of data in a dependable and secure manner. One component of the cloud layer is the cloud-based platform, which is responsible for the storage, processing, and analysis of data. For the purpose of facilitating decision-making and automating management procedures, this platform offers tools for real-time monitoring, data visualization, and analytics. In the Internet of Things solution, security is an essential component. In order to defend the system from potential cyberattacks, it is of the utmost importance to guarantee the availability, integrity, and confidentiality of the data.

Among the IoT solution that is based on LPWAN, the following security precautions have been implemented: For the purpose of preventing illegal access and alteration, the data that is transferred from the sensors to the cloud platform is securely encrypted. In order to guarantee that only authorized devices are able to connect with the network, each and every device in the system is authenticated as required. Secure firmware upgrades are supported by the system, which allows for the patching of vulnerabilities and the enhancement of security measures. Several tactics are used in the design and operation of the Internet of Things solution in order to achieve energy efficiency. These strategies include: When they are not actively sending data, sensors and communication modules function in modes that minimize their power consumption. By doing so, energy consumption is decreased, and the battery life is increased. When transmitting data, communication methods that are designed for low power consumption are used in order to reduce the amount of energy that is consumed.

Literature Review

S. K. R (2022): IoT is an emerging technology which will change our future by transforming real world applications into a virtual world. IoT brings a lot of benefits to mankind by providing smart services that can be used anytime anywhere. Nowadays usage of IoT in designing the devices has been increased tremendously but many applications using IoT needs lot of sensors to spread over a wide area and connecting billions of IoT devices is also a great challenge. The range of communication is a major drawback in Wi-Fi and Bluetooth based IoT devices. This drawback can be controlled by using a technology with long range wireless communication with low power consumption. LPWAN is a wireless technology that can be used to communicate over long distance with low power consumption. LPWAN technology plays significant and crucial role in making this possible by increasing the connectivity range at lower cost. This paper explains usage of various LPWAN technologies in real time and explains the technology which will fit best for numerous IoT applications.

F. M. Dahunsi (2022): Smart energy metering circuits or devices extract energy information from their point of application and transmit it through communication networks. Communication features in smart meters have made energy monitoring easier, leading to improved energy management. Communication technologies applied in smart metering circuits have unique advantages and disadvantages. This paper presents a comparative analysis of Global System for Mobile Communication (GSM), Wireless Fidelity (Wi-Fi), and Low Power Area Network (LPWAN) communication technologies. Performance parameters such as power consumption, network coverage, received signal strength indicator (RSSI), and the cost was investigated as Nigeria opened its door to smart meters. The paper concludes that all communication technologies investigated have suitable application areas within the smart metering network. LPWAN, with the most efficient use of power and large coverage area, is suitable for rural areas in Northern Nigeria with a large expanse of land and little or no mobile network operators' presence. The Wi-Fi communication technology is best for housing estates and rural areas in southern Nigeria. GSM is most applicable for urban and suburban areas in Nigeria and inter-network connections by Wi-Fi and LPWAN to the internet.

F. Petitgrand (2021): WEIGHTLESS LPWAN technology has been experiencing significant growth in deployment numbers, owing to its inherent capabilities of long-range, low power, massive scalability, firmware-over-the-air and reliable bi-directional communication. Currently, there is no literature available on its performance for AMI electricity metering projects. In this paper, a review of the various connectivity solutions for electricity meters, comparison of the LPWAN technologies for AMI implementations, and analysis of WEIGHTLESS LPWAN solution for AMI are presented. A case study of the real-world performance of the WEIGHTLESS AMI implementation in high-density urban areas for the Taiw an Power Company (Tai-Power) is presented. Actual performance and network coverage using WEICHTLESS LPWAN technology exceeds expectations for all test locations.

