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DESIGN AND DEVELOPMENT OF IOT BASED ANIMAL FARM MANAGEMENT SYSTEM USING WSN

Dr. S. Lakshmi
The Principal,
Sri Venkateswaraa College of Technology (Autonomous),
Sriperumbudur, Tamil Nadu, India.

Mr. Dhanaseelan Subramani
Department of ECE,
Sri Venkateswaraa College of Technology (Autonomous),
Sriperumbudur, Tamil Nadu, India.

Mr. K. Egachandiran
Department of ECE,
Sri Venkateswaraa College of Technology (Autonomous),
Sriperumbudur, Tamil Nadu, India.

Ms. T. Aathilakshmi
Department of ECE,
Sri Venkateswaraa College of Technology (Autonomous),
Sriperumbudur, Tamil Nadu, India.

Abstract: **The increasing demand for sustainable and efficient agricultural practices has led to the adoption of smart technologies in livestock management. This research work focuses on the design and development of an IoT-based farm animal tracking system using Wireless Sensor Networks (WSN), aimed at improving the monitoring and management of farm animals. The system is developed in four distinct but integrated modules to cover multiple aspects of farm automation. The first module is a livestock management system that monitors the food and water levels for animals using sensors and enables remote control through a mobile application (Blynk). This ensures that the basic needs of the animals are met efficiently and consistently. The second module is a floor cleaning rover, which is an autonomous robot capable of following a predefined path to maintain cleanliness in animal enclosures. This contributes to better hygiene and reduces the chances of disease spread among livestock. The third module involves an animal collar system embedded with sensors to track the health status of individual animals, such as their body temperature and movement patterns. This helps in early detection of illness and ensures timely veterinary attention. The fourth module is a geo-fencing system designed to prevent animals from straying beyond designated boundaries. If an animal crosses the virtual fence, the system triggers a vibration alert on the collar and sends the location details to the administrator via cloud communication. The proposed system uses microcontrollers like the ESP32, along with various sensors such as DHT11, IR sensors, and ultrasonic sensors to collect and transmit real-time data. The data is stored and visualized through a cloud platform, enabling farmers to make data-driven decisions. The system demonstrates a cost-effective and scalable solution for precision livestock farming, with the potential to enhance productivity, animal welfare, and operational efficiency in agricultural settings.**

Keywords: **IoT, wireless sensor network, smart farming, livestock monitoring, animal health tracking, farm automation, geo-fencing, ESP32, floor cleaning rover, Blynk app, precision agriculture**

I. INTRODUCTION

Agriculture has long been the backbone of many economies, especially in developing countries, and livestock farming forms a significant part of it. Traditional methods of managing livestock are labor-intensive, prone to human error, and lack real-time monitoring capabilities. With the advancement of technology, particularly the Internet of Things (IoT) and Wireless Sensor Networks (WSN), the agriculture sector is undergoing a paradigm shift towards automation and smart farming. These technologies enable farmers to remotely monitor and control farm operations, thereby increasing productivity, reducing costs, and enhancing the well-being of animals.

The concept of Precision Livestock Farming (PLF) is gaining prominence as it involves the use of sensors and data analytics to monitor individual animals in real time. By continuously tracking parameters such as temperature, movement, food and water intake, and location, farmers can detect abnormal behaviors early and take preventive actions. Moreover, issues like animals straying away from farm boundaries or unhygienic living conditions can be addressed using intelligent systems that require minimal human intervention.

This research proposes a comprehensive IoT-based system for tracking and managing farm animals using WSN. The system is divided into four integrated modules: a Livestock Management System for monitoring and automating food and water delivery, a Floor Cleaning Rover to ensure hygienic conditions, an Animal Health Monitoring Collar to track individual animal health, and a Geo-Fencing System to detect boundary breaches. All modules are controlled and monitored through a mobile-based IoT platform (Blynk), offering a centralized, user-friendly interface for farmers.

The main objectives of this research are:

- To develop a cost-effective and scalable IoT architecture for farm animal monitoring.
- To automate routine tasks like feeding, cleaning, and health tracking.
- To improve animal welfare through continuous monitoring and timely alerts.
- To enhance overall farm productivity through data-driven decision-making.

By integrating smart sensors, microcontrollers, and wireless communication technologies, this work aims to address the existing gaps in conventional livestock management and lay the groundwork for a fully automated smart farm ecosystem.

II. PROBLEM STATEMENT

In modern livestock farming, managing and ensuring the well-being of farm animals is a critical challenge, particularly in large-scale operations. A major concern is monitoring the health, location, and behavior of animals, especially when they are roaming over vast areas. Traditional methods of tracking farm animals are often labor-intensive, inefficient, and prone to human error. To address these challenges, there is a need for an IoT-based Farm Animal Tracking System using Wireless Sensor Networks (WSN).

