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Real-Time GPS Tracking and Health Monitoring for Animals using IoT and Mobile Application

1st V. Usha
Dept. of CSE
Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology ,
Chennai, India
v.ushavelusamy@gmail.com

2nd Sandeep Karagatla
Dept. of CSE (AI&DS)
Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology ,
Chennai, India
sandeepkaragatla@gmail.com

3rd P. Sheela Gowr
Associate professor
Vels Institute of Science, Technology & Advanced Studies ,
Pallavaram , Chennai
Sheela.se@velsuniv.ac.in

4th P.M.G Jegathambal
Assistant professor
Vels Institute of Science, Technology & Advanced Studies ,
Pallavaram , Chennai
pmgjegathambal1991@gmail.com

5th A. Lizy
Dept. of Artificial Intelligence and Machine Learning
Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology ,
Chennai, India
lizyliju@gmail.com

6th V. Sathya
Dept of Information Technology
Velammal Engineering College
Chennai, India
v.sathyavelusamy@gmail.com

***Abstract*— The Internet of Things (IoT) grounded solution of Real Time Global Positioning System (GPS) tracking with Health Monitoring of Animals for Owners to track their animals like cows, buffaloes, dogs etc. This GPS module and a heartbeat sensor are attached to the animals in order to be able to follow them closely. This data is sent to a mobile app, and the owner can see their heart on the map as well as monitor its pulse. Based on analysis of such heart rate variations, the system determines when it is seeing an abnormal activity related to e.g. stress (increased heart rate) or potential health risks (no sign of a heartbeat), which could be interpreted as fear or death. Each animal has an initial heart rate level that is set, and when this rate exceeds it, the system sounds an alert to indicate danger. This method is especially helpful for keeping an eye on animals in urban areas, areas close to forests, and areas with high rates of theft and loss. The project demonstrates the successful execution of a reliable, real-time animal monitoring system with practical applications in both urban and rural environments.**

***Keywords*—GPS Tracking, Heartbeat Sensor, Mobile Application, Animal Safety, Real-time Monitoring, LoRa device.**

I. Introduction

Tracking and monitoring animals, such as pets and farm animals, may be quite difficult for owners in both urban and rural settings. In cities and villages, domestic animals such as dogs, cows, and buffaloes frequently roam freely, making it challenging for their owners to find them when they go missing. For instance, a farmer in a remote village may lose a cow and have no means to track it, forcing him to search manually, relying only on footprints and word of mouth. Similarly, an owner may find their buffalo collapsed, but by the time help arrives, it is too late.

Animals in rural locations are at risk of theft, accidents, and loss, particularly when they are near forests and highways. Existing tracking techniques, such as physical searching, are time-consuming and ineffective in ensuring the safety and welfare of animals.

In addition to location tracking, real-time health monitoring is equally important. Stress, fear, or potential health emergencies can be detected through changes in an animal's heartbeat. Monitoring the animal's heart rate in real time can help detect abnormal situations, such as elevated stress levels (increased heart rate) or potential death (absence of a heartbeat). A system that integrates both location tracking and health monitoring can provide a comprehensive and proactive solution to these issues.

Existing animal tracking solutions primarily rely on RFID-based tracking, Bluetooth trackers, or standalone GPS devices, which often lack real-time health monitoring capabilities. While RFID systems provide identification, they do not offer continuous location tracking. Similarly, Bluetooth-based trackers have limited range and are ineffective in large outdoor environments. Conventional GPS trackers provide location data but do not include biometric health monitoring, making them inadequate for detecting stress, illness, or emergencies in animals.

In contrast, our proposed system combines GPS tracking with real-time heart rate monitoring, providing a comprehensive solution for both location and health management. Unlike existing solutions that focus solely on movement tracking, our system ensures proactive health monitoring by detecting abnormal heart rate fluctuations, enabling early intervention. Additionally, our system incorporates geofencing alerts, which notify owners if an animal strays beyond a predefined safe zone—a feature often missing in traditional trackers.

Another major distinction is the seamless mobile app integration, which allows users to receive instant alerts on both location and health anomalies. While conventional GPS trackers require manual tracking, our system automates notifications and anomaly detection, ensuring real-time awareness and faster response. Furthermore, the use of a microcontroller (ESP32) with Bluetooth and Wi-Fi support enhances data transmission efficiency, making the system more scalable and adaptable for both urban and rural environments.

