and Management

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***Abstract*—Human-wildlife conflicts pose serious threats to crops and human safety in forest-adjacent areas, necessitating innovative solutions. This project presents a smart IoT-based system that leverages ESP-NOW communication on ESP8266 modules to monitor and manage animal movement in real time. Key features include a directional buzzer for localized alerts, a Django-based web interface utilizing Web Sockets for instant updates, and automated messaging to notify nearby villages. With a phpMyAdmin database for reliable data management, this scalable and proactive system effectively mitigates conflicts, ensuring the safety and coexistence of both humans and wildlife.**

Key Words: ESP8266, ESP-NOW Protocol, Realtime Alert Notification, Real-time Web Application, Web Sockets, Directional Buzzer,

I. INTRODUCTION

Human-wildlife conflicts pose a significant threat to agricultural productivity and human safety in areas adjacent to forests. Animals straying out of their natural habitats often cause extensive crop damage and endanger human lives. Existing solutions are inadequate due to the lack of real-time monitoring and timely alerts necessary for effective conflict management. This project addresses these challenges by leveraging IoT technology to develop a smart system for tracking and managing animal movements. The system facilitates proactive interventions through hardware alerts, real-time updates, and automated notifications. It integrates the ESP-NOW communication protocol, ensuring efficient and low-power data transmission for seamless operation.

II. LITERATURE SURVEAY

The reviewed literature highlights various IoT-based approaches aimed at mitigating human-wildlife conflicts through early detection, real-time monitoring, and alert systems. Several studies utilize advanced technologies such as Raspberry Pi, GSM modules, sensors, and deep learning algorithms like YOLO. For instance, a 2021 study proposed a system combining YOLO and a Raspberry Pi to detect and alert drivers about wildlife on highways, reducing accidents. Similarly, IoT-enabled animal detection systems using image processing and machine learning, such as those integrating YOLOv8, have been shown to enhance farm security and ensure humane wildlife deterrence. GSM-based systems also play a vital role in sending timely alerts to stakeholders, such as in Tanzania's low-cost early warning system that uses PIR sensors, GPS, and cameras.

Traditional methods like electric fences and loud noises are increasingly complemented by IoT-driven innovations. Smart solutions, including piezoelectric sensors and infrared detection, offer a more robust alternative, particularly in addressing challenges like habitat loss and crop damage caused by wildlife intrusions. Limitations include dependence on network connectivity, environmental factors affecting accuracy, and computational resource demands for real-time processing. However, these systems collectively demonstrate the potential of IoT and AI to mitigate human-wildlife conflicts, protect endangered species, and promote sustainable coexistence between humans and wildlife.

Traditional barriers, such as electric and chili fences, have been augmented by IoT-driven solutions. Studies like the 2018 "IoT-Enabled Smart Elephant Detection System" highlight the use of machine learning for species recognition and behavioral tracking, while others utilize piezoelectric and infrared sensors for animal intrusion detection. Another study focuses on forest highway safety, employing a Raspberry Pi with a Pi camera and YOLO to warn drivers of wildlife presence. Despite the advancements, limitations such as reliance on network connectivity, environmental constraints on detection accuracy, and computational resource demands remain challenges. Nevertheless, these systems collectively demonstrate the potential of IoT and AI to enhance wildlife monitoring, reduce human-wildlife conflicts, and contribute to sustainable ecological practices. The integration of IoT in ecological research not only improves wildlife monitoring but also enables predictive analytics through AI and machine learning.

IoT platforms have also been applied for ecological research, such as the 2015 study "Internet of Things for Wildlife Monitoring," which integrates GSM-based trackers and cloud services for habitat observation and behavior analysis. While these systems showcase high potential, they face limitations like dependence on stable network infrastructure, low-light detection inefficiencies, and environmental factors that may reduce accuracy. Despite challenges, the ongoing integration of IoT, AI, and machine learning demonstrates a transformative approach to addressing human-wildlife conflicts and supporting

biodiversity conservation. The integration of IoT in ecological research not only improves wildlife monitoring but also enables predictive analytics through AI and machine learning, offering insights into animal behavior and migration patterns.

III.METHADOLOGY

The **Smart IoT System for Human-Animal Conflict Detection and Management** employs a combination of hardware, software, and communication protocols to provide an efficient and reliable solution for tracking animal movements and mitigating conflicts. The methodology involves the following components:

A. Hardware Implementation

1. **ESP8266 Devices**:

- Low-power ESP8266 modules were used for communication between transmitters attached to animals and a central receiver (base station).
- The transmitters operate using the ESP-NOW protocol for lightweight and efficient data transmission.

