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IoT technology for animal health monitoring in the livestock sector

Tecnología IoT para el monitoreo de la salud animal en el sector ganadero

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Abstract

The article highlights two models of innovative prototypes of measuring collars equipped with advanced sensors to prevent and monitor animal health in the context of Livestock 4.0 through the Internet of Things (IoT). One of the models used the MKR-NB1500 board with LTE-M cellular connectivity, while the other used the ESP8266 board with connectivity through its WIFI module. Both prototypes incorporate sensors to monitor body temperature using the DS18B20 sensor, blood pressure with the MAX30102, livestock activity with the MPU6050 and geolocation with the NEO-6M GPS module. The scheme integrates the Arduino Cloud platform for the collection of data generated by the sensors. The descriptive methodology is used to conduct a comprehensive review of scientific articles and an analysis of the IoT technology suitable for the control of each aspect of monitoring. A survey is carried out in Google Forms and interviews with veterinarians to identify priority monitoring variables, such as body temperature, geolocation, activity and heart rate. The sample includes representative ranchers from the provinces of Manabí, Los Ríos and Guayas on the Ecuadorian coast. With the participation of 12 livestock farmers, the method provides a deep understanding of the expectations of key users before the implementation of the prototype, providing valuable information to adapt and improve the collar design in the context of Livestock 4.0.

Keywords: livestock 4.0; IoT; advanced sensors; LTE-M; Cloud IoT platform; emerging technology.

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Resumen

El artículo destaca dos modelos de prototipos innovadores de collares de medición, equipados con sensores avanzados para prevenir y monitorear la salud animal, en el contexto de la Ganadería 4.0, a través de la Internet de las Cosas (IoT). Uno de los modelos utilizó la placa MKR-NB1500 con conectividad celular LTE-M, mientras que el otro empleó la placa ESP8266, con conectividad a través de su módulo WIFI. Ambos prototipos incorporaron sensores para controlar la temperatura corporal mediante el sensor DS18B20, la presión arterial con el MAX30102, la actividad del ganado con el MPU6050 y la geolocalización con el módulo GPS NEO-6M. El esquema integró a la plataforma Arduino Cloud para la recopilación de datos generados por los sensores. La metodología descriptiva se utilizó para realizar una revisión exhaustiva de artículos científicos y un análisis de la tecnología IoT adecuada para el control de cada aspecto del monitoreo. Se llevó a cabo una encuesta en Google Forms y entrevistas a veterinarios para identificar las variables de monitoreo prioritarias, como la temperatura corporal, geolocalización, actividad y pulso cardíaco. La muestra incluyó ganaderos representativos de las provincias de Manabí, Los Ríos y Guayas en la costa ecuatoriana. Con la participación de 12 ganaderos, el método proporcionó una comprensión profunda de las expectativas de los usuarios clave antes de la implementación del prototipo, brindando información valiosa para adaptar y mejorar el diseño del collar en el contexto de la Ganadería 4.0.

Palabras clave: ganadería 4.0; IoT; sensores avanzados; LTE-M; plataforma Cloud IoT; tecnología emergente.

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Introduction

Cattle farming plays a fundamental role in the agricultural industry. This activity not only provides animal food products such as meat, milk and eggs, but also raw materials for the textile, pharmaceutical and cosmetic industries. Furthermore, cattle farming contributes significantly to the global economy, creating jobs and generating profits in many countries. According to the National Institute of Census and Statistcs (Instituto Nacional de Estadística y Censos) (INEC, 2023), in Ecuador, in the year 2022, the cattle sector had the biggest population, with a total of 3.9 cattle heads in the whole country, followed by pig livestock; the national daily production of dairy was 5.5 million liters, with a yield of 6.8 liters·cow^{-1}.

Therefore, as the backbone of food and resources production, cattle farming faces evermore complex challenges in the modern era. One of the fundamental problems for efficiency and well-being in cattle raising is late detection of health issues. The inability to quickly identify illness and ailments indicators does not only affect production, but also compromises the health of the animals, which has economic consequences. Traditional cattle management is limited by the dependence on visible signs for illnesses, which causes reactive and often delayed interventions.

