Base Station Creation for Powder Valley Nature Center Copperhead Snake Tracking

ESE 498 Capstone Design Project Proposal

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Abstract

We are working in collaboration with Dr. Benjamin Jellen and another senior design group to create a tracking system for copperhead snakes in the Powder Valley Nature Center. The goal of the system is to allow scientist to track the snakes and pinpoint their exact location. We will do this using LoRa technology in conjunction with a time difference of arrival algorithm. The system will have a set of base stations that receive information packets from implantable devices in snakes. The information packets will then be sent to a main base station where a time difference of arrival algorithm will be used to determine the exact location of the snakes. A portable locating solution will also be developed for in-the-field locating of the snakes. We will assemble all the necessary parts to establish a working system to be tested and implemented.

Introduction

Dr. Benjamin Jellen is an ecologist researching copperhead snakes living in the Powder Valley Nature Center located in Kirkwood, Missouri. Dr. Jellen and his team hope to better understand the snake's overall ecology and population dynamics, with an emphasis on working with the public to change negative associations about venomous snakes.

We are creating a system that allows the snakes to be tracked so that Dr. Jellen can determine their exact location and go out and find them. The current system being used requires the user to find the snakes with a tracking pole which is not accurate and can be time consuming. In addition, the current system has a high power consumption, and the batteries in the implantable devices need to be replaced through a surgical procedure every 8 months.

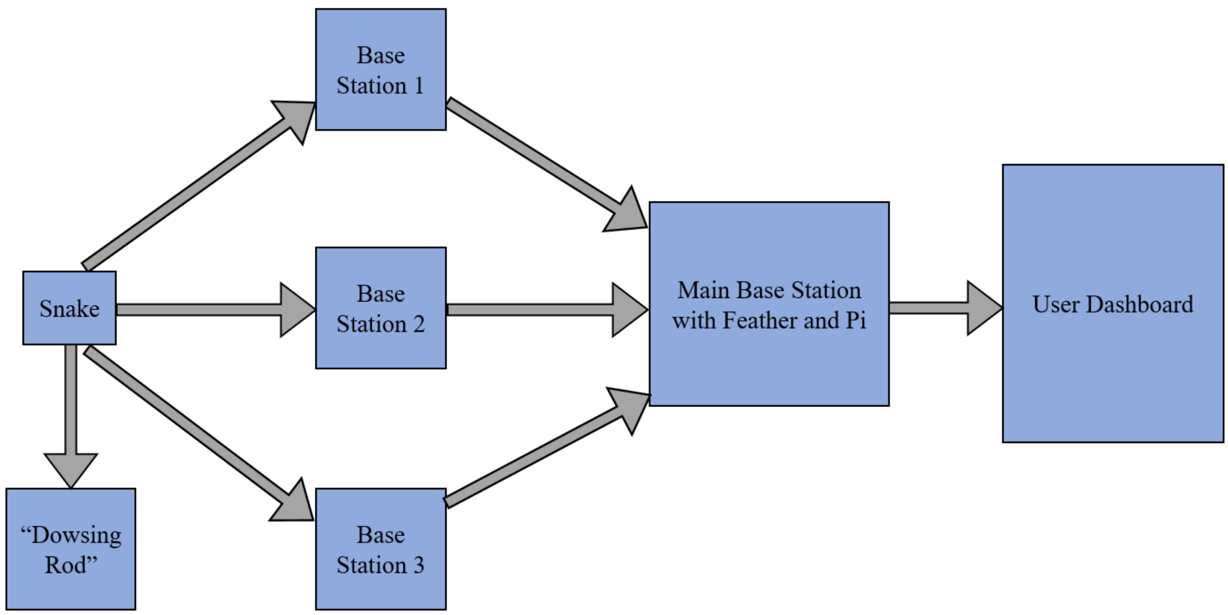
Two previous senior design groups have worked on this project. The first group started in the spring of 2020 and established a radio connection between implantable trackers and a single base station. Their implant was too large to be placed in a snake, and their power consumption was still quite high. The second group worked on the project in the fall of 2020 with the goal of decreasing the implants size and power consumption. Their tracker was much smaller but had a GPS unit in every tracing device, which still used too much power.

