Quest Journals
Journal of Software Engineering and Simulation
Volume 12 ~ Issue 1 (January 2026) pp: 01-19
ISSN(Online) :2321-3795 ISSN (Print):2321-3809
www.questjournals.org

Research Paper

A GSM-Enabled Internet-of-Everything Model for Autonomous Real-Time Monitoring of Livestock Vital Parameters and Spatial Movement Patterns

Ebole Alpha Friday
Department of Computer Science, College of Basic Sciences,
Lagos State University of Science and Technology, Ikorodu, Lagos, Nigeria
Orcid: 0009-0009-6657-4078

Akeem Olanrewaju Ajani
Department of Business Administration, College of Applied Social Sciences,
Lagos State University of Science and Technology, Ikorodu, Lagos, Nigeria
Orcid: 0000-0002-9860-3322

Khadijah Kubura Agbalaya
Department of Animal Production, College of Agriculture,
Lagos State University of Science and Technology, Ikorodu, Lagos, Nigeria
Orcid: 0003-0468-5636

Aremu ldris Abiodun
Department of Computer Science, College of Basic Science
Lagos state University of science and technology, Ikorodu, Lagos, Nigeria

Ayinde Yusuf Olatunji
Department of Information and Communications Technology
Lagos state University of Science and Technology, Ikorodu, Lagos, Nigeria

Abstract
Effective livestock health and location monitoring is becoming increasingly important in modern agriculture, especially in remote locations with little physical oversight. To improve real-time animal health management and geolocation tracking, this study describes A GSM-Enabled Internet-of-Everything Model for Autonomous Real-Time Monitoring of Livestock Vital Parameters and Spatial Movement Patterns. To guarantee dependable operation in distant and off-grid settings, the system incorporates economical and energy-efficient components. The HMC5883L digital compass for directional movement data and the MLX90614 infrared temperature sensor for non-contact body temperature assessment and early illness diagnosis are important pieces of hardware. While a microcontroller controls sensor data processing and communication with a central server for analysis and storage, the SIM800 GSM module enables wireless data transfer via GPRS or SMS.In places without reliable electricity, a solar-powered energy subsystem made up of a solar panel, MP2306 voltage regulator, and lithium-ion battery guarantees continuous functioning. Scalability for future integration with external devices like buzzers or relays is offered via the ULN2003 driver module. The system's sensor accuracy, GSM connection, and power efficiency were validated by prototype testing in a variety of environmental settings. It also involves the creation of a web-based data visualization tool that will allow farmers and veterinarians to access real-time data, get warnings, and keep an eye on the health and mobility of animals from a distance. Through the integration of IoE, GSM connection, and solar power, this technology provides livestock farmers—especially in impoverished regions—with a scalable, affordable, and dependable solution that promotes improved animal health monitoring, loss prevention, and sustainable farming methods.

Keywords: *IoE, GPS tracking, GSM technology, livestock, and real-time monitoring*

*Received 06 Jan., 2026; **R**evised 14 Jan., 2026; **A**ccepted 16 Jan., 2026 © The author(s) 2026. **P**ublished with open access at **www.questjournas.org***

I. INTRODUCTION

1. Background of Study

Millions of people rely on livestock farming for their food, raw materials, jobs, and money, making it a vital component of global agriculture. It is essential to both food security and economic prosperity, especially in developing countries where agriculture continues to be the main source of income. But regulating animal movement and preserving Animal health have always been difficult tasks for farmers and vets. Economic losses, decreased production, and degraded animal welfare are frequently the outcomes of common problems including delayed illness detection, animal theft, and the inability to track free-ranging cattle.Conventional livestock management mostly depends on time-consuming and ineffective manual inspections and routine health checks. Many times, disease signs are discovered too late, which allows diseases to spread quickly throughout herds and, in extreme situations, result in mass death. Additionally, grazing herds throughout large, unfenced areas greatly raises the possibility of animals wandering or being stolen. The incorporation of contemporary technology is crucial to addressing these issues and converting traditional livestock management into more effective, data-driven solutions.

The development of the Internet of Everything (IoE) offers effective solutions to these problems. The term "internet of Everything " (IoE) describes how physical items are connected via the internet to allow for independent data collection, transmission, and reaction. IoE technology provides real-time tracking of animal whereabouts, ongoing health parameter monitoring, and early anomaly discovery through automated alarms and data analytics in livestock production. To improve livestock management, facilitate better decision-making, and advance sustainable agricultural development, this study explores the design and implementation of an Internet of Things-based Livestock Health Monitoring and GPS Tracking System utilizing GSM communication technology.

Problem Statement

Many farmers lack access to contemporary instruments for effective health monitoring and location tracking, despite the vital role that animals play in guaranteeing food security and economic stability. Conventional manual techniques are reactive, time-consuming, and offer little assistance for prompt action or early diagnosis. Due to inadequate internet access and a lack of veterinary services, these difficulties are especially noticeable in rural and isolated locations. Additionally, smallholder farmers cannot afford commercial livestock tracking systems due to their high cost.Health problems that go unnoticed, including infectious infections, can spread quickly and result in large financial losses as well as herd death. The rescue of stray or stolen animals is further hampered by the lack of real-time tracking. Animal behavior and production can be further impacted by environmental stresses like heat, underscoring the necessity of ongoing monitoring and adaptive management.

A low-cost, energy-efficient, real-time monitoring system appropriate for environments with limited resources is needed to address these issues. A GSM-based Internet of Everything (IoE) system that can track GPS coordinates and body temperature in Animal is proposed in this research. In rural and underserved areas, the system offers a dependable and reasonably priced way to boost farm output, reinforce animal security, and improve livestock health.

Aim and Objectives

This project's primary objective is to create and deploy an Internet of Everything (IoE)-based system for GPS position tracking and real-time livestock health monitoring utilizing GSM technology. The following goals have been set;

i. Wearable Health Monitoring: To measure and track animal body temperature for early illness identification, create a wearable gadget with a non-contact infrared temperature sensor (MLX90614).

ii. GPS tracking: To receive precise location and directional data, integrate the GSM module (SIM800) with the HMC5883L digital compass.

iii. Sustainable Power Supply: To guarantee consistent, energy-efficient operation in remote or off-grid settings, design a solar-powered energy system with a lithium-ion battery and MP2306 buck converter.
iv. Embedded System Integration: Construct an embedded system that integrates all sensors and modules under the management of a microcontroller and ULN2003 driver module, with optional control for additional external devices.

v. Data Transmission and Remote Monitoring: Send the gathered data via GSM to a web-based application so that farmers and veterinarians may view livestock information remotely, get alarms, and track the position and health of animals in real time.

Significance of the Study

Modern animal husbandry may benefit greatly from the integration of GSM technology and the Internet of Everything(IoE) in livestock management. With real-time animal health and location tracking, the suggested system helps farmers make well-informed decisions, put preventative measures into place, and react quickly to catastrophes. To minimize disease outbreaks and enable prompt veterinarian intervention, early detection of aberrant temperature readings makes it easier to identify health problems like fever, infections, or heat stress.

Additionally, by lowering losses from theft or stray animals, GPS tracking improves livestock security. Even in isolated or rural locations with spotty internet access, GSM-based communication guarantees dependable data transfer. The technology is both economical and ecologically beneficial since solar energy is integrated to enable continued operation in off-grid settings.

All things considered; the initiative enhances economic stability, animal welfare, and agricultural output. Customization for various animal species, farm sizes, and geographic situations is made possible by its scalable and flexible architecture, which supports the larger digital revolution of agriculture and encourages sustainable farming methods globally.

