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Beast Sentinel: Smart IoT-Based Wildlife Tracking and Intrusion System

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Abstract: Human-wildlife conflict has emerged as a serious concern in regions adjacent to wildlife sanctuaries, particularly where predators such as tigers and leopards stray into human settlements. These encounters often result in loss of life, property damage, and retaliatory harm to wildlife. Traditional methods of monitoring, such as manual patrolling and camera traps, are often inefficient and reactive, lacking the capability for real-time alerts. To address this critical issue, our project proposes a smart IoT-based wildlife tracking and intrusion alert system. The system utilizes GPS and motion sensor-enabled collars fitted on wild animals to track their movements continuously. When a predator enters a predefined danger zone, such as within 2 kilometres of a village, the system automatically sends SMS alerts to villagers and forest authorities. The solution ensures early detection, real-time tracking, and timely intervention, significantly reducing the risk of human-wildlife conflict. The design also includes features like solar-powered operation for remote areas and cloud-based data logging for further analysis. This project aims to promote safer human-wildlife coexistence through the power of modern technology.
Keywords: Internet of Things, ESP32, GPS, GSM, Human-Wildlife conflict, Monitoring, Collar

I. INTRODUCTION

The proposed system is an IoT-based wildlife monitoring and alert solution meticulously designed to mitigate human-wildlife conflicts, particularly in villages situated near forested regions. This innovative approach integrates modern technology with wildlife conservation efforts by employing GPS and motion sensor-enabled tracking collars that are securely fitted onto wild predators such as tigers and leopards. These intelligent collars function continuously, monitoring the real-time movement and behavioural patterns of the animals. As soon as a predator approaches or enters a predefined danger zone, typically a 2 km radius surrounding a village, the system is triggered to take immediate action. It sends out automated alerts in the form of SMS notifications or phone calls to both villagers and forest officials, thereby enabling timely precautionary measures. This rapid communication ensures that residents can safeguard themselves, their livestock, and their property before any harm occurs. Moreover, the system features a centralized, user-friendly dashboard that provides real-time tracking and visualization of the animal's location and movement history. Forest officials and relevant authorities can access this dashboard remotely, which facilitates quicker and more informed decision-making. This functionality not only aids in managing emergency situations but also contributes to the creation of a historical movement database for better future planning and predictive analysis. By combining cutting-edge IoT devices with data-driven insights, this proactive solution aims to foster a safer living environment for rural populations while promoting peaceful coexistence with wildlife. In the long run, it has the potential to reduce the frequency of violent encounters, prevent unnecessary harm to both humans and animals, and support wildlife conservation through ethical and non-invasive means.

II. LITERATURE SURVEY

First, the application of the Internet of Things (IoT) in wildlife conservation has significantly evolved, providing real-time monitoring, tracking, and alert systems to mitigate threats to biodiversity. The reviewed literature emphasizes innovations ranging from sensor integration to artificial intelligence for enhanced wildlife surveillance.

1) Internet of Things – Wildlife Conservation and Its Challenges

(Ratnesh Kumar Choudhary, 2020)

Choudhary's study provides a foundational overview of IoT applications in animal tracking and health monitoring. The proposed system employs collar kits embedded with multiple sensors—heart rate, temperature, pulse, and respiratory sensors—alongside a GPS module and ZigBee transmitter. This setup allows continuous data flow to monitoring stations. The paper also identifies two key categories of implementation barriers: natural challenges (like terrain and weather) and technical challenges (including sensor precision, energy limitations, and network reliability)

2) IoT-Based Wildlife Monitoring System
(Sushma Sree et al., 2023)
This paper introduces the concept of virtual fencing, utilizing GPS and sensor nodes to create invisible barriers that deter wildlife from entering risky zones like highways or urban edges. The system integrates deforestation monitoring through satellite imagery and sensor cameras, which helps in detecting illegal logging and forest degradation. Unlike traditional physical barriers, this approach respects animal behaviour and supports non-intrusive ecosystem management. 7

3) Human-Wildlife Conflict Early Warning System Using IoT and SMS
(Ronoh et al., 2022)
Ronoh et al. focus on human-wildlife conflict (HWC) mitigation using low-cost, low-power systems in Tanzanian national parks. The system utilizes a Passive Infrared (PIR) sensor, a Raspberry Pi camera, GPS, and YOLO-based machine learning algorithms to detect, classify, and alert authorities via SMS when wildlife enters human-dominated areas. This model demonstrates the integration of edge AI and IoT to provide proactive, real-time responses to conflict scenarios.