By integrating location tracking, biometric monitoring, and smart alerts into a single platform, our system surpasses conventional methods, offering a holistic and technologically advanced approach to pet and livestock safety. This unique combination of GPS, health monitoring, and real-time notifications establishes the novelty of our proposed solution, making it a superior alternative to traditional tracking systems.

II. LITERATURE SURVEY

Previous research investigations focused on the use of IoT and GPS technology for tracking animals, with the main focus on position monitoring systems. Most current methods for tracking animal movements make use of GPS modules, and they have proven successful in wide-open spaces. Still, the majority of these devices only have tracking capabilities; they lack health monitoring features. According to some examination, wearable sensors can be used to detect an animal's body heat and pulse in order to find early warning signs of sickness or stress. However, the combination of continuous health monitoring and real-time monitoring of GPS signals. Real-time alerts when abnormal heart rates or other severe circumstances are discovered are sometimes not possible with current technologies. In the past few years, one feasible development has been the application of mobile applications to deliver real-time warnings and visualise animal data. However, very few solutions provide a complete package that combines health monitoring and GPS tracking into a single, user-friendly platform. By combining heart rate monitoring and real-time GPS position tracking into a single device, this effort closes the gap between these two crucial functions and advances previous research.

Helwatkar, A. et al., addressed in [1] the considerable transition in dairy farming into higher, profitable organisations as a result of market forces. They studied the rising need for technological advances that minimise prices and human involvement while raising production, concentrating on controlled animal health monitoring. Their research identified prevalent illnesses in dairy cows that may be identified using harmless, inexpensive sensing innovations, then linked these diseases to animal behaviour and particular sensors. This system attempts to automate health event detection, improve livestock health and production, and reduce examination and healthcare expenditures.

Patil, A. et al., highlighted [2] the limitations of existing clinical procedures to track animal health, pointing out that they give periodic information and cost large resources. Their proposed system mounts hardware on the animal's body to provide real-time health monitoring, eliminating the need to wait for veterinary expertise. This technology not just enhances individual animal wellness, it additionally aids in the rapid identification and avoidance of common illnesses. It uses four sensors temperature, heart rate, and two rumination sensors along with a Zigbee device and Arduino microcontroller to transmit data to a graphical user interface (GUI) for display on a PC.

Sundara Moorthi, P.et al., proposed [3] device for monitoring the health of any livestock while also avoiding theft or loss of animals. The device uses sensors to collect medical data including temperature, pulse rate, and thinking, while using short-term wireless networking and internet connections to relay data to the owner's family. This enables continuous monitoring of animal health and location. A mobile application serves as the user interface, providing real-time updates on the animals' conditions and their presence within the farm. The system is designed to improve the overall health management of the herd by enabling early detection of issues and facilitating immediate intervention. Additionally, the theft prevention feature ensures that the animals remain within the designated area. This prototype has been developed and tested, demonstrating the practicality of allowing farm owners and laborers to remotely monitor animal health from anywhere in the world, thus significantly reducing labor efforts and enhancing farm management efficiency.

Keertana, P. et al., created in [4] method for detecting and tracking animal health using ZigBee technology. By using sensors like blood pressure, and oxygen consumption sensors to monitor animal health, this approach responds to the growing concerns about animal mobility and health. An analog-to-digital converter is used to transform the data collected by these sensors, and GUI displays the results. ZigBee technology integration improves system functionality in a variety more situations. The novelty of the system lies in its simultaneous ability to monitor and track animals, providing a feasible solution for real-time health tracking and movement monitoring.

Sharma, B. et al., discussed in [5] the critical role of dairy cattle health monitoring in enhancing global dairy production, especially as farmers face increasing health issues, disease outbreaks, and rising costs in the dairy sector. In order to overcome these challenges, scientists examined automated health monitoring systems built specifically to monitor dairy cattle that use wireless sensor networks (WSNs). These devices continually monitor cow health factors such as body temperature, pulse, and movement, and store the results in a centralised database. Farmers can access this information remotely, allowing them to make real-time decisions regarding animal health and farm management. WSN technology offers a low-cost, efficient method for early disease detection and control, reducing human labor and intervention while improving herd health. The study highlights that this advanced automation significantly enhances productivity and reduces farm operation costs by providing actionable insights based on cattle health data, even from distant farm locations.

