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A COMPREHENSIVE REVIEW OF IOT APPLICATIONS IN SMART LIVESTOCK MANAGEMENT FOR ENHANCED EFFICIENCY AND PRODUCTIVITY

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Abstract

The integration of Internet of Things (IoT) technology into agriculture, particularly in the management of livestock, has the potential to revolutionize the industry by enhancing productivity, animal welfare, and resource efficiency. This survey examines the current landscape of IoT applications in smart livestock environments, exploring various technologies, such as sensors, GPS, RFID, and automated systems. Key areas of impact include real-time monitoring of animal health, behavior, and environmental conditions, as well as the optimization of feeding, breeding, and waste management processes. The study highlights the benefits of IoT in providing farmers with actionable insights through data analytics, which can lead to improved decision-making and operational efficiencies. This article reviews 24 research papers for livestock and explores the potential of computer-assisted methods for livestock environment and staging. Additionally, the survey identifies challenges such as the need for robust data security, high initial investment costs, and the requirement for technical expertise. By addressing these challenges, IoT can significantly contribute to the development of sustainable and intelligent livestock farming practices. This paper provides a comprehensive overview of the role of IoT in smart livestock environments, emphasizing its potential to transform agricultural practices and promote sustainable farming.

Keywords: Animal Health, Internet of Things (IoT), Real-time Monitoring, Precision Agriculture Smart Livestock Management,

Introduction

An emerging paradigm, the Internet of Things (IoT) bridges the gap between the digital and physical realms to address practical issues. The Internet of Things (IoT) envisions the networked physical and virtual components of everyday life that are capable of gathering data, processing it, and sharing it with one another [1-4]. Smart grids, autonomous cars, healthcare, data gathering, and smart farming are just a few of the significant service providers, sectors, and organizations that have received a lot of attention thanks to the Internet of Things [5-6].

Internet of Things (IoT) paves the way for smart agriculture by collecting, analyzing, and processing data in real-time; this improves farm management as a whole and empowers farmers to make better choices [7-8]. Three subdomains, namely Precision Farming, Greenhouse, and Livestock, can be used to classify the increasing influence of the Internet of Things on agriculture [9–10].

Reviewing and synthesizing available studies in the realm of IoT enabled cattle management is the purpose of this article. For both expansive pastures and more limited farms, the cattle business has been radically transformed by the open and compelling nature of the Internet of Things (IoT), as well as its scalability and interoperability [11, 12]. Wearable sensors and equipment, such smart collars, make it easy to monitor and track the health of animals. Many additional deployments have been integrated into IoT-based livestock, including ideal environment and field supervision for feeding techniques, in addition to monitoring and managing animals' health [13–15]. Furthermore, another crucial component of the IoT-based livestock sector is analysis of beehives. The behavioral analysis and odor gas have been monitored using a number of wireless sensors [16–17].

Figure 1: A typical IoT based livestock system [Source: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9681084]

Figure 1 show the conventional architecture of an IoT system, which consists of four subsystems: items, gateways, communication technologies, and cloud infrastructure. In the context of the IoT, "Things" are defined as inanimate things that can exchange data and carry out tasks either with or without the intervention of a person [18–21]. The items include a wide variety of sensing devices, including IoT sensors, actuators, buzzers, and more. While the Internet of Things gateways process, encrypt, manage, and filter data, among other essential tasks, they also translate protocols. A gateway in an IoT livestock ecosystem communicates with the cloud and exchanges data pertaining to the animals' health via various sensors and devices [22–24].

II. Literature survey

Abdullahi, U. et al. (2019) The goal of this article has been to provide the groundwork for the actual use of IoT solutions for livestock monitoring in Nigeria, with the end goal of increasing efficiency and productivity to ensure food security, combat cattle rustling, and improve animal welfare. This paper suggests utilizing the new LoRa technology, which was emerging as a potential solution for Internet of Things (IoT) devices with low power consumption and extremely long range, taking into consideration the specific characteristics of rural areas in Nigeria, where mobile coverage and related internet connectivity can be nonexistent or extremely limited.