4) Internet of Things for Wildlife Monitoring
(Xiaohan Liu et al., Chinese Academy of Sciences)
Liu and colleagues offer a comprehensive breakdown of the system architecture for wildlife IoT platforms, emphasizing three major functions: location tracking, habitat monitoring, and behaviour recognition. The study explores different communication technologies (GSM, LTE, IEEE 802.15.4) and introduces a G-tracker prototype that includes satellite positioning, low-power MCU, and solar-powered charging. They also discuss resource-saving mechanisms like MCU sleep cycles and onboard data filtering to improve operational lifespan in remote conditions.

III. METHODOLOGY

The proposed methodology for this project involves the design, development, and deployment of a smart IoT-based system that continuously monitors the movement of wild animals and generates real-time alerts when they approach human settlements. The system aims to prevent human-wildlife conflict by integrating GPS and wireless communication technologies. Initially, the target species (such as tigers or leopards) and their typical movement patterns will be identified, followed by the definition of danger zones, particularly areas within a 2 km radius of villages. The architecture of the IoT-based alert system will then be designed accordingly.

In the hardware development phase, a smart collar will be created using components such as a GPS module for real-time tracking, a GSM module (SIM800L or SIM900) for sending SMS alerts, a motion sensor (either PIR or an accelerometer) to detect active movement, and a microcontroller like ESP32 or Arduino to serve as the processing unit. The collar will also include a solar charging circuit and a battery to ensure uninterrupted operation in the wild. Virtual geofences will be established using the GPS coordinates of sensitive zones, and the system will be programmed to detect breaches of these virtual boundaries.

Upon detection of a breach, the microcontroller will process the GPS data and trigger alerts through the GSM module, notifying villagers, forest guards, and a central monitoring unit via SMS or phone calls. Optionally, a real-time web-based dashboard may be developed to display the animal's current location, log movement history to a cloud platform such as Firebase or Google Cloud, and send push notifications to forest officials via mobile apps or web interfaces.

The system will then undergo testing, including the simulation of animal movement to evaluate the accuracy of GPS tracking, alert triggering mechanisms, and the efficiency of the solar power module. After thorough testing, the system will be deployed in a controlled environment where feedback can be gathered.

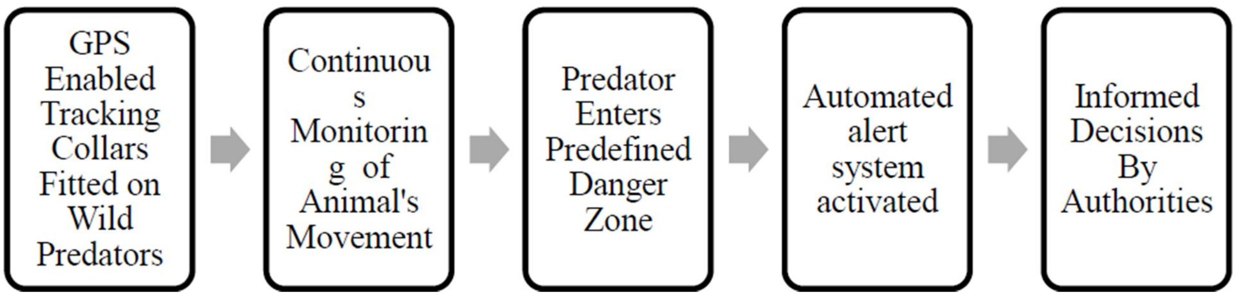

Fig 1. Block diagram of the proposed system

1) GPS-Enabled Tracking Collars Fitted on Wild Predators: Smart collars with GPS and motion sensors are attached to wild animals to track their movement continuously.
2) Continuous Monitoring of Animal's Movement: The system keeps a constant check on the animal's location using IoT-enabled collars.
3) Predator Enters Predefined Danger Zone: When the animal moves into a designated high-risk area near human settlements, the system identifies it as a potential threat.
4) Automated Alert System Activated: Instant alerts are sent via SMS or phone calls to villagers and forest officials, enabling timely preventive action.
5) Informed Decisions by Authorities: Officials use live data and alerts to coordinate emergency responses, deploy teams, or guide villagers, ensuring safety and rapid action.