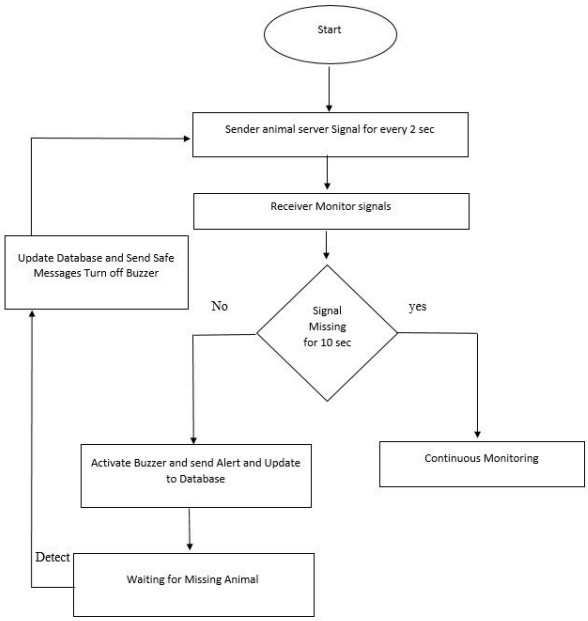

Fig 1 : Flowchart

2. **Alert Systems**:

   A buzzer system is installed at the base station to provide immediate audio alerts in the direction of the animal breach.

B. Software Development

1. **Web Application**:
   A Django-based web application was developed to provide a user-friendly interface for monitoring and managing animal activities.
2. **Database Management**:
   A phpMyAdmin database is used to store historical data on animal movements and system events.

C. Communication Protocols

1. **ESP-NOW Protocol**:
   This lightweight, low-power wireless communication protocol facilitates quick and reliable data transmission between devices without the need for Wi-Fi.
2. **Web Sockets Integration**:
   Real-time updates on animal movements are achieved through Web Sockets, enabling dynamic communication between the server and client.

IV.IMPLEMENTATION DETAILS

1.Signal Transmission by Animals (Sender):

In Fig 1 Each animal in the system is equipped with a lightweight ESP8266-based transmitter designed for efficient and low-power communication. These transmitters send location signals to a central receiver every 2 seconds, ensuring continuous monitoring of the animal's status. The signals provide critical data indicating whether the animal is within the designated safe zone or has breached the boundary. This frequent transmission enables real-time tracking, allowing the system to detect potential breaches promptly. The ESP-NOW protocol is utilized to ensure reliable and fast communication between the transmitter and receiver, even in remote areas with limited network connectivity. This robust mechanism forms the backbone of the system, ensuring accurate and timely detection of animal movements to trigger appropriate responses.

2.Signal Monitoring by Receiver (Base Station):

The base station, equipped with an ESP8266 module, serves as the central hub for monitoring signals transmitted by the devices attached to the animals. It continuously listens for incoming signals from all transmitters at regular intervals of 2 seconds, ensuring real-time monitoring of each animal's status. Each signal received provides the base station with critical information about whether the animal is within the designated safe boundary. If all signals indicate the animals are within the safe zone, no action is taken. However, if a signal shows that an animal has breached the boundary, the base station waits for a confirmation period (e.g., 10 seconds) to ensure the breach is not temporary. Once confirmed, the system triggers an alert mechanism that includes activating a buzzer directed toward the breach location, updating the database with the status of the breach, and sending real-time notifications to nearby villagers and stakeholders. The ESP-NOW protocol ensures reliable and efficient communication, even in remote areas, enabling the system to take timely and effective measures to mitigate human-wildlife conflicts.

3.Detection of Missing Signal:

If a signal from any transmitter is not received by the base station within a predefined timeframe of 10 seconds, the system interprets this as an indication that the

corresponding animal might have moved out of the designated boundary. This time delay acts as a buffer to prevent false alarms caused by temporary disruptions, such as signal interference or momentary obstacles in the transmission path. Once the system flags a missing signal, it initiates a sequence of actions to manage the situation proactively. These actions include activating alert mechanisms, such as a directional buzzer that provides an audible cue towards the breach location, and updating the central database to log the incident. Simultaneously, automated notifications are sent to concerned authorities and nearby villagers, ensuring rapid dissemination of information. This approach ensures timely intervention to mitigate risks associated with human-wildlife conflicts while maintaining system reliability through its fail-safe detection mechanism.