Akhigbe, B. et al. (2021) these authors research presents a systematic assessment of IoTT's use in LsM based on PRISMA guidelines, with an emphasis on LsM as a rigorous process with detailed protocols. This laid the groundwork for thinking about the IoT, a technology that was both very logical and very rigorous, for LsM. The IoT was going to be very important in LsM's administration. The main characteristic of LsM was its ability to identify objects via sensing and observation, among other things.

Chatterjee, P. et al. (2021) By continuously and effectively tracking the actions of dairy cows, the proposed technique can detect certain physiological conditions including fever, cyst, mastitis, pneumonia, black quarter, foot and mouth disease, etc. The IoT architecture, which comprises hardware devices, a cloud system, and an end-user framework, makes this feasible.

Dineva, K., & Atanasova, T. (2021) Automated smart livestock monitoring systems that need little to no human involvement continue to be a challenging issue, even the present state of technology. A smart livestock system's architecture was effectively designed in this research. The findings fulfilled the system's functional objectives, and the testing of all architectural sensitive points was a success. That the designed architecture was well-suited for further integration in cattle ranches was evident from this.

Dutta, D. et al. (2022) These authors study has shown the development, testing, and implementation of a smart, Internet of Things (IoT)-enabled gadget called monitor that can monitor the behavior of cattle both in the barn and out in the field. The gadget can monitor the cattle's acceleration, temperature, and walking pace, and then send that data straight to a server using a Subscriber Identity Module (SIM)-based Global System for Mobile (GSM) module. The next step would be to classify cattle activities automatically using the collected data and an intelligent system. Farmers and owners can keep a closer eye on their livestock using this technique since the way animals move has a direct correlation to how healthy they were.

Hassan, M. et al. (2023) There has been a paradigm shift in agriculture since the advent of wireless sensor networks powered by the IoT were used for livestock management. This all-encompassing method allows ranchers and farmers to optimize farm output and animal welfare via data-driven decision-making that incorporates behavior analysis, health monitoring, and livestock tracking.

Houngue, P. et al. (2020) Ranchers and farmers were now able to gather valuable data thanks to the IoT agriculture applications. If large landowners and small farmers want to be more competitive and environmentally conscious in their output, they need to install smart technologies that take advantage of the IoT market. Successful usage of agricultural IoT-based solutions by ranchers and small farmers was key to meeting demand, which was expected to increase at a fast pace due to the growing population.

Ilyas, Q. M., & Ahmad, M. (2020) The purpose of this research was to suggest a geographical paddock design for tracking the location and movement of cattle. Tracing animals that go beyond the usual entry points requires farmers to strain themselves in a traditional livestock tracking system. The technology alerts the farmers whenever the cattle attempt to cross the zone's specified border.

Mate, S. et al. (2022) Livestock goods including milk and animal welfare were the subject of this paper's discussion of accurate livestock husbandry via the use of sensors, the IoT, and blockchain technology. Livestock farming systems rely heavily on the use of biometric and non-invasive sensors to gather real-time data from dairy animals such as buffalo, camels, cattle, sheep, etc. Using the Internet of Things (IoT), livestock farming systems can communicate with their animals and utilize that data to make decisions based on a variety of environmental factors, such as humidity, gasses, temperature, and more. In the event that a customer rejects food for any reason, blockchain technology guarantees that the product can be tracked and the ledger can be used to determine where the food came from.

Table 1: Survey Table of IoT Applications in Livestock Management

Author	**Year**	**Methodology**	**Advantage**	**Limitation**
Abdullahi et al	2019	IoT and LoRaWAN for livestock monitoring in Nigeria	Wide coverage and low power consumption	Limited bandwidth and data rate
Akhigbe et al.	2021	Review of IoT technologies for livestock management	Comprehensive overview of current technologies and trends	Broad scope, less detailed analysis of individual technologies
Chatterjee et al.	2021	IoT-based healthcare framework for livestock	Enhanced health monitoring and early disease detection	High initial setup costs
Dutta et al.	2022	MOOnitor: IoT-based multi-sensory device for cattle activity	Real-time activity monitoring and data analytics	Requires continuous power supply
Hassan et al.	2023	IoT-based wireless sensor networks for livestock management	Integrated health monitoring, location tracking, and behavior analysis	Complex installation and maintenance

Mohanty, A. et al. (2024) After conducting extensive research, the author have discovered that the use of IoT applications greatly improves the efficiency of farm management, the wellbeing of animals, and the economic sustainability of the enterprise. Modern data management systems and high-tech sensors allow for automated procedures that simplify farming operations and improve the precision of decisions made in real time.