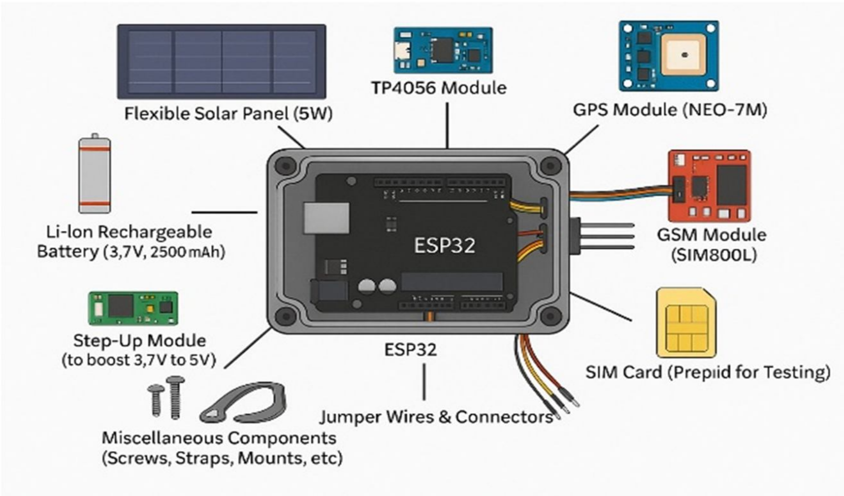

Fig 2. Circuit Diagram

The smart collar circuit combines an ESP32 microcontroller with a GPS (NEO-7M) and GSM module (SIM800L) to enable real-time location tracking and communication. It is powered by a 3.7V, 2500mAh Li-ion battery, which is charged via a 5W flexible solar panel connected through a TP4056 module. A step-up converter raises the battery voltage to 5V for the modules. The ESP32 communicates with the GPS via UART (pins 21 and 22) and transmits location data through the GSM module using a prepaid SIM card. All components are connected with jumper wires and housed in a compact enclosure.

IV. MODELING AND ANALYSIS

The successful implementation of the *Beast Sentinel* project relies on the integration of both hardware and software components. The system's core functionality, real-time wildlife tracking and alert generation, is highly dependent on IoT hardware. Each module plays a critical role in detecting animal movement, processing data, and communicating alerts. The components used and their respective roles are described below: for each quantity that you use in an equation.

A. Hardware Requirements

1) ESP32: Acts as the main microcontroller unit responsible for data processing, GPS coordinate reading, and communication control.

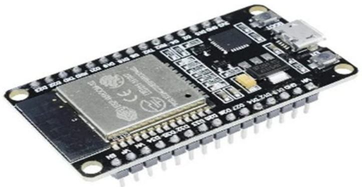

Fig. 3 ESP32

2) GPS Module NEO-7M: Continuously tracks the animal’s geographic location with high accuracy and helps in setting up geofencing boundaries.

Fig. 4 GPS Module Neo 7m

3) GSM Module A7670C: Used to transmit SMS or phone call alerts to villagers and forest authorities upon detecting a breach into the predefined danger zone.

Fig. 5 GSM Module SIM800L

B. *Software Description*

The embedded software is developed using the Arduino IDE and written in C/C++ for the ESP32 microcontroller. The primary functions of the code include GPS data acquisition, geofence monitoring, and SMS notification.

The ESP32 reads real-time GPS coordinates from the NEO-7M GPS module using serial communication. These coordinates are continuously compared against predefined geofence boundaries (defined as a polygon of latitude and longitude points) using a point-in-polygon algorithm.

If the tracked object enters or exits the geofenced area, the ESP32 triggers the SIM800L GSM module to send an SMS alert to a predefined mobile number. The code also includes provisions for parsing NMEA GPS sentences, managing power consumption, handling errors such as GPS fix loss or GSM failure, and retry mechanisms for SMS delivery.

The software is modular, allowing for easy adaptation of the geofence area and update of contact information. Debugging and logging are supported through the serial monitor for real-time tracking during development and testing.

C. Mobile Application

The mobile application is specifically designed for forest officers to monitor and respond to potential human-wildlife conflict. It serves as an interface to track the real-time location of predators (e.g., tigers or leopards) equipped with the GPS-GSM-enabled collar device.

The app is developed using Flutter, making it cross-platform compatible (Android/iOS). Integration with Google Maps API allows for accurate visualization, while backend communication is handled using HTTP over GSM to ensure low-bandwidth operation even in remote areas.

V. CONCLUSION

The integration of GPS and GSM technologies through a collar-based tracking system offers a practical and scalable solution for mitigating human-wildlife conflict. By enabling real-time location monitoring of predators such as tigers or leopards, the system ensures timely alerts to forest officials when animals approach or enter human settlements. The geofencing mechanism, coupled with SMS notifications, empowers authorities to take swift preventive actions, thereby enhancing both wildlife conservation efforts and public safety.