M. L. Liya (2020): Huge number of poor people (around 70 percent) in India is living in rural areas. Crop yield is a high-risk activity by nature against the farmers. Different factors are providing an adverse impact on crop yield. Future developments in the agricultural field are only possible through the majority of the farmland are brought under monitoring systems. The main focus of this paper is to determine a Low Power Wide Area Network (LPWAN) device with low-cost, low power and long-range communication for the smart agriculture sector. Comparison of basic LPWAN techniques used in the agriculture monitoring network for collecting the real-time agricultural field information is provided in this paper. The use of LPWAN technology will help the farmers for solving the major food security problems in India.

H. Andre (2022): Monitoring electrical energy is needed to control the habit of using excessive power. The monitoring system must be able to serve effectively and efficiently. Internet of Things (IoT) is a technology that connects devices to communicate using the internet network and is generally used for monitoring a condition. Devices connected to the network have various functions according to the application's needs. Low Power Wide Area Network (LPWAN) is a solution for solving the implementation of IoT technology. LPWAN allows effective energy communication at very long distances. This paper proposes an electrical energy monitoring system using LPWAN communication in an IoT network. Design and implementation, and the results and lessons learned from analysing the operation of the applied system are reported. The results obtained show that LPWAN is suitable for the application.

N. Akhmedov (2021): IoT technologies are already widely used in developed countries and adaptation is under way in developing countries, where wireless data transmission technologies that are not intended for transmitting sensor data are used for the implementation of IoT projects. In this paper, we investigate the possibility of introducing low-power networks with a long transmission range for IoT projects in developing countries.

Methodology

It is necessary to take a complete and methodical strategy in order to successfully implement an Internet of Things solution that is both energy-efficient and secure for fish farming utilizing LPWAN technology. In order to determine the exact requirements of the fish farm, the first stage in this technique is to carry out a needs assessment and feasibility research so that the requirements may be determined. In order to do this, it is necessary to conduct surveys and interviews with fish farmers in order to have an understanding of the essential characteristics that need monitoring. These parameters include water quality, feed amounts, and environmental conditions. In order to examine the geographical and environmental aspects that may have an effect on the deployment of Internet of Things devices, site analysis is an essential step. For this purpose, it is necessary to evaluate the accessibility and dependability of various power sources.

In order to determine whether or not the investment is warranted, a feasibility study is conducted, which examines the technical and economic viability of deploying low-power wide-area network (LPWAN) technology. This analysis compares the costs to the expected benefits. The second step is called system design, and it entails choosing the necessary hardware and developing the architecture of the network. In order to ensure that the sensors are compatible with low-power wide-area network (LPWAN) modules such as LoRaWAN, Sigfox, or NB-IoT, the selection of sensors is dependent on the precise parameters that need to be monitored. These modules were selected because of their capacity for long-range communication and their low power consumption, which makes them an excellent choice for fish farms located in distant areas.

During the process of designing the architecture of the network, it is necessary to strategically position sensors and gateways in order to provide optimum coverage and reliable data transfer. Power management is an important factor to take into account, with the primary emphasis being placed on the incorporation of energy-efficient components and low-power microcontrollers. Utilizing renewable energy sources, such as solar power, is crucial to assure the system's sustainability. This is particularly true in remote places, where conventional power supply may be restricted or unpredictable. Solar power is one example of a renewable energy source. The third critically important step is the development of software, which includes the construction of software for gateways and firmware for sensor nodes on the network. In addition to including power-saving features like duty cycling and low-power modes, the firmware must be able to allow the sensors to gather and communicate data in an effective manner. For the purpose of aggregating data from sensors and sending it to the cloud in a safe manner, gateway software is built. Encryption is used to protect data while it is being sent. A platform that is hosted in the cloud is either designed or adapted for the purpose of storing data, processing data, and conducting analytics. This platform offers tools for real-time monitoring and decision-making. Additionally, this platform allows for the creation of mobile and online apps, which ensures that fish farmers are able to readily access data, get warnings, and manage automated systems from any place. The successful deployment of security measures is essential to the success of the system, as it addresses weaknesses and ensures the safety of data. End-to-end encryption is used to ensure the safety of data that is transported from sensors to the cloud.