Neethirajan, S., & Kemp, B. (2021) these authors research examined Precision Livestock Farming (PLF) technologies that aid farmers in increasing productivity while also addressing consumer concerns. These technologies include biometric and biological sensors, big data, and blockchain technology. Digitalization, via precision livestock farming technology, has the potential to allay some of the rising consumer concerns over animal welfare, environmental sustainability, and public health, which might lead to a decrease in demand for animal products as the global population continues to climb. For example, the European Green Deal's Farm-to-Fork Strategy can be strengthened by the digitalization of cattle farming, which opens up chances to display and analyze systemic changes.

Nóbrega, L. et al. (2018) Vineyard weed management was an important issue. It necessitates a substantial investment of time and money from winemakers. In addition, manufacturers aim to evade the present mechanical or chemical solutions in favor of ones that improve product quality. Since sheep often consume weeds for food, they were considered a greener option.

Raba, D. et al. (2020) A novel monitoring method for animal feed storage bins was introduced in this study. It consistently provides volume predictions with errors below 5%. These authors' estimates have a relative full scale inaccuracy of up to 1.15 percent, on average, when compared to the data from the weighing system. The technology was built to facilitate extensive rollouts. It can be charged by solar energy and runs on batteries.

Raja, T. et al. (2020) Technology transfer has tremendous potential with the latest information technology instruments for information distribution. Identifying, organizing, and making accessible to livestock rearers information in a user-friendly way requires a systematic and coordinated strategy. Livestock farmers' ability to make informed decisions will undoubtedly be improved by the use of information technology strategies that make use of regional languages in the transmission of technology for livestock raising.

Simoyi, L., & Mugauri, C. (2022) An Internet of Things (IoT) cattle monitoring system tailored to Zimbabwean conditions was certainly within the realm of possibility. Getting the GPS, GSM, battery, and SIM card didn't cost more than $60 United States dollar (USD). Utilizing energy-efficient components and the free LoraWan signal transmission technology can further decrease this.

Swain, S. et al. (2024) The goal was to predict potential health issues. Symptoms, past medical history, and physiological indicators were all part of the extensive set of criteria. Noteworthy to remark was the fact that RF achieved the highest accuracy rate (84%). Light GBM, gradient boost, Lp boost, and cat boost were boosting models that, when used with the RF model, significantly increase prediction accuracy. Based on this comprehensive evaluation, the RF model with cat boost performed the best in predicting cow health risks, with a maximum accuracy of 88%.

III. Advanced techniques

3.1 Iot Based-Livestock

When it comes to livestock, the IoT network is the main component for tracking and monitoring the animals' actions. By providing constant support and access to the IoT backbone, an IoT network ensures the upkeep of the whole livestock infrastructure and enables the transmission and receiving of livestock data. In this part, we will have a look at the layout, design, and platform of the IoT-Livestock network.

3.2 Iot-Livestock Topology

Internet of Things livestock network architecture specifies best practices for keeping tabs on animals' well-being via the coordination of various IoT-based livestock network components. Figure 3 shows an Internet of Things (IoT)-Livestock architecture that uses an intelligent gateway to monitor the health of cows. The AHM gateway is made up of several health monitoring sensors and equipment, as well as wireless standard interfaces. Everything that has been gathered can be examined, analyzed, stored, and shown via AHMGateway. In Figure 4, an alternative architecture for remote monitoring is shown. In this setup, animals' vital signs are recorded using wearable sensors and portable medical equipment. The next step is to store and evaluate the obtained data using different devices that are used for aggregation. The health of animals can be monitored by veterinarians or other health specialists from anywhere in the world via analysis and aggregation. In addition, a network architecture was necessary for topology in order to facilitate the streaming of medical movies. Examples of such linked networks include WiMAX, IMT-Advanced, and the Internet Protocol (IP), all of which are shown in Figure 4's suggested architecture and can be used to transmit movies pertaining to animal cardiology.