Younis, S. et al., explored in [6] the increasing significance of biosensors as versatile recognition tools in both biomedical and environmental applications, particularly within livestock and aquaculture. These biosensors are capable of assessing behavioral, immunological, and physiological responses in animals, facilitating innovative monitoring techniques tailored to various environmental and physiological factors. Their study highlights the reliability, ease of use, and sensitivity of biosensors, which provide rapid analyses of critical monitoring parameters. In livestock management, nano biosensors play a pivotal role in health monitoring, disease detection, reproductive cycle assessment, and evaluation of animal feeding and grazing behaviors. In addition, these sensors can monitor antibiotic adverse effects and animal life conditions. The large-scale implementation of advanced biosensing technologies is expected to make continuous monitoring more accessible and affordable for farmers, ultimately enhancing animal production and welfare within the agricultural sector. The integrated data from these biosensors will significantly benefit the agricultural industry by promoting improved livestock management practices and productivity.

Kumar, A. et al., introduced [7] an innovative animal wellness tracker that measures a variety of indicators of health, including rumination, pulse rate, body heat as well as outside factors such as heat. This system further evaluates the stress levels of animals using the thermal humidity index. This technology is very useful in delivering cost-effective health care treatments for cattle. A working model was created and examined, displaying incredible precision in monitoring the health of animals. This system holds promise for enhancing animal welfare and facilitating timely interventions based on real-time data.

Neethirajan, S. et al., discovered [8] the burgeoning market of biosensors in animal health management, which is rapidly gaining traction globally. The research highlights various sensors currently under development for monitoring animal health, with many at different stages of commercialization. While several technologies for accurate health assessments and disease diagnoses are primarily designed for humans, adaptations are being made for animal applications. Despite the advancements, there remains a critical need for the integration of existing sensors into a cohesive online monitoring system that allows real-time observation of animal health without delay. The review discusses various wearable technologies for livestock, nano biosensors, and advanced molecular diagnostic techniques aimed at detecting infectious diseases in cattle. It also compares these technologies, highlighting their advantages and disadvantages in the context of animal health management. Overall, the paper provides valuable insights into the latest developments in biosensor technology and its implications for future improvements in animal welfare.

Sridhar, et al., discussed [9] the significance of controlled motion monitoring in doing highly statistical evaluations of animal behaviour and mechanics. This strategy improves consistency by reducing the influence of observers and enabling regular procedures. However, present mechanised tools for monitoring are restricted, notably in their accessibility, open-source nature, and capacity to follow unmarked species in loud surroundings. The authors illustrate Tracktor's efficacy through four case studies, demonstrating its ability to track various animals under different scenarios. Tracktor's primary characteristics include the ability to track particular persons.
amidst noise (such as distorted object shapes), resilience to experimental perturbations (like varying lighting conditions), and the capability to track multiple unmarked individuals while preserving their identities. Ultimately, Tracktor emerges as a versatile, reliable, and user-friendly automated tracking solution compatible with all operating systems, offering unique features not found in other available freeware.

Shiragaonkar, et al., in [10] emphasize the critical role of food in human sustenance and highlight the immense significance of the agricultural industry. The challenges faced by this sector are exacerbated by factors such as the rapidly growing global population, decreasing farmland due to industrialization, the migration of farmers to urban centers, and the impacts of climate change. The authors argue that a robust and evolving agricultural industry is essential for sustaining the global population. Historically, agriculture was the cornerstone of the world economy until the 18th century. The first industrial revolution, initiated around 1760 with the invention of the steam engine, introduced large-scale mechanization into farming. This shift led many farmers to abandon their agricultural practices in favor of urban opportunities, seeking better socioeconomic conditions. The subsequent industrial revolutions further intensified this trend, resulting in increased abandonment of agricultural lands.

Panicker, J.G. et al., [11] discussed the deployment of a LoRa wirelessly mesh network connection for wide-area wildlife monitoring. Their research explores how LoRa technology can be utilized to track animals over long distances with minimal power consumption. The study highlights the advantages of LoRa mesh networks in improving connectivity in remote areas, ensuring seamless data transmission even in challenging environments. By leveraging LoRa, the system enables real-time monitoring, reduces dependency on cellular networks, and provides a cost-effective solution for large-scale animal tracking. Their findings contribute to the development of efficient, low-power IoT-based animal tracking systems that enhance livestock management and wildlife conservation.

