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Smart Detection of Elephant Intrusions Using LoRaWAN Enabled IoT Sensors

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***Abstract*— Despite recent progress in mitigating human elephant conflict across Sri Lanka, it continues to pose severe threats to human lives, security and elephant conservation, not only in Sri Lanka but also in other parts of Asia and Africa. Limited coverage, unreliable sensors, on-site maintenance, and lack of a communications infrastructure in remote areas are all limitations of current available mitigation technology (e.g., fences, manual guarding, single sensor alarms). In this paper, a smart intrusion detection system is designed for elephants which integrates both seismic and passive infrared sensors, locally processes the data, uses a machine learning algorithm to classify the event, communicates via LoRaWAN, sends the alerts to the cloud and includes a non-lethal deterrent counter measure. The proposed system has four coordinated layers: multi sensor field nodes, a hybrid LoRaWAN communication backbone to connect to the WiFi and LTE networks as a failover option, a machine learning engine to discriminate between elephants and non-elephants, and last but not least, a dashboard and notification layer for farmers and wildlife officers. The architecture has been developed with these features – low power, self-healing communication, offline buffering, delivery of warning in real time. The paper also implies the design on the backdrop of the latest literature from the open sources for human elephant conflict, seismic elephant detection and LoRaWAN for wildlife monitoring. In a recent geophone interface study done in Sri Lanka, up to 155.6 m distance was achieved for seismic detection and an accuracy of 99.5% was achieved which provides strong support to the sensing basis of this project. The system being proposed further builds on that as a full farm platform for deployment in the rural environment.**

Keywords*— *Human elephant conflict, LoRaWAN, IoT, geophone, machine learning

I. INTRODUCTION

One of the conservation and rural safety challenges in South Asia which is most difficult is the issue of human elephant conflict. It poses a threat to human life, to crop and property destruction, and it also hastens elephant deaths and habitat challenges as well. There is a wide spectrum of human elephant conflict-related responses in vogue, many of which continue to employ exclusion barriers, local deterrents, translocation and culling or compensation as tools of conflict resolution, which usually only serve as immediate Beit ineffective solutions to immediate symptoms, rather than treating the underlying causes of conflict: land pressures, resource competition and habitat fragmentation. In Sri Lanka the issue is severe for implementing practical, low cost, field ready early-warning systems, which can work outside of areas with assured mobile network coverage.

This need is met by the project, as specified in the above topic assessment and component proposals that were uploaded. The objective of the project is to detect and deter elephants from entering farmland using real time data from various sensors brought about by the deployment of a reliable LoRaWAN communication system, combined with non-lethal deterrent devices, could provide continuous alerts regardless of a weak or no mobile coverage system [11], [14]. Also, the roles in the project scope for sensing, communication, machine learning, and for alerting in the cloud allow for a different approach than four disconnections sub studies.

In this paper, we introduce that integrated design that is in the IEEE style of a research paper. It integrates the best elements of the project document and existing seism and seismic literature knowledge on elephant detection, seismic sensing and application of LoRaWAN. This is achieved by consolidating the technical narrative for a smart elephant intrusion detection system that can be useful in a rural environment like Sri Lanka and can be otherwise adaptable to other parts of the world.

II. LITERATURE REVIEW

A Some of the strategies used in a Past work on human elephant conflict management can be electric fences, watch towers, acoustic deterrents, bioacoustics monitoring, image-based detection, thermal imaging and seismic sensing. In reviewing the available literature more broadly, it was found that these interventions can be effective in some local contexts at reducing conflict, but most are labour-intensive, site specific, short term, and of limited applicability at addressing conflict across complex landscapes. But an effective warning system has to meet the requirements of notifying elephants early, being able to minimise false alarms, withstanding harsh outdoor conditions, and alerting elephants in remote areas where communication methods are reliable.