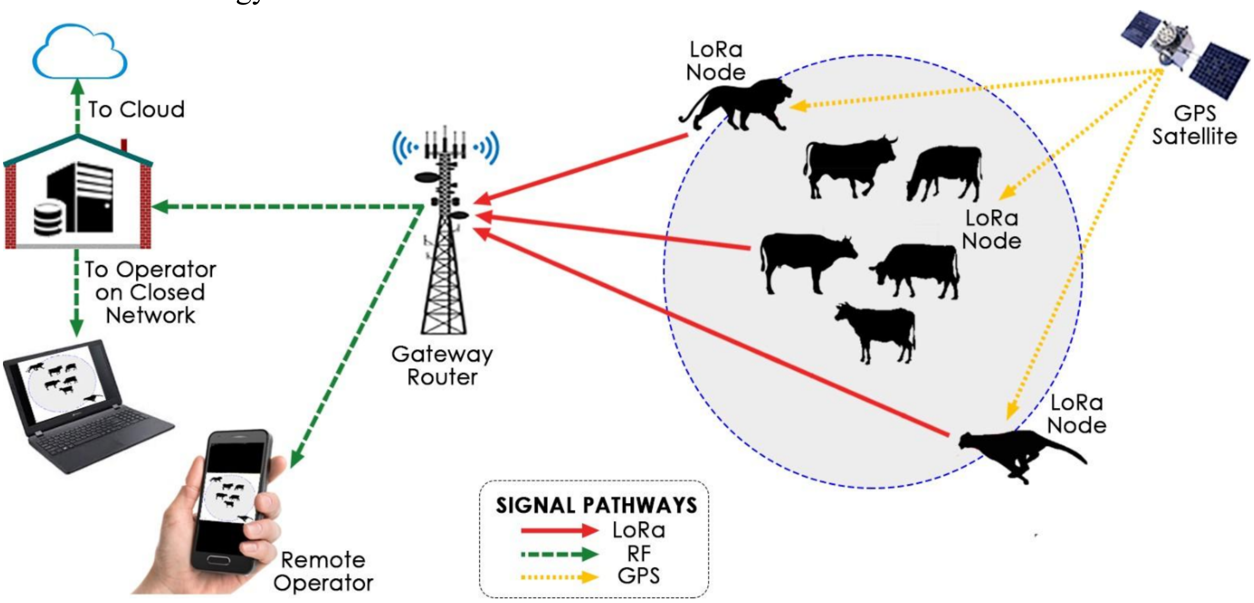


Figure 2: Remote monitoring topology for animals [Source: https://www.semanticscholar.org/paper/A-LoRa-Wireless-Mesh-Network-for-Wide-Area-Animal-Panicker-Azman/7f7d3958f21d46d9919f5c3b4362f1421959c268]

The identification of medical functions and related activities is, thus, the basic aspect of the IoT-Livestock architecture. Using the IoT, Figure 2 depicts a topology for animal health testing using ultrasound. The system manager receives the first signal from the animals' ultrasound after it has been captured by linked sensors and wearable devices. Upon receipt, the system manager checks the data for accuracy, extracts relevant characteristics, categorizes signals, and then forwards the data to a veterinarian for potential veterinary treatment. In addition, sensors and wearable devices can have their ultrasonic signals recorded and saved by using an ultrasound signal capture service. Conversely, ultrasonic signals can be authenticated and sent over the internet using a secure transmission service. System managers are responsible for controlling all networked devices and making sure that services like record service manager, feature extraction, and categorization have the resources they need. The data is extracted from ultrasound applications on smartphones, stored in a MySQL database, and then sent to an IoT livestock health directory via the extraction and categorization service. Data pertaining to the animals' health is handled and stored in a database by use of ultrasound signals and stuff gathering. Here, it's up to data analytics tools and database monitoring methods to sift through the information gleaned via feature extraction and categorization. The demand on a framework, including bandwidth and storage, is still monitored and calculated. Important features of this medical directory include the ability to transmit data securely, record and extract ultrasound signals, and categorize findings. This directory allows the veterinarian or livestock management to remotely view the ultrasound data, eliminating the need to visit the farm.

3.3 Iot Livestock Applications

The Internet of Things has several potential uses in the livestock industry, one of which is providing managers with the means to increase their animals' output on a worldwide scale while simultaneously decreasing the amount of time and effort spent on manual labor.