Jaikaeo, C. et al., [12] described the creation and testing of an affordable gadget for real-time animal identification using Satellite and LoRa communication. Their research is on creating a low-cost, energy-efficient connected to the internet of surveillance system for monitoring cattle movement and whereabouts across wide territories. By integrating LoRa technology, the system enables long-range, low-power communication, making it suitable for deployment in remote and rural environments where cellular coverage is limited. The research highlights the advantages of GPS-LoRa integration, allowing farmers and livestock owners to track their animals in real time while minimizing operational costs. The study also emphasizes the field-testing phase, where the device was deployed in practical environments to evaluate its accuracy, efficiency, and durability. Their findings contribute to the development of scalable and affordable livestock monitoring systems, enhancing farm management, improving security, and reducing the risk of lost or stolen animals.

Dos Reis, B.R. et al., [13] addressed the usage of a LoRa wireless sensor network to track grazing livestock's whereabouts and behaviour. They highlighted the importance of the technology in providing real-time tracking of livestock, which helps farmers improve herd management, monitor animal behavior, and ensure their welfare. The use of LoRa (Long Range) sensors enables the efficient monitoring of large-scale pastured areas without the need for costly infrastructure or frequent manual checks. Their research emphasized how this system can reduce labor costs, enhance animal tracking accuracy, and optimize grazing practices, ultimately leading to better resource utilization and improved farm productivity.

Antoine-Santoni T et al., [14] deliberated AMBLoRa, an online monitoring and sensing system for observing behaviors of animals via long-range communication. They focused on the integration of LoRa technology for real-time tracking and behavioral monitoring of animals. This system enables efficient, long-range communication while minimizing power consumption, making it suitable for continuous animal monitoring in various environments. Their research highlights the system's potential to enhance wildlife and livestock management by providing valuable data on animal movements and behaviors, which can contribute to better health monitoring, security, and resource management.

Kocer, H.E. et al., [15] discussed developing a LoRa-based stray animal tracking system. Their research explores the use of LoRa technology to monitor and track stray animals, aiming to enhance animal control and management in urban and rural areas. The system allows for real-time location tracking over long distances with low power consumption, making it suitable for tracking animals in vast regions or places with limited infrastructure. Their findings contribute to improving stray animal management, ensuring better public safety.

III. METHODOLOGY

The IoT-based animal tracking and health monitoring system leverages LoRa (Long Range) as shown in Figure 1. The communication and sensor-based technology provide real-time location tracking and health monitoring for livestock and pets. This system is particularly beneficial in remote areas where cellular networks are unreliable or unavailable. The architecture consists of multiple hardware components working together to ensure continuous monitoring. The GPS module (NEO-6M) provides real-time latitude and longitude coordinates, allowing farmers to track their animals' movements. Meanwhile, the heartbeat sensor (MAX30102) monitors the animal's vital signs, helping detect stress, illness, or abnormal health conditions at an early stage.

A. Proposed System Architecture Diagram

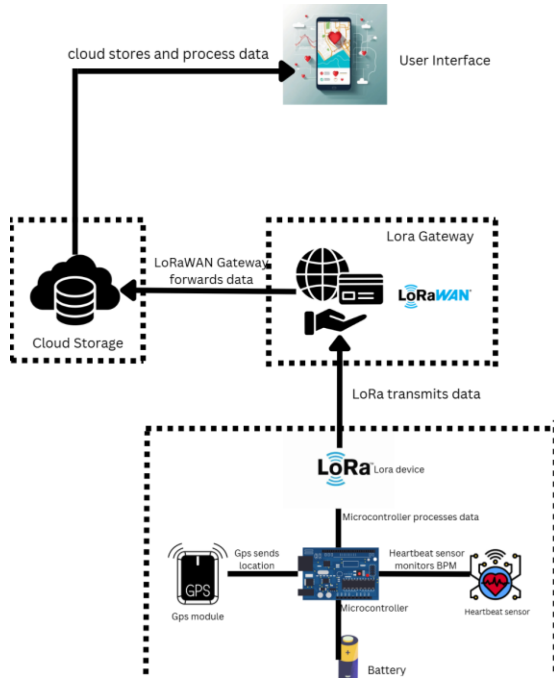

Figure 1: Architecture diagram

These sensors are controlled by a microcontroller (ESP32), which processes the collected data and transmits it through a LoRa module (RFM95) to a LoRa gateway.

