



IoT-Based Cattle GPS Tracker with Stress Detection Neck Belt for Smart Livestock Monitoring

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Abstract : Livestock monitoring is an essential component of modern-day agriculture. However, the conventional approach does not offer the facility of continuous monitoring. In the present work, an IoT-based cattle monitoring system is designed and implemented. The system uses GPS technology for tracking the location of the cattle. In addition, the system includes the facility of physiological parameter monitoring. A neck belt is designed to monitor the temperature and heart rate of the cattle. A NodeMCU is integrated into the system for real-time monitoring. The data is transmitted wirelessly to the cloud. The system is designed to offer the facility of remote monitoring. The system is observed to be reliable and energy-efficient. It is suitable for real-time applications.

IndexTerms - Cattle, GPS, Stress, Wi-Fi

I. INTRODUCTION

A. Background of the Project

Effective livestock management is vital for the health, productivity, and profitability of livestock. Conventional monitoring techniques heavily depend on manual observation. However, manual observation is often inefficient for monitoring livestock behavior. With the advent of new technologies in the field of wireless communication systems, the concept of smart monitoring is becoming a reality.

B. Problem Definition

Farmers often face difficulties such as losing cattle, theft of cattle, and delayed detection of health problems. This is because of the lack of monitoring systems, which would allow farmers to quickly react to unusual conditions. Moreover, the GPS tracking systems currently in use do not offer health monitoring capabilities, thus reducing their effectiveness.

C. Literature review /Existing System and Limitations

At the moment, livestock monitoring is mostly carried out through manual monitoring and basic GPS collar devices, which offer location tracking capabilities [6], [7]. Nevertheless, these devices do not offer health monitoring and are not able to track and sense conditions such as stress in animals. Recently, IoT-based livestock monitoring solutions have been proposed in the literature, which use sensor devices and wireless communication technologies for real-time monitoring and health analysis [6]-[9]. Nevertheless, the majority of the GPS collar devices have limited communication capabilities and are mostly operated in offline modes.

D. Proposed System Overview

To overcome these challenges, the design and development of an integrated IoT-based cattle monitoring system through a wearable neck belt device will be proposed in this paper. The proposed system will offer a comprehensive solution by incorporating the features of real-time tracking of the geographical position of the cattle along with health monitoring. GPS technology will be employed in the system to precisely determine the geographical position of the cattle. In addition, the system will incorporate physiological sensors to track health parameters such as body temperature and heart rate, which can be utilized to detect stress conditions and early symptoms of diseases.

The data collected from the GPS module and the sensor is processed by the microcontroller. The microcontroller is the main component of the system. The data is sent to the cloud using various types of wireless communication. The data is sent to the cloud using various types of wireless communication technologies like Wi-Fi or GSM.

II. SIGNIFICANCE OF THE PROPOSED SYSTEM

❖ *Importance and Relevance*

In this era of smart agriculture, livestock management plays a significant role in the efficient productivity and well-being of cattle. Traditional methods of livestock management are inefficient and unable to provide continuous information regarding animal movement and their health status. The proposed Cattle GPS Tracker with Stress Detection Neck Belt fills this gap in traditional livestock management and thus makes this project highly relevant to the current trend in livestock management and smart farming. The proposed project involves real-time monitoring and continuous tracking and stress analysis of cattle using GPS and physiological sensors. Communication between the neck belt and the central controller helps in real-time access to information regarding cattle movement and their health status, thus making this project highly relevant to the concept of Smart Farming and the Digital India initiative.

A. Benefits to Farmers

The system will provide the following benefits to the farmer:

1. **Reducing Manual Effort:** The system will reduce the need for manual supervision of the animals.
2. **Improving Productivity:** Healthy and less-stressed animals will result in greater milk yield and productivity.
3. **Centralized Location:** The system will allow the farmer to monitor multiple animals from a single location.
4. **Low Cost:** The system will utilize IoT technology, including NodeMCU, GPS, and sensors, which will be relatively inexpensive.