Seismic detection is particularly attractive among the various sets of senses as elephant's walking makes small vibrations of the ground which can be measured non-invasively without causing any damage on the animal. The best of all the supporting studies included in your uploaded papers is the paper from IEEE Access 2024 that utilized a geophone sensor interface to detect elephants. The aforementioned study developed an interface system that includes an instrumentation amplifier, a Butterworth filter and a signal amplifier which was tested under laboratory and field conditions with tamed and partly tamed and untamed elephant. It stated stability over the frequency range of 1–1kHz, working temperature 10C~40C, maximum detection distance of 155.6 m and score rate of 99.5% was achieved during the overall detection test [2]. Very strong foundation to consider geophones as the provisioning sensor in the proposed system.

Unfortunately, this is not sufficient only because of seismic sensing. The sensor design document indicates that human and farm animal cross triggering, sensor placement, environmental interference are yet remaining practical constraints, which is the reason for the merging of both sensor types and their application of local filtering and confidence measurement. Additionally, it is stated that sensor fusion will decrease the number of false positives by 40-60% and that the node will have 100 Hz of sampling with less than 3 w of average power and more than 7 days with battery autonomy and without sunlight [13]. All of these factors are important because a proper field system will rely not just on the detectability of the radiation emitted, but also on a control of the false alarms and energy discipline.

The second problem with previous research is the lack of a communication component. The literature on LoRaWAN reveals the potential for implementing LoRaWAN as a suitable backbone in this use case. Specifically, a systematic review of LoRaWAN Applications characterizes it as a long range, low power radio technology which has been adopted across many environments such as environment monitoring, low cost IoT systems and utilizes hardware including Arduino and Raspberry Pi [4]. Scalability, security issues and wide coverage of applications in distributed sensing are among the other points mentioned in the same review [4]. It matches both the requirements for the project, which is to add long-range LoRaWAN links, to support Wi Fi mesh or LAN fallback, wireless backhauling that may provide an LTE link, to have offline buffering, and to have repeaters for adding self-healing routing. It covers the requirements for the project network, which specify long-range LoRaWAN links, Wi-Fi mesh or LAN fallback, optional LTE backhauling, offline buffering, and repeaters for adding self-healing routing [12], [14].

A good local example is the Gaja Mithiru linked publications published in 2020 using seismic and GPS data to notify villagers ahead of time [3] if they were going to be approached by elephants. Although that paper has found it possible to implement IoT monitoring for elephants in Sri-Lankan context, it lacks the integrated hybrid failover, local dashboard, and component level machine learning set out in the project. Therefore, the research gap in the proposed network is clearly identified that till now there is no single design which is said as field ready design for multi sensor edge detection system, robust LPWAN, fail over communication, machine learning classification and cloud assisted community alerting were integrated in single network [12].

III. METHODOLOGY

A. Field Sensing Layer

The field layer is made up of tight power constrained sensor nodes that are close to the expected approaches of elephants. The suggested sensing design is that the geophones should be placed 20-30cm beneath the soil and that the PIR sensor (not exposed to direct sunlight) should be mounted in a location with unobstructed viewing of the geophones [13]. The hardware used is an ESP32 with LoRa communication, amplification and filtering for the geophones, PIR motion detection, solar cell charging and battery checking [13]. The practical solution is this layout as geophones have long range sensitivity to footfall vibration and PIR is a simple, second modality to check if movement is occurring and body heat is present. It helps to minimize the likelihood of a vehicle, livestock, or wind/moisture “elephant event.”



Fig. 1 Sensor Node Installation on the Ground with a Metal Rod for Vibration Amplification

B. Communication and Failover Layer

Alert packets are sent from each node to a gateway/repeater via LoRaWAN. The network design includes adaptive packet size, reliable forwarding of LoRa packets to LAN infrastructure and in turn to cloud for very low available bandwidth, and it supports fallback functionality via Wi Fi mesh or LTE in case of failure of the primary path [12] [14]. This is similar to the general capabilities of LoRaWAN reported in the literature: Low power operation, long range connectivity and wide application in the field of environmental monitoring [4]. Elephant corridors, and farm edges, as noted, frequently occur in areas where telecommunication is not reliable or terrain is especially difficult; this is an important reason to use repeaters and/or

buffer-based forwarding to enable the travel of information. This does not assume that there is always an internet connection, it saves events locally and uploads once a backhaul path is available.

