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IoT-Based Animal Health Monitoring System

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Abstract

Continuous monitoring of livestock and pet health is critical for preventing disease spread, reducing labor dependencies, and enhancing agricultural productivity. Traditional animal husbandry relies heavily on manual inspections, which frequently miss early indicators of systemic distress and lead to delayed therapeutic interventions. This research presents an integrated, Internet of Things (IoT)-enabled non-invasive animal health and environmental monitoring framework. The system incorporates a multi-sensor array—comprising an LM35/DS18B20 body temperature sensor, an optical pulse/heart rate sensor, a DHT11 ambient temperature and humidity sensor, and an NMEA-based GPS tracking module interfaced with an ATmega328P processing platform (Arduino Uno/Nano). Telemetric data acquisition and cloud synchronization are accomplished using an ESP8266 Wi-Fi transceiver and a SIM-based GSM module, enabling real-time telemetry streaming to the ThingSpeak IoT platform and automated SMS alerting. Experimental validation across bovine and feline specimens demonstrated robust real-time tracking of vital physiological metrics (38.50°C–39.50°C baseline body temperature; 48–84 BPM heart rate) alongside microclimatic parameters. The continuous data streaming architecture eliminates human oversight error, supports early disease diagnosis, and provides a scalable framework for precision livestock management.

Keywords: Internet of Things; Animal Health Monitoring; Precision Livestock Farming; Telemetry; ESP8266; Sensor Networks; Microclimatic Sensing.

How to Cite This Article

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Introduction

Animal healthcare monitoring plays an indispensable role in controlling pathogen dissemination, protecting public health, and optimizing livestock reproduction cycles. Unfavorable environmental conditions, poor sanitation, and nutritional deficiencies directly exacerbate biological vulnerability in animals, facilitating disease propagation. Effective livestock management necessitates maintaining clean, dry, and thermally regulated habitats that permit unrestricted mobility and consistent access to nutritional inputs.

Conventional diagnostics rely on periodic visual checks or invasive veterinary examinations, which fail to capture continuous physiological trends and often detect pathological conditions only after significant clinical progression. Advanced sensing topologies offer non-invasive alternatives. Attached external sensors capture surface bio-metrics, whereas non-attached or invasive implantable sensors monitor internal visceral metrics. Modern wireless sensor networks (WSN) leverage short-range technologies (such as Bluetooth and Zigbee), long-range communications, and Internet of Things (IoT) middleware architectures to transmit physical data over long distances.

This study introduces an integrated, non-invasive IoT animal monitoring platform designed to record core physiological parameters (body temperature and heart rate) alongside microclimatic conditions (ambient temperature and ambient relative humidity). The captured data is processed onboard via microcontroller architecture, rendered locally on a liquid-crystal display (LCD), uploaded to a cloud-based dashboard (ThingSpeak), and routed through cellular communication networks for remote telemetry and automated alerting.

Literature Review

The shift from manual, labor-intensive livestock management to automated, industrialized farming paradigms has driven significant technological evolution in animal health tracking over the last two decades:

- Electronic identification systems introduced around 2001 utilized static database logging via ear tags, neck collars, and ruminal bolus sensors.
- Mobile observation units (BMOO) developed in 2003 incorporated PIC microcontrollers and Bluetooth wireless links to aggregate sensor data within short transmission radii (<10 m) to restrict local infection vectors.
- Wireless sensor motes introduced in 2012 enabled distributed in-network processing for continuous cattle monitoring.
- Bhosale et al. presented an IoT health monitoring framework combining temperature sensors, accelerometers, and GPS units to relay cattle physical states directly to remote veterinary centers.
- Shinde et al. demonstrated a cattle health tracking layout utilizing behavioral and bio-sensing nodes to map heart rates and thermal outputs, significantly reducing inspection overhead.
- Kumari and Yadav developed a prototype using a Raspberry Pi 3 controller integrated with bio-sensors to capture physiological metrics alongside environmental variables, transmitting real-time analytics to cloud interfaces and Android applications.

Research Gap

Despite previous technological advances, several limitations persist in existing systems:

1. Many deployed frameworks rely solely on short-range transmission protocols (e.g., local Bluetooth or point-to-point Zigbee) without seamless cloud backend routing.
2. Standard commercial implementations lack multi-tier notification redundancies (such as simultaneous cloud graph visualization and cellular GSM text alerts).
3. Most systems focus exclusively on animal biological vitals while omitting microclimatic parameters (ambient air quality, temperature, and humidity) that trigger environmental stress.
4. High computational costs and high power consumption restrict the widespread adoption of wearable livestock hardware.