IV. Monitoring Applications

Thanks to the Internet of Things (IoT), farmers can check in on their fields from anywhere, even when they're not physically there. This manner, a choice can be taken in real-time regardless of where we are in the globe. Research on the use of IoT-enabled devices in precision livestock farming has mostly focused on exploring how to maximize cattle growth by monitoring, tracking, and forecasting health-related variables. Wearable sensors and gadgets shown in Figure 3 provide an excellent situation for livestock monitoring. Data collected is sent for further processing and display using various connection technologies (2g, 3g, 4g).

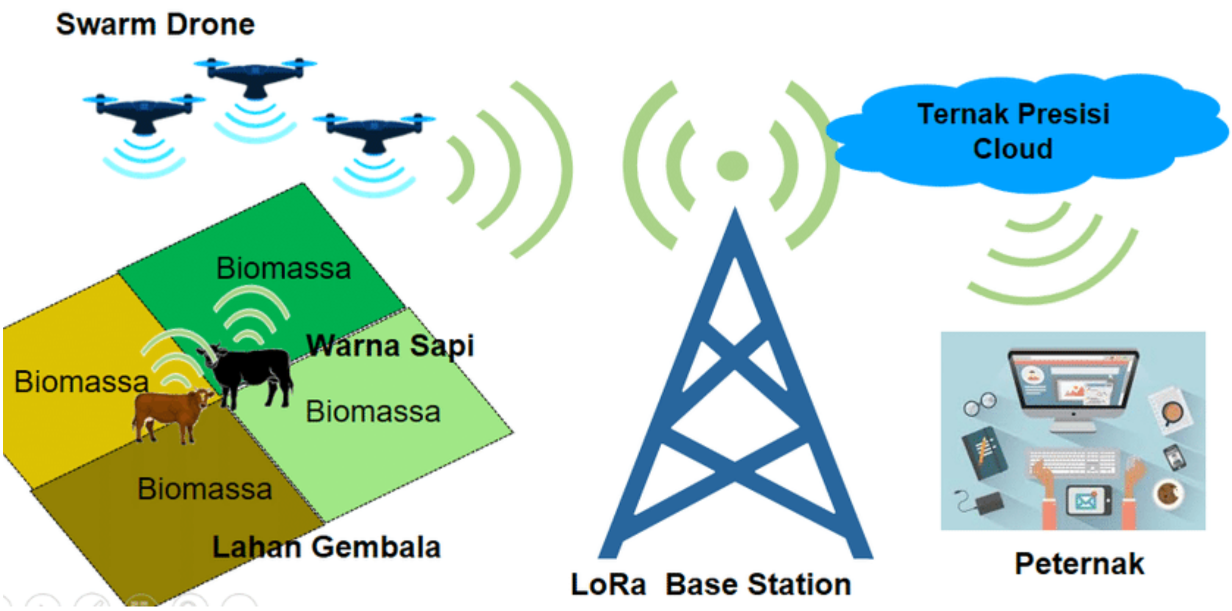
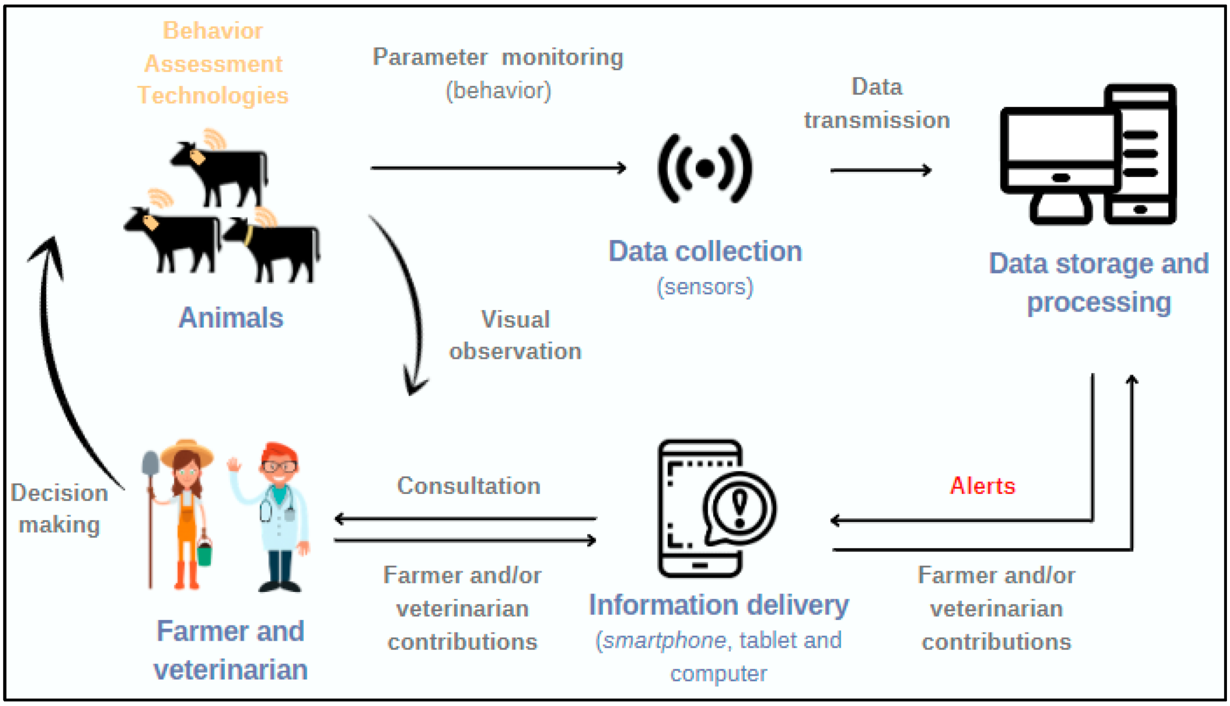