The lack of efficient tools to continually monitor animal health is intensified in the context of Livestock 4.0, where automatization and digitalization are essential to reach optimal levels of efficiency. The current gap between emerging technologies and their practical implementation in the daily management of cattle highlights the urgent need for innovative solutions that tackle this issue directly.

Besides the challenges related to animal health, the cattle industry faces a persistent threat in many regions: cattle rustling. The stealing of cattle does not only cause economical loss for the cattle farmers, but it also creates an environment of insecurity in cattle production. This problem is aggravated by the lack of effective tools for tracing and monitoring cattle movement in a constant manner.

It becomes pertinent to mention the Internet of Things as a solution to the previously mentioned issues in the cattle sector, due to the high applicability that this technology offers in many areas of the industry, such access to Internet in devices. This concept derives from the technological advancement and the need to share and control things in the environment (Li et al., 2015). Without a doubt, the advances in the Internet of Things have provided an unique opportunity to tackle many challenges. Based on this, Livestock 4.0, which according to the Dairy Industry Center of Ecuador (CIL Ecuador, 2023), refers not only to the automatization of production processes, but also involves industrial machinery, computers, electricity and robotics. All of these contribute to higher efficiency in cattle production by using tools such as drones, sensors, chips and others devices in the IoT family.

The Internet of Things (IoT) offers great advantages for the cattle sector, specially in the leading countries of the industry, wherein it experiences fast development. Many studies highlight the use of technology in different aspects of cattle production. These include advances in localization and tracing the cattle, advanced nutritional management and the implementation of automatized milking. This progress in the application of IoT technologies contributes significantly to the modernization and efficiency of the cattle sector.

This research highlights the rise of Livestock 4.0 as a paradigmatic shift. The integration of emerging technologies, in particular the Internet of Things (IoT), has started an era where constant and real-time monitoring of the cattle's health is not only possible, but imperative. Even with the growing awareness of the potential benefits associated with Livestock 4.0, the implementation of these technologies in daily management is still a challenge. Therefore, this study presents the previous research that has established the theory base, discussing the theoretical foundation of IoT in agriculture and animal monitoring.

Nonetheless, translating these theories into practical solutions, especially in the context of early detection and health issue prevention, represents a noticeable gap that this research attempts to tackle. For that purpose, this study identifies, with the help from cattle farmers and animal health professionals, the key variables for the monitoring and well-being of bovines. This initial process allows to determine the appropiate IoT technologies to design a technological model capable of collecting data from these variables and visualizing them in real time thorugh a platform, which facilitates the detection of anomalies in cattle.

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The architecture of the Internet of Things (IoT)

Martin (2019) mentioned in their study that the Internet of Things (IoT) constitutes a network that links numerous devices. But then questions arises of how these are managed and supervised, as well as how the data these generate is handled. The devices and objects are linked to a specific IoT platform, which compiles and processes data coming from the sensors. Afterwards, tools for statistical analysis are applied to present the relevant information. These platforms are designed to filter the information and select the useful data following a defined pattern. For example, when measuring the pollution in a lake, if all measurements are found inside a logical range, an extremely high value may be seen as incorrect by the sensor. If it were considered as accurate data, it could generate errors in the statistics. These platforms are known as data centers and are located in the cloud, where they receive and process data. The origin of this data is Edge.

Edge is the place where many physical activites are carried out and includes all the devices that are constantly collecting and sending data. These devices need a destination wherein to send the data to be collected. Initially, the could served this purpose, but due to the fast rise in the number of connected devices, an interim space known as Fog has surged.

At first, the data centers at Edge looked like small-scale versions of the data centers from the cloud service providers. As the number of devices grew, these centers moved way from traditional models and became more abstract: they go from being centrilized to being distributed, from homogenous to heterogenous, from having only one owner to many owners. The decentrilized servers that act as middlemen between the cloud adn Edge are known as Fog, which is a place where the data from a "small" set of sensors are preporcessed and prepared to be sent to the cloud, where they are centralized. The act as a "middlemen" between the Edge and the Cloud.

Following the architecture of the Internet of Things, it is necessary for this research to define the devices that belong to "Edge", from which the sensors from IoT are conceptualized. Tokio School (2022) defined those as electronic chips that have an integrated circuit that is compatible with the standards of regular communication in the world of IoT and that allow to extract data from the real world through physical interaction. In other words, these are the electronic "detectives" that gather clues about what goes on in the real world and share them with the IoT system.