Novelty

This work implements a low-cost, hybrid communication system that unifies physiological vital tracking (heart rate and core body temperature) with environmental microclimate monitoring (humidity and ambient temperature). The design features dual cellular/Wi-Fi telemetry (GSM + ESP8266) interfaced directly with an ATmega328P controller, providing cloud analytical charting on ThingSpeak alongside SMS alert capability. The non-invasive sensor assembly functions reliably across both large livestock (bovine) and domestic pets (feline).

Objectives

1. Design a hardware-software system to measure physiological (body temperature, heart rate) and environmental (ambient temperature, humidity) parameters in real time.
2. Develop controlling mechanisms for data thresholding and local/remote notification.

3. Construct a cloud-enabled user dashboard for graphical visualization and historical data logging via IoT platforms.
4. Enable early anomaly detection to trigger timely therapeutic interventions.
5. Facilitate continuous remote access to reduce reliance on frequent manual checks.
6. Optimize agricultural resource allocation and mitigate financial loss from undetected livestock mortality.

Materials and Methods

System Architecture

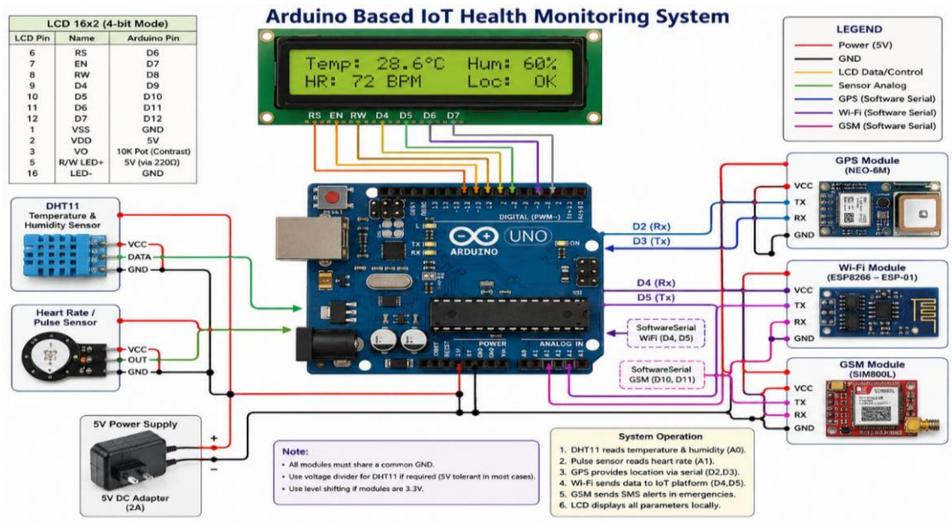

Fig. 1. *Hardware circuit schematic depicting interconnections between the ATmega328P controller, bio-sensors, environmental nodes, LCD, GPS, ESP8266 Wi-Fi, and GSM modules.*

The overall architecture centers around an ATmega328P microcontroller board (Arduino Uno / Nano). The inputs consist of a DHT11 relative humidity and temperature module, an optical pulse sensor, an LM35/DS18B20 body temperature sensor, and an NMEA GPS module. Outputs and transmission components include a 16×2 character LCD, an ESP8266 Wi-Fi trans-ceiving node, and a GSM module powered by a regulated direct-current adapter source.

The structural arrangement of the electronic processing system and sensor lines is depicted in Fig. 1.

Hardware Component Specifications

The component details used in the prototype are listed in TABLE 1.

Table 1. *Component Specifications*

Parameter / Component	Functional Specification / Description
Microcontroller	ATmega168 / ATmega328P (Arduino Nano / Uno architecture)
Operating Voltage	5V DC
Recommended Input Voltage	7V– 12V DC
Extreme Input Voltage Limits	6V – 20V DC
Digital I/O Pins	14 (6 supporting Pulse-Width Modulation - PWM)
Analog Input Pins	8 channels
DC Current per I/O Pin	40mA
Flash Memory	16KB (ATmega168) / 32 KB (ATmega328P); 2 KB} used by bootloader
SRAM / EEPROM	2KB SRAM, 1 KB EEPROM (ATmega328P)
Clock Frequency	16MHz crystal oscillator
Board Dimensions	0.73× 1.70 (45mm ×18mm); Mass: 5 g
Visual Display Unit	16× 2 Character LCD (Liquid Crystal Display)

Ambient Sensor (DHT11)	Calibrated digital output; 3.5V–5.5 V DC; NTC thermal element
Body Temp Sensor (LM35)	Linear +10mV ℃; range -55℃ to +150℃ accuracy pm 0.25℃
Body Temp Sensor (DS18B20)	1-Wire digital thermometer; range -55℃ to +125℃
Wi-Fi Module	ESP8266 SOC; integrated TCP/IP stack; 3.3V logic level
Cellular Transceiver	GSM Modem (UART Serial Interface)
Positioning Module	GPS Satellite Receiver (minimum 3-satellite tracking for 2D position)

Detailed Pin and Interface Descriptions

The standard pin configurations for the Arduino Nano hardware implemented during prototyping are summarized in TABLE 2.