The LoRa gateway plays a crucial role by receiving the transmitted data and forwarding it to a cloud-based server. The cloud stores, processes, and analyzes the incoming data using AI-based anomaly detection algorithms to identify any unusual animal behavior or health issues. This ensures that farmers receive real-time updates about their livestock's well-being. The data is accessible through a mobile application, which provides location tracking, health status updates, and instant alerts in case of emergencies. Users receive notifications via SMS, WhatsApp, or push notifications, ensuring timely intervention when needed.

A major advantage of this system is its long-range communication, enabling tracking up to 10-15 km in rural areas and 2-5 km in urban environments. Additionally, Low power usage ensures prolonged battery life, making it ideal for continuous operation in remote environments. This system also aids in early health detection, reducing mortality rates by allowing farmers to act quickly when health anomalies are detected. Furthermore, livestock loss due to theft or straying is minimized, as the location of each animal is always available in real-time. Compared to traditional GPS tracking, which relies on costly cellular networks, this LoRa-based system is a cost-effective alternative for large-scale animal monitoring.

The use cases for this technology extend beyond farming and livestock management. It can be applied to wildlife monitoring in national parks, helping researchers track endangered species. Additionally, pet owners can use the system to ensure their pets' safety, especially in urban areas with high traffic. By integrating LoRa with IoT, this solution enhances smart farming and precision agriculture, making livestock management more efficient, cost-effective, and reliable. This innovation ultimately contributes to improving animal welfare and reducing losses, making it an essential tool for modern farmers and researchers.

The mobile application, developed using cross-platform technologies such as React Native or Flutter, is integral to the system as it provides the interface through which the user interacts with the data. The app is designed to show the pet's current location on a map, using APIs such as Google Maps to provide a visual representation of the pet's whereabouts. Alongside location information, the app displays the pet's heart rate, allowing owners to quickly assess whether their pet is safe or experiencing physical distress. If the heart rate goes beyond the pre-defined safe levels or if the pet leaves the geofenced area, the app provides notifications or alerts, allowing the owner to take action immediately. This type of system is particularly useful for pet owners who live in environments where their animals may wander, such as farms, suburban homes, or villages close to highways or forests. The system allows for quick detection of potential threats to the pet's safety, whether from wandering into dangerous areas or experiencing health issues that may not be immediately visible.

System precision is directly dependent on the reliability of its hardware components. GPS modules typically offer location accuracy within a few meters, which is sufficient for most pet tracking applications, especially when geofencing is involved. Heart rate sensors like the MAX30100 are capable of providing reliable pulse measurements, which are critical for identifying health issues such as elevated heart rates caused by fear or stress, or an abnormally low heart rate that could indicate severe danger or even death. Featuring a way to monitor both location as well as health data instantaneously, this system allows people with pet's confidence in mind knowing that their animal's safety and well-being are continually tracked, allowing for shorter reaction times in emergency circumstances.

The use of a microcontroller such as the ESP32, which has built-in Bluetooth and Wi-Fi capabilities, ensures that data transmission is seamless and reliable. Featuring a way to monitor both location as well as health data instantaneously, this system allows people with pet's confidence in mind knowing that their animal's safety and well-being are continually tracked, allowing for shorter reaction times in emergency circumstances. The entire system works cohesively to offer an innovative solution for pet tracking and health monitoring, bringing the benefits of advanced technology into everyday pet care. The Animal Health Monitoring System combines several components to track an animal's health and location in real-time. Figure 2 shows the NEO-6M GPS module continuously transmits the animal's live coordinates. The MAX30102 heartbeat sensor measures pulse rate, while the ESP32 microcontroller handles all data and communication. The RFM95 LoRa module provides long-range wireless transmission, allowing data to be transferred to the owner without the need for an internet connection or SIM card.