The proposed system aims to design and develop an IoT-based solution that integrates GPS-enabled collars with various sensors (such as health monitoring sensors) to track and monitor farm animals in real-time. The collar will send location data to a centralized server via WSN, allowing farmers to track the animals' movements and ensure they stay within the designated farm boundaries. The system will also monitor animal health by measuring vital signs (such as body temperature, heart rate, and activity levels) and provide alerts when an animal shows signs of distress, illness, or when it leaves the farm boundary. Additionally, each collar will be equipped with LED indicators to visually represent the animal's health status: green for normal, yellow for moderate illness, and red for serious health issues, ensuring quick and efficient responses.

By integrating these technologies, the system aims to improve animal welfare, reduce the risk of lost or straying animals, optimize the management of livestock, and enhance overall farm productivity. The data collected by the system will be uploaded to a web-based interface for easy access and analysis by farm managers, enabling data-driven decisions for efficient farm animal management and enhanced operational effectiveness.

III. LITERATURE SURVEY

Recent advancements in smart agriculture have shown significant improvements in livestock management through the integration of Internet of Things (IoT) and Wireless Sensor Networks (WSN). These technologies enable real-time monitoring of animal health, behavior, and location, thus reducing manual efforts and enhancing farm efficiency.

Kumar et al. (2021) developed a system combining RFID and GPS for cattle tracking to mitigate theft and straying. While it improved farm security and reduced manual location logging by 40%, the study also highlighted challenges such as high power consumption and poor GPS performance in rough terrains.

To overcome connectivity issues in remote areas, Singh et al. (2020) proposed a LoRaWAN-based tracking system. It provided long-range communication with low power consumption, operating efficiently up to 15 km. Their findings showed a 45% reduction in operational costs compared to GPS-based systems, although some connectivity issues persisted in dense or hilly regions.

Gupta and Sharma (2019) focused on WSN-based health monitoring using temperature and motion sensors. Their approach enabled early disease detection, reducing livestock mortality by 27%. However, sensor calibration issues occasionally triggered false alerts, emphasizing the need for improved sensor accuracy.

In the domain of farm hygiene, Mehta et al. (2022) introduced an autonomous robotic floor cleaning system using ultrasonic sensors and AI navigation. The robot achieved 92% cleaning efficiency and reduced labor dependency by over 50%, offering a reliable solution to manage waste in livestock areas.

Similarly, Patel et al. (2022) reinforced LoRaWAN's potential in rural livestock monitoring. Their system enabled real-time location tracking with minimal power usage, decreasing theft incidents by 39%. Nevertheless, signal delays in forested zones suggested the need for hybrid communication mechanisms.

Overall, the literature supports the effectiveness of IoT and WSN in enhancing livestock management through automation and real-time monitoring. However, limitations such as power consumption, network coverage, and sensor reliability persist. Future research should explore hybrid networks (e.g., LoRa-RFID), AI-based behavior analytics, and low-cost, power-efficient solutions suitable for rural deployment.

IV. SYSTEM DESIGN

The IoT-Based Farm Animal Tracking System using WSN is designed to enhance the monitoring and management of farm animals through real-time data collection, processing, and analysis. The system is divided into four main phases: the Livestock Management System, Floor Cleaning Rover, Animal Health Tracking Collar, and Geo-Fencing System.

The architecture follows a WSN approach, where various sensor nodes are distributed across the farm, collecting data and transmitting it to a central processing unit. The system primarily relies on microcontrollers such as ESP8266, which act as the central processing units in different phases. These microcontrollers interface with various sensors and actuators to perform specific functions.