Our goal is to create a system that uses less power, so the snakes don't undergo surgery as frequently. To do this there cannot be GPS units in the tracking devices. We will focus on designing and implementing the base stations and user interface with LoRa technology while a partnering team works to design the implantable devices. The goal is to create a supporting base station system that allows for the implantable devices to be compact in size with minimal power consumption. Specifically, we will be using a system of four Adafruit Feathers connected to GPS units, and one headquarter station to determine locational data based on temperature reading signals.

Proposed Technical Approach

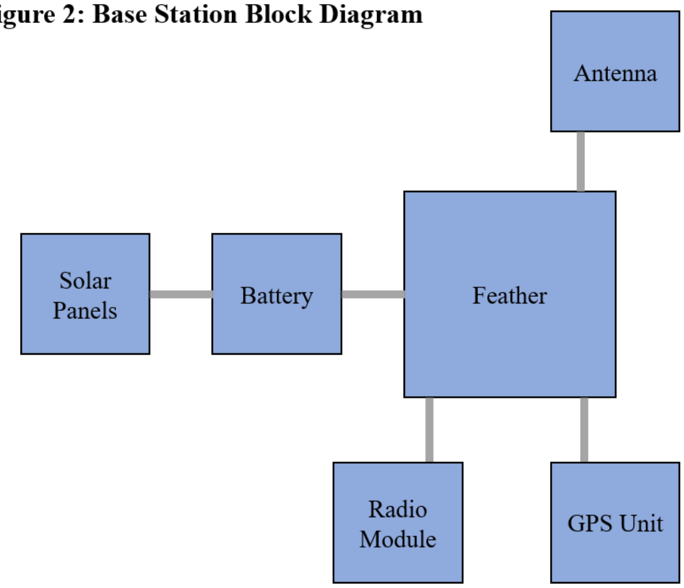
In order to keep the implant devices small in size with low power consumption they cannot contain a GPS unit. In order to accomplish this, LoRa technology and a time difference of arrival (TDOA) algorithm will be used to obtain location information. The overall system block diagram is shown below in figure 1. The tracking devices implanted in the snakes will regularly send a signal simultaneously to 3 different base stations each containing an Adafruit Feather MO with a LoRa radio. When the base stations receive the signal, they will each time stamp it, and send the information packet to the main base station. The main base station will contain an Adafruit Feather MO with a LoRa radio and a Raspberry Pi. The feather will receive the information packet and send it to the Pi which will run a TDOA (time difference of arrival) algorithm. The algorithm will produce approximate location data for the snake tracker that will then be uploaded to a user dashboard. When Dr. Jellen needs to go out and track the snakes, a second, mobile locating device will be used to determine the exact location of the snake utilizing the approximate location generated by the three base stations.

Figure 1: System Block Diagram



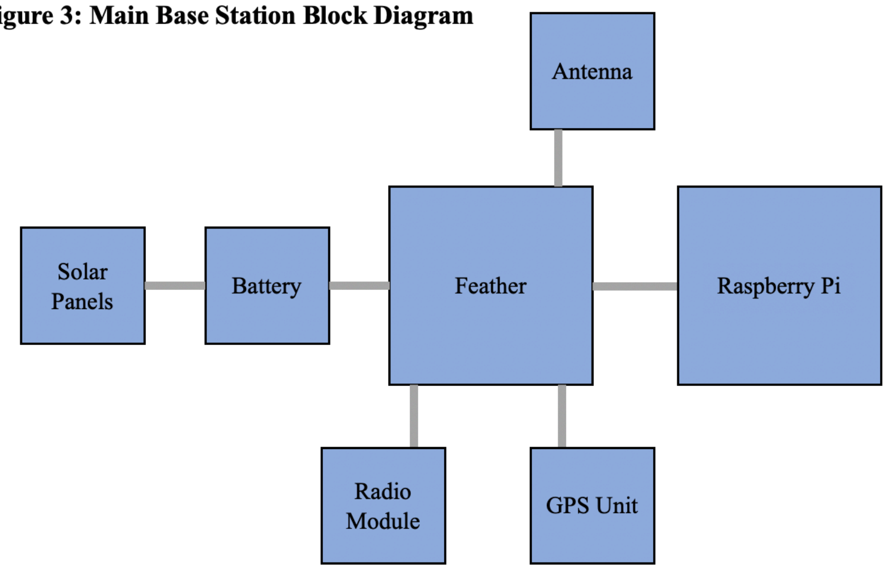
The base stations all contain an Adafruit Feather MO with a RFM95 LoRa radio that operates at 900 MHz. They are powered by solar panels and connected to battery backup. They will also contain a GPS unit for a precise, synchronized clock (which is necessary for the TDOA algorithm computations). Figure 2 below shows a block diagram for the base stations.

