# ECE 445

SENIOR DESIGN LABORATORY

PROJECT PROPOSAL

---

# Distributed Species Tracker

---

**Team No. 10**

Ryan Day
(rmday2@illinois.edu)
Jonathan Yuen
(yuen9@illinois.edu)
Max Shepherd
(maxes2@illinois.edu)

TA: Hanyin Shao
Professor: Olga Mironenko

February 9, 2023

# 1. Introduction

## 1.1. Problem

Invasive species are organisms that find their way into an environment of which they are not a native. They are capable of inflicting great harm on their new ecosystems leading to the death of native species as well as significant economic damage in some cases. Removing invasive species is an incredibly intensive and difficult task, the burden of which sometimes even falls on civilians who are called to look out for the invading species in order to provide intel on their location and help prevent any further spreading. Some other common methods for invasive species control include chemical control, bringing in new predators, or even uprooting parts of ecosystems in a desperate attempt to prevent the spread of the invasive species [1].

Endangered species are creatures that are on the brink of extinction. A lot of conservation efforts are made in order to restore the population of the species, including gathering the animals and breeding them in a controlled environment, as well as monitoring them via a tracking chip or satellite [2].

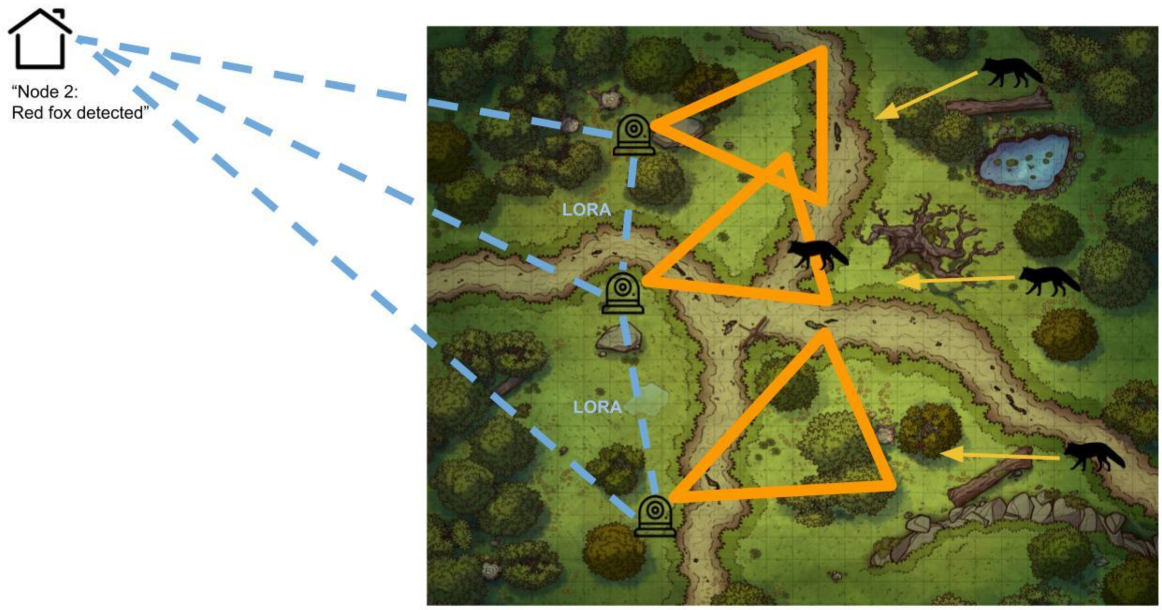
## 1.2. Solution

We propose a network of nodes that, once deployed in the wild, can capture images and process them to determine whether or not a species of interest has been in a certain area. The nodes will communicate with one another in order to compile a report of all of the places and times that an animal was seen. This can be an improvement on satellite imaging that is hindered by trees and overbrush and is also an improvement over the manual scouring of wilderness that is often used in the hunt of invasive and endangered species. The network, if deployed for long enough, can offer valuable data and present a comprehensive view of a species' behavior.