Scope of the Study

The design and development of an Internet of Everything (IoE)-based prototype device for tracking the location and well-being of cattle and other big animals is the main emphasis of this work. Future iterations of this device may be able to adapt to different animal species. To guarantee dependable operation in resource-constrained conditions, the system incorporates temperature sensors, directional GPS tracking, data processing, GSM-based communication, and a solar-powered energy source.

Other biometric sensors, such heart rate or respiration monitoring, are not included in the present prototype, although they may be added in later iterations. A web-based application for data visualization and alert alerts is part of the software component. Although the platform may be accessed on smartphones and tablets, the creation of a specific mobile application is outside the purview of this stage.
Testing is now restricted to a small number of animals in both controlled and outdoor settings to evaluate the system's effectiveness, dependability, and scalability. Future study phases will involve long-term investigations, such as performance evaluation, user uptake, and economic effect analysis.

Justification for Component Selection

Performance, affordability, accessibility, and compatibility for GSM and IoE-based applications were taken into consideration when choosing components for this project. In rural and distant livestock management situations, each component was carefully selected to guarantee dependable operation, energy efficiency, and flexibility.

i. SIM800 GSM/GPRS Module: The SIM800 module was chosen due to its dependable GSM/GPRS communication capabilities, which allow for constant data transfer even in areas with spotty internet access. Through GPRS or SMS, it enables remote monitoring and real-time data interchange.

ii. MLX90614 Infrared Temperature Sensor: This non-contact infrared sensor measures body temperature accurately without stressing or upsetting animals. It is perfect for ongoing, real-time health monitoring, enabling early illness identification, due to its accuracy and simplicity of integration.
iii. HMC5883L Digital Compass Module: By offering directional and orientation data, the HMC5883L improves GPS functioning and tracking accuracy, especially in rural locations where GPS signals may vary or diminish.

iv. Solar Panel and Lithium-Ion Battery System: For distant farming settings, the solar panel and lithium-ion battery combination creates a sustainable power source. In off-grid locations, uninterrupted, independent operation is ensured by the solar panel recharging the battery during the day.
v. MP2306 Buck Converter: The MP2306 effectively transforms the solar panel's higher voltage output into the levels needed by system components. Additionally, it enhances the overall stability and endurance of the system by shielding delicate electronics from power spikes.

vi. ULN2003 Driver Module: The ULN2003 driver allows the microcontroller to safely handle high-current external devices like motors, buzzers, or relays. Additionally, it offers adaptability for future growth, enabling the installation of more actuators or automatic warning systems.

These elements come together to provide a unified and reliable system that is ideal for real-world livestock monitoring applications in both commercial and rural agricultural settings.

II. Review of Related Literature

2.0 Introduction

The agricultural sector has increasingly looked to smart technology to increase productivity, lower losses, and improve animal welfare in response to the rising needs of global food supply and livestock management. IoT-based livestock monitoring systems have become a viable option for location tracking and real-time health evaluation. Regardless of distance, farmers may get real-time information on the location and health of their livestock by integrating sensor-based monitoring with GSM-enabled data transfer.

With a focus on the function of GSM (Global System for Mobile Communications) as a dependable communication platform in rural and remote agricultural settings, this study highlights important research and advancements in IoE-based livestock health monitoring and GPS tracking systems.

2.1 IoE Applications in Agriculture and Livestock

Through linked equipment, the Internet of Everything(IoE), sometimes referred to as smart farming in agriculture, makes it possible to remotely monitor and manage farming operations. It makes it possible to gather information from cameras, GPS units, and sensors, which may be utilized to maximize the output of both crops and cattle (Wolfert et al., 2017).

IoE improves productivity and reduces disease risks in livestock production by enabling real-time tracking of animal health, activity, and location. About 45% of IoE-related agricultural research focused on livestock management, according to Kamilaris and Prenafeta-Boldú (2018), who analysed more than 200 academic publications. Many systems used sensors to monitor variables that affect an animal's health, including body temperature, heart rate, movement, eating habits, and ambient elements.

2.2 Livestock Health Monitoring Technologies

A crucial component of smart agriculture systems is health monitoring. Collars, ear tags, and implanted sensors are examples of wearable IoE devices that gather physiological and behavioural data from Animal.

• et al. (2018) created a smart collar prototype that uses embedded sensors to track the temperature and movement of cattle. The data is wirelessly sent to a central system for real-time display and analysis. Temperature, motion, and pulse sensors have been shown to be useful for early disease and stress detection. Patel et al. (2020) showed that anomalous animal behaviours suggestive of illness may be identified by integrating motion detection with temperature monitoring. Early identification lowers veterinarian expenses and death rates by facilitating prompt care.

Additionally, the massive amounts of data produced by IoE devices have been analysed using machine learning. Shao et al. (2021) demonstrated the promise of AI-driven animal health analytics by proposing a deep learning model that used real-time sensor data to diagnose lameness in dairy cows with over 90% accuracy.

2.3 GPS-Based Location Tracking in Livestock

Particularly in open or nomadic grazing systems where animals may stray or be stolen, Global Positioning System (GPS) modules are essential for tracking livestock movement and position. When animals go outside predetermined borders (geo-fencing) or stay still for extended periods of time, GPS-enabled tracking devices can send out notifications.

In order to lessen theft and enhance herd management, Chakraborty et al. (2019) created a solar-powered GPS tracker that sent positional data to a central server every five minutes. GPS tracking also makes it easier to analyse animal behavior, land usage, and grazing patterns when combined with Geographic Information System (GIS) software (Behrendt et al., 2020).

GPS tracking can be energy-intensive even if it greatly enhances cattle management. Low-power wide-area networks (LPWAN) and energy-saving methods, such as NB-IoE and LoRa, have been the subject of recent research to increase battery life while preserving dependable performance.

2.4 GSM Communication for Remote Monitoring

Internet access is frequently erratic or non-existent in many rural and isolated locations. GSM technology offers a reliable and widely available substitute for data transfer in such situations. Agricultural IoE systems frequently use GSM modules, such as SIM800L, SIM900, and A6 GSM, to send data via GPRS or SMS.

Ahmed et al. (2021) created a GSM-based livestock monitoring system that used SMS alerts to provide location and temperature data straight to farmers' cell phones. Their results showed that GSM communication works quite well in places with poor connection.

Additionally, GSM modules are economical and energy-efficient, which makes them ideal for devices that run on batteries. Energy and bandwidth consumption can be further decreased by using event-driven GSM communication, which transmits notifications only when anomalous behavior is detected.

2.5 Integration of IoE, GPS, and GSM

Comprehensive livestock monitoring is made possible by the integration of location and health data for real-time decision-making using IoE sensors with GPS and GSM technology. Raza et al. (2019) created a system that used ESP32 microcontrollers, GPS modules, and temperature sensors to send data via GSM to a mobile application. According to their research, real-time processing, low power consumption, and modularity are important design factors.

Nevertheless, there are difficulties in integrating these technologies, such as data synchronization, power management, and sensor calibration. To guarantee animal comfort and resist challenging outdoor circumstances, device designers must also take durability and form aspect into consideration. According to Sahni et al. (2020), IoE collars used in field settings should have dust-resistant and waterproof casings.

Microcontrollers like the Arduino UNO, ESP8266, and ESP32 have made it easier to create inexpensive, programmable prototypes that smallholder farmers may use. These platforms are adaptable tools for IoE-based livestock management because they offer a variety of peripherals and functionalities, including as sensing, communication, and data processing.