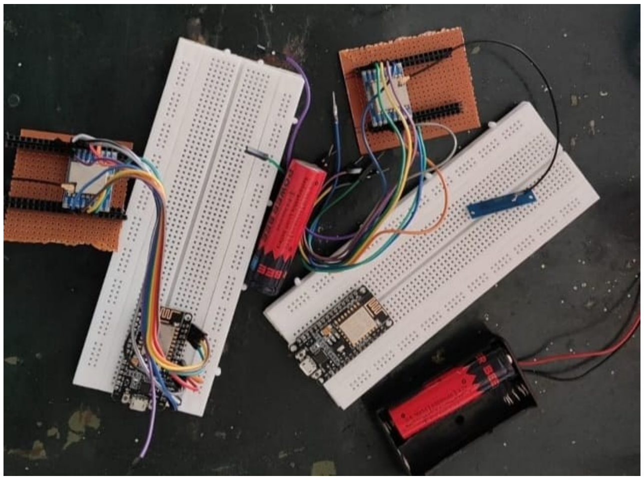

Figure 2. Circuit Diagram

A battery pack powers the entire device, making it ideal for distant monitoring. This arrangement allows for more effective health tracking and location monitoring, which improves animal safety. The heart rate monitoring module further strengthens pet safety by detecting variations in pulse rate, which helps identify stress, discomfort, or potential health issues. By establishing dynamic thresholds based on normal resting heart rates, the system provides timely notifications in case of abnormal conditions, enabling early intervention and preventive care. The integration of GPS and biometric data significantly improves pet safety by offering real-time insights into both location and well-being.

Beyond functionality, the system is designed for ease of use through a smartphone application that provides instant notifications, eliminating the need for continuous manual monitoring. The use of a microcontroller (ESP32) with Bluetooth and Wi-Fi capabilities ensures seamless communication between sensors and the mobile app, enhancing reliability and responsiveness. Its adaptability makes it beneficial for a wide range of applications, including tracking farm animals in large rural areas, monitoring pets in high-risk urban environments, and even preventing animal theft and loss

Table 1. Heartbeat Range for Common Pets and Livestock

PET'S	BPM (BEATS PER MINUTES)
Dog	60 - 140(varies by size)
Buffalo	60 - 70 BPM
Cow	48 - 84 BPM
Horse	28 - 44 BPM
Goat	70 – 90 BPM
Cat	140 – 220 BPM
Hen	250 – 350 BPM
Donkey	44 BPM

Table 1 delivers the different pets and corresponding heartbeats are provided.

Table 2 provides a detailed comparison of various electronic modules commonly used in embedded and IoT applications, highlighting their accuracy, measurement range, resolution, and operating temperature. It includes four key devices: the GPS Module (NEO-6M), Heartbeat Sensor (MAX30102), Microcontroller (ESP32), and LoRa Module (RFM95). The GPS module offers a positional accuracy of Circular Error Probable (CEP) < 2.5 meters, operates globally and functions throughout the temperature range of -40 degrees Celsius to 85 degrees Celsius.

Table 2. Key Parameters and Specifications of IoT Sensors

Device	**Accuracy (Accu)**	**Detection limit**	**Resolution**	**Working Temperature**
GPS Module (NEO-6M)	CEP < 2.5 m	anywhere	-	-40 °C to 85 °C
Heartbeat Sensor (MAX30102)	SpO_2: ±2%, Heart Rate: ±3 bpm	25–250 bpm (Heart Rate), 0–100% (SpO_2)	High sensitivity	-40 °C to +85 °C
Microcontroller (ESP32)	Clock Accuracy: ±10 ppm	160 MHz	12-bit ADC, 32-bit processor	-40 °C to 85 °C
LoRa Module (RFM95	Receiver Sensitivity : -148dBm	Up to 15 km (Rural), 2-5 km (Urban)	168 dB link budget	-40 °C to +85 °C

The heartbeat sensor provides ±2% accuracy for SpO_2 and ±3 bpm for heart rate, measuring heart rates between 25–250 bpm and oxygen saturation from 0–100%, with high sensitivity. The ESP32 microcontroller features a clock accuracy of ±10 ppm, operates at 160 MHz (ESP32) or 16 MHz (Arduino), and has a 12-bit ADC with a 32-bit processor, making it suitable for various computational tasks. Lastly, the LoRa module (RFM95) has a receiver sensitivity of -148 dBm and is capable of communicating at ranges of up to 15 km in remote areas and 2-5 km within city contexts, benefiting from a 168 dB link budget. All devices in the table share a wide operating temperature range of -40°C to 85°C, making them reliable for various environmental conditions. This comparison helps engineers and developers select the appropriate components for IoT, wireless communication, and embedded systems projects.