Tokio School (2022) mentioned that the sensors are capable of converting input measure such as humidity, temperature, pressure, among others, into a measurable signal that is interpreted by electronic devices. After this conversion and transmission of information, the compiled data can be stored to be subsequently processed and analyzed. The sensors act as specialized translators of the physical environment language, for example, they take into consideration variables such as humidity, temperature and pressure, and translate them into code that can be read by the electronic devices. Afterwards the code is transmitted through the network, so that the devices can "read" it. Once the data is received, it is stored in the database to be studied and analyzed in-depth. It is as if the sensors were interpreters that allow the electronic devices to understand what goes on in the real world.

PowerBank. It is an external battery or portable charger that stores energy and is used to charge other electronic devices, such as mobile phones, smart watches and other devices that are charged with an USB cable; it is very important to take into consideration for the bovine health monitoring system.

Protoboard. Jiménez and González (2001), citing Blauvelt, indicate that the protoboard is a board with orifices in it that are electronically connected between them. The orifices allow mounting electronic equipment and wires to connect them. The plate is made from an isolating material and a conducting material. In other words, it is a tool used in electronics to make prototypes and experiments with electronic devices.

Connectivity. According to Pérez (2019), the networks of IoT are generally wireless due to convenience, and the technologies that are used are 3G, 4G, Bluetooth and ZigBeel. Wireless technologies are systems and devices for communication that transfer data without the need for cables. These systems use electromagnetic waves, such as radio frequencies and microwaves, for transfering information between devices. The wireless technologies are fundamental in various applications, including mobile communications, Wi-Fi networks, Bluetooth, RFID, and emerging technologies such as 5G, allowing connectivity without geographical boundaries and facilitating the movement and interconnectivity between devices in diverse environments.

In the case of cloud connectivity, two ways of communication have to be mentioned: the use of the LTE-M technology (Long-Term Evolution for Machines), which offers reliable connectivity, energy efficiency and data safety, which makes it a powerful technology for improving the the productivity and sustainability of ecuadorian cattle farms. Hernández et al. (2022) mention that LTE-M, also known as LTE-MTC and LTE Cat M, LPWAN is a low-potency technology that facilitates the recycling of existing LTE infrastructures, offering extensive coverage. Developed by 3GPP, LTE-M allows using devices and services desgined for IoT. Another alternative is using a WIFI connection, for which a LTE router has to be acquired, and which should be based on the

IP protocol, suporting both IPv4 and IPv6 (Radicelli-García et al., 2018).

These two types of connectivity are different in the sense that LTE (Long Term Evolution) is a technology for high-speed bandwidth mobile communication which provides access to mobile internet on smartphones and tablets. On the other hand LTE-M is a variant of LTE desgined specifically for IoT devices that offers a more efficient connectivity and with lower energy consumption than traditional LTE, which makes it ideal for IoT devices that require long-lasting batteries and that can be placed in remote areas.

The Internet of Things (IoT) platforms are software environments that facilitate development, deployment and management of IoT apps and devices. These platforms provide a set of tools and services that enable connectivity, data collection, analysis, security and remote control of devices connected to the network. Quintanilla and Cartagena (2019) mention that an IoT platform is the base for all devices to be interconnected and be able to create their own ecosystems. In other words, and according to Link-labs, a web-integrated Internet of Things (IoT) platform is the software that links hardware, access points, and data networks to the apps that are normally used by the users.

The IoT platforms that can be included in a project of this nature, should have the following characteristics established by Quintanilla and Cartagena (2019; p 8):

1. Connectivity and normalization. With different protocols and data formats on a "software" interface, it guarantees accurate data transfer and interaction between all devices.
2. Device management. It makes sure that all the connected "things" are working correctly.
3. Databases. Scalable data storage from the devices based in the cloud to higher levels in terms of data volume, variety, speed, and accuracy.
4. Action processing and management. It provides data based on the rules of action from event-spread that allow the execution of "smart" actions based on specific data from the sensor.
5. Analytics. It carries out a series of complex analysis of basic data sets and machine learning.
6. Visualization. It allows human beings to observe the trends in data dashboards, where it is vividly represented through graphs.
7. Additional tools. The IoT allows prototype developers to test and commercialize to visualize, manage and contol connected devices.
8. External interfaces. They are integrated with third-party systems and the rest of IT bandwith in the ecosystems through an interface functionality of application programs (API), developer kits and software, and links.