Figure 3: [Source: https://www.researchgate.net/figure/Drones-for-grass-biomass-surveillance-and-detection-of-cattle-objects_fig4_339399886]

4.1 Disease Monitoring

Similarly, doing it manually is a tedious and time-consuming operation; hence, animal diseases can be infectious; consequently, it is crucial to detect them in a timely manner to save other farm animals. This kind of scenario calls for a vehicle health monitoring system. Farmers can easily monitor the health of their animals with the help of IoT devices. Animal behavior can be studied and recorded using sensors that can be worn or mounted. In the future, while making decisions like whether or not to see a doctor, the farmers can use the acquired data. In addition to this, farmers can simply identify any unusual behavior in their animals by using Internet of Things (IoT) sensors, which then notify them via messaging or other ways. By monitoring an animal's movements with the use of sensors like accelerometers, a veterinarian or livestock management can identify any illness. In order to detect diseases, disease monitoring devices mainly capture an animal's normal physiological data, including its temperature, mooing, heart rate, and weight fluctuations.



[Figure 4: Disease Monitoring architecture Source: https://www.mdpi.com/2076-2615/12/19/2623]

4.2 Stress Monitoring

Animals subjected to stress without proper care not only endanger human health but also cost businesses money. Animals make less milk when fed the same nutritious food when their stress levels rise because their core temperature and respiratory rate rise in response to the increased stress. Additionally, the animal's stress levels rise due to a lack of moisture content in the summer, which might ultimately lead to mortality. Veterinary observation and objective measuring techniques made possible by Internet of Things (IoT) sensors and wearable devices have helped to overcome these obstacles. The cloud platform saved the identified metrics collected by the Internet of Things (IoT) sensors. The insemination cost was decreased and milk output was significantly increased by the discovered factors. Another important part of the goat and sheep meat supply chain is the transporting of live animals. Preventing the loss of life or serious injury to the sheep that can result from transportation stress is, therefore, of paramount importance.

4.3 Environment Monitoring In Animal Shelter

Despite the proliferation of animal shelters in nations like Japan and Taiwan, among others, there are a number of environmental concerns that make it clear that housing animals in cages does nothing to boost cattle production. To ensure the well-being of the animals housed there, several methods based on the Internet of Things are being considered for use in environmental monitoring systems. The suggested design allows for the monitoring of both the living environment and physiological parameters by veterinarians and management.