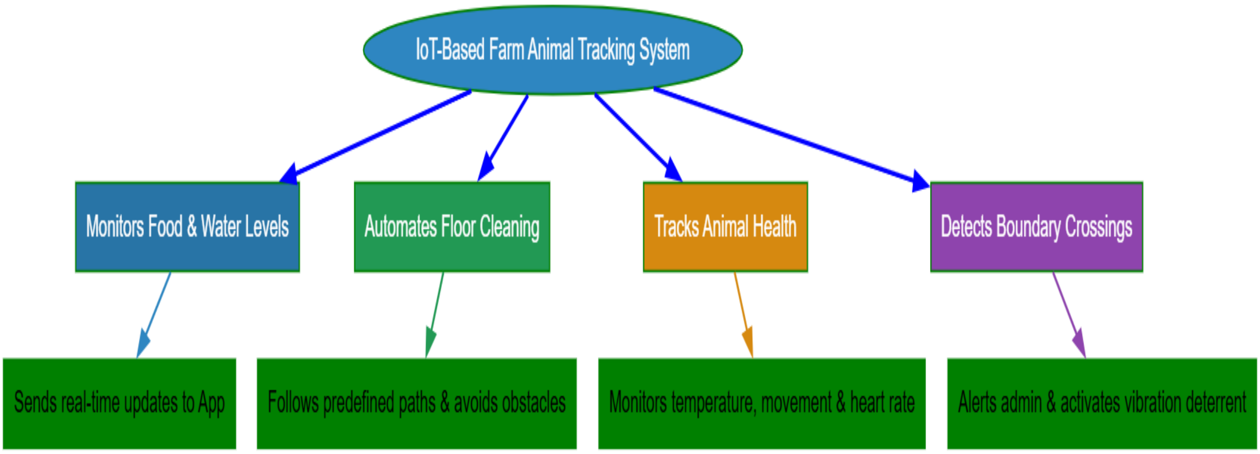

Figure.1: General System Architecture

The Livestock Management System integrates sensors to monitor food and water levels for the animals. Data from ultrasonic sensors and water flow sensors is processed by the ESP8266 microcontroller, which then transmits the readings to a mobile application using Wi-Fi or Bluetooth. The Blynk App serves as the user interface for monitoring and managing livestock feeding.

The Floor Cleaning Rover is an autonomous system responsible for maintaining hygiene in the animal shelter. It is equipped with IR sensors that enable it to detect and follow a designated path while avoiding obstacles. The motors and motor drivers control its movement, and the entire system is monitored through the Blynk App using Wi-Fi or Bluetooth communication.

The Animal Health Tracking Collar is a wearable device designed to monitor animal health parameters such as body temperature, movement, and heart rate. It incorporates a temperature sensor, an accelerometer (MPU6050) for movement detection, and a heart rate sensor to track vital signs. The ESP8266 microcontroller processes the collected data and transmits it via LoRa or Bluetooth to the administrator's interface on the Blynk App.

The Geo-Fencing System ensures that animals remain within a predefined area. A GPS module (Neo-6M/SIM808) continuously tracks the animal's location. If an animal crosses the defined boundary, a compact vibrator attached to the collar is activated to provide sensory feedback. The ESP8266 microcontroller processes the location data and transmits alerts via LoRa or GSM to notify the farm administrator through the Blynk App.

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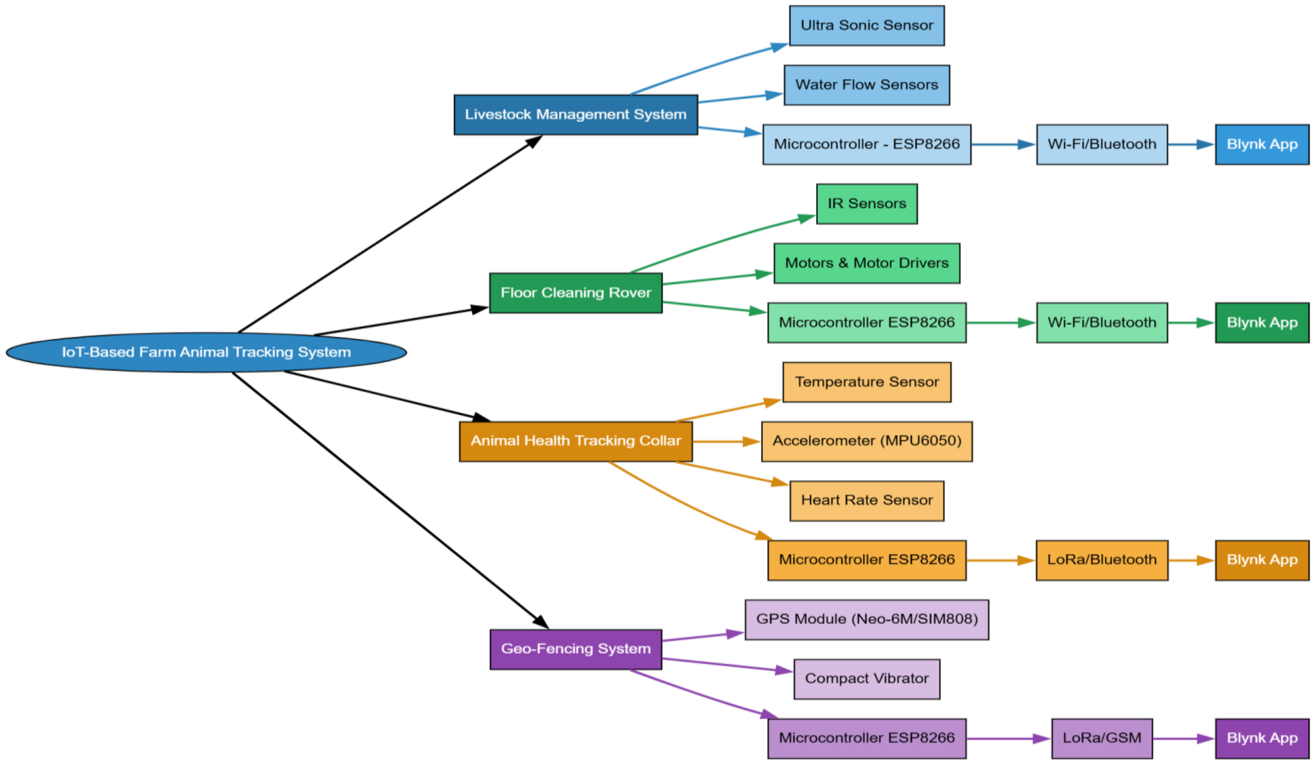