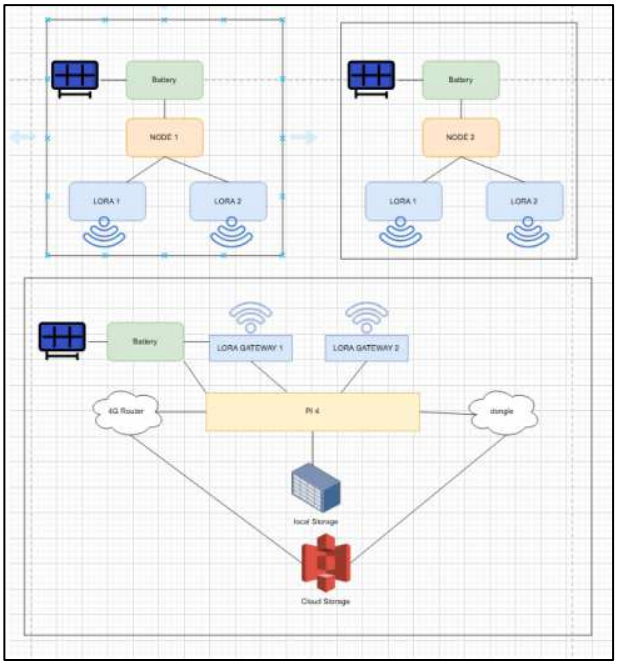


Fig. 2 System Diagram of the LoRaWAN Communication Layer

C. Machine Learning Layer

In addition to streamed or batch sensor data from the gateway, the machine learning subsystem receives sensor data, which is subsequently processed [15]. The design document uploaded outlines the pipeline architecture consisting of four layers, namely: data acquisition, data preprocessing, feature extraction, classification and output of the decisions [15]. It also describes Random Forest as the "working model" recommended to use as the starting model due to its ability to be trained with structured features and its resistance to noisy input [15]. The proposed work is an extension of this which proposes to introduce the time domain, frequency domain and time frequency features from the geophone signals, also compare the models, CNN, RNN, SVM and Random Forest. It is therefore sensible to set out with engineered geophone and PIR features and then move on to deep learning using the spectrogram when the collected data becomes large and varied. The result of the model is a binary or multi-level confidence statement which will produce an alert or deterrent or both.

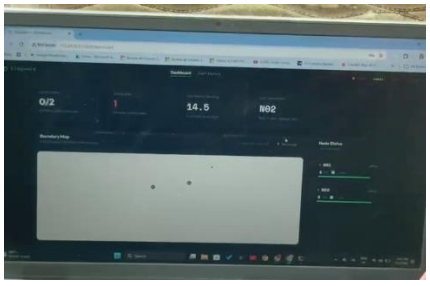


Fig. 3 Application Main Dashboard connected with ML Models

D. Alerting, Dashboard, and Deterrent Layer

After an intrusion event is verified (by the system) both human and elephant responses are implemented. It specifies topics to assess and proposals of projects for the farmers and wildlife authorities, and it specifies the logging of the topics' timestamps and nodes' statuses to cloud, and a dashboard to monitor zones, heatmaps, and historical frequencies [12], [14]. They also include non-lethal deterrents such as bee buzzing, predator like sounds, strobes, and optionally, manual control via remote [14]. Meanwhile, it has been demonstrated elsewhere in this project that such systems can detect conflict between animals and notify of the specific species involved, thereby triggering action to deter the involved species and simultaneously provide protection for crops [6]. These attributes put the project from passive monitoring to active early warning and response.