B. Market Potential / Societal Impact

Livestock management is a significant component of the rural economy of India. The inclusion of IoT technology for cattle management signifies a shift in the application of technology for precision livestock management. The need for a smart and efficient livestock management system has arisen. This proposed system has potential for application in the following sectors:

1. Dairy farms and livestock management organizations
2. Government and private sectors of animal health management
3. Some of the start-ups involved in AgriTech and smart farm management

From a general point of view, the proposed technology will help the country to avoid economic losses and promote the welfare of animals and the environment.

III. SYSTEM ARCHITECTURE

A. Block Diagram Explanation

The proposed system is based on an **IoT-enabled architecture** that connects a wearable neck belt on the cattle with a **central monitoring unit**.

The main functional blocks include:

1. **Power Supply Unit:** The power supply unit provides a stable DC voltage supply to the entire system. The power supply is usually a rechargeable Li-ion battery or a 5V regulated supply.
2. **Microcontroller Unit (NodeMCU ESP8266):** The microcontroller unit is the core component of the entire system, which processes the data received from the sensors and sends the data wirelessly using Wi-Fi or GSM technology.
3. **GPS Module:** The GPS module is used to track the location of the cattle in real-time, and the microcontroller receives the location in the form of latitude and longitude values through serial communication and sends the values to the monitoring interface [11].
4. **Physiological Sensors:** The physiological sensors include a temperature sensor, which is used to measure the body temperature of the cattle, and a pulse/heart-rate sensor, which is used to detect the stress levels in the cattle and is attached to the neck belt of the cattle.

5. Wireless Communication Module (GSM/Wi-Fi): This module is used to transfer the collected data to a cloud server or mobile application. The farmer can access the data in real time through a dedicated dashboard.
6. Mobile/Web Application Interface: This will show all the received data, i.e., the location of the cattle, body temperature, and stress levels. It will also send alerts if abnormal conditions occur.
7. The entire communication is smooth between the device attached to the neck and the controller

B. Circuit Diagram Explanation

1. The NodeMCU's 3.3 V or 5 V power supply will be used to power all the sensors and the GPS module.
2. The GPS module's TX pin will be connected to the RX pin of the NodeMCU for serial data transmission.
3. The heart rate and temperature sensors will be connected to pins for continuous data sampling.
4. The GSM will be connected to UART communication for data transmission to the mobile network.
5. The battery management circuit will be used for safe charging and power supply to all modules.

The above connections will enable the system to receive data from sensors, process through the microcontroller, and then transmit it wirelessly to the user interface.

C. System Flow / Data Flow Diagram

1. Start / Initialization: The system is powered on, and all the initialization takes place.
2. Data Acquisition: The body temperature and heart rate are measured, and the GPS location is acquired.
3. Data Processing: The microcontroller collects all the data, processes it, and checks if there is any abnormal condition.
4. Data Transmission: The data is transmitted to the cloud or the mobile application via Wi-Fi/GSM.
5. Monitoring & Alert: The user interface displays all the information. If there is any abnormality, a message is sent.
6. Continuous Loop: The process continues so that the communication between the wearable and the monitoring system is not disrupted.

D. Hardware and Software Interfacing Overview

1. Hardware Interfacing:

- a) NodeMCU and GPS Module: Serial communication.
- b) NodeMCU and Temperature Sensor: Analog signal.
- c) NodeMCU and Heart Rate Sensor: Digital/analog signal processing.
- d) NodeMCU and GSM/Wi-Fi Module: Wireless communication.
- e) Battery and Power Circuit: Regulated DC voltage.

2. Software Interfacing:

- a) Arduino IDE/ESP Home/Python: Used for programming and uploading code to the NodeMCU.
- b) IoT Platform (Blynk/ThingSpeak/Firebase): Stores and displays real-time data.
- c) Mobile App/Web Interface: Displays the GPS position of the cattle, their health condition, and other notifications.
- d) Data Communication Protocols: HTTP/MQTT is used for data transfer.