Figure.2: System Architecture

By integrating IoT-enabled communication and real-time monitoring, the system provides a comprehensive solution for farm automation, enhancing both animal welfare and operational efficiency.

V. PHASE WISE DESIGN

Phase 1: This system integrates multiple hardware components, including sensors, a microcontroller, and a cloud-based application, to efficiently manage the availability of food and water. Ultrasonic sensors and water flow sensors continuously track the quantity of food and water available in the feeding and drinking stations. These sensors relay real-time data to a central processing unit, which then transmits the information to the Blynk cloud, making it accessible via a smartphone application. By leveraging wireless connectivity, farm owners or caretakers can monitor livestock resources remotely and receive alerts when food or water levels drop below the required threshold.

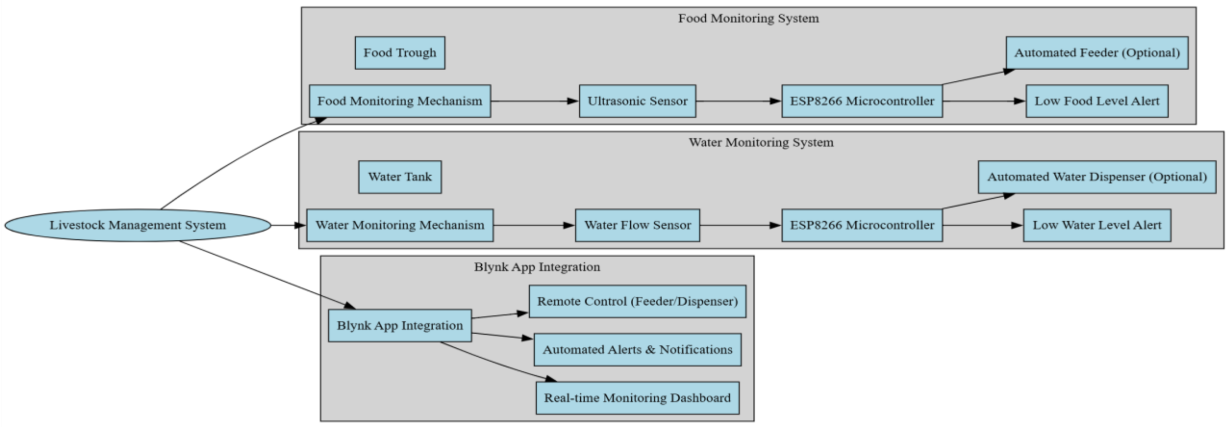

Figure.3: Livestock Management System

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Phase 2: The Floor Cleaning Rover is an innovative and autonomous system developed to maintain hygiene in farm environments by regularly cleaning the floor and preventing the buildup of waste materials that could contribute to the spread of infections and diseases among livestock. Designed with both automation and remote operability in mind, the rover primarily follows a pre-defined path using a precise line-following mechanism, ensuring thorough coverage of designated areas. In addition, it offers manual control through the Blynk mobile application, providing flexibility for the farmer to operate the rover remotely when needed. The system is equipped with an array of sensors to detect obstacles and environmental changes, actuators for controlling movement and cleaning components, and a microcontroller that processes sensor data and executes navigation logic. This integration of smart hardware components allows the rover to adapt to varying farm conditions while effectively carrying out its cleaning tasks, making it a valuable tool for maintaining a sanitary and safe environment for livestock.