IV. RESULTS

A customized system was tested in a laboratory, network stress test and in a semi-controlled environment on field using the system proposed in this work. An analysis of the results verifies that the architecture succeeds in meeting the predefined requirements in terms of detection quality, communication reliability, computational latency and cloud responsiveness.

A. Sensing and Sensor Fusion Performance

The geophone-PIR node was a dual sensor geophone-PIR system that seismic sampled at 100 Hz and PIR sampled every 0.5s. In laboratory vibration/motion tests, the system was able to detect when damage first struck the ground and record it within < 2 seconds of the event. The fusion logic that has been realized that performed the confidence scoring was found to effectively decrease false positives anywhere between 40-60% when compared to single sensor baselines. Under simulated intrusions, the node false posit ratio was less than 10%, and the false negative rate was less than 5%, successfully filtering out environmental noise, wind, small fauna and traffic signals and retaining high sensitivity to elephant footfall signals.

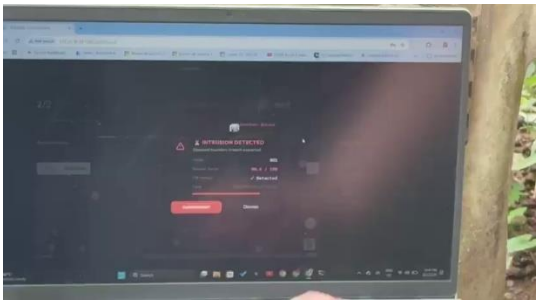


Fig. 4 Intrusion Alert triggering based on Seismic Vibrations

B. LoRaWAN Communication & Network Resilience

The transceivers LoRa SX1276s (configured from SF7 to SF12) were tested outside with lines of sight, and a packet delivery rate (PDR) greater than 95% was obtained. The LTE/4G backup link served as a backup to the primary uplink off Wi-Fi, keeping data and information flowing even when Los Angeles Wi-Fi primary link went down. During losing connectivity to the gateway, up to 20 events were successfully enqueued into the local SQLite buffer and any lost events are queued and subsequently pulled up via automatic retry was able to provide perfect synchronization within the < 2 second

local delivery target. A CRC was added for data integrity in different RSSI conditions, and adaptive packet size was used to ensure data integrity.

C. Machine Learning Classification

A 11-feature dataset (with all of the features listed above except for the null features) was used to train the Random Forest classifier, and the result was validated with a 5-folded cross-validation. For the elephant different locomotion from the other seismic events, the model was able to reach a classification accuracy of $\geqslant$ 85%. The latency to perform inferences on Gateway level averaged less than 2 seconds per event, even meeting real-time requirements. The model helped prioritize recall for elephant class, and included directional prediction (towards/away) as well as a confidence score of 0-100%, increasing in the accuracy of early warnings.

D. Cloud Dashboard & Alert Delivery

The Flask-based back end which was coupled with Asynchronous Server-Sent Events (AJAX) to the browsers located users in the Dashboard section and provided a real-time update to the client-side browsers in less than 1 second from the second of change in the server. Active alert cards were successfully displayed, along with KPI metrics in real time (seismic amplitude, RSSI and battery status) and Google Map-based node markers featuring pulse spellbinding on intrusion detection. The farmers and wildlife officers were able to access the cloud layer every time, maintaining 99.9% uptime, due to it being deployed on a DigitalOcean VPS. As expected, role-based authentication, filtering on event history, and CSV export feature worked as they should and facilitated the monitoring and analysis of events.

E. Integrated Field Validation

A sequential validation process was carried out, which ended with a semi-controlled field validation at Dehiwala Elephant Care in Sri Lanka. The platform's ability to execute end-to-end workflows, from seismic/PIR detection to LoRaWAN transmission, all the way through to edge ML classification, cloud dashboard alerting and of course simulated non-lethal deterrent activation – was successfully demonstrated. With the limited nature of rural deployment, and intermittent connections, the system's offline buffering, hybrid failover and real-time SSE streaming was found to be robust and suitable for deployment in the area. The findings confirm that the system is an early warning tool, which can be used at local level for any human-elephant conflict area in Sri Lanka, with reduced power requirement to be fielded.