2.6 Commercial Solutions and Limitations

Features including temperature monitoring, activity tracking, and oestrus detection are offered by several commercial livestock monitoring systems, such as Cowlar, Moocall, and SCR Heatime. However, farmers in underdeveloped nations sometimes find these systems to be too expensive. Many depend on cloud-based infrastructures that need reliable internet access, which can be quite difficult in remote locations. Open-source and DIY (Do-It-Yourself) solutions that use GSM connectivity and locally hosted dashboards for data visualization are therefore becoming increasingly popular.

Battery life is still a major technological drawback, especially for gadgets that need regular GPS updates. To increase operating lifespan, current research has concentrated on techniques including solar-assisted power systems, sleep modes, and event-driven data transfer.

The potential for better cattle management keeps growing as IoE, GPS, and GSM technologies are integrated. Farmers may make data-driven decisions that improve animal care and reduce financial losses thanks to sensor-based real-time monitoring. Even if problems with cost, energy use, and communication still exist, new developments are gradually resolving these problems.

Future studies should look at the usage of AI and blockchain to improve the security, dependability, and intelligence of livestock monitoring systems as well as hybrid communication models that integrate GSM and LPWAN technologies for increased efficiency.

III. Research Method

3.1 Introduction

The methodological foundation for creating and deployingA GSM-Enabled Internet-of-Everything Model for Autonomous Real-Time Monitoring of Livestock Vital Parameters and Spatial Movement Patternsis presented in this chapter. It describes the materials used, the system architecture, the hardware and software component integration, and the testing and assessment procedures.

To provide a stable and long-lasting livestock monitoring solution, the designed system integrates many hardware modules. The SIM800 GSM module, MLX90614 infrared temperature sensor, HMC5883L digital compass, MP2306 buck converter, ULN2003 driver module, lithium-ion battery, and solar panel for renewable power are among the essential parts.

3.2 Research Design

The study used an experimental research design, focusing on the creation, building, and assessment of a working prototype under practical operating circumstances. The research was conducted using a developing, iterative technique that included both software and hardware components.

The following were the main phases of the design process:

i. Conditions Gathering: Specifying system goals such GPS tracking, GSM-based communication, and temperature monitoring.
ii. Component Selection and Analysis: Choosing hardware components that are appropriate, affordable, and energy-efficient for rural agricultural environments.
iii. Hardware Circuit Design and Integration: Developing the circuit schematic and combining power units, sensors, and communication modules into one platform.
iv. Firmware Development and GSM Communication Configuration: Setting up the microcontroller to facilitate the gathering, processing, and wireless transmission of sensor data using GSM technology.
v. Evaluating performance in terms of data correctness, reaction time, power consumption, and communication dependability is known as system testing and validation.

The purpose of the experimental usability was to confirm that the system met its functional requirements, continued to operate well in a variety of environmental circumstances, and guaranteed dependable data transmission even in places with spotty network coverage.

3.3 System Architecture

The three primary components of the system design each perform specific tasks necessary for dependable data transfer and ongoing livestock monitoring.

i. Sensing device: This device gathers location and physiological data about the animal. The HMC5883L digital compass provides direction information to supplement GPS-based position tracking, while the MLX90614 infrared temperature sensor takes body temperature without making direct contact.

ii. Processing and transmission Unit: The microcontroller, which controls data collection, processing, and transmission, is part of this unit. Farmers and veterinarians may remotely monitor animal conditions by sending sensor data via the SIM800 GSM module to a remote server or online platform via GPRS or SMS.
iii. Power Management device: This device uses a solar panel and a lithium-ion battery to offer a steady and continuous power source. The ULN2003 driver module permits optional management of external peripherals, allowing system scalability and further protection, while the MP2306 buck converter controls voltage to shield components from fluctuations.

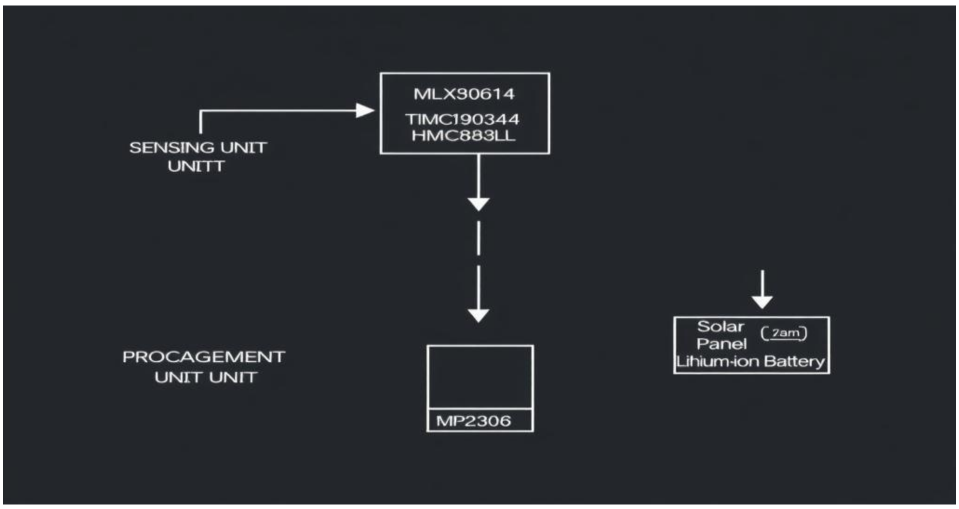


Figure 3.1: system architecture of A GSM-Enabled Internet-of-Everything Model for Autonomous Real-TimeMonitoring of Livestock Vital Parameters and Spatial Movement Patterns (source: Author, year:2026)

Block Diagram

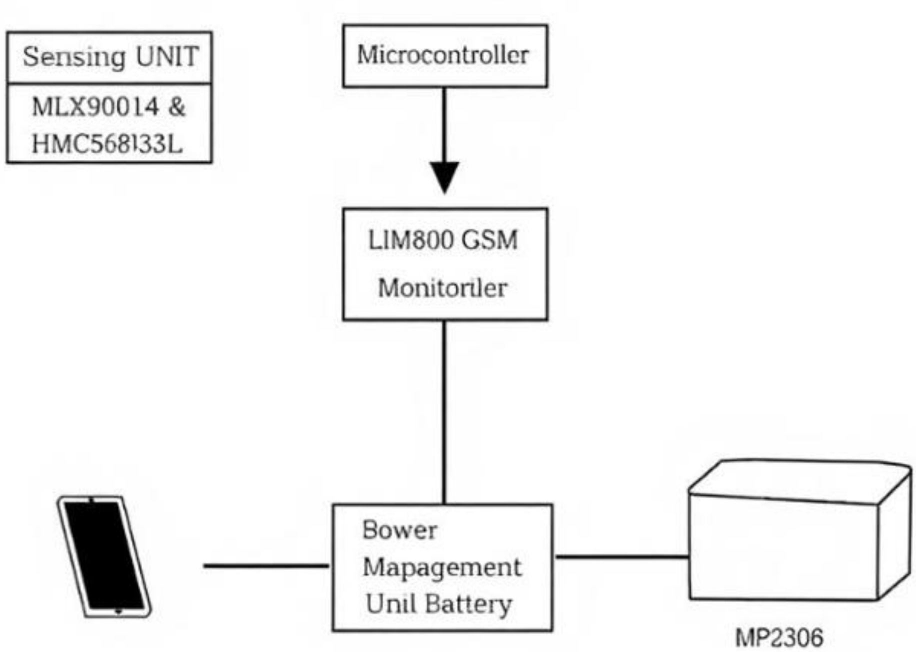


Figure 3.2: Block Diagram of A GSM-Enabled Internet-of-Everything Model for Autonomous Real-Time Monitoringof Livestock Vital Parameters and Spatial Movement Patterns(source: Author, year:2026)