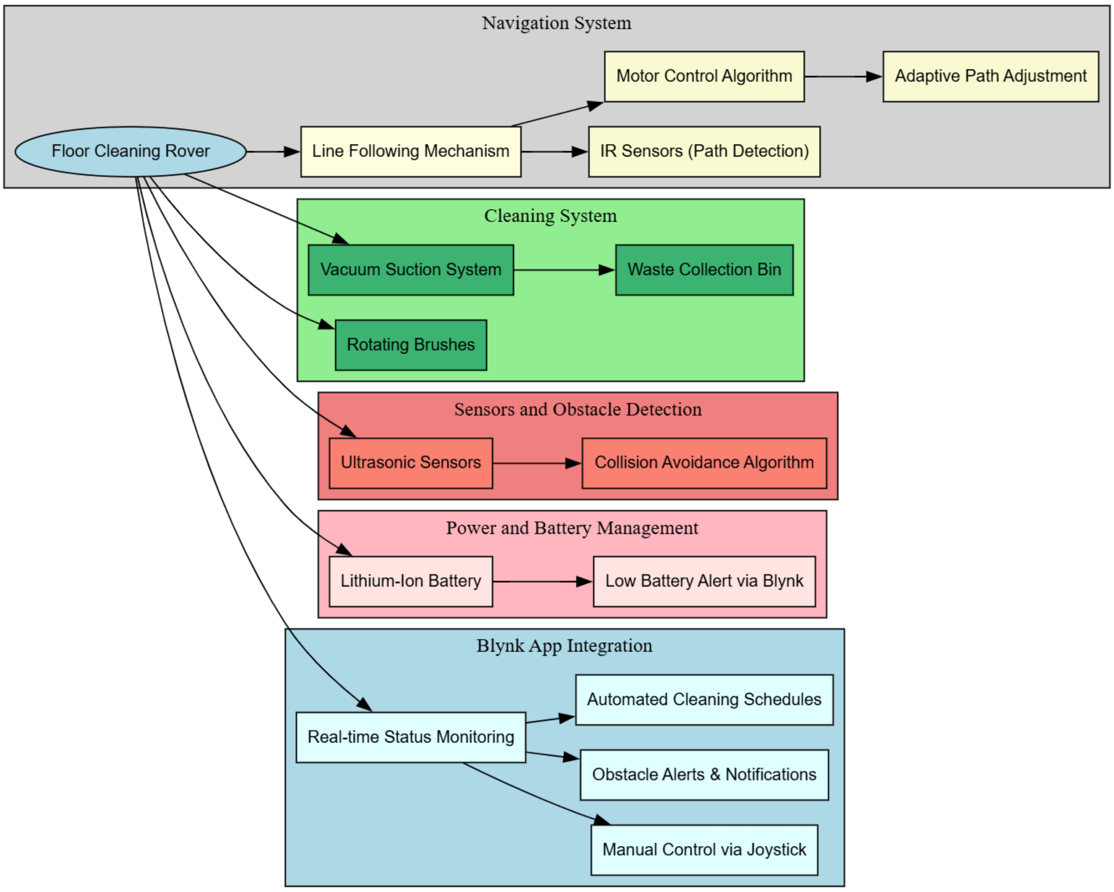

Figure.4: Floor Cleaning System for Farms

Phase 3: The Animal Health Monitoring Collar forms a crucial part of the IoT-based farm animal tracking system, focusing on the real-time monitoring of vital physiological and environmental parameters of farm animals. The primary objective of this phase is to ensure the overall health and well-being of each animal by detecting any early signs of illness, discomfort, or abnormal behavior. This system plays a vital role in modern livestock management where timely health interventions directly impact animal welfare, farm productivity, and the reduction of operational losses.

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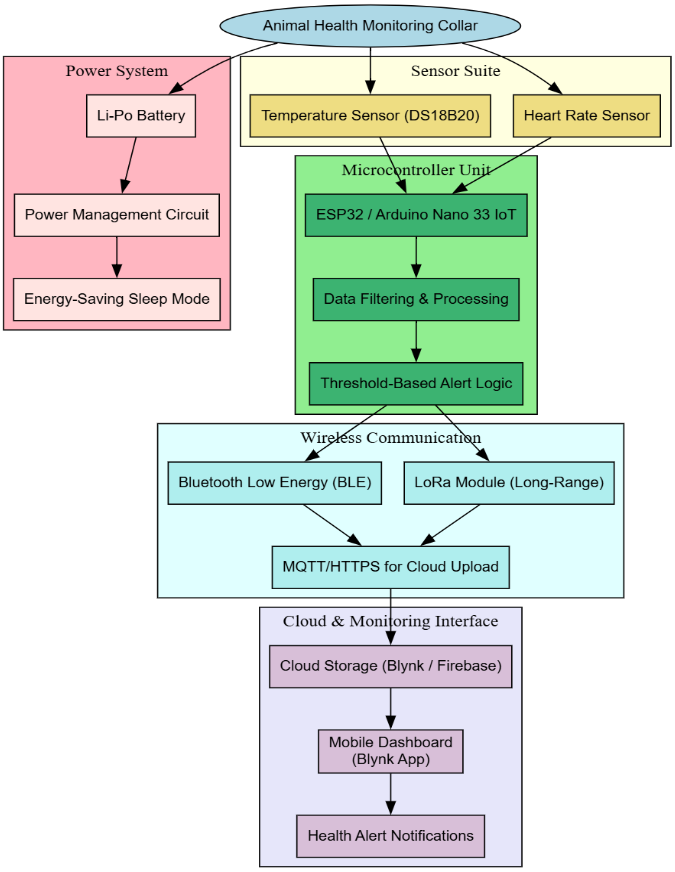

Figure.5: Animal Health Monitoring Collar

Phase 4: The geo-fencing system is the fourth and final phase of the farm animal tracking project. It serves to confine the movement of animals within a predefined virtual boundary and promptly alert the administrator when any animal exits the permitted zone.