Figure 2: Base Station Block Diagram



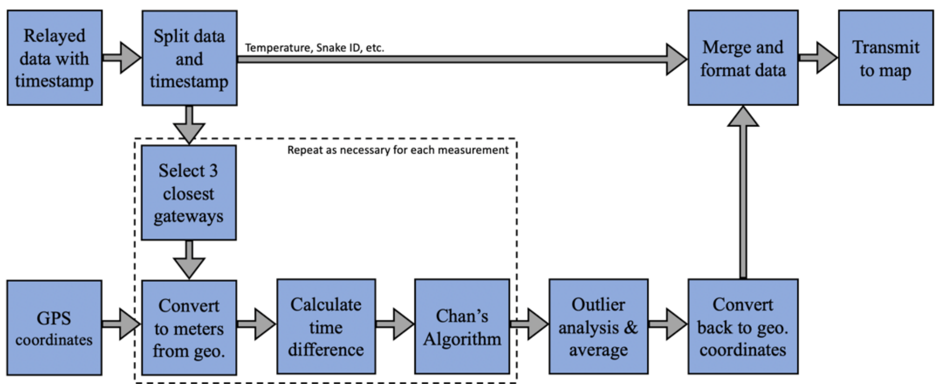
The block diagram for the main base station is shown below in figure 3. In addition to the components in the other base stations, the main base station has a Raspberry Pi. This Pi will run the algorithm which computes the implant location based on the TDOA data from the base stations. It will also be used to upload the computed solutions to a user dashboard which will display the last reported location of the snakes. It will also be responsible for relaying commands from the user dashboard to the secondary base stations to start the "active tracking" mode of the implants.

Figure 3: Main Base Station Block Diagram



The block diagram for the time difference of arrival (TDOA) algorithm is shown below in Figure 4, which will run on the main base station. The algorithm computes the location of the snake using the GPS coordinates of three base stations and the difference between arrival times of the signal to the base stations. The algorithm uses the three closest base stations based on earliest arrival time, and uses Chan's Algorithm to compute the location. To reduce the effect of noise on the time measurements, multiple measurement can be taken in sequence, with the resulting location averaged to reduce this variance. The location, as well as the other data such as the snake's temperature, is transmitted to the user dashboard.