Table 2. *Arduino Nano Pin Layout Specifications*

Pin Number	Name	Type	Description
1–2, 5–16	D0–D13	I/O	Digital input/output ports 0 to 13
3, 28	RESET	Input	Active-low system reset line
4, 29	GND	Power	Ground potential connection
17	3V3	Output	+3.3V regulated power supply output
18	AREF	Input	Analog-to-Digital Converter reference input
19–26	A7–A0	Input	Analog input channels 0 to 7
27	+5V	Output/Input	+5 V regulated output line or external input line
30	VIN	Power	Unregulated external input voltage line (6V–20V)

For local user feedback, a 16×2 liquid crystal display is attached to the processing board. The pin routing for the LCD module is detailed in TABLE 3.

Table 3. *16×2 LCD Interface Pin Specifications*

Pin Number	Symbol	Function / Description
1	VSS	System Ground connection
2	VCC	Module Operating Voltage connection +5V DC
3	VEE	Display Contrast Adjust via variable potentiometer
4	RS	Register Select: RS=0 (Command Register), RS=1 (Data Register)
5	R/W	Read/Write Select: R/W=0 (Write operation), R/W=1 (Read operation)
6	EN	Enable line; initiated via positive-going latch pulse
7–14	DB0–DB7	8-bit bidirectional Data Bus lines
15	LED+	Backlight Anode (+5V) connection
16	LED-	Backlight Cathode (Ground) connection

Mathematical Modelling and Governing Equations

Temperature Sensor Characterization

The analog voltage output of the LM35 thermal transducer scales linearly with Centigrade temperature according to (1):

$$V_{out} = S_T \cdot T_{body} \quad (1)$$

where S_T = 10 mV/°C represents the sensitivity scale factor, V_{out} is the analog voltage output, and T_{body} represents the measured biological temperature.

The raw 10-bit Analog-to-Digital Converter (ADC) count value N_{ADC} generated by the ATmega328P micro-controller under a reference voltage V_{ref} = 5.0 V translates to temperature via (2):

$$T_{body} = \frac{N_{ADC} \cdot V_{ref}}{1024 \cdot S_T} = \frac{N_{ADC} \cdot 5000\ mV}{1024 \cdot 10 mV/°C} \quad (2)$$

Heart Rate Determination

Heartbeat frequency calculation uses periodic photo-plethysmo-graphic (PPG) pulse counts evaluated over time intervals according to (3):

$$BPM = \left(\frac{N_{pulses}}{\Delta t}\right) \cdot 60 \quad (3)$$

Where, N_{pulses} indicates total detected peak signals within sampling duration Δt (measured in seconds), yielding calculated beats per minute (BPM).

Microclimate Humidity and Heat Index Modeling

Ambient relative humidity (RH) and temperature T_{amb} measured by the DHT11 module combine to form the effective environmental heat stress condition, modeled using the reduced Steadman heat index equation shown in (4):

$$HI = c_1 + c_2 T_{amb} + c_3 RH + c_4 T_{amb} RH + c_5 T_{amb}^2 + c_6 RH^2 \quad (4)$$

where c_1 through c_6 are regression constants used to monitor heat stress risk in domestic and agricultural animals.

Experimental Setup and Testing

Circuit Integration and Modular Testing

The system components were evaluated independently before assembly, ensuring signal continuity across each interface:

1. Voltage regulation stages were verified under variable DC inputs (6 V–12 V) to maintain a stable output of +5.0 V and +3.3 V.
2. Serial communication buses (UART between Arduino, ESP8266, and GSM) were configured at a matching baud rate (9600 bps).
3. Analog sensor nodes were validated against calibrated reference tools.

The structural integration of the experimental circuit inside the protective casing is shown in Fig. 2 and Fig. 3.