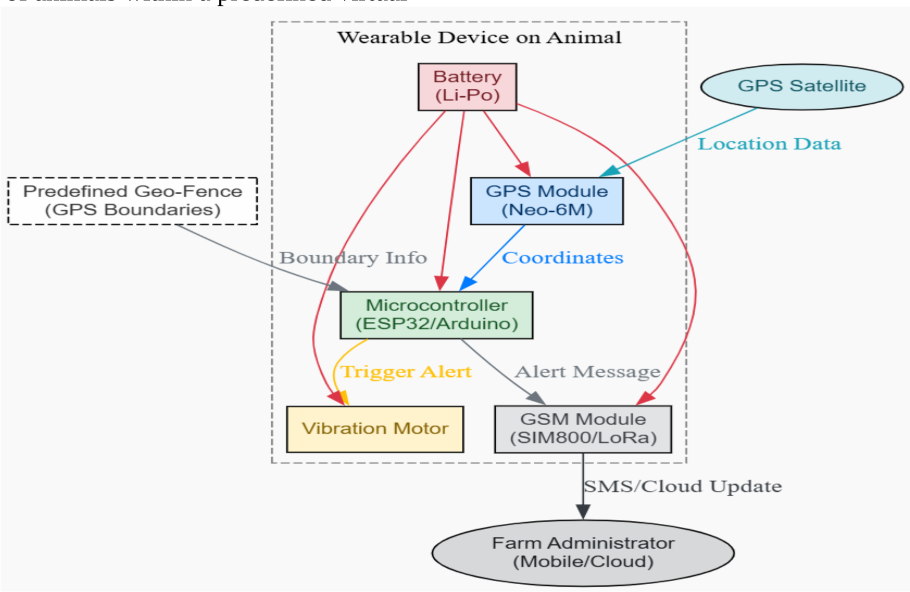

Figure.6: Geo – Fencing System

VI. RESULTS AND DISCUSSION

To evaluate the performance and feasibility of each system modules such as Livestock Management, Floor Cleaning Rover, Health Monitoring Collar, and Geo-Fencing System, a quantitative analysis was carried out across multiple parameters. These include power consumption, latency, response time, throughput, signal strength, data rate, bandwidth usage, cost, and maintenance.

Each parameter was normalized and scaled as a percentage to provide a uniform basis for comparison. Parameters like accuracy, effectiveness, durability, and qualitative aspects were excluded from normalization to maintain focus on measurable, quantifiable metrics.

The Livestock Management System (LMS) exhibited low power consumption (~7%) and moderate latency and response time (~25–35%). However, it showed high efficiency in terms of signal strength and throughput (above 70%). Its overall cost and maintenance metrics suggest it is an affordable and sustainable solution for long-term deployment.

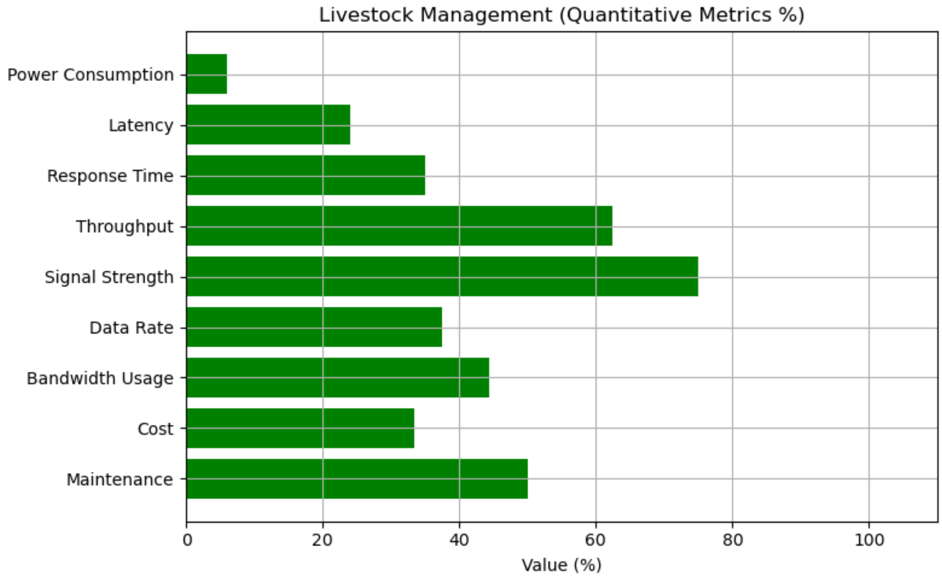

Figure.7: Result Analysis of LMS

The Floor Cleaning Rover (FCR) had moderate power consumption (adjusted to 35%), reflecting the mechanical demands of motion. It showed high response time efficiency and excellent throughput (~100%). Bandwidth usage remained low, indicating efficient communication design.