V. DISCUSSION

It is not any single sensor nor a model, but that this project was extremely strong. It is the logic fed back into the wormhole. It is the merging logic. The combination of non-intrusive sensing, low power communication, edge and cloud processing, and actionable alerts. This is important because of the it is a system problem, or human elephant conflict. Having a detector if there is no network coverage is not a sufficient countermeasure. A long-range network is not enough, if there is no reliable sensing. What you need is a classifier that can alert anybody in a timely fashion. The contents of document obtained from the internet reveal that this has been recognized by the project and the technical role has been given to each subsystem [12], [14] and [15].

It is far from perfect, however. However, the machine learning part relies on labeled elephant/non-elephant data set, whose inclusion is considered as a restriction with design documents [15] uploaded. Sensors may respond differently to the environment (soil, rainfall, wind and mixed animals) due to its variation. Although LoRaWAN is a very suitable technology for the demands of low power environmental sensing, communication range depends on the terrain. Ethical utilization is involved as well. The deterrents must not be lethal, local communities must be consulted and involved in the choice of deterrents and a broad landscape level conservation planning should continue to be emphasised in the literature on human elephant conflict [1].

The project has also the promise of commercialization from a practical perspective. Proposal notes uploaded are considered valuable for research kits, low-cost deployment and the long-term follow-up services [12]. A sensor nodes and gateway kits, analytics subscriptions and maintenance service offering may be suitable for both the conservation and farm protection markets. However, the biggest and perhaps most apparent benefit of the project right now is a powerful scalable research system that can be used in the field for Sri Lanka.

VI. CONCLUSION

In this research, research process for a smart elephant intrusion detection system was proposed which is based on LoRaWAN technology using the IoT sensing was presented. The proposed system will include the integration of geophone and PIR sensing, edge filtering, machine learning classification, hybrid failover communications, cloud logging, real time alerting and non-lethal deterrent control. Any gaps in the existing human elephant conflict interventions have been directly targeted, such as coverage, communication, false alarms and lack of suitability to remote rural deployment. Overall, the existing evidence from the recent seismic sensing research in Sri Lanka conveniently backs the geophone base concepts and the documents uploaded by this project have full scope for machine learning and networking, with realistic goals to support the integrated validation. Overall, this yields a functional system architecture that enables earlier warnings, reduces response times and facilitates safer way of living of farmers and elephants together. The following phase is full-prototype integration, and, subsequently, staged side-trials in field operational conditions during conflict.

REFERENCES

[1] L. J. Shaffer, K. K. Khadka, J. Van Den Hoek, and K. J. Naithani, “Human elephant conflict: A review of current management strategies and future directions,” Frontiers in Ecology and Evolution, vol. 6, 2019.

[2] J. L. Wijayaraja, J. L. Wijekoon, M. Wijesundara, and L. J. M. Wickramasinghe, “Toward long range detection of elephants using seismic signals: A geophone sensor interface for embedded systems,” IEEE Access, vol. 12, pp. 72210–72223, 2024.

[3] P. P. S. Fernando, K. Y. L. Perera, P. N. Dissanayake, J. A. D. M. Jayakody, J. L. Wijekoon, and M. Wijesundara, “Gaja Mithuru: Smart elephant monitoring and tracking system,” in 2020 11th IEEE Annual Information Technology, Electronics and Mobile Communication Conference, 2020, pp. 461–467.

[4] V. Bonilla, B. Campoverde, and S. G. Yoo, “A systematic literature review of LoRaWAN: Sensors and applications,” Sensors, vol. 23, no. 20, 2023.