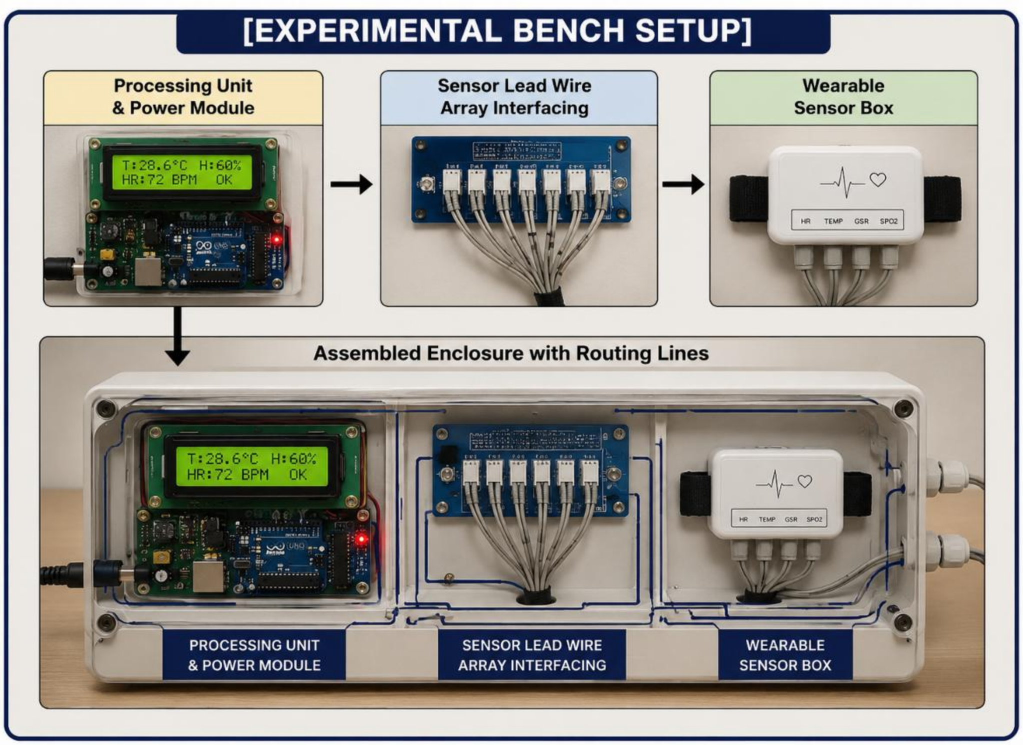

Fig. 2. *Bench assembly showing modular electronics and wiring leads prior to field enclosure.*

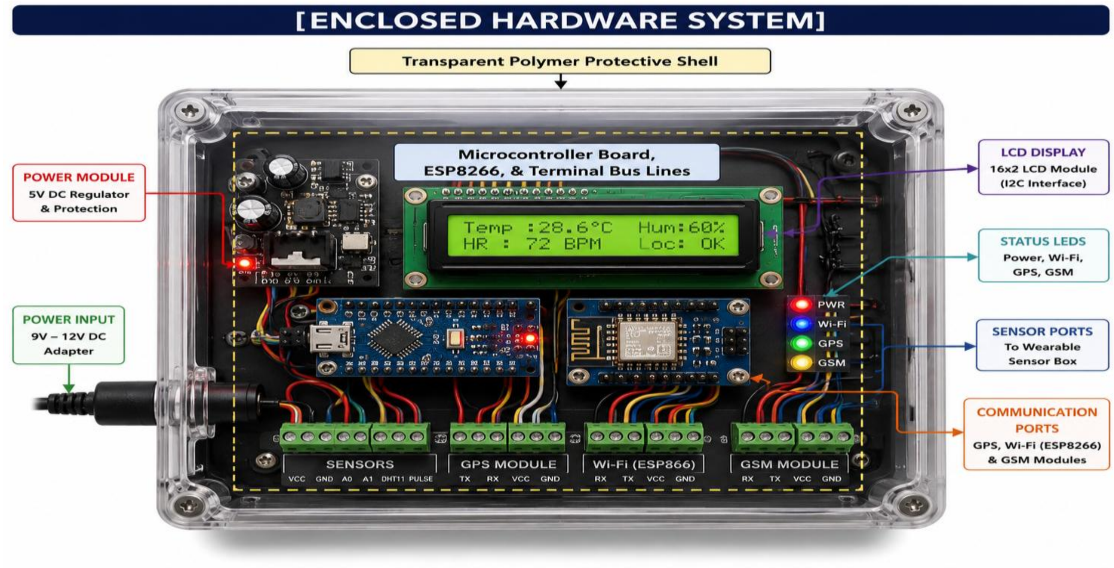

Fig. 3. *Fully assembled, portable, weather-resistant hardware unit housing the control electronics.*

Experimental Protocol

Field evaluations were performed on both bovine (cattle) and feline (cat) subjects to verify multi-species compatibility:

- Cattle Trials: Conducted on site in Talegaon Dabhade. Wearable sensor harnesses were mounted externally on cattle subjects as shown in Fig. 4. Core body temperature and heartbeat rates were recorded continuously across various ambient conditions.
- Feline Trials: Tested on domestic cat subjects as shown in Fig. 5. Sensors were attached non-invasively using soft fabric wraps to measure physiological response metrics, while transmitting telemetry directly to an adjacent laptop station.