This semester, we aim to provide a proof of concept for this idea by building a small set of these nodes and demonstrating their ability to recognize an animal and log its whereabouts in a way that is redundant and node-failure-tolerant.

In order to do this, we will fit each node with a camera that will take images to be processed. If the species being monitored is detected, its location will be sent over the network of nodes via a routing subsystem. A power subsystem will supply and regulate power to the modules in each node. A sensor subsystem will provide GPS data and infrared detection.

## 1.3. Visual Aid




## 1.4. High Level Requirements

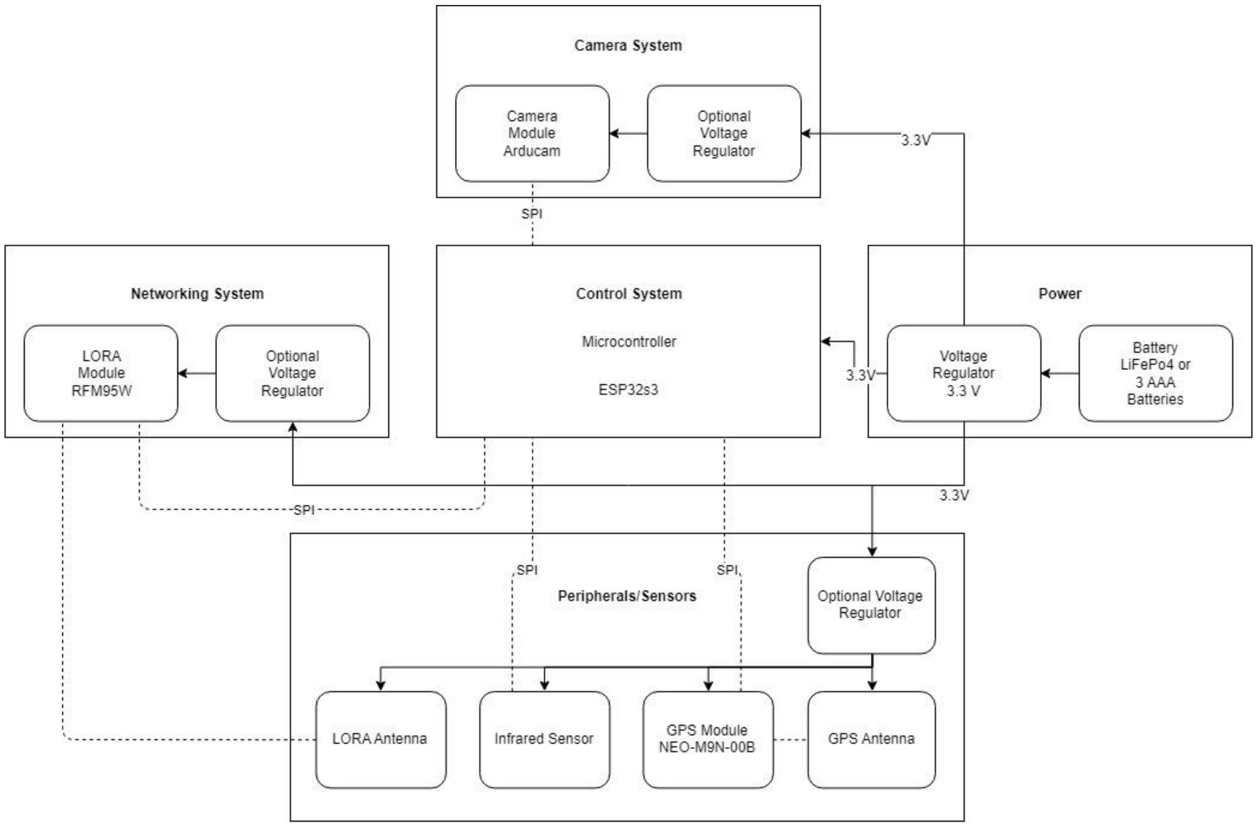
Data redundancy - We should be able to demonstrate that data gathered on any arbitrary node is reflected on the rest of the nodes in the network.