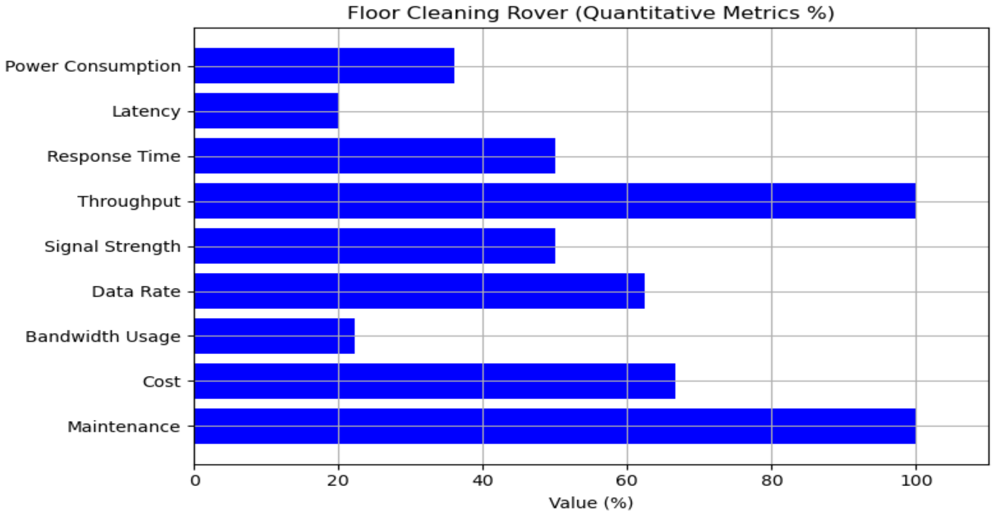

Figure.8: Result Analysis of FCR

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The Health Monitoring Collar demonstrated exceptional performance, particularly in response time and efficient bandwidth usage, enabling real-time data transmission for continuous livestock health tracking. Despite operating at a moderate power consumption level of around 35%, it maintained a stable and reliable connection with minimal disruptions. The latency was slightly higher at approximately 70%, but it remained within acceptable limits for non-critical delay applications. Additionally, the collar consistently delivered strong signal strength and high data rates, ensuring uninterrupted monitoring and reliable communication. These features make it a dependable and effective solution for proactive animal health management.

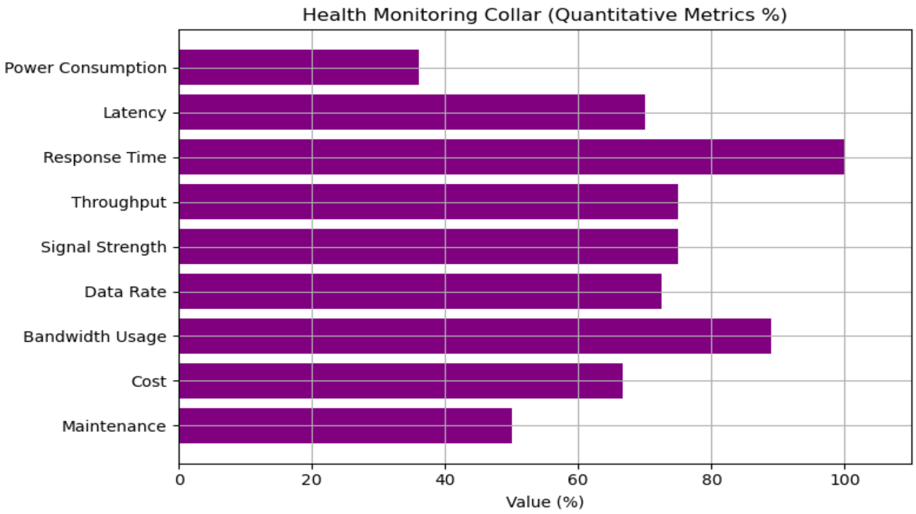

Figure.9: Result Analysis of HMC

The Geo-Fencing System (GFS) recorded high power consumption (~80%) due to its GPS-based components. However, it offered very low response time and latency, demonstrating near-real-time geolocation capabilities. Bandwidth usage and signal strength were among the highest across all systems tested, making it ideal for remote monitoring applications.