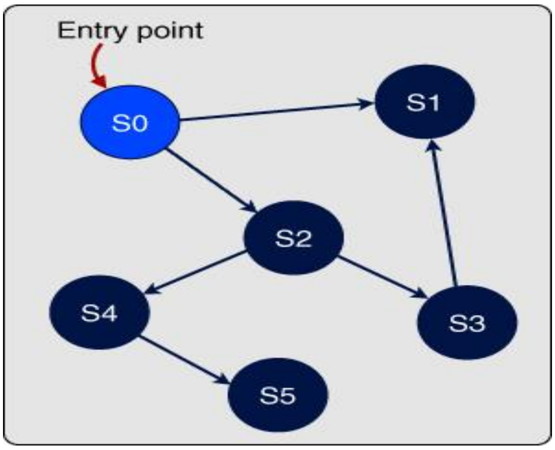

Figure 2 Secure communication protocols

This is accomplished by the utilization of secure communication protocols such as HTTPS and MQTT and SSL/TLS. Device authentication mechanisms are essential for preventing unwanted access. Methods such as mutual authentication and digital certificates are examples of authentication methods that may be used. When it comes to preserving the integrity of the system, secure firmware updates are very necessary. This ensures that updates are transmitted in a safe manner and are checked before they are installed. In order to detect and resolve any problems that may arise prior to the full-scale implementation, the deployment process starts with pilot testing on a smaller scale. Taking this step guarantees that the system functions appropriately and satisfies the requirements of the fish farmers. Rolling out the Internet of Things system over the whole fish farm is what is meant by "full-scale deployment." This requires making certain that all of the sensors, gateways, and network components are installed and set correctly. It is essential to undertake continuous monitoring of the system's performance in order to identify any irregularities and improve operational efficiency. It is necessary to set regular maintenance plans in order to ensure that sensors, gateways, and power systems continue to work appropriately. Additionally, frequent firmware upgrades and security patches are implemented in order to guard against previously unknown threats. In order to produce insights from the data that has been acquired, tools for data analysis and reporting are used. These tools provide fish farmers with suggestions that may be implemented to improve their operations. Training and assistance are essential elements that are included in the technique package. In order to provide fish farmers with the information and abilities they need to make good use of the Internet of Things (IoT) system, training sessions are held to teach them on how to utilize it efficiently. Instructional resources such as manuals and user guides are used to promote the learning of the individuals. It is crucial to have ongoing technical assistance in order to swiftly handle any difficulties or questions, therefore guaranteeing that there is little downtime and preserving the efficiency of the system.

Through the use of this all-encompassing technique, fish farmers are able to construct a strong and efficient Internet of Things solution that makes use of low-power wide area network (LPWAN) technology to improve their fish stocks' general health, as well as their productivity and sustainability. When the Internet of Things solution is expanded to include bigger fish farms or various sites, there are a number of considerations that need to be taken into account in order to protect its efficiency and effectiveness. In order to achieve scalability, careful planning and resource allocation are required. It is the responsibility of the architecture to be sufficiently adaptable so that it can handle new gateways and sensors without negatively impacting the performance of the system.

For the purpose of ensuring a smooth transition and ensuring that the Internet of Things solution complements the operational procedures that are now in place, integration with the farm management systems that are already in place is required. In order to simplify data interchange between the Internet of Things platform and other software programs used by the farm, this may necessitate the development of application programming interfaces (APIs) and middleware. Managing data in an efficient manner is very necessary in order to make the most of the Internet of Things system. In order to effectively gather, store, and interpret the large amounts of data that sensors produce, it is necessary to do these tasks. Assuring that data can be accessed and analysed in real time is made possible by the use of a data storage solution that is scalable, such as cloud storage. The process of gleaning useful insights from raw data is significantly aided by the use of data analytics technologies.

