LoRaWAN implementation in acoustic and visual detection of coyotes

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***Abstract*—The existence of wild coyotes in the United States, particularly in Indiana, results in serious damage to pets, livestock, and even humans. Currently, there are scarcely any specialized solutions or devices created to solve the problem. Therefore, this project aims to detect wild coyotes with acoustic sensors within a certain area, in order to prevent possible damage from coyotes. On the basis of existing acoustic detectors for detecting animals, LoRaWAN and camera sensors are contained to improve the range and accuracy of detection. This research includes machine learning to differentiate coyotes' howl from other animals' sounds, which is illustrated in another paper. [+machine learning part]. Acoustic sound data collected by microphone sensors are sent to the model running localization and classification through LoRaWAN and LoRaWAN network server, The Things Stack. Collected data are filtered by the frequency filtering algorithm to reduce the file size. After analysis, the location of coyotes appears on the map of the user interface which becomes intuitive and user-friendly for users.**

***Index Terms*—LoRaWAN, Sound Localization, The Things Stack, NodeMCU, TDOA, Data Compression, MQTT**

I. Introduction

According to the 2015 USDA study on death due to predator and non-predator causes, coyotes were responsible for 53.1 percent of the loss in calves. [1] Coyotes attack not only livestock but also humans, which shows that coyotes pose a serious threat to farms. In order to make the program commonplace for farmers, however, the program is designed to be cost-effective and user-friendly. The project takes place in Indiana since coyotes are native and particularly prevalent in Indiana. Therefore, this project aims to detect coyotes more efficiently under a low budget.

Existing studies show solutions to detect animals with acoustic detection. However, these methods involve either Celular or WiFi, which are not applicable in rural areas due to the low communication range and high cost of edge devices. Therefore, this project aims to build a coyote detection system with less cost and an improved range. To do so, LoRaWAN is applied as network technology. LoRaWAN is a Low Power, Wide Area networking protocol (LPWAN) designed to wirelessly connect battery-operated 'things' to the internet in regional, national, or global networks, and targets key Internet of Things (IoT) requirements such as bi-directional communication, end-to-end security, mobility and localization services. [2] It is used to expand the range of detection. Once acoustic sensors detect coyotes howling, Esp32 sends sound packets through LoRaWAN to gateways. Data packets are then sent to the machine learning server, where sound sensor data in the packet are extracted to be classified. After the sound classification process, camera sensors reconfirm the accuracy of the acoustic detection. Camera sensors are particularly installed in places like chicken coops or pet houses where attacks most likely happen. Hence, the object of the project is to create a system to protect farmers and livestock from coyotes. The project is at a low cost as it only requires a few camera sensors for visual classification. By identifying the general location of wild coyotes with acoustic sensors, a specific camera within the area can be assigned to capture the image of the coyote, assuring the accuracy of the sensor. Moreover, the device provides a visual form instead of coordinates for better visualization. For example, mapping is used to visualize the system, which can immediately locate coyotes. LoRaWAN meets the requirements for applying to large farms. It provides for long-range communication between end devices to gateways from 5 to 7 km, not requiring a licensed spectrum. It also has extremely low power consumption and supports 10+ years of battery life. LoRaWAN is a multi-usable, scalable, and cost-effective communication protocol. To conclude, the system can be installed in farms to effectively prevent attacks from coyotes.

Identify applicable funding agency here. If none, delete this.

II. Literature Review

Yan-Ting Liu *et al* wrote the paper: "A Solar Powered Long Range Real-Time Water Quality Monitoring System by LoRaWAN". The paper uses LoRaWAN to implement the real-time Internet of Things monitoring system. [3] It monitors water temperature, turbidity, conductivity, and pH with sensors and sends the data to the LoRaWAN gateway. After receiving data, the gateway performs data processing and transmits it to the network server using MQTT. Finally, it visualizes the result on the monitor. The architecture of this project is relatable to the coyote detection project. By contrast, the two projects require different types of sensors. Moreover, since the water quality does not change frequently, sensors send data to the gateway every 30 minutes. On the other hand, the coyote project has to constantly collect acoustic data.

Potluri studied signal localization estimation using the hyperbolic Time Difference Of Arrival (TDOA) method in the paper. [4] This study suggests two Position Location (PL) methods as the most commonly used ones. One is Direction Finding (DF), and the other is Hyperbolic TDOA. Hyperbolic TDOA is applied to this project because it does not need the time that the sound source occurs. Its simplicity compared to highly complex DF methods is also the reason why this project choose to use it to locate the coyote sound. In Potluri's paper, four microphone sensors are used to estimate the three-dimensional location of the sound source. However, this project uses three microphone sensors since acoustic localization is used to mark the coordinates of the sound source on the map, consequently, only longitude and latitude of it are needed.

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