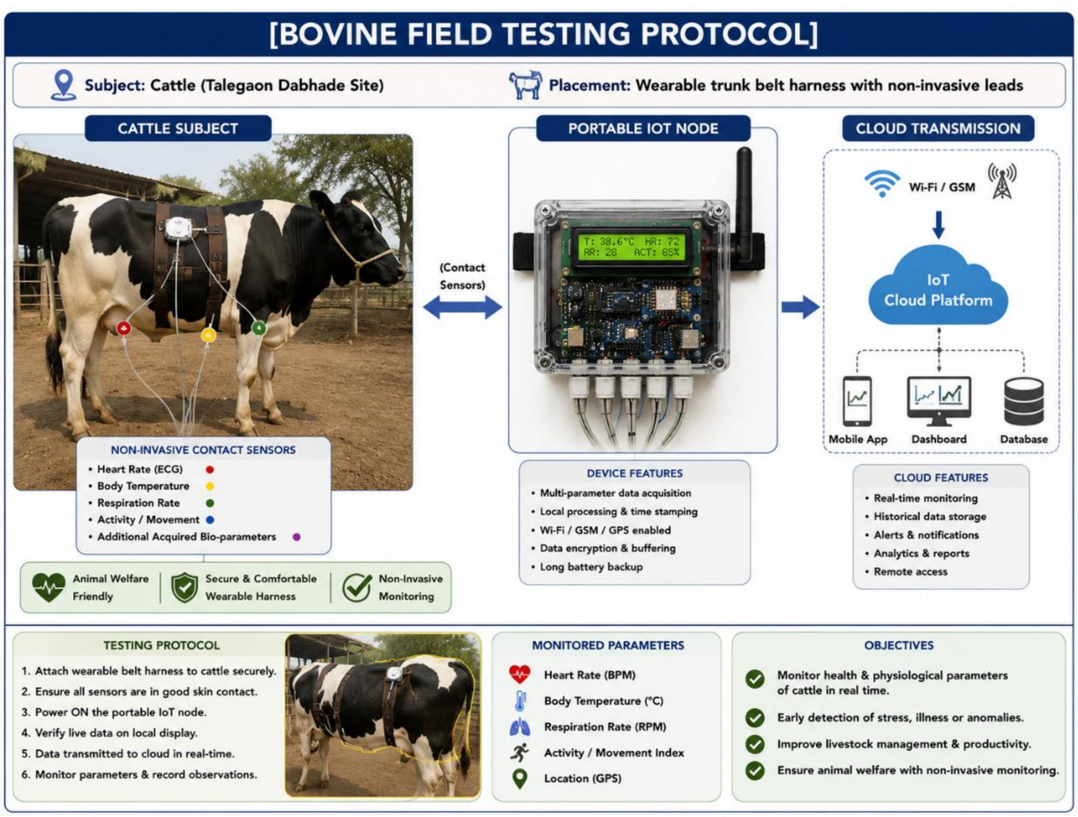

Fig. 4. *Experimental setup and non-invasive sensor placement during cattle trials at Talegaon Dabhade.*