IV. DESIGN AND OBJECTIVES

A. Design Methodology

The proposed system is based on a modular design approach that integrates hardware and software to achieve efficient real-time cattle monitoring. The design is based on Internet of Things concepts, in which sensors are used to collect data from cattle, and a microcontroller is used to process data sent wirelessly to a monitoring platform, as shown in figure.1.

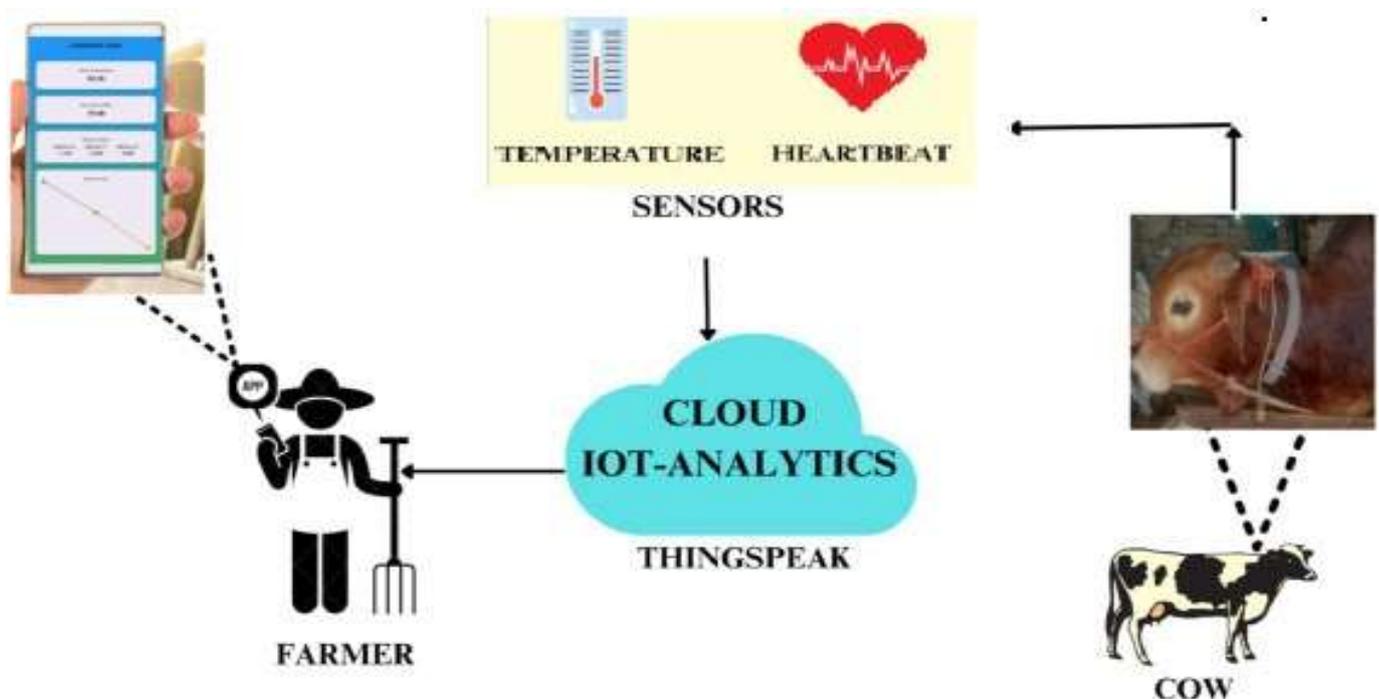


Fig.1. Block diagram for smart cattle neck belt [XII]

The design process includes the following steps:

1. Requirement Analysis: Determining the need for real-time location tracking and stress detection in cattle.
2. Hardware Selection: Selecting appropriate hardware such as NodeMCU, GPS module, heart rate sensor, temperature sensor, GSM/Wi-Fi module, and power supply.
3. Circuit Design: Integrating hardware such as sensors and modules through proper electrical connections.
4. Firmware Development: Writing code for NodeMCU using Arduino IDE to effectively fetch data from sensors and send them to the cloud server.
5. Communication Setup: Configuring Wi-Fi or GSM for efficient data transmission from the device to the cloud server.
6. Application Development: Creating a mobile or web-based application to display real-time data from cattle.
7. Testing and Calibration: Testing and calibrating the device for efficient working in different environmental conditions.