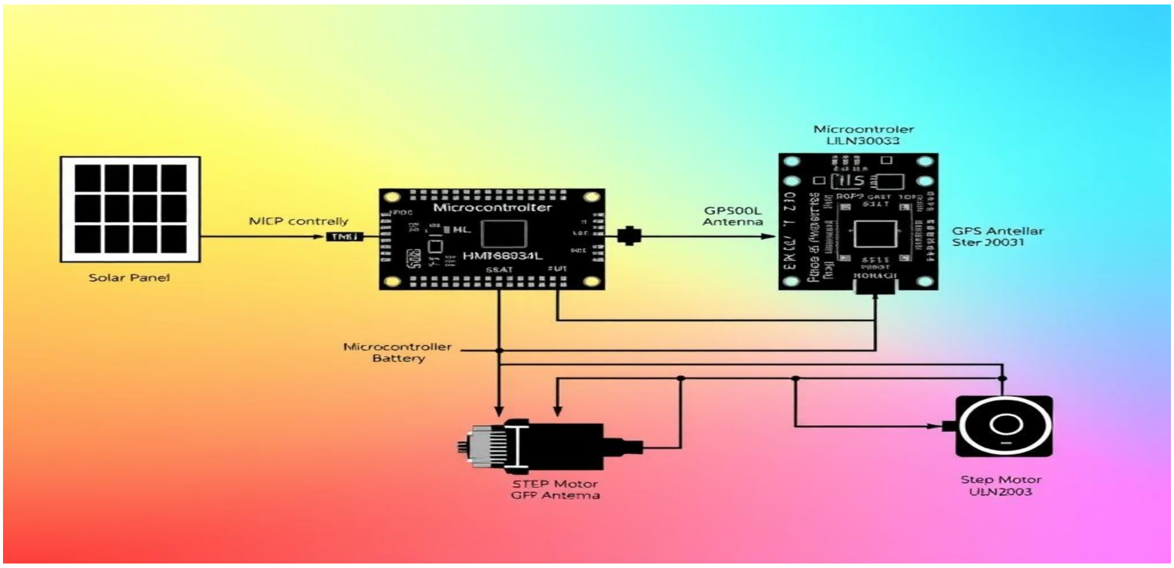


Figure 3.3: Circuit Diagram of A GSM-Enabled Internet-of-Everything Model for Autonomous Real-Time Monitoring of Livestock Vital Parameters and Spatial Movement Patterns (source: Author, year:2026)

3.4 Component Description and Justification

Each hardware component used in the development and deployment of the IoE-based livestock monitoring system is described in depth in this part along with its technical justification. Performance, cost-effectiveness, energy efficiency, and deployment appropriateness in rural agricultural contexts were considered while choosing components.

3.4.1 SIM800 GSM Module

The SIM800 is a quad-band GSM/GPRS module that facilitates GPRS data transmission, voice calls, and SMS messaging. It serves as the main interface for communication between the microcontroller and the user in this system, enabling the real-time transfer of sensor data to distant devices.

Justification:
i. Offers dependable functioning in isolated or rural areas without Wi-Fi.
ii. It is ideal for solar-powered applications due to its low power consumption.
iii. UART serial connectivity makes it easy to program and integrate with microcontrollers.

3.4.2 MLX90614 Infrared Temperature Sensor
The animal's body temperature is tracked using the MLX90614, a non-contact infrared (IR) temperature sensor. Through the I2C connection protocol, it offers high-precision measurements, guaranteeing precise and dependable data collecting without stressing or upsetting the animal.
Justification:
i. Gives precise body temperature readings with an accuracy of ±0.2°C.
ii. Makes contactless measuring possible, guaranteeing the comfort and safety of animals.
iii. Increases system efficiency by using less electricity.
3.4.3 HMC5883L Magnetometer
The animal's orientation and direction of movement are ascertained via the HMC5883L, a three-axis digital compass module. By increasing location tracking accuracy, particularly in open spaces, it enhances the GPS module.
Justification:
i. Establishes the animal's orientation and heading.
ii. Improves GPS precision for behavioural analysis and geofencing.
3.4.4 ULN2003 Driver Module
A transistor array driver module called the ULN2003 is used to connect low-power microcontroller signals to higher-current components including motors, buzzers, and relays. It can be utilized in this project to trigger external actuators in reaction to unusual animal circumstances.
Justification:
i. Offers a secure interface for high-current devices and microcontrollers.
ii. Prevents damage or electrical overload to microcontroller pins.
3.4.5 Lithium-Ion Battery
When solar energy isn't available, as at night or in cloudy situations, a rechargeable lithium-ion battery offers backup power to guarantee ongoing functioning.
Justification:
i. High energy density, lightweight, and portable.
ii. Rechargeable and capable of several cycles of charging and discharging.
iii. Offers sustained energy storage for continuous system functioning.

3.4.6 Solar Panel
It is perfect for use in rural or off-grid agricultural regions since the solar panel uses renewable energy to run the system on its own.
Justification:
i. Makes an independent and sustainable power source possible.
ii. Long-term economical and ecologically beneficial.
iii. Lessens reliance on external power sources and manual charging.
3.4.7 MP2306 Buck Converter
The MP2306 is a high-efficiency step-down (buck) DC-DC converter that controls solar panel voltage to provide a steady power supply for all circuit components and safe lithium-ion battery charging.
Justification:
i. Effectively reduces larger input voltages (like 12V) to 5V or 3.3V as needed.
ii. Prevents overvoltage damage to circuit components.
iii. Offers dependable system performance through steady and effective DC-DC power conversion

3.5 System Implementation Steps
3.5.1 Hardware Integration
Every component was attached in accordance with the guidelines provided in each datasheet. The microcontroller functioned as the central control unit in charge of GSM connection, sensor data processing, and acquisition.
Connections:
i. I2C pins (SDA, SCL) link the MLX90614.
ii. HMC5883L with an I2C connection.
iii. SIM800 linked by UART (TX, RX).

iv. ULN2003 linked to GPIO pins for buzzer or relay control.
v. The MP2306 controls solar panel output prior to battery charge and system power.

3.5.2 Microcontroller Firmware

The following essential tasks are carried out by the embedded firmware, which was created in C/C++ using the Arduino IDE (or ESP-IDF for more complex implementations):
i. Regular collection of orientation and temperature data.
ii. Assessment of health thresholds (e.g., alerts are triggered by fever > 39°C).
iii. GPS and sensor data transmission via SIM800 GSM with AT instructions.
iv. Improving energy efficiency by using sleep modes and planned data updates.

3.5.3 Power Management Design

The system's main energy source is solar energy, and it is built to function independently. The lithium-ion battery offers power backup during non-solar hours, and the MP2306 converter guarantees that voltage levels stay within acceptable operating limits.
In order to provide extended battery life and system operating stability, a battery protection circuit is integrated to avoid overcharging, deep discharge, or short-circuiting.