4.Database Update and Alert Activation:

When a boundary breach is detected, the system promptly initiates a series of critical actions to address the situation effectively. Firstly, it activates a buzzer strategically positioned in the direction of the animal's movement, serving as an immediate auditory warning for nearby villagers. This alert helps draw attention to the breach and allows local communities to prepare or take protective measures. Simultaneously, the system updates the central database with comprehensive details about the incident, including the time of the breach, the unique ID of the animal involved, and its last known location. This real-time data logging ensures accurate record-keeping for future analysis and enables tracking of recurring patterns or hotspots. Additionally, the system leverages a web application to send automated alerts to connected devices, such as smartphones or computers, ensuring that all stakeholders—including authorities, wildlife personnel, and farmers—are informed promptly. These notifications provide actionable information, such as the breach location and potential risks, enabling stakeholders to coordinate and respond effectively to mitigate the impact of the breach.

5.Real-Time Notifications:

The system includes a robust web application, developed using Django for the backend and JavaScript for the frontend, to ensure real-time communication and seamless user interaction. This application leverages Web Sockets technology to establish a continuous connection with the database, enabling instantaneous fetching of updates as soon as a boundary breach is detected. When an animal moves out of its designated boundary, the database is updated with the relevant details, such as the time of the breach and the animal's unique identifier. These updates are immediately pushed to the web application in real-time. Through this mechanism, stakeholders, including villagers, farmers, and wildlife officials, are instantly notified about the breach. The notification system provides critical details, such as the animal's last known location and the direction of movement, allowing stakeholders to respond proactively. This real-time notification system ensures that no delays occur in communicating potential risks, thereby enabling swift action to mitigate damage to crops and prevent harm to human lives. The integration of Web Sockets ensures that the communication remains efficient and responsive, even under varying network conditions.

6. Monitoring for Safe Return:

Once a boundary breach is detected and the necessary alerts are issued, the system continues to monitor the animal's status to determine whether it returns to the designated safe area. After the breach is confirmed, the base station keeps tracking the animal's position through periodic signals from the transmitter. If the animal moves back within the designated boundary, the system detects this return and deactivates the buzzer, signaling that the threat has passed. The system then updates the database with the new status, marking the animal as safely returned. Additionally, notifications are sent to stakeholders, such as villagers and wildlife authorities, informing them that the animal is no longer outside the designated boundary, thus ensuring they are aware of the situation's resolution.

7. Safe Status Update:

When the system detects that the animal has returned to the designated safe boundary, it initiates a sequence of actions to communicate this development. First, the buzzer, which was previously activated to alert nearby villagers of the breach, is deactivated, signaling that the situation has returned to normal. Simultaneously, the system updates the database to reflect the new status of the animal, logging details such as the time of return and the animal's identification. This ensures that records are accurate and up-to-date.

8.Continuous Monitoring:

The system continuously operates in real-time to monitor all signals, ensuring a cycle of detection, alert, and resolution for any further breaches.

V. RESULTS

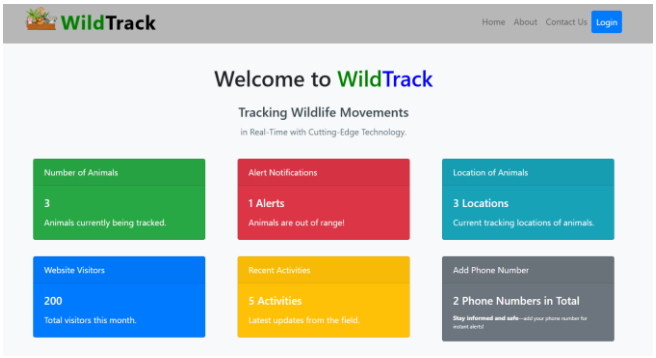

Fig 2: Home page of Wild Track(web application of forest)

In Fig 2 The home page of the web application is designed to provide a comprehensive overview of the system's functionality through an intuitive and user-friendly interface. It features several dynamic cards, each serving a specific purpose. These include **Number of Animals**, which displays the count of monitored animals; **Alert Notifications**,

showcasing real-time alerts regarding boundary breaches; and **Location of Animals**, providing precise location updates for each animal. Additional cards include **Website Visitors**, which tracks engagement metrics, and **Recent Activities**, summarizing the latest system actions and updates. A dedicated **Add Phone Number** card allows stakeholders to seamlessly register contact details to receive notifications. All these cards are updated in real time, ensuring stakeholders have immediate access to critical information and alerts.