Detection accuracy and speed - The system shall be able to classify the animal we are monitoring with an accuracy of 70% or higher and take less than 1 second.

Battery life - The system shall operate on constant use for over 24 hours

# 2. Design

## 2.1. Block Diagram




## 2.2. Subsystem Overview

### 2.2.1. Networking Subsystem

This subsystem will establish the network over which the nodes will communicate. These nodes will replicate local GPS data amongst themselves. We will use a LoRa transceiver in order to achieve the reliable transfer of relatively small byte packets over a long range. A driver for the LoRa module and algorithms for the mesh network will be implemented in software and run on the microcontroller. The LoRa module will communicate with the microcontroller over SPI to receive the data that it should handle the transmission of. This module needs a 3.3V supply from the power module and draws at least 150 mA of current.

### 2.2.2. Power Management Subsystem

This subsystem handles discharging and voltage regulation. Since we are using replaceable LiFePo4 batteries, we will not need a charging circuit and will only need to monitor discharging. While the LiFePo4 already provides a stable continuous 3.3V +/- 0.1V power source, the output will be fed through a voltage regulator to ensure a consistent power source before powering the microcontroller and sensors.

#### 2.2.3. Camera Subsystem

This subsystem will take images of its surroundings once triggered by the infrared sensor. The image will then be processed and run through a classifier that will determine whether or not the image contains the species of interest. If the classifier outputs a positive classification, the microcontroller will compile a packet of data to be sent to the networking submodule.

#### 2.2.4. Sensor Subsystem

This subsystem will be responsible for gathering GPS data and hosting the infrared sensor. The GPS data will be processed in the MCU and packaged into the data to be transmitted by the networking submodule when needed. The infrared sensor will detect living creatures in the proximity of the node and trigger a photo to be taken by the camera.

#### 2.2.5. Microcontroller

The microcontroller will host the RFM95W drivers, as well as the software that handles communication with the GPS sensor, infrared sensor, and camera.

### 2.3. Subsystem Requirements

#### 2.3.1. Networking Subsystem

- Each node must be able to successfully discover and connect with the network of Species Trackers.
- Each node must be capable of sending the required data (GPS location, node number, timestamp) over the network or forwarding data to its neighbors to achieve data replication and redundancy. If a packet is dropped, the nodes should re-send the data so that it is received properly.
- The range of the communication between nodes should be at least 1 kilometer.

#### 2.3.2. Power Management Subsystem

- This subsystem must provide overcurrent, overvoltage, undervoltage, and short-circuit protection
- This subsystem must provide a stable $3.3 \pm 0.1$ V power source that supports up to 1.5 A of current draw
- The LiFePo battery must be easily accessible and replaceable.
- The LiFePo battery must be able to last for 24 hours.

#### 2.3.3. Camera Subsystem

- This system should be able to host a classifier trained to identify any animal, including the animal we choose to use for our demonstration.
- The classifier should have accuracy, precision, and recall values of 70% or higher and the classification should be performed within 1 second of the infrared sensor being triggered.

### 2.3.4. Sensor Subsystem

- The GPS module must provide a location that is 5-10 meters away from the true location of the node
- The IR Sensor must be able to trigger the camera to take a photo if a living animal is within 5 feet (on a bigger budget, we would invest in sensors with much greater range).

### 2.3.5. Microcontroller

- The microcontroller should be capable of executing the code that manages the LoRa module, the sensors, and the image processing such that the latency for gathering and processing data from the sensors does not exceed 1s. Therefore, when a picture is taken, the packet of data composed of GPS location and timestamp should be on the way to the LoRa module within 1 second so that the information pertaining to the animal sighting is as accurate as possible.