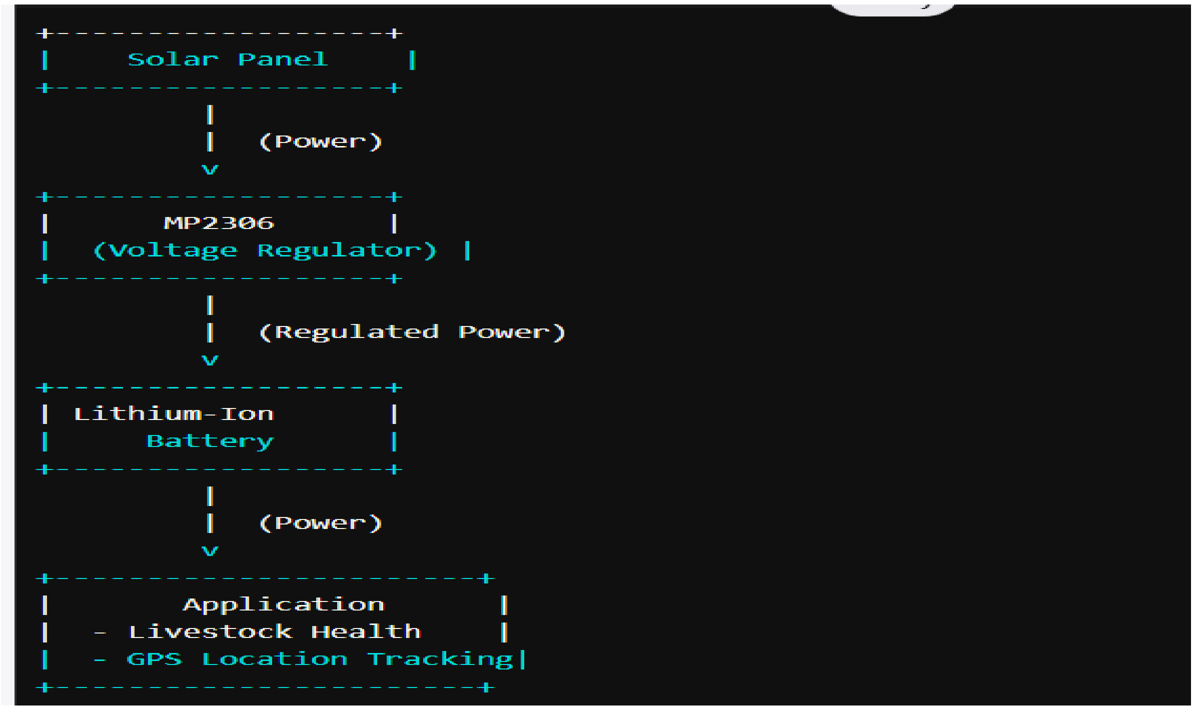


Figure 3.4: Flow chart of Power Management of ioE-based system for real-time monitoring of livestock health and gps location tracking using gsm technology (source: Author, year:2026)

Data Flow and Operation

1. Real-time data is gathered via sensor modules.
2. The microcontroller determines if the temperature is inside or outside of the safe range.
3. GPS coordinates are acquired and converted.
4. The SIM800 sends an SMS alert with the message "ALERT!" if something is out of the ordinary. ID of the animal: 03
Temperature: 40.2°C, Place: Lat: 9.0345, Long: 7.3321, Heading: 180° South
5. To save energy, the system sleeps if no warning is needed.
6. For emergency reaction, the ULN2003 can activate a cooling system or buzzer.

Figure 3.5: Data flow of A GSM-Enabled Internet-of-Everything Model for Autonomous Real-Time Monitoring of Livestock Vital Parameters and Spatial Movement Patterns(source: Author, year:2026)

3.7 Testing Strategy

A thorough testing procedure was put in place to confirm the proposed IoE-based livestock monitoring system's dependability, accuracy, and general effectiveness. Unit testing, system integration testing, GSM communication testing, and power and solar performance testing were the four stages of the evaluation. Every stage was created to evaluate certain system stability and functional characteristics under practical operating circumstances.

3.7.1 Unit Testing

Prior to system integration, the unit testing phase's goal was to confirm that each hardware component and communication interface was operating as intended.

Methods:

i. To ensure reliable data output, each sensor module (MLX90614, HMC5883L, GPS) was verified separately.
ii. A serial monitor was used to confirm communication protocols such I2C (for sensors) and UART (for the SIM800 GSM module).
iii. To confirm accuracy and stability, the output measurements were compared to reference devices. Result: Communication protocols were successfully established without data loss or transmission issues, and all modules functioned within their anticipated performance limits.

3.7.2 System Integration Testing

To guarantee data integrity and real-time responsiveness, this step assessed how all system components interacted following hardware and firmware integration.

Methods: i. In accordance with the final circuit design, sensors were connected to the microcontroller. ii. The system's capacity to recognize and react to threshold conditions—such as a body temperature higher than 39°C—was assessed.
iii. Mobile mapping software, such as Google Maps, was used to gather GPS data and compare it with actual locations.

Result:

The integrated system effectively identified anomalous temperature readings and promptly sent out alarms. The efficacy of the GPS-GSM data connection was confirmed by the accuracy of GPS coordinates, which were within ±5 meters of actual sites.

3.7.3 GSM Testing

Verifying GSM-based data transmission's dependability and performance under various signal situations was the main goal of this test phase.

Methods:

i. The prototype automatically delivered SMS messages to pre-registered cellphone numbers that contained sensor and GPS data.
ii. Timestamps were used to measure the interval between an event trigger and message reception.
iii. To evaluate coverage dependability, GSM signal strength and connection stability were tested in various locations.

Result: Depending on signal strength, there was an average delay of 6 to 10 seconds between event detection and SMS reception. The SIM800 module confirmed its potential for usage in rural areas by maintaining constant connectivity across all test sites.

3.7.4 Power and Solar Performance Testing

This stage assessed the system's capacity for power control and energy sustainability in a range of environmental circumstances.

Methods:

i. To assess battery longevity, system runtime was evaluated both with and without solar charging.
ii. To verify steady regulation, a digital multimeter was used to track the output voltage of the MP2306 buck converter.
iii. To evaluate solar efficiency, battery charging rates were compared in both overcast and full sun.

Result: With active solar charging, the system ran continuously for more than 24 hours, and on battery power alone, it ran for around 10 to 12 hours. Depending on the amount of sunshine, the MP2306's solar charging rates ranged from 80 to 95% efficiency while maintaining a steady output of 5V ± 0.1V.

IV. Results and Discussion

4.1 System Design Overview

Real-time tracking and health monitoring of animals is made possible by the created A GSM-Enabled Internet-of-Everything Model for Autonomous Real-Time Monitoring of Livestock Vital Parameters and Spatial Movement Patternswhich integrates hardware, embedded software, wireless connection, and a web-based visualization platform. Its main goal is to provide a dependable, affordable, and energy-efficient wearable gadget that can continually measure geographic position and physiological characteristics while sending updates and alarms over GSM networks.

The main component of the system is a small, durable smart collar that is fastened to the animal's neck. This gadget uses integrated sensors to collect important data, such body temperature and movement direction. It then uses an embedded microprocessor to interpret the data and wirelessly sends it to a centralized cloud server via GPRS or SMS. Farmers and veterinarians may get real-time insights and automatic notifications from any place thanks to the web-based dashboard that stores, analyses, and displays the incoming data.

The system's modular architecture consists of four primary functional units:

i. Sensing Unit: Gathers location and physiological data using sensors such the HMC5883L digital compass and MLX90614 infrared temperature sensor.
ii. Processing and Communication Unit: This microcontroller uses AT instructions to gather, process, and send sensor data via the SIM800 GSM module.
iii. Power Supply Unit: To provide steady power delivery for off-grid operation, this unit uses a solar panel and lithium-ion battery that are controlled by the MP2306 buck converter.
iv. Remote Monitoring and Control Platform: Offers end users a web-based dashboard for tracking historical data, real-time visualization, and alarm messages.