Based on the previously presented, the study planned to design a systematic model based on IoT that allowed to monitor the health and wellbeing of the bovine cattle.

Materials and methods

The research was carried out with a descriptive methodology that employed an exhaustive review of scientific literature and analysis of IoT technology that is adequate for the management of each monitoring (Guevara et al., 2020; p. 171). A Google Forms survey was done to identify the variables for priority monitoring according to the perspective of the participants, such as body temperature, geolocation, physical activity or movement, and heartbeat, complemented with an interview with the veterinarian. The mixed approach and direct observation allowed for the gathering of data about the specific preferences and needs of the cattle farmers in relation with the smart collar technology. The sample consisted of cattle farmers from the target population, and the data collection was done through an structured survey.

The unit of analysis consisted of cattle farmers from different communities in the Ecuadorian coast, from the provinces of Manabi, Los Rios and Guayas. The sample was represented by 12 cattle farmers. For the quantification, statistical techniques were applied to measure the responses from the surveyed farmers using the PSPP software.

The methodology provided a deep understanding of the key users's expectations before the implementation of the prototype, providing valuable information for the adaptation and improvement of the design of the collar within the context of Livestock 4.0

There are many tools with more usefulness in the IoT context that facilitate the management, data collection and remote control for connected devices. Each one has its own characteristics and approaches, some of them are described in table 1.

Table 1. The most used IoT platforms.

Plataform	Description	Link
Arduino Cloud	Online Arduino platform that facilitates the remote connection and management for Arduino-based projects. It enables the collection and visualization of data, as well as the remote control for IoT devices.	https://create.arduino.cc/cloud
Google Cloud IoT	It offers an integral solution for the needs of Iot, from the connectivity and management to the processing and analysis of data, backed up by the infrastructure and experience of Google Cloud.	https://cloud.google.com/iot
Blynk	IoT platforms that provide an easy-to-use interface for the creation of apps for Arduino, Raspberry Pi and other devices. It allows the visualization of data, device remote control and the creation of personalized interfaces through a mobile app.	https://blynk.io/
AWS IoT	An Amazon Web Service that allows the connectivity and management of IoT devices. It offers functionalities such as data collection, analysis and security for IoT scale projects.	https://aws.amazon.com/iot-core/
IBM Watson IoT	IBM Internet of Things' platoforms that provide services for connectivity between devices, and IoT data collection and analysis.	https://www.ibm.com/products/maximo/remote-monitoring
Microsoft Azure IoT	The Microsoft Azure service is desgined for creating, implementing and managing IoT solutions. It enables for real-time data collection and analysis.	https://azure.microsoft.com/en-us/services/iot-hub/

Results and discussion

Once the information from the *in situ* visits, interviews and surveys has been gathered, the results are presented as follows. The interview allowed to obtain the data to monitor the temperature and heartbeat, and the more common symptoms that bovines have, the frequency with which cattle farmers do check-ups to their animals, and the level of acceptance for the measuring collar by the bovine, as explained by table 2.

Table 2. Veterinarians' answers from the interviews.

Criteria	Answer
Most common symptons in bovine cattle.	Loss of appetite, fever and weakness (little physical activity).
Normal body temperature range (°C) in bovine cattle.	Adult cow: 37.7 °C minimum/38.5 °C average/39.0 °C maximum. Veal: 38.5 °C minimum/39.0 °C average/39.5 °C maximum.
Normal blood pressure ranges (lpm) in cattle.	Adult cow: 40 minimum/60 average/80 maximum. Veal: 80 minimum/95 average/110 maximum.
Opinion: would the cows accept the measuring collars?	Milking cows are more docile than beef cows, so the former would accept the collar without much issue.
Frequency of medical check-ups in bovine cattle.	Occasionally, once a month.

Table 3 shows the survey results of the criteria that helped to identify the importance of health and well-being of cattle, the variables that should be monitored and the level of acceptance for implementing a cattle monitoring system with IoT technology.

Table 3. Suvey answers from the cattle farmers.