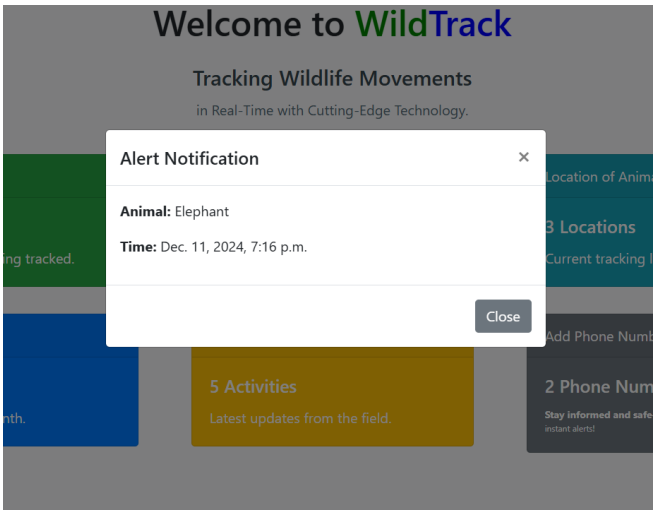

Fig 3: Alert Notification incase animal go out of the region (User View)

In Fig 3 This section represents the **Alert Notification** system, providing detailed information about animals that have moved out of their designated range. Each notification includes the animal's identification, along with the precise time and date of the breach, ensuring stakeholders are promptly informed for swift action.

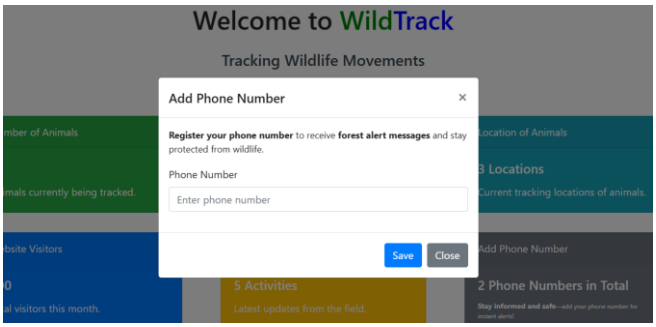

Fig 4: Phone Number form for users to send a alert Notification

In Fig 4 This pictorial representation illustrates the total number of users configured to receive alert notifications. It highlights the system's capability to effectively disseminate critical updates to all registered stakeholders. These users are typically stakeholders, such as villagers, authorities, or other concerned individuals, who need to be informed about potential boundary breaches or animal movements in real-time. The representation underscores the system's scalability and efficiency in delivering critical updates promptly to all registered users. By ensuring that the notifications reach the intended recipients without delay, the system enhances its reliability and responsiveness in mitigating risks and ensuring timely action during emergencies. This feature reflects the robustness of the alert mechanism, ensuring inclusivity and broad coverage across multiple stakeholders. These users are typically stakeholders, such as villagers, authorities, or other concerned individuals, who need to be informed about potential boundary breaches or animal movements in real-time.

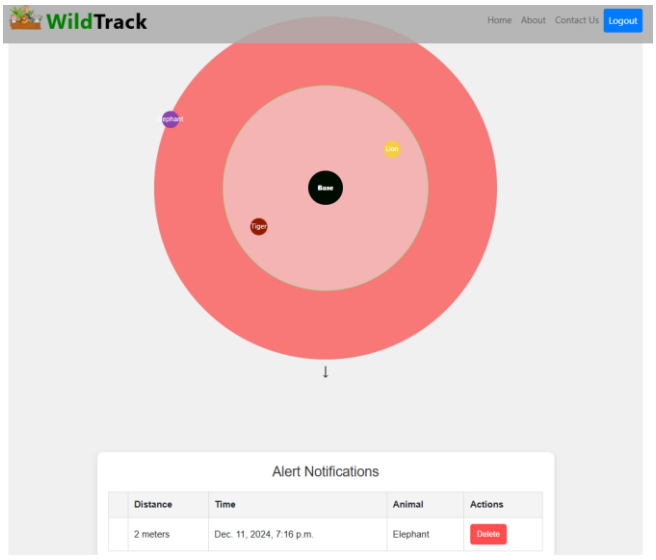

Fig 5: Live Tracking of Animals and providing a actions to delete animals for forest department login only