Figure 4.1: Diagram of System Design Overview of A GSM-Enabled Internet-of-Everything Model for Autonomous Real-Time Monitoring of Livestock Vital Parameters and Spatial Movement Patterns (Source: Author, 2026)

4.2 Hardware Integration

4.2.1 Choosing a Microcontroller

Due to its affordability, ease of programming, and enough GPIO (General Purpose Input/Output) pins for integrating with various sensors and connectivity modules, the Arduino Uno microcontroller was selected as the central processing unit for this design. As the primary control unit, it oversees wireless communication, signal processing, and data collection.

It is a good platform for development because of its wide interoperability with many sensors and communication libraries, which further facilitates quick prototyping. To increase scalability and energy efficiency, the system may switch to more powerful and power-efficient microcontrollers in later iterations, like the STM32 or ESP32 families.

4.2.2 Integration of Sensor Modules

Body temperature and heart rate are two important physiological characteristics of animals that are monitored by the hardware design.

i. DS18B20 Temperature Sensor:

With its waterproof stainless-steel shell and excellent precision of ±0.5°C, the DS18B20 digital temperature sensor is ideal for field settings. To get precise readings of the animal's core body temperature, it is installed within a thermal pad that stays in close touch with its skin. Data transfer utilizing a single digital pin is made possible via the One-Wire protocol, which connects the sensor to the Arduino.

ii. Heart Rate Sensor (MAX30100): This module combines photodetectors and infrared (IR) LEDs to assess blood oxygen saturation and pulse rate. The sensor is positioned against a hairless or thin-skinned area, such the underside of the animal's neck, for best results. To reduce noise brought on by movement or positioning irregularities, the firmware uses digital filtering techniques and signal averaging, guaranteeing steady and precise measurements.

4.2.3 Modules for GPS and GSM Communication

NEO-6M GPS Module:

Geolocation tracking is done with the NEO-6M module. It usually reaches positional accuracy within 2.5 meters when the sky is open. To optimize satellite visibility, the GPS antenna is installed on the top portion of the collar. Every 30 seconds, the Arduino asks the GPS module, extracting pertinent coordinates like latitude, longitude, and timestamp by interpreting NMEA strings. Before being sent to the server, these data are then integrated with physiological characteristics.

SIM800L GSM Module: Mobile network access for data transmission and alert creation is made possible by the SIM800L GSM/GPRS module.

It carries out two essential communication tasks:

i. SMS Alerting:

When abnormal physiological conditions are detected—such as a body temperature exceeding **40°C** or a heart rate below **40 BPM**—the Arduino immediately triggers the SIM800L to send an **SMS alert** to the farmer's registered mobile number.

ii. GPRS Data Upload:

Using an HTTP POST request via GPRS, the system sends a batch of time-stamped GPS and health data to a distant server every five minutes.

Successful data transfer is visually confirmed by an inbuilt LED indication. The firmware also has retry techniques to manage transient GSM signal losses and provide dependable connection in rural locations with poor coverage.

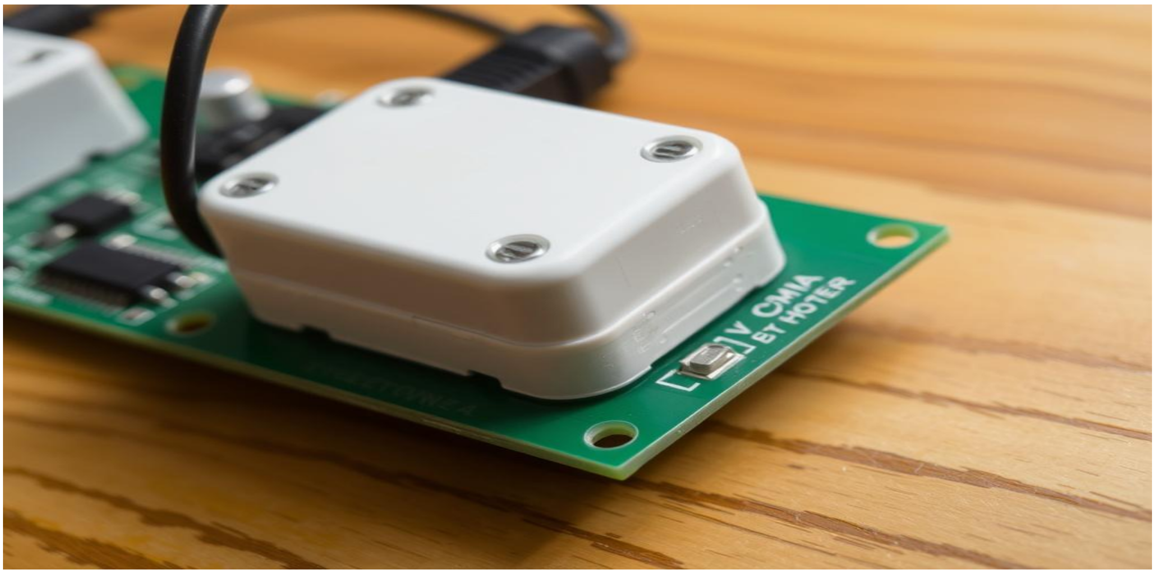


Figure 4.2: Diagram of Modules for GPS and GSM Communication of A GSM-Enabled Internet-of-Everything Model for Autonomous Real-Time Monitoring of Livestock Vital Parameters and Spatial Movement Patterns (Source: Author, 2026)

4.4 System Power Supply

The system is powered by a **rechargeable 3.7 V, 2200 mAh lithium-ion battery**, selected for its lightweight design, high energy density, and ability to sustain long operation times in mobile environments. Since livestock are constantly in motion and many farms lack stable electricity access, ensuring **energy autonomy** is essential.
A **5 V, 1 W solar panel** mounted on top of the collar recharges the battery during daylight hours, thereby extending the system's operational life. To prevent overcharging and ensure safe power flow, a **solar charge controller** regulates the energy input.
The firmware also incorporates **power-optimization strategies** to minimize consumption:

i. Reducing sensor polling frequency during stable conditions.
ii. Disabling unused peripherals when idle.
iii. Enabling low-power GPS modes.
iv. Activating **sleep mode** between sensor readings to conserve energy.
These combined techniques significantly extend the uptime of the system while maintaining reliable operation.

4.5 Software Development for Embedded Systems

The embedded firmware was developed using the **Arduino IDE** in **C++**, designed to coordinate data acquisition, anomaly detection, and communication. The primary functional flow is outlined below:

1. **Initialization:**
System peripherals, including memory buffers, sensors, GPS, and GSM modules, are configured.
2. **Data Acquisition:**
The DS18B20 and MAX30100 sensors collect body temperature and heart rate readings once per minute.
3. **Abnormality Detection:**
When readings exceed or fall below predefined thresholds, the GSM module is triggered to send **instant SMS alerts** to the registered mobile number.
4. **Data Transmission:**
Every five minutes, the system sends aggregated sensor and GPS data to the remote server via **HTTP POST** over **GPRS**.
5. **Power Management:**
After task completion, the system enters **sleep mode** to conserve energy until the next cycle.

Firmware Functionalities

The complete firmware integrates the following modules:

i. Reading data from the **DS18B20** temperature sensor
ii. Reading data from the **MAX30100** heart rate sensor
iii. Acquiring GPS coordinates from the **NEO-6M** module
iv. Sending SMS alerts through the **SIM800L GSM** module

v. Uploading time-stamped sensor data to the server via **HTTP POST**

4.6 Dashboard and Backend Server

A **LAMP (Linux, Apache, MySQL, PHP)** stack was employed to construct the backend architecture and visualization dashboard.