B. Design Considerations

There are various design factors considered for optimization, which are as follows:

1. Cost Efficiency: The project has utilized cost-effective and readily available resources for implementation, making it accessible for medium and small-scale farmers.
2. Power Consumption: The power consumption of the project is minimal for long-term use, especially in remote areas, as rechargeable batteries are utilized.
3. Communication Range: Wi-Fi is utilized for short-range communication, whereas GSM/LoRa can be utilized for long-range communication, especially for rural areas.
4. Durability and Comfort: The neck belt of the project is designed to be light, water-resistant, and comfortable for cattle without irritation.

5. Accuracy: GPS and physiological sensor accuracy is highly optimized for precise tracking and measuring stress levels.

Scalability: The design of the project has been optimized for monitoring multiple cattle by connecting multiple devices to a central controller/cloud server.

C. Objectives of the System

The main objectives of the Cattle GPS Tracker + Stress Detection Neck Belt system are:

1. To develop a wearable IoT-based system for real-time monitoring of the cattle.
2. To track the exact GPS location of the cattle and avoid theft or loss of the livestock.
3. To detect the levels of stress by monitoring the physiological parameters of the animals like temperature and heart rate.
4. To ensure the seamless transmission of data to the mobile or web interface for easier monitoring by the farmers.
5. To provide instant alerts during abnormal conditions like stress, fever, etc.
6. To reduce manual supervision and increase the efficiency of the livestock management system.

To develop an energy-efficient and cost-effective system suitable for rural areas.

D. Constraints / Challenges

During the design and development phase, there are some challenges and limitations that may come up:

1. **Battery Life:** The GPS and sensor usage may consume the battery life quickly; therefore, efficient use of the power source is critical.
2. **Signal Availability:** GPS signals may not be very accurate in areas where there is too much vegetation or in enclosed spaces.
3. **Environmental Conditions:** Dust, rain, and animals may interfere with the functionality of the device.
4. **Data Accuracy:** There may be slight variations in the physiological sensor readings due to skin contact.
5. **Cost vs. Performance Balance:** Balancing cost factors with performance and quality of parts.
6. **User Training:** Farmers would need to be aware of the interface of the application or web tool.

V. CONSTRUCTION AND WORKING

A. Hardware Setup and Wiring:

Figure 2 demonstrates the hardware circuit configuration of the proposed Cattle GPS Tracker with Stress Detection Neck Belt. The hardware components of this proposed system include a NodeMCU ESP8266 microcontroller, which serves as the CPU of this system and is responsible for collecting and transmitting data.

The MAX30102 sensor is used for measuring physiological signals such as heart rates, which helps in detecting stress in cattle. A DS18B20 temperature sensor is used for monitoring body temperature in cattle and is connected using a single-wire digital communication protocol.

For tracking the geographical position of cattle, a GPS NEO-6M module is used and connected using serial communication (UART) protocol. A SIM800L GSM module is used for facilitating wireless communication in this proposed system. The power supply for this system is provided by a 3.7V lithium battery pack, and a voltage booster module is used for regulating and providing the necessary voltage for this system. This hardware configuration of this proposed system helps in efficient monitoring of cattle health and geographical positions.