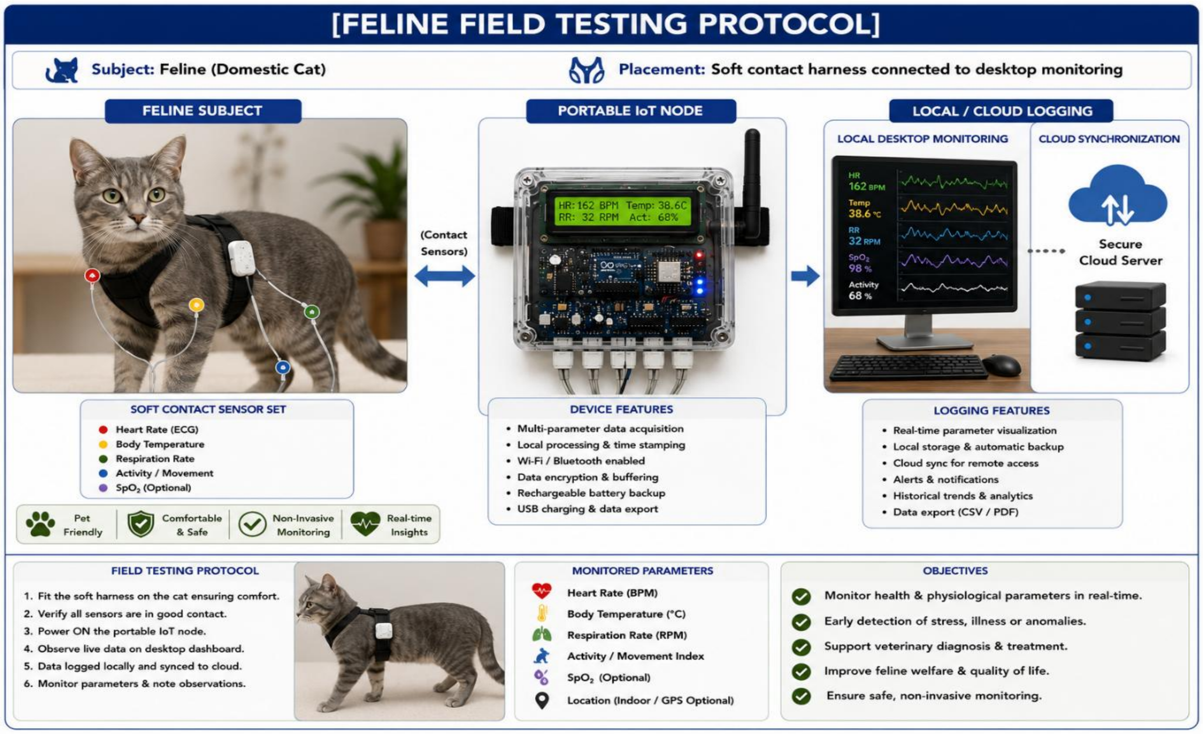

Fig. 5. *Experimental setup showing bio-sensor attachment and real-time validation on a feline test subject.*

Results and Discussion

Physiological and Environmental Data Logging

System performance was evaluated by tracking bio-metric responses under standard operating conditions. Baseline physiological ranges recorded across healthy test subjects are summarized in TABLE 4.

Table 4. *Measured Health Parameters*

Parameter	**Healthy Baseline Range**	**Critical Threshold Value**	**Observed Diagnostic Condition**
Core Body Temp (Tbody)	38.50°C – 39.50°C	> 41.00°C	High fever / acute systemic infection
Core Body Temp (T_{body})	38.50°C – 39.50°C	< 37.50°C	Indigestion, mild fever, poisoning
Heart Rate (BPM)	48 – 84 BPM (Cattle)	> 90 BPM or < 40 BPM	Cardiac distress, acute stress response
Ambient Temp ($T_{amb.}$)	20.0°C – 32.0°C	> 35.0°C	Environmental thermal stress risk
Relative Humidity (RH)	40% – 70%	> 85%	Pathogen growth risk

IoT Cloud Analytics (ThingSpeak Synchronization)

Real-time sensor logs were transmitted through the ESP8266 node to the ThingSpeak server platform. The platform separated incoming streams into four dedicated monitoring channels, as shown in Fig. 6:

- Field 1 Chart: Real-time pulse rate tracking (BPM) over time.
- Field 2 Chart: Ambient relative humidity trends (RH, %) over time.
- Field 3 Chart: Ambient temperature variation (T_{amb}, °C) over time.
- Field 4 Chart: Biological body temperature monitoring (T_{body}, °C) over time.