4.4 Feed Intake Monitoring

One of the best ways to get a picture of how healthy an animal is as a whole is to watch how much food it eats. A healthy cow would ruminate for 500 to 600 minutes daily and eat for three to four hours continuously. Cows ruminate by chewing at a regular, repetitive pace for around fifty seconds per bolus. Animals' resting and grazing patterns provide light on their eating habits. Insights like this allow farmers to use Internet of Things (IoT) technology to their advantage by adjusting feeding settings to avoid food waste and overfeeding.

4.5 Rumination Monitoring

As part of the ruminating process, we can see how an animal breaks down food. An average cow will ruminate for 500 to 600 minutes per day if she is in good health. The rumination monitoring device, which is attached to the animal's nose, gives a precise indicator of the animal's health. By tracking how often an animal chews, an accelerometer collar can determine how long an animal spends ruminating and can tell whether an animal's rumination behavior is healthy or harmful.

4.6 Humidity Monitoring

Finch went over how air humidity, a kind of humidity, impacts the temperature regulation of cattle. The evaporation of heat by animals is a natural defense mechanism against high temperatures, but when humidity levels are too high, the temperature differential between the air and skin drops, reducing this defense's effectiveness. A change in breast milk content can also result from an increase in relative humidity.

4.7 Poultry Monitoring

Modern poultry farms place critical demands on the atmosphere of the chicken house, regardless of technical advancements in breeding and rearing. Most crucial to the well-being of chickens are environmental elements like temperature, CO_2, NH_3, and humidity. Modern monitoring tools, including the Internet of Things (IoT), provide poultry farm managers a scientific foundation for management and help them maximize management efficiency while keeping production costs low.

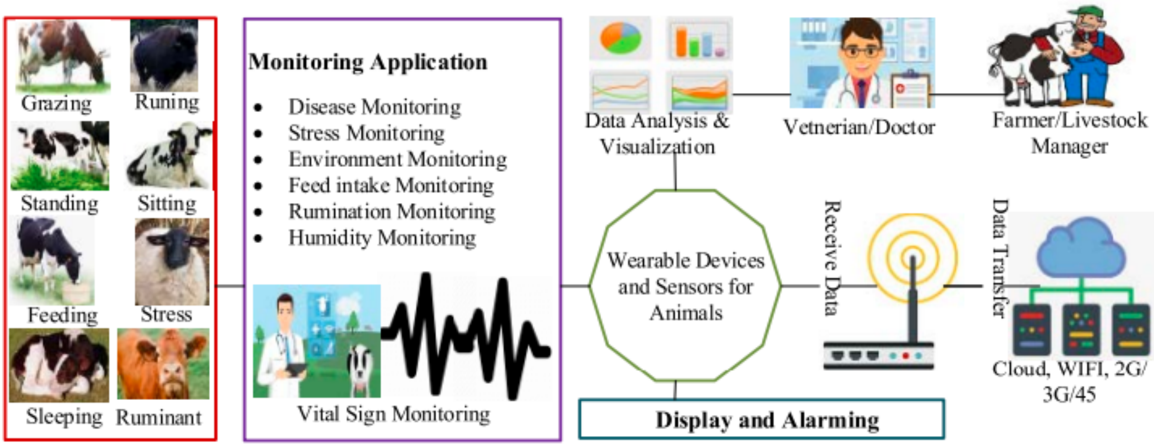


Figure 5: IoT-livestock monitoring scenario [Source: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9681084]

V. Tracking Applications

Technological progress has made it feasible to handle data in real-time and over extended periods of time, allowing for continuous study across all animal groups.

Thanks to the high amount of information provided by IoT solutions, monitoring both domestic and wild animals is made simpler. To ensure that sick cattle are properly treated, livestock owners might use General Packet Radio Service (GPRS) sensors to identify them. Here we have explored tracking applications for both wild and domestic animals.

5.1 Wildlife Tracking

There are a plethora of tracking gadgets available for use in locating animals. Wild animals are tracked using Internet of Things (IoT) sensors, both wearable and non-wearable. To lessen the burden on electrical grids and facilitate the monitoring of animals over wider regions, a system based on wireless ad hoc networks has been suggested. In addition, ZigBee-based monitoring techniques and wearable GPRS collars have been put in place to study the monkeys' actions in the Mexican forest. The integration of cloud-based data management, sensor-based camera networks, and image processing methods for animal identification has also been the subject of several research.