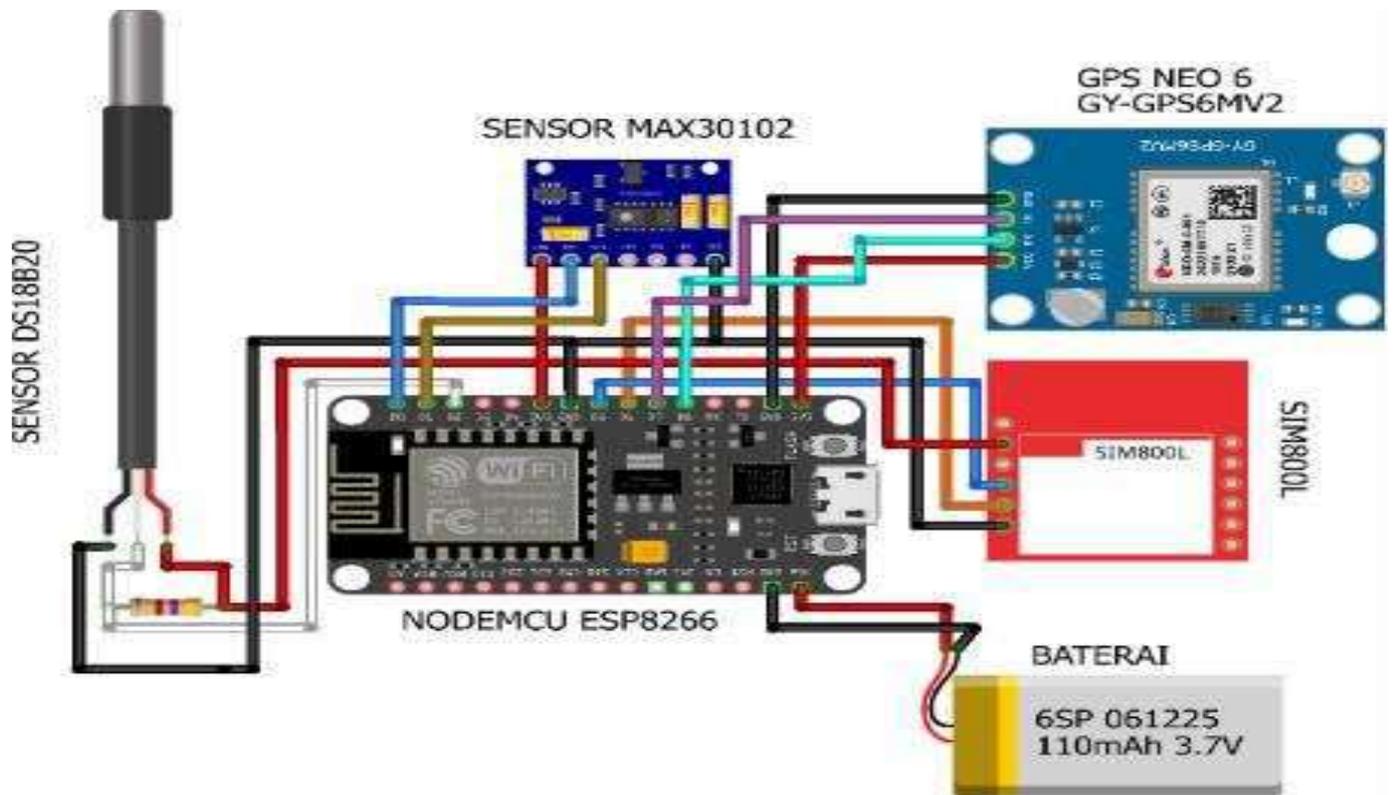


Figure. 2 . circuit diagram of the proposed cattle monitoring system [XIII]

B. Wiring Overview:

1. The Node MCU works as a central controller unit and supplies a regulated voltage of 3.3 V/5 V DC to all modules.
2. The GPS module is connected to the UART pins of the Node MCU to receive GPS data in terms of latitude and longitude.
3. The temperature sensor module DS18B20 is connected to a digital GPIO pin using One-Wire protocol to measure body temperature.
4. The pulse/heart rate sensor module SEN-11574 or MAX30100 can be connected to a digital or analog input pin to measure stress level.
5. The GSM/Wi-Fi module can be connected to a serial port to transfer data wirelessly.
6. A Li-ion battery pack can be used to supply a voltage of 3.7 V or 9 V to the system along with a charging module like TP4056 to make it reusable.