IV. RESULT AND DISCUSSION

The execution of the GPS tracking and heart rate monitoring system successfully provided both real-time location data and health status updates of animals. The system was tested in different environments, including open fields, urban areas, and indoor locations, to assess the accuracy and reliability of the GPS module and heart rate sensor. The experimental setup involved equipping the animal with a GPS module and a heart rate sensor, which transmitted data to a mobile application via a microcontroller. The application continuously displayed the pet's location on a map and real-time heart rate readings, with alerts generated if abnormal values were detected.

To evaluate GPS tracking accuracy, multiple test runs were conducted in various terrains. In open environments, the GPS module provided accurate location updates within a margin of 2–5 meters, ensuring precise tracking. The geofencing feature was successfully tested by setting a predefined boundary, triggering alerts whenever the pet moved beyond the permitted area. However, in dense urban areas, GPS accuracy was affected, with deviations of 10–15 meters due to signal obstruction by buildings. Similarly, indoor testing showed limitations, where signal loss occurred frequently, suggesting the need for additional Wi-Fi or Bluetooth-based positioning support for better indoor tracking.

The heart rate monitoring system effectively captured the pet's heartbeat in various conditions, including resting, active movement, and stressful scenarios. Baseline measurements were established, and real-time heart rate values were compared against predefined thresholds. During normal resting conditions, the heart rate readings remained stable, with minor fluctuations of ±2 BPM, which aligns with standard veterinary pulse monitors. In stress-inducing conditions—such as exposure to loud noises or unfamiliar surroundings—a noticeable increase in heart rate was observed, triggering alerts to the mobile application. Additionally, the system successfully detected heartbeat absence or irregularities, immediately notifying the owner of potential health emergencies. However, slight variations in readings were observed during high-movement activities, where motion artifacts affected the accuracy of the sensor. Implementing motion compensation algorithms in future iterations could further improve data reliability.

The mobile application played a crucial role in the system's usability, providing a user-friendly interface for real-time tracking and health monitoring. The live map updates and notifications functioned smoothly, but usability improvements were noted for small-screen devices. Due to the large amount of real-time data, some readability issues were identified, particularly in the display of tabular data containing timestamp, latitude, longitude, heartbeat rate, and temperature. Enhancing the UI design with collapsible sections, scrolling options, and graphical representations would significantly improve data presentation.

To further validate the system's effectiveness, a comparative analysis was conducted with existing pet tracking devices and veterinary heart rate monitors. Unlike most commercial pet trackers, which only offer GPS-based location tracking, the proposed system integrates both tracking and health monitoring. Similarly, while veterinary heart rate monitors provide detailed pulse readings, they lack real-time location tracking. This unique combination of features positions the proposed system as a comprehensive solution for pet and farm animal safety.

Despite the system's success, certain limitations were identified. The power consumption of the device requires optimization, as continuous GPS and heart rate monitoring can significantly drain the battery, particularly in large farm animals where frequent charging is impractical. Additionally, improving GPS accuracy in indoor and dense urban environments is a priority for future development. One potential enhancement is integrating AI-based health analytics, allowing the system to predict illnesses based on historical heart rate trends rather than just detecting anomalies.

Overall, the IoT-based animal tracking and health monitoring system has demonstrated reliable performance in real-world conditions. By offering real-time alerts, geofencing capabilities, and heartbeat analysis, it provides an effective tool for pet owners and livestock managers to ensure the safety and well-being of their animals. Future enhancements will focus on improving energy efficiency, enhancing indoor tracking accuracy, and integrating AI-driven predictive analytics, making the system more robust and scalable for wider adoption.

Animal Health Monitoring Data

Timestamp	Latitude	Longitude	Heartbeat Rate (BPM)	Temperature (°C)
2024-02-11 10:00:01	12.9716	77.5946	72	38.5
2024-02-11 10:00:05	12.9717	77.5947	75	38.8
2024-02-11 10:00:10	12.9718	77.5948	70	39
2024-02-11 10:00:15	12.9719	77.5949	78	38.6

Figure 3. Output in mobile application

Figure 3 shows an "Animal Health Monitoring Data" table with real-time updates on animal health indicators including timestamp, latitude, longitude, heartbeat rate, and temperature. On a mobile device, the layout may require changes to improve reading. The table may become difficult to browse due to the limited screen width, causing content to wrap or columns to shrink. Using responsive design strategies such as horizontal scrolling, collapsable rows, or a card-based style would improve usability. Furthermore, establishing proper space and font sizes improves readability on smaller displays.