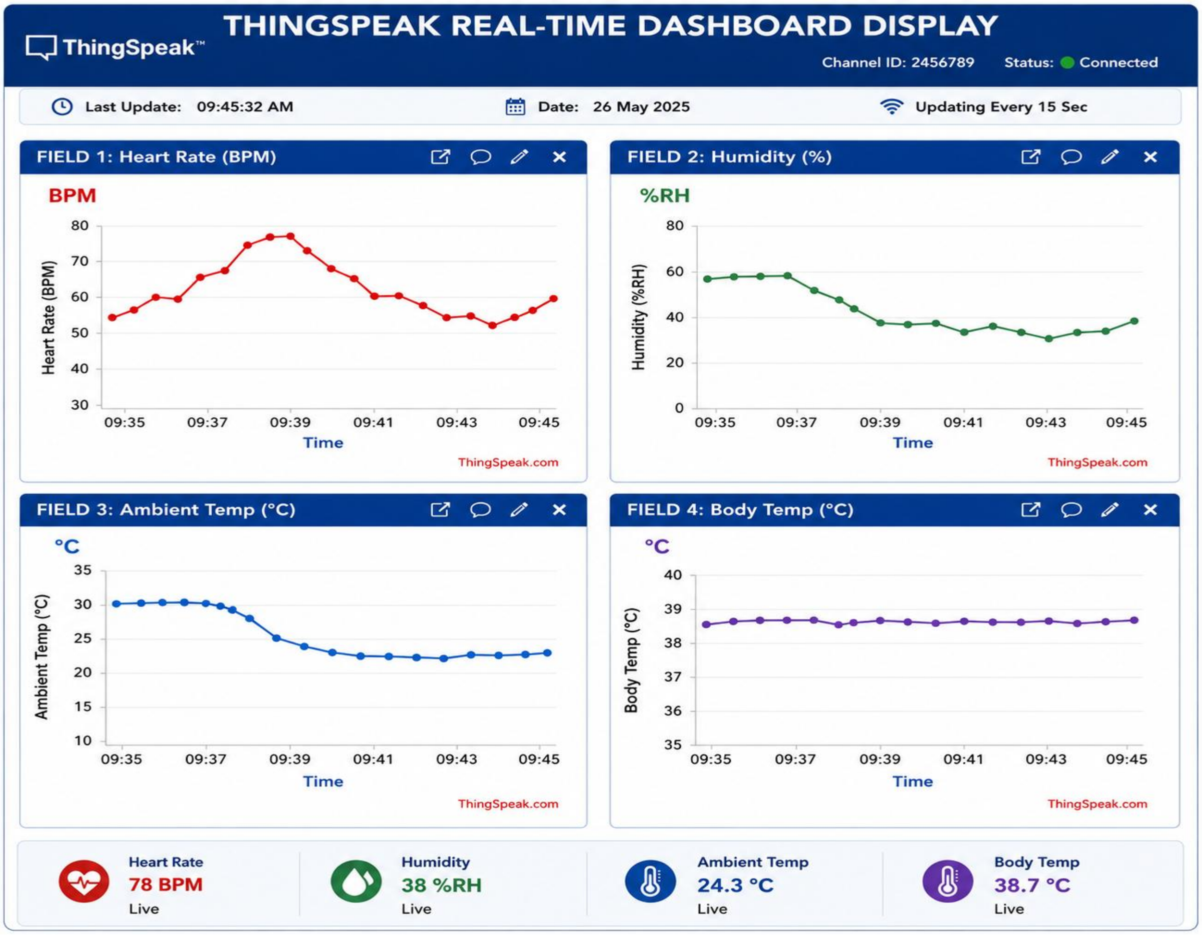

Fig. 6. *Real-time telemetry dashboard on the ThingSpeak IoT platform showing parameters across Channel Fields 1–4.*

Continuous telemetry allowed immediate identification of physiological anomalies. When core body temperatures exceeded 41.0°C or dropped below normal baseline ranges, the system dispatched automated warning alerts over cellular networks via the onboard GSM module.

Engineering Implications

1. Automated Diagnostic Logging: Replaces manual checkups with continuous digital telemetry, preventing diagnostic errors caused by infrequent visual checks.
2. Low-Power Design: Utilizing ATmega microcontrollers alongside low-power sensors reduces overall energy consumption, making the system suitable for battery-powered field operation.
3. Dual Telemetry Redundancy: Integrating both ESP8266 Wi-Fi nodes and GSM cellular connections ensures uninterrupted data streaming across both urban facilities and remote grazing areas.

Industrial Applications

- Precision Livestock Farming (PLF): Scalable monitoring of dairy cattle herds to improve milk production yields.
- Veterinary Quarantine Facilities: Non-contact biological tracking that minimizes pathogen exposure risks for attending staff.
- Pet Healthcare: Continuous home monitoring for recovering domestic animals and pets.

Sustainability

Continuous real-time tracking provides early warning of health issues, reducing disease outbreaks across livestock herds. Early treatment minimizes pharmaceutical overuse, lowers veterinary expenses, and reduces mortality rates, supporting sustainable livestock production systems.

Limitations

1. The prototype documentation does not specify long-term battery management features, such as deep-sleep cycling or solar harvesting circuits.

2. Hardware enclosure details for prolonged field use under extreme weather conditions (IP ratings) are not provided in the source report.
3. Physical movement artifacts can temporarily impact photoplethysmographic heart rate readings during intense animal motion.

Future Scope

- AI-Driven Predictive Analytics: Integrating machine learning models directly into cloud backends to forecast disease onset based on subtle physiological shifts.
- Energy Harvesting Integration: Incorporating solar panels or kinetic energy generators to extend field operating lifespans.
- Enclosure Optimization: Designing miniaturized, IP67 waterproof collar enclosures for rugged agricultural use.
- Expanded Sensor Arrays: Adding multi-axis accelerometers for behavioral rumination tracking and air quality sensors for comprehensive environmental management.

Conclusion

This study successfully implemented and validated a low-cost, integrated IoT health and environmental monitoring framework for animals. Combining core body temperature sensing, heart rate evaluation, microclimate monitoring, and GPS location tracking into a single ATmega328P platform enables continuous, non-invasive health assessment. Dual Wi-Fi and GSM telemetry ensures reliable data delivery to local LCD displays, cloud analytical dashboards (ThingSpeak), and mobile notification systems. Field trials across bovine and feline subjects confirmed real-time operational stability. This automated approach eliminates manual monitoring errors, supports early therapeutic intervention, and offers a scalable platform for modern precision livestock management.