## 2.4. Tolerance Analysis

### 2.4.1. Data Transfer Reliability

One of the challenges of our project is reliably replicating data throughout the network of our nodes. Since the use case of our project is to drop nodes off in the wild and leave them there for an extended period of time and intermittently pull compiled data from the network, we do not have heavy restrictions on the minimum time a packet should spend in transit between two nodes (“airtime”). Instead, we care more about data transfer reliability across a long distance of at least 1 kilometer. To make our data transfer more reliable, we will configure values like the spreading factor and coding rate of our packets.

The spreading factor represents the number of spreading chips per data bit and a higher spreading factor means that more chips are used to spread each data bit, which results in a lower data rate but a higher processing gain. The processing gain is the ratio of the signal's bandwidth to the data rate and it represents the enhancement of the signal-to-noise ratio (SNR) that results from the spreading process. The higher the processing gain, the higher the signal's SNR and the higher the reliability of the transmission [3].

The coding rate is also configurable and denotes the ratio of data bits to redundant bits that can be used to help correct messages being received. A higher coding rate means that there are more redundant bits in the packet for each data bit, increasing the packet’s durability in the face of interference.

We can configure our LoRa modules so that they have a spreading factor of 9, a coding rate of 4/8, and a bandwidth of 125 kHz. Assuming an average payload size of 50 bytes (16 bytes for latitude and longitude coordinates, 25 bytes for the timestamp, a byte for the node number, remaining bytes for a description of the classified animal), this yields an airtime of 476.16 ms [4]. This configuration is not incredibly fast but will make sure that our packets are sent reliably.

# 3. Ethics and Safety

1. Our project is designed to interact with nature and stay outdoors for extended periods of time. It is important that the contents of our tracker nodes, including LiPo batteries, are well-contained in order to avoid pollution or the harming of animals. We will ensure that our batteries, PCBs, and LoRa modules are encapsulated safely in a container so that it can be deployed and then recovered in a way that leaves no trace on the environment in which it was stationed. By doing so, we are doing our best to comply with the IEEE code of ethics that calls for "ethical design and sustainable development practices" [5].

2. When using radio frequency transmission, there are a number of issues that can arise such as interference with other signals. When designing our networking module, we will make sure that we are transmitting at an unrestricted frequency and acting in full compliance with the FCC. Our project's use case is to be deployed in relatively remote areas, so the risk of interfering with outside signals is low.

3. When working on our project, we will abide by the IEEE code of ethics by being open to criticism of our work from our teammates, TA's, and professors. We organized set meeting times throughout the week designed to keep ourselves up to date on the progress made by our teammates and created a shared Gitlab project that will host our code in an effort to maintain technical transparency. We will also always be ready to pivot and embrace different design parameters and restrictions if our research turns up ethically-binding reasons to do so. Before starting work on our project, we completed lab safety tutorials and received nominal training in the areas of PCB design and soldering to make sure that we are undertaking only the tasks for which we are qualified. Finally, while working in a group, we will treat each other fairly and respectfully, culturing an environment that welcomes the exchange of ideas and promotes productive, enjoyable work.

## REFERENCES

[1]
"Control Mechanisms | National Invasive Species Information Center," *Invasivespeciesinfo.gov*, 2019. https://www.invasivespeciesinfo.gov/subject/control-mechanisms
[Accessed:09-Feb-2023].

[2]
A. New, "A New Way to Track Endangered Wildlife Populations from Space," *Yale E360*, 2021. https://e360.yale.edu/digest/a-new-way-to-track-endangered-wildlife-populations-from-space
[Accessed:09-Feb-2023].

[3]
A. Jebril, A. Sali, A. Ismail, and M. Rasid, "Overcoming Limitations of LoRa Physical Layer in Image Transmission," *Sensors*, vol. 18, no. 10, p. 3257, Sep. 2018, doi: https://doi.org/10.3390/s18103257 [Accessed:09-Feb-2023].

[4]
"LoRaTools," *Loratools.nl*, 2023. https://loratools.nl/#/airtime [Accessed:09-Feb-2023].

[5] "IEEE code of Ethics," *IEEE*. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed:09-Feb-2023].