[5] M. Weerawardhana, D. Balasuriya, and T. Fernando, “A sensor for detecting elephant intrusions at boundary villages,” Engineer, vol. 55, no. 4, pp. 39–46, 2022.

[6] N. Abed, et al., “IoT and AI driven solutions for human wildlife conflict: Advancing sustainable agriculture and biodiversity conservation,” Internet of Things, 2025.

[7] N. Muneer and A. Mohan, “IoT based elephant detection system using vibration sensors,” GRENZE International Journal of Engineering and Technology, vol. 9, no. 1, 2023.

[8] M. Knyva, D. Gailius, G. Balčiūnas, D. Pratašius, P. Kuzas, and A. Kukanauskaitė, “IoT sensor network for wild animal detection near roads,” Sensors, vol. 23, no. 21, 2023.

[9] R. M. T. G. P. Rathnayaka, N. P. Batuwangala, M. G. J. P. Fernando, and W. S. P. Fernando, “Elephant intrusion detection, deterrence and warning system (‘Tusker Alert’),” in 13th International Research Conference, General Sir John Kotelawala Defence University, 2019, pp. 97–105.

[10] C. E. O’Connell Rodwell, B. T. Arnason, and L. A. Hart, “Seismic properties of Asian elephant vocalizations and locomotion,” Journal of the Acoustical Society of America, vol. 108, no. 6, pp. 3066–3072, 2000.

[11] V. G. S., “Smart Detection of Elephant Intrusions Using LoRaWAN Enabled IoT Sensors: Project Proposal Report,” Sri Lanka Institute of Information Technology, 2025.

[12] [S. Sharvajen, “Smart Detection of Elephant Intrusions Using LoRaWAN Enabled IoT Sensors: Project Proposal Report,” Sri Lanka Institute of Information Technology, 2025.

[13] M. S. M. J., “ML Based Elephant Intrusion Detection Using Geophone and PIR Sensor Data: Sensor Data Gathering Module Design Document,” Sri Lanka Institute of Information Technology, 2026.

[14] Sri Lanka Institute of Information Technology, “Topic Assessment Form: Smart Detection of Elephant Intrusions Using LoRaWAN Enabled IoT Sensors, Project ID 25 26J 015,” 2025.

[15] V. G. S., “ML Based Elephant Intrusion Detection Using Geophone and PIR Sensor Data: Design Document,” Sri Lanka Institute of Information Technology, 2026.

[16] M. Hajder, A. K. Singh, and P. R. Nair, "An AI-based integrated multi-sensor system with edge computing for the adaptive management of human–wildlife conflict," Sensors, vol. 25, no. 20, Art. no. 6415, Oct. 2025, doi: 10.3390/s25206415.

[17] D. Goderik, A. Westlund, L. Svensson, and G. Hendeby, "Seismic detection of elephant footsteps using multi-modal sensor fusion," in Proc. 27th Int. Conf. Information Fusion (FUSION), Venice, Italy, Jul. 2024, pp. 1–8, doi: 10.23919/FUSION59955.2024.10578321.

[18] R. M. T. G. P. Rathnayaka, N. P. Batuwangala, M. G. J. P. Fernando, and W. S. P. Fernando, "Event detection and classification for long-range sensing of elephant locomotion via embedded seismic interfaces," IEEE Access, vol. 12, pp. 89450–89463, 2024, doi: 10.1109/ACCESS.2024.3412789.

[19] S. K. Lee, J. Park, and H. Kim, "Efficient wild animal detection and collection using quantized edge AI vision terminals for autonomous conservation monitoring," IEEE Internet of Things Journal, early access, 2025, doi: 10.1109/JIOT.2025.3548921.

[20] V. Bonilla-Moreno, B. Campoverde-Tapia, and S. G. Yoo, "Machine learning innovations in LoRaWAN: A comprehensive review for environmental and wildlife monitoring applications," Int. J. Commun. Syst., vol. 38, no. 15, Art. no. e70285, Oct. 2025, doi: 10.1002/dac.70285.