Criteria	**Analysis**
Importance of health and well-being in cattle.	Cattle farmer think that it health and well-being are very important, since 92% of surveyed answered positively.
Way of monitoring animals' health.	50% of cattle farmers monitor the health of their cattle through regular vet check-ups, 25% monitor just by observing, and 25% do lab tests and eventually go to the vet.
Acceptance to a measuring system with internet-connected technology.	33% of cattle farmers see the use of the technology as favorable for their cattle, in order to monitor their health and well-being. The other 67% see it as favorable.
Important variables for monitoring.	For cattle farmers it is very important to measure body temeprature, which got 67% of answers, followed by geolocation with 58%, the activity or movement and heartbeat were also considered importnant, with 59% of the vote. With regard to cud, 41% considered it important to monitor, while 8% thought that weight and feed intake were the most important.
Advantages of implementing a monitoring system with access to internet.	50% of cattle farmers mentioned that implementing a monitoring system would give them more efficiency in feeding and taking care of the cattle, 42% said it would improve early illness detection, and 8% said it would help fight against cattle stealing.

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Tabla 3. Anwers from the surveys to the farmers. Continued...

Criteria	Analysis
Competitiveness in the market.	50% said that the use of the technology in their farms would allow, to some extent, to be more comeptitive, and 42% considered that it would greatly contribute to being competitive, while 5% were not really sure.

Figure 1 present the four variables that are considered for the monitoring process and data collection. These were selected taking into account the criteria with 50% or more answers: body temperature 67%, geolocation 58%, activity or movement 50% and heartbeat 50%. These responses gave way to determining the IoT devices that will be used in the health and well-being monitoring system.

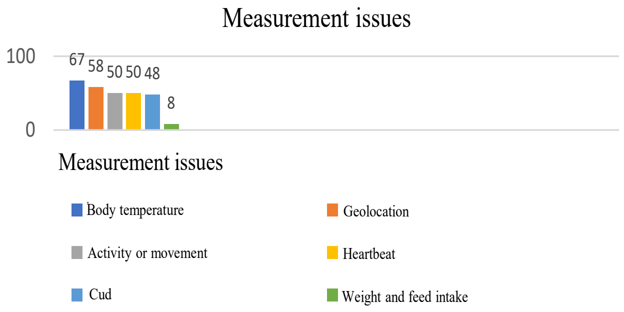

Figure 1. Monitoring variables.

The variables that were prioritized by the surveyed are the factors that influence cattle well-being. As in the case of prolonge exposure to extreme weather conditions, like high high temperatures, which can cause caloric stress and fever, affecting the well-being and production fo the cattle. Sharma and Koundal (2018) mentioned that the exposure to high temperatures activates thermoregulatory mechanisms in cattle, which can slow down metabolism, feed intake and productivity.

Fever in bovines can happen due to many reasons, from infections to intoxications, so it is crucial to identify the cause in rorder to have the appropiate treatment and prevent contagion among the cattle. For this, the DS18B20 sensor allowed to measure the temperature, and one of its advantages was accuracy, and its high compatibility with the MKR-NB1500 and ESP8266 plaques.

According to Medina y López (2021), DS18B20 is a sensor that measures body temperature. It shows readings between 9 to 12 bits and it has three pines: Vdd, GND and DATA. This family of sensors is characterized by being resistance to water and dust. According to research by Scozzina et al. (2023), the DS18B20 sensor was chosen because it functioned correctly within the necessary range of temperature, and they also tested the compatibility with the plaques they used for the prototype.

Bovine movement is another monitored variable of priority for farmers in relation to health and well+being in cattle. A bovine, according to Guzmán (2021), when it is laying most of the day and is not cudding 8 to 9 hours a day, may probably be suffering from an ailment, illness or wound. The lack of movement in cattle can be cause by many reasons, such as limited space, illness, wounds, stressful environmental factors and reproductive issues. A thorough observation of this behavior can help to tackle these issues, assuring the optimal well-being of the animals.