The accompanying mobile application provides an intuitive and secure interface for officers to track animal movement, manage geofence zones, and respond to incidents efficiently. With the use of accessible components such as the NEO-7M GPS module, SIM800L GSM module, and a flexible power system, the design remains cost-effective and field-deployable.

Overall, the system demonstrates a viable and impactful approach to wildlife monitoring and conflict prevention, and can be further enhanced in the future through solar optimization, long-range communication (e.g., LoRa or 4G/5G), and AI-driven behavior prediction.

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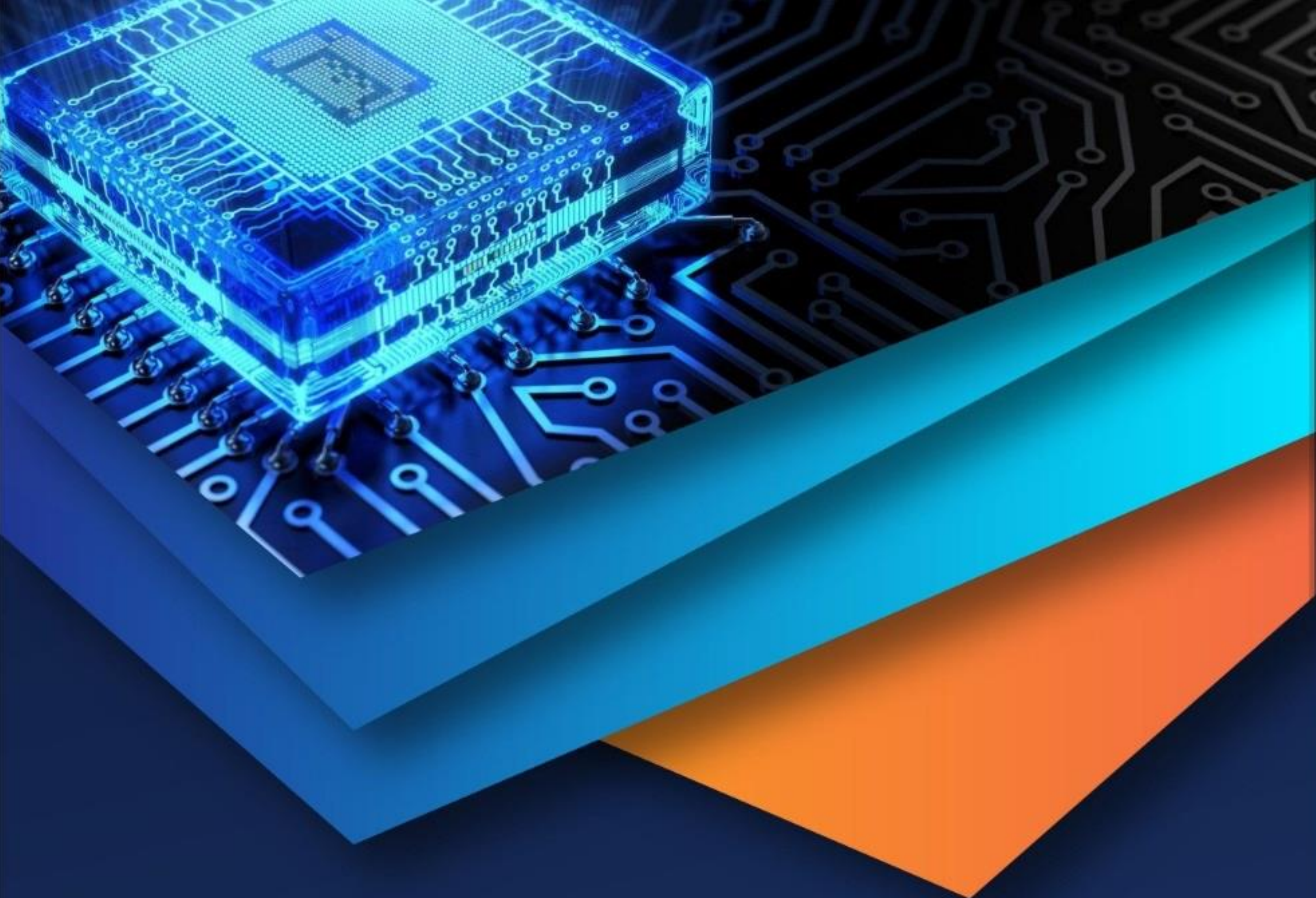

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