V. CONCLUSION

The GPS tracking and heart rate monitoring system integrates real-time location tracking with biometric monitoring to enhance pet safety and health management. The GPS module ensures accurate tracking, while geofencing alerts owners when pets move beyond designated boundaries. The heart rate sensor detects abnormalities, enabling early intervention. A mobile app with Bluetooth and Wi-Fi support ensures seamless data transmission. Future enhancements include AI-driven predictive analytics, multi-sensor fusion, cloud-based storage, and LoRa communication for extended coverage. Energy-efficient hardware and veterinary integration can further improve usability, making this system a scalable, intelligent solution for pet owners and livestock farmers.

REFERENCES

[1] Helwatkar, A., Riordan, D. and Walsh, J., 2014. Sensor technology for animal health monitoring. *International Journal on Smart Sensing and Intelligent Systems*, *7*(5), pp.1-6.
[2] Patil, A., Pawar, C., Patil, N. and Tambe, R., 2015, October. Smart health monitoring system for animals. In *2015 International Conference on Green Computing and Internet of Things (ICGCIoT)* (pp. 1560-1564). IEEE.
[3] Sundaramoorthi, P., Rajeenamol, P.T. and Anoopkumar, M.V., 2020. Animal health monitoring with missing and theft prevention device using wireless sensor network and internet of things. *International Journal of Advances in Signal and Image Sciences*, *6*(1), pp.38-44.
[4] Keertana, P., Vanathi, B. and Shanmugam, K., 2017. A survey on various animal health monitoring and tracking techniques. *International Research Journal of Engineering and Technology*, *4*(2), pp.533-536.
[5] Sharma, B. and Koundal, D., 2018. Cattle health monitoring system using wireless sensor network: a survey from innovation perspective. *IET Wireless Sensor Systems*, *8*(4), pp.143-151.
[6] Younis, S., Zia, R., Tahir, N., Bukhari, S.Z., Khan, W.S. and Bajwa, S.Z., 2022. Nanosensors for animal health monitoring. In *Nanosensors for smart agriculture* (pp. 509-529). Elsevier.
[7] Kumar, A. and Hancke, G.P., 2014. A zigbee-based animal health monitoring system. *IEEE sensors Journal*, *15*(1), pp.610-617.
[8] Neethirajan, S., 2017. Recent advances in wearable sensors for animal health management. *Sensing and Bio-Sensing Research*, *12*, pp.15-29.
[9] Sridhar, V.H., Roche, D.G. and Gingins, S., 2019. Tracktor: image-based automated tracking of animal movement and behaviour. *Methods in Ecology and Evolution*, *10*(6), pp.815-820
[10] Shiragaonkar, R., Rokhade, A., Naik, O.S., Ammanagi, S., Hebbale, P. and Motagi, L., Futuristic Animal Health Surveillance and Tracking System with IOT Integration.
[11] Panicker, J.G., Azman, M. and Kashyap, R., 2019, February. A LoRa wireless mesh network for wide-area animal tracking. In *2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT)* (pp. 1-5). IEEE.
[12] Jaikaeo, C., Jansang, A., Li-On, S., Kitisriworapan, S., Tangtrongpairoj, W., Phonphoem, A., Valls-Fox, H., Menassol, J.B., Viet, D.H., Sripiboon, S. and Sangmalee, A., 2022. Design and field test of a low-cost device for real-time livestock tracking using GPS/LoRa communication. *Applied Engineering in Agriculture*, *38*(6), pp.885-901.
[13] Dos Reis, B.R., Easton, Z., White, R.R. and Fuka, D., 2021. A LoRa sensor network for monitoring pastured livestock location and activity. *Translational Animal Science*, *5*(2), p. txab010.
[14] Antoine-Santoni, T., Gualtieri, J.S., Manicacci, F.M. and Aiello, A., 2018, July. AMBLoRa: a wireless tracking and sensor system using long range communication to monitor animal behavior. In *the Seventh International Conference on Smart Cities, Systems, Devices and Technologies* (pp. 35-40). IARIA.
[15] Kocer, H.E. and Kocak, B., 2024, July. LoRa Based Stray Animals Tracking System. In *2024 59th International Scientific Conference on Information, Communication and Energy Systems and Technologies (ICEST)* (pp. 1-4). IEEE.