Therefore, the MPU6050 sensor is the ideal device that combines an accelerometer and a gyroscope, which allows to measure both the linear acceleration and the angular veolocity in three axis. As mentioned by Muñoz (2021), the sensor is an inertial measuring unit that works in the X,Y,Z axis, measuring the dynamic acceleration, inclination and vibration. Its use allows to register unusual movements and abnormal behavior in cattle. For example, it could detect limping and abrupt movements that could be signs of health issues. It could also detect estrus periods in cows, among others. According to Rojas (2019), communication can be done both through SPI and bus I2C, thus contributing to data obtention.

The cattle geolocation variable is crucial to farmers for many reasons, because it provides valuable information about the location of their anumals. This variables has various uses, such as preventing stealing, helping to manage the herd, and prevent conflicts among them. This stool is essential for improving management, the safety and well-being of cattle, as well as contributing to the operational efficiency and following the regulations in the cattle industry.

The sensor has a NEO-6M GPS, because it determines geospatial location with high accuracy. This coincides with Ponce et al. (2018), in that it is a module that enables obtaining geolocation information and has a ceramic antenna connected to Ublox NEO-6M GPS receptor, which receives signals from the Global Navigation Network Satellites GNNS.

On the other hand, Loja y Naula (2022) suggested the use of the sensor by the NMEA protocol, which has the $GPRMC data chains with parameters of hour, length, orientation and date.

Heartbeat monitoring in bovine cattle is also a valuable practice for the health and well-being of animals. Precise measurements of heartbeats provides crucial information about the cardiovascular health of bovines, enabling the detection of medical problems and stress symptoms. Heartbeat can vary depending on age, physicial activity and status, and constant surveillance of it can help to identify early signs of illness or other adverse conditions.

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The MAX30102 device is the sensor that can identify changes in heartbeat and oxygen saturation, which can indicate stress or ailments in the animals.

Vélez (2020) likewise mentions that the integrated module for measuring heartbeat includes two LEDs, a photodetector, optic and electronic elements with low noise and environmental light elimination. In the research carried out by Wang et al. (2021), they used this sensor because it can obtain frequency readings between 20 and 200, and between 50 to 100% of oxygen saturation in the blood. The energy source was between 3.3 and 5 watts.

Therefore, the design of two IoT-based modules that can monitor the health and well-being of cattle is proposed. The variables are measured by the folloing devices: The DS18B20 sensor for body temperature, MAX30102 for blood pressure, MPU6050 for activity and movement of cattle, and GPS NEO-6M for geolocation. The two boards used in the design interacted correctly with the sensors: MKR-NB1500 and ESP8266. Both are used in IoT-based proctes.

The MKR-NB1500 is developed by Arduino, and designed for Internet of Things (IoT) applications that require LTE-M mobile connectivity. It is also energy-efficient, capable of sensor integration and flexible programming. On Arduino (2023) it is mentioned that this board "can communicate between NB-IoT and LTE-M networks, and is useful for projects in remote areas with low power". The use of this board allows for direct connection between each bovine, and is totally independent of every other device in the network. Its use depends on the coverage of the farm. On the other hand, the ESP8266 boards connects to WI-FI, thus, it provdes connection to the Arduino cloud, for which a LTE router would be needed.

According to TECmikro.com (2023), ESP8266 is a developer board based on the ESP8266 microcontroller. It has a WI-FI connection, it is used to create apps in a easy and quick way, and has gained popularity for its low cost and flexibility. The module integrates a USB-serial interface and a voltage regulator of 3.3V, for easy connection and programming.

The design of the first model uses the ESP8266 board, which would be interconnected with the 4G LTE router (figure 2). The second model used the MKR-NB1500 board that worked with the chip with IoT LTE-M technology, as shown in figure 3. The chosen IoT platform was Arduino Cloud because the electronic components that have been selected are compatible with this platform.

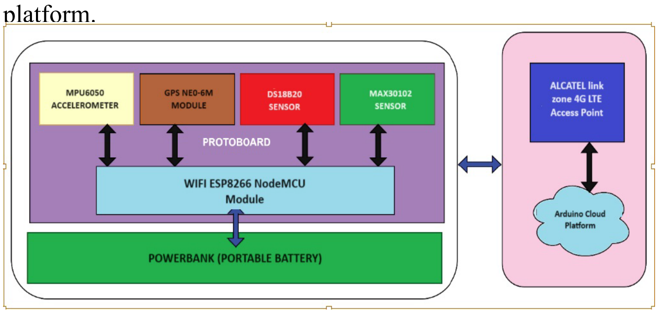

Figure 2. Monitoring system model with the ESP8266 board.