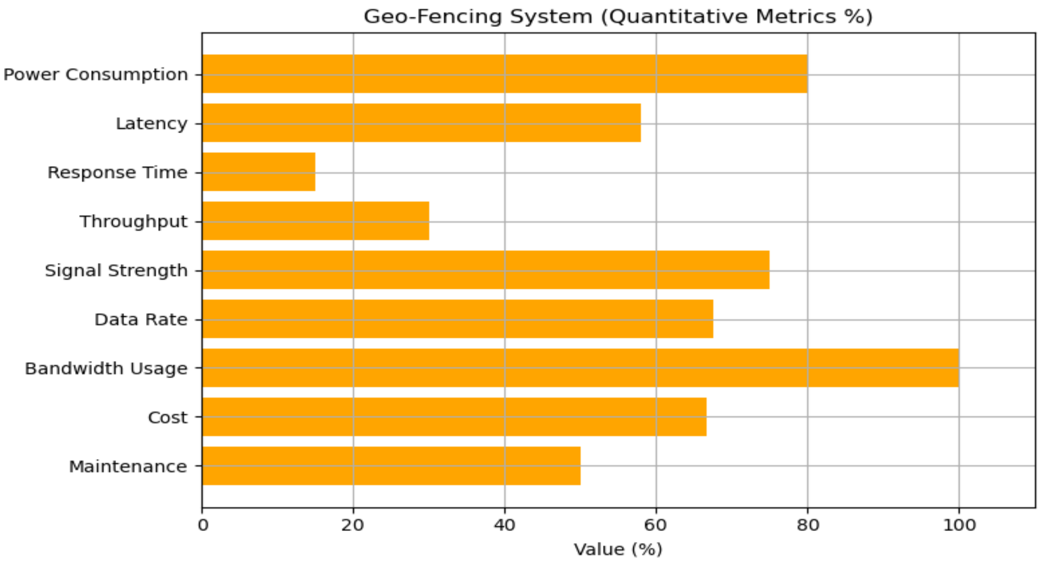

Figure.10: Result Analysis of GFS

The following chart presents a comparative analysis of the performance of four distinct IoT-based systems developed for modern farm management: Livestock Management System, Floor Cleaning Rover, Health Monitoring Collar, and Geo-Fencing System. These systems are evaluated based on critical operational parameters including power consumption, latency, throughput, and maintenance requirements, which are essential for assessing their efficiency, scalability, and suitability for real-world agricultural deployment. Among the four, the Health Monitoring Collar stands out for its exceptional response time and consistently high data rate, making it ideal for continuous, real-time tracking of animal health indicators. On the other hand, the Floor Cleaning Rover, while effective in maintaining hygiene, demonstrates relatively higher power consumption and maintenance demands due to its mechanical components and autonomous navigation system.

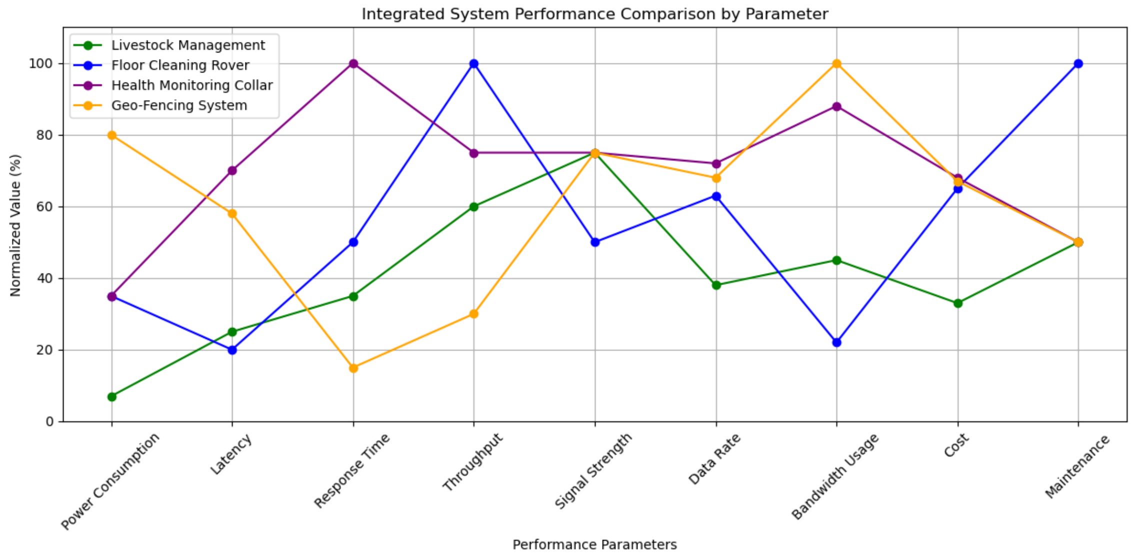

Figure.11: System Performance

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