C. Sensor and Module Configuration

Each sensor and module in the system has a specific function and is configured accordingly. Here are the configurations for each module in the system:

1. **GPS Module Configuration:** GPS sends real-time data in the form of NMEA protocol containing latitude and longitude. The microcontroller reads the required information and updates the current position of the cattle after a few seconds [4].
2. **Temperature Sensor Configuration:** The temperature sensor reads the body temperature in the form of voltage. The NodeMCU reads the voltage and converts it into Celsius using the ADC (Analog to Digital Converter) and calibration values.
3. **Heart-Rate Sensor Configuration:** The pulse sensor reads the changes in blood circulation and calculates the heart rate. The microcontroller reads the data and determines the stress level based on abnormal pulse patterns.
4. **Communication Module Configuration:** GSM or Wi-Fi credentials such as SSID, password, and server name are programmed in the microcontroller. After establishing a connection, data is transmitted securely to the IoT cloud or app.

5. Power Module: A battery circuit is connected for power supply and is configured for overcharge protection.

D. Software Implementation (Code Overview)

The code for this system is written using the Arduino IDE, which provides a simple interface for writing and uploading code for the Node MCU.

The key software functions of this system are as follows:

1. Initialization: This function initializes serial communication, sensor pins, and Wi-Fi/GSM connection.
2. Sensor Data Acquisition: This function acquires data from sensors, i.e., temperature and heart rate, after a specific time interval.
3. GPS Data Parsing: This function parses GPS data strings and retrieves coordinates using a GPS library.
4. Data Processing: This function processes data into a more meaningful and easily understandable format.
5. Data Transmission: This function sends data to an IoT cloud using HTTP/MQTT protocol.
6. Alert Generation: This function generates an alert if temperature and heart rate exceed normal limits..

E. Communication Process (GPS + Sensor + App)

The communication in the system occurs at three levels:

1. Data Acquisition Layer: In this layer, the neck belt device uses the sensor and GPS module to collect the physiological and location information.
2. Processing & Transmission Layer: In this layer, the NodeMCU processes the information and sends it wirelessly to the cloud server by using Wi-Fi or GSM communication.
3. Monitoring Layer: In this layer, the cloud server or mobile app receives the information and displays it to the farmer, including the exact location of the cattle on the map.
 - a) The farmer can view the information in real-time from anywhere.
 - b) In addition, if any unusual stress or temperature level occurs in the cattle, the system immediately sends a message to the farmer.

The three levels of communication in the system allow for communication between the cattle device and farmer.

F. Applications

The Cattle GPS Tracker + Stress Detection Neck Belt has numerous applications in agriculture, cattle rearing, and cattle farming:

1. Real-time cattle tracking in open grazing or large cattle farming.
2. Cattle stress detection for preventive health care.
3. Prevention of cattle theft and tracking of lost cattle.
4. Performance tracking in cattle farming for improved productivity.
5. Integration into smart farming systems for centralized cattle management.

VI. PERFORMANCE ANALYSIS

A. Test Results

The prototype was tested in different environmental conditions to check the performance of the system.

1. The GPS module was able to get the coordinates within 8-12 seconds of power up.
2. The sensor readings were within the expected range, such as the temperature and heart rate.

3. The communication between the hardware and the mobile app was smooth with minimal packet loss, i.e., <3%.
4. The system was able to update the data at an interval of 1 second.

All modules, including GPS, the microcontroller, and the sensors, were integrated and tested for the transmission of real-time data

B. Accuracy and Response Time

Accuracy and response time were major parameters of concern during testing.

1. GPS Accuracy: $\pm 5\text{m}$ accuracy under open sky and $\pm 10\text{m}$ accuracy under urban or obstructed conditions.
2. Sensor Accuracy: $\pm 2\%$ deviation from standard reference values.

Response Time: Average response time of the system was recorded at 1.5 seconds, which includes sensor data collection, GPS update, and data transmission.

Such accuracy and response times are suitable for small-scale IoT and tracking-based applications.

C. Power Efficiency

Power consumption was analyzed for both idle and active modes:

1. Idle Power Consumption: Approximately 50–70 mA.
2. Active Mode Consumption: Peaks at 150–200 mA for GPS transmission and Wi-Fi/Bluetooth transmission.
3. Battery Backup: With a 2000 mAh Li-ion battery, the device can run for 8–10 hours continuously.