In Fig 5 This representation demonstrates the system's ability to perform live tracking of animals within the designated boundary. It provides a real-time visual update of the animal's location, allowing stakeholders to monitor its movement continuously. If an animal breaches the boundary and moves out of the specified range, the system immediately detects this and reflects the updated status visually in the representation. This live tracking feature not only aids in real-time monitoring but also facilitates quick decision-making by alerting stakeholders to potential risks. breach is immediately noticeable, enhancing the system's effectiveness in managing

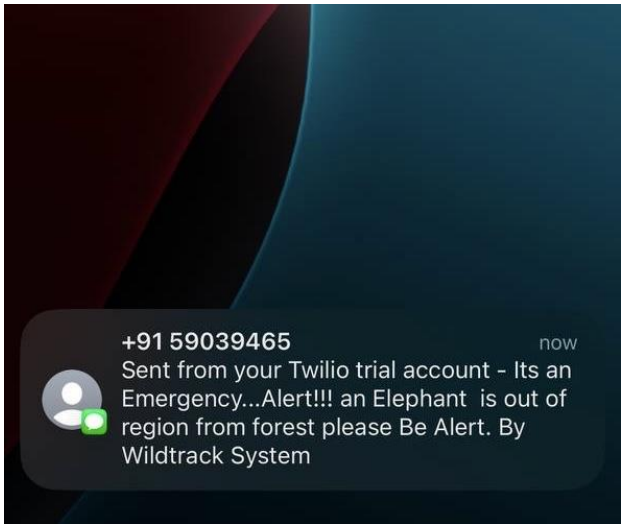

Fig 6: Alert Notification Send to Surrounding Villages

Fig 7: Safe Notification Send to Surrounding Villages

Fig 6 and 7 depict the critical alert and notification mechanisms of the system designed to inform surrounding communities. When an animal breaches the designated boundary, an immediate alert notification is sent to nearby individuals, warning them of the potential danger. This notification includes precise details such as the animal's ID, time, and date of the breach, enabling prompt awareness and action. Additionally, once the animal returns safely to its designated area, a follow-up "safe now" message is dispatched to the same stakeholders. This ensures effective communication, keeping the surrounding people informed about both potential threats and their resolution. The dual notification system enhances the safety and confidence of the communities by maintaining real-time updates on animal movements. It also underscores the system's focus on both proactive alerts and timely reassurance.

VI. CONCLUSION

Human-wildlife conflicts pose significant challenges, causing harm to both humans and animals while threatening agricultural productivity and livelihoods. This project addresses these challenges by providing an IoT-based solution for real-time monitoring and management of animal movements. The integration of ESP-NOW and Web Sockets ensures efficient communication and seamless real-time updates, making the system highly responsive. With the ability to detect boundary breaches and provide immediate alerts, the solution empowers communities to take preventive actions, mitigating risks to both life and property.

The system's innovative use of hardware and software strikes a balance between cost-effectiveness and functionality. Directional buzzer alerts and automated notifications ensure that even remote communities are promptly informed about potential threats. The inclusion of a web application with real-time updates ensures that stakeholders, from villagers to authorities, can stay informed and take coordinated action. This not only minimizes economic losses from crop

destruction but also reduces the likelihood of dangerous confrontations between humans and animals.

Scalability is a key strength of this solution, allowing it to adapt to larger regions or different types of wildlife. The modular nature of the hardware setup and the flexibility of the software make it an ideal candidate for deployment across various ecosystems. By fostering coexistence between humans and wildlife, the system contributes to long-term sustainability. It also promotes a proactive approach to conflict management, which is essential in regions where human expansion encroaches upon natural habitats.

Looking ahead, future enhancements such as AI-based prediction models and machine learning algorithms could significantly improve the system's accuracy and predictive capabilities. These upgrades could enable early warnings based on animal behavior patterns, further reducing risks. Additionally, integrating renewable energy sources for powering the system and expanding its compatibility with other IoT ecosystems could enhance its environmental sustainability. Overall, this project not only addresses an urgent issue but also lays the groundwork for more advanced and comprehensive solutions in the future.

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