Acknowledgment

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Nomenclature

Symbol	Definition	Units
T_{body}	Core Biological Body Temperature	$^\circ\text{C}$
T_{amb}	Ambient Environment Air Temperature	$^\circ\text{C}$
V_{out}	Transducer Output Voltage	V / mV
S_T	Temperature Sensor Sensitivity Scale Factor	$\text{mV}/^\circ\text{C}$
N_{ADC}	Analog-to-Digital Converter Digital Integer Output	Dimensionless
V_{ref}	ADC Operating Reference Voltage	V
RH	Ambient Relative Humidity	$\%$
BPM	Heart Pulse Frequency (Beats Per Minute)	min^{-1}
N_{pulses}	Accumulated Pulse Counts	Dimensionless
Δt	Pulse Sampling Time Interval	s
HI	Environmental Heat Stress Index	Dimensionless

Abbreviations

Abbreviation	Expansion
ADC	Analog-to-Digital Converter
BPM	Beats Per Minute
CPU	Central Processing Unit
EEPROM	Electrically Erasable Programmable Read-Only Memory
GPS	Global Positioning System

GSM	Global System for Mobile Communications
I/O	Input / Output
ICSP	In-Circuit Serial Programming
IoT	Internet of Things
LCD	Liquid Crystal Display
NMEA	National Marine Electronics Association
NTC	Negative Temperature Coefficient
PLF	Precision Livestock Farming
PPG	Photoplethysmography
PWM	Pulse-Width Modulation
RAM	Random Access Memory
SLR	Systematic Literature Review
SOC	System on Chip
SPI	Serial Peripheral Interface
SRAM	Static Random Access Memory
TTL	Transistor-Transistor Logic
UART	Universal Asynchronous Receiver-Transmitter
WSN	Wireless Sensor Network

References

1. P. S. Kurhe and S. S. Agrawal, "Real time tracking & health monitoring system of animal using ARM7," *International Journal of Engineering Trends and Technology*, vol. 4, no. 3, pp. 43–45, 2013.
2. P. Verma and J. S. Bhatia, "Design and development of GPS-GSM based tracking system with animal health monitoring," *International Journal of Computer Applications*, vol. 975, p. 8887, 2014.
3. S. Sk, M. Sateesh, G. N. V. Chaitanya, and G. Prakash Babu, "Implementation of GSM based accelerometer and temperature monitoring system," *Research Journal of Engineering Sciences*, vol. 2, no. 3, pp. 43–45, Apr. 2013.
4. R. B. Sathe and A. S. Bhide, "GPS based animal tracking and health monitoring system," *World Journal of Science and Technology*, vol. 2, no. 4, pp. 97–99, 2012.
5. P. Keertana and B. Vanathi, "IoT based animal health monitoring and tracking system using ZigBee," *International Journal of Research and Technical Innovation (IJRTI)*, vol. 2, no. 4, pp. 2456–3315, 2017.
6. R. Brugarolas, T. Latif, J. Dieffenderfer, K. Walker, S. Yuschak, B. L. Sherman, et al., "Wearable heart rate sensor system for wireless canine health monitoring," *IEEE Sensors Journal*, vol. 16, no. 10, pp. 3455–3464, May 2016.
7. H. Wang, A. O. Fapojuwo, and R. J. Davies, "A wireless sensor network for feedlot animal health monitoring," *IEEE Sensors Journal*, vol. 16, no. 16, pp. 6420–6431, Aug. 2016.
8. K. Anuj and G. P. Hancke, "A ZigBee-based animal health monitoring system," *IEEE Sensors Journal*, vol. 15, no. 1, pp. 614–623, Jan. 2015.
9. P. Anushka, P. Chetana, P. Neha, and T. Rohini, "Smart health monitoring system for animals," in *Proc. Int. Conf. Green Comput. Internet Things (ICGCIoT)*, 2015, pp. 1412–1415.
10. M. Brložnik and V. Avbelj, "Wireless electrocardiographic monitoring in veterinary medicine," in *Proc. 38th Int. Conv. Inf. Commun. Technol. Electron. Microelectron. (MIPRO)*, May 2015, pp. 356–359.
11. C. Hung, B. Koukil, Y. Zha, A. Tai, Y. C. Tai, and T. K. Hsiai, "A wireless ECG recording system for small animal models of heart regeneration," *IEEE Transactions on Biomedical Engineering*, vol. 62, no. 1, pp. 340–347, 2015.
12. R. N. Handcock et al., "Monitoring animal behavior and environmental interactions using wireless networks, GPS collars and satellite remote sensing," *Sensors*, vol. 9, no. 5, pp. 3586–3603, 2009.