The low power microcontrollers used for the device help enhance power efficiency.

D. Range and Reliability

Range tests were conducted for wireless communication and GPS signals:

1. Wi-Fi Transmission Range: The belt, have Up to 30 meters line-of-sight
2. Reliability: Our belt, do have 97% of uptime during testing

With minimal data transmission errors during the testing. The system has a stable connection and provides performance even in fluctuating signals.

E. Observations

Based on the experiments conducted and analysis done, the following was observed:

1. The system works well in terms of overall reliability and high accuracy in the executing real-time applications.
2. The response time of the system is very minimal, thus making it suitable for the fast dynamic monitoring systems.
3. The optimization of power consumption can be further enhanced by incorporating sleep modes and periodic update methods rather than continuous data transmission.
4. The environmental conditions, such as the presence of high-rise structures or nearby metallic objects, slightly influence the GPS system's overall accuracy.
5. The overall performance of the system can be regarded as satisfactory and properly aligns with the objectives set in the early chapters of the project.

VII. COMPONENT DETAILS

A. Microcontroller / Processor

Component Used: NodeMCU ESP6266 The microcontroller acts as the brain of the system. It receives data from various

sources like sensors, GPS devices, etc., processes the data, and then forwards the data to the connected applications.

Features:

1. 32-bit dual-core processor (in ESP6266)
2. In-built Wi-Fi and Bluetooth connectivity
3. Multiple GPIO pins for interfacing devices
4. Low power consumption via sleep modes
5. In-system programmable flash memory

Function of the Component Used in the Project: The microcontroller is used to collect data from various sources like sensors. It processes the data from the GPS devices and forwards the data to the mobile applications..

B. GPS Module

Component Used: NEO-6M GPS Module. GPS is a module that provides real-time location data in terms of coordinates in the form of longitude and latitude by communicating with GPS satellites.

Features:

1. High sensitivity GPS receiver
2. UART communication interface
3. EEPROM memory for configuration
4. LED for GPS status
5. 3.3V-5V supply

Function in Project: GPS is used for obtaining location data, which is then sent to the microcontroller for further transmission.

C. Sensors

1. Heart Rate Sensor (MAX30100): It measures heart rate by detecting variations in blood flow when it's in contact with the animal's skin
2. Temperature Sensor (DS18B20): It measures body or environmental temperatures and provides digital output using One-Wire protocol
3. Motion / Vibration Sensor (SW-420): It's used to sense motion/vibration in safety alert systems

Function in Project: The sensors are used to obtain vital or environmental data that's relayed to the microcontroller to forward it to the monitoring platform.

D. Power Supply

Component Used:

Two 3.7V, 2600mAh Li-ion batteries connected in parallel provide a total capacity of 5200mAh, ensuring an operation time of 18-20 hours under continuous monitoring mode.

Features:

1. Voltage regulator - LM7805
2. Protection of short circuit and overload conditions
3. Portable power option - Rechargeable Li-ion battery

Function in Project:

It provides uninterrupted power supply to the microcontroller and other modules for continuous operation..

E. Communication Modules

Component Used:

Two 3.7V, 2600mAh Li-ion batteries connected in parallel provide a total capacity of 5200mAh, ensuring an operation time of 18-20 hours under continuous monitoring mode.

Features:

1. Voltage regulator - LM7805
2. Protection of short circuit and overload conditions
3. Portable power option - Rechargeable Li-ion battery

Function in Project:

It provides uninterrupted power supply to the microcontroller and other modules for continuous operation..

F. Other Supporting Components

The following passive and support devices will be used for the stable operation of the system:

1. Resistors: For current limiting and biasing circuits.
2. Capacitors: For filtering and voltage stabilization.
3. Voltage Regulator ICs: For maintaining a stable voltage supply to modules.
4. Connecting Wires and Breadboard: For easy testing and prototyping.
5. LED Indicators: For displaying status and debugging purposes.
6. Switches and Jumpers: For reset and mode selection operations.