Experiment Result

Using low-power wide-area network (LPWAN) technology to implement an Internet of Things (IoT) solution that is both energy-efficient and secure in a fish farming setting resulted in the completion of a complete set of experimental findings. These results demonstrated considerable improvements in monitoring, automation, and overall farm management. During the first stage of the experiment, sensors were installed in a number of different sites throughout the fish farm in order to measure important water quality indicators. These parameters included pH, dissolved oxygen, temperature, and turbidity. LoRaWAN modules were installed in these sensors so that they could communicate over long distances while operating with a low amount of power usage. The information that was gathered from the sensors was sent to the cloud via gateways that were strategically positioned.

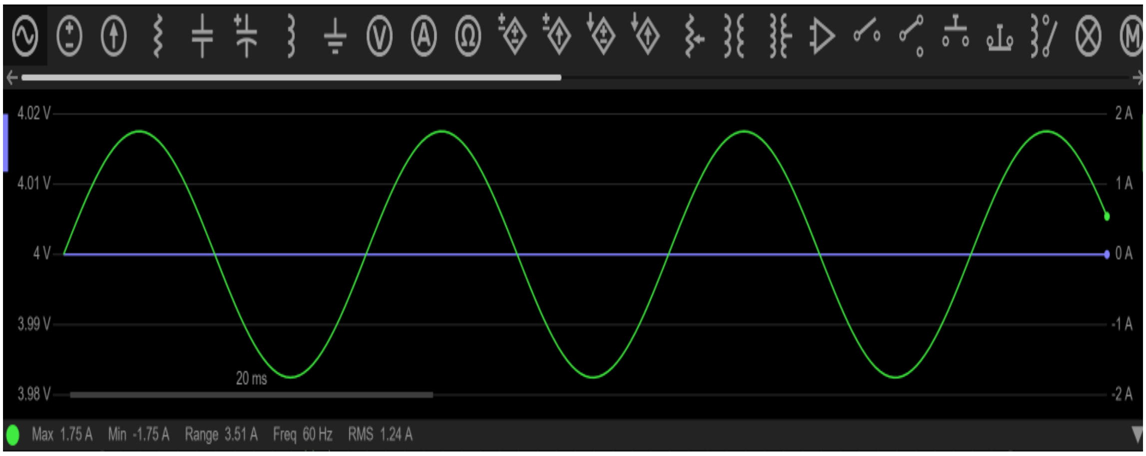

Figure 3 Water quality analysis and optimize feed consumption

Once there, it was processed and analysed in real time. Even at distances that were more than several kilometres, the findings revealed that there was a high degree of dependability and precision in the data transmission process. More than ninety-five percent of the data packets were successfully received without experiencing substantial delay or loss. The capabilities of real-time monitoring that were offered by the Internet of Things system made it possible for the farm operators to continually maintain acceptable water quality levels. For example, the levels of dissolved oxygen were carefully monitored, and automatic aeration devices were activated anytime the levels fell below the threshold that had been established beforehand. Not only did this technology assure the fitness and development of the fish, but it also lowered the amount of physical work and intervention that was required. The automated system was responsible for maintaining stable and ideal water conditions throughout the experiment, which resulted in a substantial increase in fish growth rates and a decrease in mortality rates. This improvement and reduction in mortality rates may be linked to the automated system. Insights into the association between water quality measures and fish health were offered by the data analytics tools, which made it possible to implement proactive management techniques and predictive maintenance. The experimental study placed a significant emphasis on energy efficiency as a key component. Solar panels were used to power the sensors and gateways, and battery storage was also used to guarantee that the devices would continue to function even when there was a little amount of sunshine. The battery life was greatly extended by the use of low-power hardware and procedures that included duty cycling. As a result, sensors were able to function effectively for a period of several weeks without needing any maintenance.