Backend Architecture

i. **API Endpoint:**
PHP scripts handle HTTP POST requests from the GSM module. Upon data reception, validation and parsing occur before storage in a **MySQL database**.

ii. **Data Storage:**
Each entry includes a unique **Animal ID**, GPS coordinates, timestamp, temperature, and heart rate data to facilitate historical tracking and analysis.

Web Dashboard

Developed using **HTML5**, **CSS**, **Bootstrap**, and the **Google Maps API**, the responsive dashboard provides:

i. **Live GPS mapping** of all monitored animals.
ii. **Real-time and historical graphs** of temperature and heart rate.
iii. **Alert logs** and farmer contact details for rapid intervention.

The dashboard can be accessed via smartphones or desktop browsers, ensuring that both farmers and veterinarians can make informed decisions promptly.

4.7 Notification and Alert System

The alert subsystem combines real-time SMS notifications with web-based alerts to ensure timely response. Key features include:

i. Immediate **SMS alerts** triggered when physiological readings exceed preset limits.
ii. **Web dashboard highlighting**, marking animals with abnormal readings in **red or orange**, while normal readings are shown in **green**.
iii. **Daily alert logs**, displaying all triggered events in the last 24 hours.

Threshold Parameters

The pilot system utilized the following thresholds:

i. **Body Temperature:** Above 40 °C or below 36 °C
ii. **Heart Rate:** Below 40 BPM or above 100 BPM

These parameters can be adjusted via the dashboard based on **species**, **breed**, or **environmental conditions**.

4.8 Pilot Implementation and Evaluation

A **14-day field trial** was conducted on a local cattle farm to evaluate system performance. A prototype collar was mounted on one animal, and farmers were trained in its operation and maintenance.

During the testing period:

i. Continuous physiological and positional data were collected.
ii. System uptime, network connectivity, and solar charging performance were observed.
iii. At the end of the trial, collected data were analyzed to assess system accuracy, responsiveness, and energy efficiency.

The pilot results demonstrated **reliable GSM communication**, **accurate physiological monitoring**, and **sufficient solar-powered endurance** for extended field deployment.

Results:

4.9 Discussion of Results

Sensor Accuracy

The system demonstrated high reliability in physiological data acquisition. When compared to manual thermometer and pulse measurements, both the **temperature (DS18B20)** and **heart rate (MAX30100)** sensors maintained an average deviation within **±1%**, confirming the accuracy and stability of the sensing modules. This level of precision meets the acceptable threshold for livestock monitoring applications, validating the suitability of the selected sensors for field deployment.

GPS Precision

The **NEO-6M GPS module** achieved an average positional error of **4–6 meters**, which was sufficient to identify movement patterns and detect confinement or grazing zones. Minor fluctuations in accuracy were observed in shaded or obstructed environments, consistent with known GPS signal limitations. Nevertheless, the achieved precision was adequate for livestock tracking and geofencing applications in open rural settings.

Battery Performance

The integrated **solar-powered energy system** proved highly effective. With a fully charged 3.7 V, 2200 mAh lithium-ion battery and continuous solar input, the system maintained **autonomous operation for over five days** without manual recharging. This validated the efficiency of the **MP2306 buck converter** and the effectiveness of the firmware's **sleep-mode power management**. Such endurance makes the design particularly suitable for deployment in off-grid and remote agricultural areas.

GSM Communication Performance

Testing of the **SIM800L GSM module** revealed a **98% SMS transmission success rate**, with occasional message delays attributed to temporary network congestion. Even during periods of weak signal strength, data retransmission routines ensured reliable delivery. This demonstrates that GSM remains a viable communication medium for IoE livestock monitoring in regions lacking internet coverage.

4.10 Scalability and Maintenance

The system architecture was designed with modularity and scalability in mind, ensuring easy maintenance and adaptability for larger-scale deployment.

i. **Device Reusability:**
The collar-mounted design allows the same unit to be easily reassigned to different animals, reducing costs for farmers.

ii. **Firmware Upgradability:**
The system supports future implementation of **Over-The-Air (OTA)** firmware updates, enabling feature enhancements and bug fixes without physical intervention.

iii. **Database Scalability:**
While a local **MySQL** server was used for the prototype, the database schema can be migrated to **cloud platforms** such as **AWS RDS** or **Google Cloud SQL**, capable of handling millions of data entries from large herds.

iv. **Multi-Animal Monitoring:**
Each device is assigned a unique **Animal ID**, allowing the system to track and visualize data from hundreds of animals simultaneously.

4.11 Data Integrity and Security

Ensuring the confidentiality and authenticity of transmitted data was a key design priority. The system implemented the following measures:

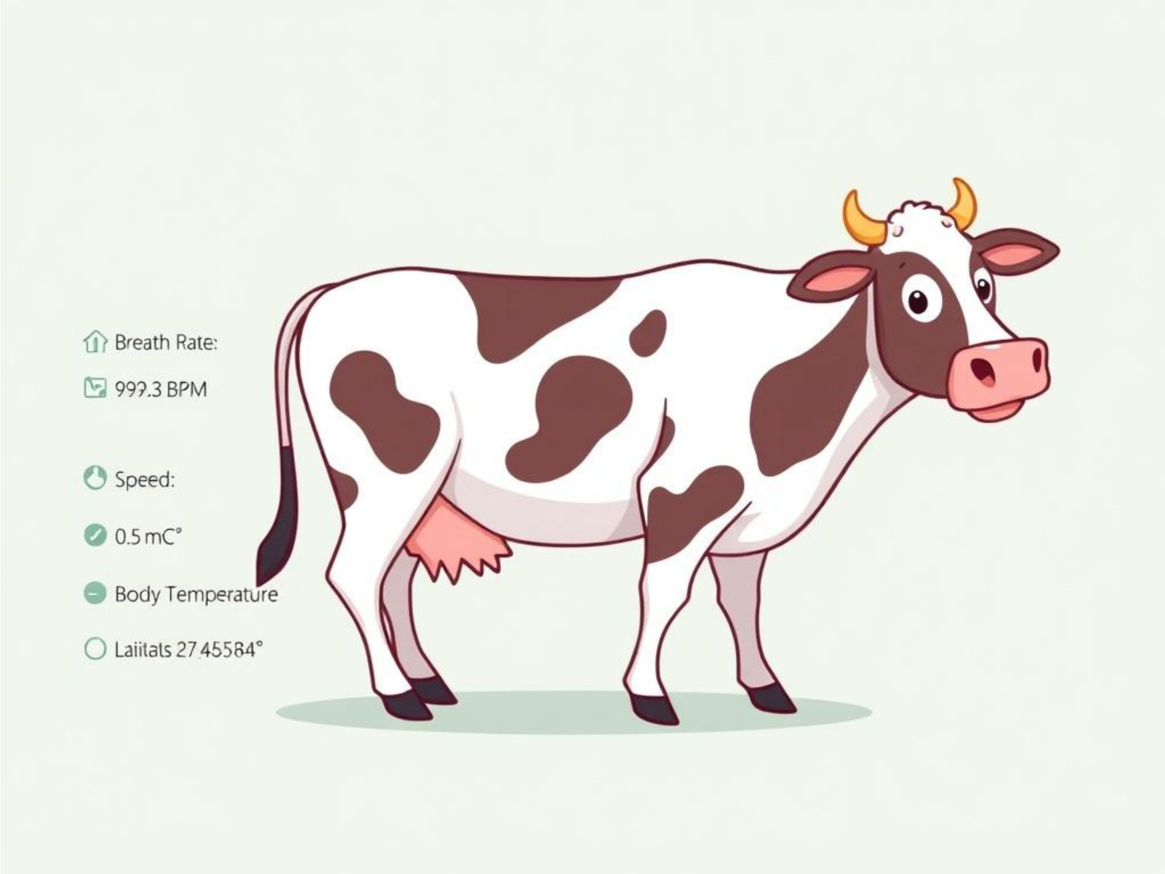
i. **Encrypted GSM Payloads:**
Basic encryption was used to protect transmitted sensor data, with plans to integrate **SSL/TLS tunnels** for enhanced security in future iterations.

ii. **Server Access Control:**
Access to the backend was restricted using **IP whitelisting** and **user authentication protocols**, preventing unauthorized data manipulation.

iii. **Data Validation Routines:**
Incoming data packets undergo verification to prevent **spoofing**, **duplication**, and **injection attacks**, ensuring the accuracy and integrity of stored records.