VIII.RESULTS, CONCLUSION, AND FUTURE SCOPE

A. Output and Results:

The system designed was successfully tested under various field conditions. It was ensured that the GPS coordinates and sensor readings were sent correctly to the monitoring system. It may be noted here that the system designed showed stable, reliable, and real-time performance under various field conditions.

B. Observed Outputs:

- a) The GPS module offered information regarding the real-time location of the animal in terms of latitude and longitude.
- b) The temperature and heart rate sensors offered information regarding changes in the physical condition of the animal.
- c) Data transmission to the mobile application via Wi-Fi/GSM was stable and consistent.
- d) Response time was within 2-3 seconds, offering near real-time monitoring.
- e) Power consumption was low, making it suitable for use in outdoors for a long period of time with a rechargeable battery.

C. Graphical / Display Output:

- Live tracking map displaying the location of the animal.
- Sensor dashboard displaying body temperature and heart rate levels.
- Alert notification generated for parameters exceeding normal limits.

D. Summary of Results:

| Sr. No. | RESULTS | |
|---------|---------------------|---|
| | PARAMETER | OBSERVED PERFORMANCE |
| 1. | GPS Accuracy | ±5 meters |
| 2. | Response Time | 2–3 seconds |
| 3. | Power Consumption | Low (runs 18-20 hours on single charge) |
| 4. | Communication Range | Up to 30 m (Wi-Fi) / Entire cellular area (GSM) |
| 5. | Data Transmission | Reliable and continuous |
| 6. | System Stability | High during continuous operation |

Table 1: summary table of results

Inference: As depicted in Table 1 above, the system has been successful in achieving its objective of monitoring the location of the cattle and the level of stress efficiently with considerable accuracy.

E. Advantages Achieved

- a) Real-time GPS tracking of cattle minimizes the risk of theft and loss.
- b) Continuous health monitoring assists in the early detection of stress or illness.
- c) Wireless communication allows for monitoring from anywhere.
- d) Cost-effective for monitoring of multiple animals.
- e) Labor is minimized for efficient management.

F. Limitations of the Study

The proposed system is considered a prototype model and may need optimization for large-scale commercial use. Some of the areas that need further investigation include battery life, network coverage in remote rural areas, and durability of sensors in harsh environments. Future developments in communication technology and energy management will improve the overall performance of the system.

G. Conclusion

The developed IoT-based cattle monitoring system successfully integrates location tracking and health sensing into a single wearable solution. By enabling real-time observation of cattle movement and physiological conditions, the system contributes to improved livestock safety and management efficiency. The implementation demonstrates stable performance, low power consumption, and practical usability in field conditions. Overall, the proposed system provides a cost-effective and scalable approach for modernizing livestock farming through smart technology and data-driven monitoring.

H. Future Scope

There are various opportunities for future improvements that can enhance the capabilities of the proposed system. For instance, the system can be integrated with cloud platforms such as Firebase or ThingSpeak, which can offer advanced features such as long-term storage of the collected data and analytics. Moreover, the system can be integrated with the LoRa communication protocol, which can allow the system to operate in vast areas of rural regions where network connectivity is low. A mobile application can be designed to offer farmers advanced features such as real-time notifications, activity logs, and data visualization. In addition, Artificial Intelligence can be integrated into the system to offer features such as stress prediction and health anomaly detection. Moreover, the system can be designed to operate on solar power, which can allow the system to operate in remote areas. In addition, the system can be integrated with humidity, motion activity, and feeding behavior sensors to enhance the accuracy of the system in monitoring the health of the livestock.

IX. ACKNOWLEDGMENT

The authors would like to express their sincere gratitude for the continuous guidance and valuable suggestions provided by the project guide for the development of this project. We would also like to express our gratitude to the Department of Electrical

Engineering, Tulsiramji Gaikwad Patil College of Engineering and Technology, for providing us necessary facilities for this project. We would also like to express our special appreciation for the institution for providing us an opportunity for innovative learning. We would also like to express our gratitude to our family and friends for their motivation and support in the completion of this project.

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