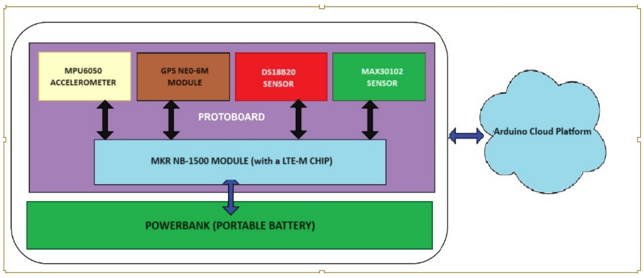

Figure 3. Monitoring system model with the MKR-NB1500 board.

Although it is true that the proposed models include monitoring the four variables already described to maintain the well-being of cattle, there are other studies about technological developments with fewer measurement functionalities, such as the one cited by Aranda et al. (2021), that through the Internet of Things (IoT) energy-efficient networks with extended reach are used for animal supervision. A specific node collects details about the location and biological status of the livestock. The solution integrates LoRa and MQTT to efficiently manage the storage and transmission of information.

The study by Toledo (2022), on the other hand, mentions a unifunctional prototype that uses GPS through an Arduino board and a SIM808 module to track the location of cattle in real time. The received coordinates are transmitted to an IoT web platform for data visualization.

In this research, the aim was to monitor the activity of the cattle, for example, whether they are fed or not, through the movements of the bovine's neck. On the other hand, in another study, to control whether they were being fed or not, an IoT-based system was designed to diagnose rumen acidosis in cattle and monitor nutritional parameters. Rumen pH and temperature values were measured with an IoT microcontroller, recording data on a server. After testing in the laboratory and in ruminants, the device allowed early detection of acidosis, facilitating timely regulatory interventions. The circuit material demonstrated durability when removed from the rumen (Gündüz and Başçiftçi, 2022).

In short, this research highlighted the importance of monitoring multiple factors to ensure the well-being of cattle, from exposure to extreme weather conditions to the control of geolocation, activity and heart rate. The comparison with other developments shows the breadth and effectiveness of the proposal, covering various functionalities for comprehensive monitoring of livestock, differentiating itself from more limited approaches in measurement.

Conclusion

The implementation of a technological system for monitoring the health and well-being of cattle in the livestock sector, without a doubt, allows for more control over cattle, because losses due to disease or cattle rustling are prevented. The livestock industry, by adopting a technological system, will have a competitive advantage in the national and international markets.

For this purpose, in this study, the variables for monitoring the health and well-being of bovines are identified, which were established by the veterinarian and by the farmers who indicated through interviews and surveys that priority in the check-up is given to: body temperature, geolocation, physical activity or movement and heart rate as the criteria with the highest priority.

An analysis of the IoT technologies available on the market has been carried out for their application in livestock monitoring systems. This analysis has covered aspects such as: sensor accuracy, wireless connectivity capacity and integration with data management platforms. This process has made it possible to identify the most appropriate IoT technology to improve the monitoring and management of livestock, thus laying the foundations for future technological implementations in the livestock sector.

Therefore, two IoT technological models are proposed as a solution to the problem faced by livestock farmers to cover the four monitoring variables. It is considered that the model with the MKR NB-1500 plate would be appropriate because it reaches to remote pleaces that do not often have internet. The two models include the use of the DS18B20, MAX30102, NEO-6M GPS sensors, and the MPU6050 accelerometer. These devices would be connected to the Arduino Cloud platform that collects monitoring data in order to visualize abnormalities.

Conflict of Interest

The authors declare that they have no conflicts of interest in this publication in any of its phases.

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Author's contribution

Author	Contribution
Grace Katiuska Viteri Guzmán	Research design; literature review, survey and interview design, analysis and interpretation of data, results, discussion and conclusion, wiriting and editing the manuscript.
Ignacio Hugo Monserrate Sánchez	Participated in the writing and editing of the connectivity section and graphs design, summary, keywords, references.
Alfredo Enrique Arrese Vilche	Participated in the review of the manuscript's content related to the IoT boards and use of the sensors, introduction and methodology.