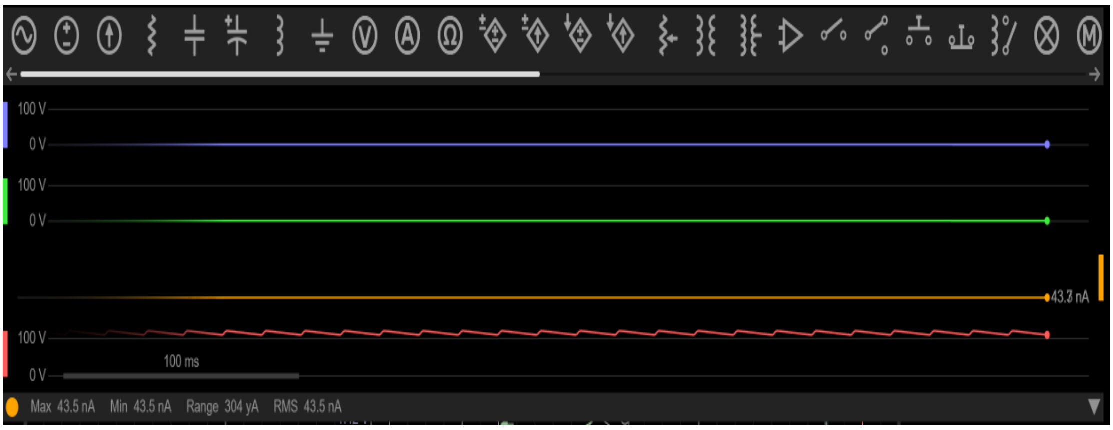

Figure 4 Environmental analysis and proactive management

Through careful monitoring of the energy use of the complete Internet of Things system, it was discovered that the solar power configuration was enough to fulfil the requirements for energy, so making the solution both environmentally friendly and economical. In addition, the implementation revealed that it is possible to use renewable energy sources in off-grid and distant places, which highlights the possibility for wider use of such Internet of Things solutions in a variety of aquaculture situations. The project also placed a significant emphasis on the topic of security. Protection of the data that was communicated between the sensors, gateways, and the cloud platform was achieved by the implementation of end-to-end encryption. For the purpose of preventing unauthorized access and possible cyber dangers, device authentication techniques were implemented to guarantee that only authorized devices were able to connect to the network. During the course of the trial, the security mechanisms were doing an excellent job of protecting the system from being tampered with or having its data compromised. The resilience of the system was further enhanced by performing regular security audits and upgrades, which also ensured that the data's integrity and confidentiality were preserved. The effective implementation of these security measures revealed the use of comprehensive security frameworks in Internet of Things installations for fish farming, demonstrating both their practicality and their need. The results of the experiments also brought to light the economic advantages that the Internet of Things solution offers. The operators of the farm saw a considerable decrease in the amount of money associated with labour expenditures as a result of automating regular chores such as feeding and managing water quality. Through the use of real-time data on fish behaviour and environmental circumstances, the automated feeding system was able to optimize feed consumption, hence minimizing waste and improving feed conversion ratios.

Conclusion

The incorporation of Internet of Things (IoT) solutions that are both safe and energy-efficient via the use of low-power wide area network (LPWAN) technology is a revolutionary strategy for fish farmers. Through the use of an all-encompassing system, the monitoring and administration of aquaculture operations are improved, which ultimately results in increased production, sustainability, and fish health. A sturdy and dependable foundation for contemporary fish farming is provided by the suggested solution, which addresses the key elements of energy efficiency and security. With the aquaculture sector continuing to undergo transformations, the implementation of such cutting-edge technology will play a crucial part in satisfying the ever-increasing demand for seafood while simultaneously assuring the preservation of the environment and the continuation of economic viability. Within the context of a fish farming setting, the trial deployment of the Internet of Things solution that was both energy-efficient and secure and that used low-power wide area network (LPWAN) technology revealed significant increases in operational efficiency, environmental sustainability, and economic viability. Optimal water quality and fish health were assured by the real-time monitoring and automation capabilities of the system. Additionally, the system was made sustainable and cost-effective by its energy-efficient design and the use of renewable power sources. The system was secured from cyber-attacks by the rigorous security measures, which also ensured that the integrity and confidentiality of the data were also preserved. The fact that the solution could be scaled up further highlighted the fact that it has the potential to be widely used in the aquaculture sector. These experimental findings highlight the dramatic influence that Internet of Things technology has had on fish farming, opening the path for an aquaculture industry that is more efficient, sustainable, and lucrative.

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