5.2 Wildlife Controlling

To prevent elephants and other wild creatures from trespassing on trains, infrasonic noises, passive nodes, and Internet of Things (IoT) sensing devices are used. Seismic and infrared sensors are also used for detection. Vehicles can be quickly alerted to potentially dangerous circumstances caused by animal crossings via the use of adaptive actuation of light signals. In order to identify and safeguard animals, sensors based on cameras that include image processing are used.

5.3 Oestrus Prediction

Farmers would incur large losses due to decreased milk output if the breeding procedure for suitable cows is not executed properly. With the use of IoT devices and sensors, oestrus detection has been greatly improved. Because pregnant cows and calves are so active, animal activity monitoring is a good way to tell when a cow is in heat. While MEMs accelerometers are useful for measuring changes in calf activity, it is difficult to transmit all of the raw data from these sensors. Due to inadequacy of bandwidth in low-power transmission channels, it might be feasible with three-axis accelerometer sensors.

VI. IOT RELEVANT TECHNOLOGIES

An specific list cannot be made due to the enormous variety of supporting technologies for IoT-livestock solutions. So, we zeroed down on a few key technologies that are transforming the cattle business via the Internet of Things.

6.1 Machine Learning (Ml)

There are a number of environmental elements that have contributed to the recent epidemic of animal heart disease. The majority of animal fatalities are caused by cardiac conditions, and pets like dogs and cats are not immune to this. Due to a lack of resources and preventative healthcare, it is difficult to make accurate predictions about the onset of cardiac illness in animals. With the use of IoT and ML technology, domestic animals can now be diagnosed with treatable cardiac problems at an earlier stage. The outcomes of the experiment show that ML methods perform better when it comes to predicting animal cardiac problems.

6.2 Cloud/Fog Computing

Opportunities abound for sectors like cattle farming when the IoT, cloud computing, and fog computing come together. Improving agricultural techniques and yield, for instance, can lead to increased production in the dairy business. Traditional cloud integration includes decision-making features and raises farmers' understanding of animal welfare issues in a practical way.

6.3 Artificial Intelligence

By using IoT devices, sensors, and video/image processing methods, poultry and dairy farms are also being revolutionized by the IoT, and not just for animal health monitoring. Furthermore, it is standard practice in sheep dairy farms to separate mothers from their lambs shortly after delivery so that the lambs can be nurtured by artificial breastfeeding. The consumption of lamb's milk, together with the prediction of future meat consumption and malnutrition, can be monitored by a distributed AI device that uses little power. A CLEC system is at the heart of the gadget, which can distinguish between individual lambs, calculate milk yields, and provide researchers and farmers with an accurate forecast.

6.4 Blockchain

The use of antiquated software has kept the cattle business operating on antiquated infrastructure. There are fewer options for cattle ranchers to manage their animals efficiently due to a lack of data transmission and exchange. Through the use of blockchain technology, farmers are able to track all relevant data and effortlessly relocate their cattle. To sum up, blockchain technology streamlines the purchasing and selling processes for cattle ranchers.

VII. Discussion

The Internet of Things (IoT) offers enormous promise for improving agricultural output, animal well-being, and resource efficiency via the use of smart livestock settings. Through the use of sensors, GPS, and RFID, animals can be continuously monitored in real-time for their health, behavior, and environmental factors. This allows for the early diagnosis of diseases and prompt treatments. As a result, production goes up and animal welfare goes up.

Internet of Things (IoT) solutions improve cleanliness, reproductive efficiency, and exact nutrition by optimizing breeding, feeding, and waste management procedures. Improved decision-making and operational efficiency are achieved via the use of data analytics produced from IoT devices. To get all the advantages, however, we have to overcome obstacles including high starting expenses, a lack of technical knowledge, and the need for strong data security.

VIII. Conclusion

The 24 research articles that made up this study were all about using the internet of things (IoT) to manage cattle. We investigated the effects of sensors, GPS, RFID, and automated systems—all components of the Internet of Things—on feeding, breeding, and waste management in real time by methodically reviewing these articles. The findings from these research demonstrate how the IoT has the ability to improve agricultural output, animal well-being, and resource use. The thorough analysis highlights the pros and cons of using IoT technology, laying a solid groundwork for smart livestock farming innovations to come.

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