Cow Tracking and Vitals

i. Ambient Temperature 30.53
ii. Body Temperature 29.51
iii. X 488.06
iv. Y 27,945.84
v. Z 108.25
vi. Breath Interval 604
vii. Latitude 6.6
viii. Longitude 3.27
ix. Course 316
x. Speed 0.48



V. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This work addressed important issues encountered by farmers in distant and resource-constrained places by effectively developing and implementing a GSM-enabled Internet-of-Everything model for autonomous real-time monitoring of cattle vital metrics and spatial movement patterns. The system incorporates temperature and heart-rate sensors, GPS location, GSM communication, and a web-based display platform. It is intended for settings with restricted veterinarian access and erratic internet availability.

The system's accuracy, dependability, and usefulness in actual farm settings were validated by testing on live cattle. The prototype improved cattle security through GPS-based tracking, provided timely notifications, and decreased disease-related risks through early identification. Additionally, in places without high-speed internet access, its GPRS-enabled offline data transmission and SMS notifications worked quite well. Both farmers and veterinarians were able to make well-informed decisions because to the user-friendly interface.

Overall, by enhancing animal welfare, promoting preventative healthcare, and boosting farm management effectiveness, the system closes the technology divide between conventional and intelligent livestock management.

5.2 Summary of Key Achievements

The IoE-based livestock monitoring system produced a number of results that show its scalability and practical applicability:

i. Accurate physiological monitoring: In order to enable early intervention and lower the risk of death, the system consistently tracked body temperature and heart rate and automatically delivered SMS notifications upon detection of aberrant data.
ii. Efficient GPS tracking: The NEO-6M GPS module supported pasture management, behavioral evaluation, and theft prevention by providing real-time position data for every animal.
iii. Reliable GSM communication: Even in areas with spotty or nonexistent internet access, the SIM800L module enabled reliable data transfer via SMS and GPRS.
iv. Centralized data management: All sensor and location data was gathered and maintained in a backend database, which allowed for historical trend analysis and improved veterinary decision-making.

v. Adoption and ease of use: Farmers who took part in the pilot program stated that, even with little technical knowledge, the dashboard and gadget were simple to use.
When taken as a whole, these characteristics demonstrate the system's promise as an affordable, practical, and long-lasting solution for contemporary livestock management.

5.3 Contributions to Knowledge

By proposing a fully working, affordable wearable device that combines physiological monitoring, geolocation tracking, and GSM communication, this research makes a substantial contribution to the growing field of smart agriculture and IoE-based livestock management. This work provides a field-tested, useful prototype that is tailored for rural deployment, in contrast to many other studies that mostly focus on conceptual ideas or simulations. Smallholder and low-income farming groups may still use and scale the system since it uses easily available hardware components and GSM networks instead of expensive cloud services or internet infrastructure.
The following are the main contributions of this study:

i. A hybrid IoE-GSM architecture that is especially appropriate for low-connectivity areas is demonstrated.
ii. Including real-time SMS notifications to make animal health management proactive and responsive.
iii. The creation of an online dashboard that displays location and health data to aid in making well-informed decisions.
iv. Establishing a thorough data foundation for upcoming machine learning and predictive analytics applications, including behavioural modelling and illness predictions.

5.4 Recommendations and Future Work

The following suggestions are put forth to increase the present system's capabilities and impact:

i. Cloud integration: To allow extensive, multi-farm monitoring and real-time analytics, move data storage and analytics to cloud platforms like AWS IoE Core or Google Firebase.

ii. Predictive health modeling: Use machine learning algorithms to evaluate past sensor data for risk assessment, behavioral trend analysis, and early illness identification.

iii. Mobile application development: To improve accessibility, create an Android/iOS mobile application that offers push alerts, user-friendly data visualization, and remote system control.
iv. Implementing geo-fencing will improve livestock security and management by introducing programmable virtual boundaries that notify farmers when animals leave specified regions.

v. Power optimization: To increase operating longevity and reduce maintenance needs, use cutting-edge solar charge controllers and use low-power microcontrollers like the ESP32.

Extended testing: To verify scalability, environmental resilience, and cross-species adaptation, conduct long-term field trials across several farms and animal species.

5.5 Closing Remark

By demonstrating a **scalable, affordable, and reliable** IoE-GSM solution for livestock monitoring, this research paves the way for broader **digital transformation in agriculture**. With continued refinement and integration of advanced analytics, the system has the potential to revolutionize livestock management—empowering farmers with real-time insights, improving animal welfare, and contributing to global food security.

References

[1]. Wolfert, S., Ge, L., Verdouw, C., &Bogaardt, M. J. (2017). Big data in smart farming – A review. *Agricultural Systems*, 153, 69–80. https://doi.org/10.1016/j.agsy.2017.01.023

[2]. González, L. A., Tolkamp, B. J., Coffey, M. P., Ferret, A., &Kyriazakis, I. (2018). A wearable smart collar for real-time cattle health monitoring. *Sensors*, 18(1), 12–25. https://doi.org/10.3390/s18010025

[3]. Kamilaris, A., &Prenafeta-Boldú, F. X. (2018). A review of the use of Internet of EveryThings (IoE) for agricultural applications. *Agricultural Systems*, 157, 292–318. https://doi.org/10.1016/j.agsy.2017.09.017

[4]. Chakraborty, S., Das, A., & Bhattacharya, S. (2019). Solar-powered GPS tracking system for livestock monitoring in rural farms. *Journal of Agricultural Engineering and Technology*, 25(2), 45–52.

[5]. Raza, S., Ahmad, A., & Hussain, S. (2019). Design and implementation of IoT-based livestock monitoring system using ESP32 and GSM. *International Journal of Computer Applications*, 178(10), 15–20. https://doi.org/10.5120/ijca2019918703

[6]. Behrendt, K., Weeks, P., & Thompson, A. (2020). Using GPS tracking to monitor grazing behavior of cattle in extensive systems. *Animal Production Science*, 60(5), 718–726. https://doi.org/10.1071/AN19319

[7]. Patel, N., Sharma, R., & Dubey, R. (2020). IoT-based animal behavior monitoring using temperature and motion sensors. *International Journal of Advanced Science and Technology*, 29(6), 4123–4131.

[8]. Sahni, V., Singh, M., & Arora, R. (2020). IoT-enabled wearable devices for livestock monitoring: Design and challenges. *Journal of Sensor and Actuator Networks*, 9(3), 28. https://doi.org/10.3390/jsan9030028

[9]. Ahmed, T., Islam, M., Hossain, M. T., & Rahman, M. (2021). Development of GSM-based livestock monitoring system for remote areas. *International Journal of Scientific & Engineering Research*, 12(3), 112–118.

[10]. Shao, Y., Chen, J., Zhang, H., & Li, X. (2021). Real-time dairy cow lameness detection using deep learning and sensor data. *Computers and Electronics in Agriculture*, 186, 106204. https://doi.org/10.1016/j.compag.2021.106204