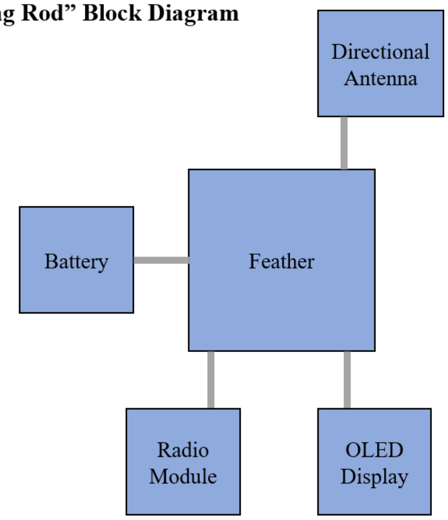
Figure 4: Algorithm Block Diagram



A user dashboard will display the site map with the last recorded location of each snake. The dashboard will allow for a time history of each snakes' position to be viewed an analyzed. In addition to the data visualization through the map, the raw positional data will be available to Dr. Jellen such that other analyses can be conducted. The base station will also have a control panel which will allow for switching between two operational modes. The first mode is a "passive tracking" in which the implants will send a signal every 4 hours, such that the location of the snake is updated 6 times a day. These signals will go to the base stations and be used to compute the approximate location of the snake. The second mode is an "active tracking" mode in which the main base station will relay the command signal to the secondary stations, which in turn transmit it to the targeted implant. The selected snake implant will then actively ping its location every second or so for a short period of time. After a user-configurable duration, the implant will revert to its primary operating mode of passive tracking. This is done to conserve power, as each transmission costs battery life. The secondary operating mode (active tracking) will not utilize the base stations to determine location. Instead, a portable "dowsing rod" will be using to locate the snake.

The "dowsing rod" will consider of a Feather M0 with LoRa radio (just like the base stations) and directional antenna. Unlike the base stations, which are equipped with omnidirectional antennas, the "dowsing rod" will have a directional antenna. Instead of using TDOA, an RSSI value will be used to determine the snake's location. A directional antenna combined with code which compares the current RSSI value to the previously reported values will allow for a “warmer/colder” sensing scheme. A directional heading can be determined and the signal strength followed to determine the exact physical location of the snake.

Figure 5: “Dowsing Rod” Block Diagram



Feasibility Study

The first senior design group to work on this project determined that communicating at 900 MHz using the Adafruit Feather devices is feasible. They were able to successfully get their system working and we are confident that the same protocol will work for our project. Various research projects using LoRa and TDoA algorithms also suggest such an approach will work and will have acceptable localization error for the constrains of the project.

A working and accurate TDOA algorithm is critical to locating the snakes using only the time of the signal’s arrival to each base station, as the lack of GPS on the snakes precludes synchronizing the implant’s clock. Starting from the outline in Pospisil et al (2020) of their implementation of TDoA-based localization over LoRa, we created a working TDoA algorithm in both Matlab and Python using Chan’s algorithm. To test our algorithm, we used the sample base station coordinates presented in Pospisil et al from their field testing, and calculated the time for an ideal signal sent from a transmitter in the center of the array to reach the base stations, representing the time of arrival. The algorithm produced the correct location of the simulated transmitter using only the arrival time and the base stations’ coordinates. This demonstrates that the TDoA algorithm can determine the coordinates of a snake using the arrival time of the signal to the base stations.

The portable unit “dowsing rod” is critical for the success of the project in order to meet the demands of Dr. Jellen and his team. The success of the portable unit depends strongly on antenna design. We believe a Yagi-Uda directional antenna provides a sufficiently strong gain and tight bandwidth to accomplish this. Acquiring the RSSI value of a signal is trivial, but determining a heading based on differential RSSI values will depend on the sensitivity of the antenna and will require field testing. Due to the cheap (and relatively simple) construction of the Yagi-Uda antenna, experimentation with design should be possible.

Procedure for Remainder of Project

From here we will establish a radio connection between the base stations and a test beacon that simulates an implant device. The system will be tested, and we will refine the algorithm and radio communication. A user dashboard that overlays the snake locations on a map will be developed. Furthermore, we will calculate the power consumption for each base station and order the appropriate solar panel and battery system for each enclosure. Once the system works in an open field, we will 3D print and assemble the weatherized enclosures. Testing will then occur in an environment similar to the nature center, and further improvements will be made.

Additionally, we will design and implement a portable directional “dowsing rod” and refine the second operational mode (“active tracking”). We will create a Yagi-Uda antenna connected to the feather. This will be tested and modified until it can accurately pinpoint the exact physical location of an implant.

Ideally, the last two weeks before we begin writing the final report will be spent testing the entire system, tracking devices included, at the nature center. This will allow us to test the system more thoroughly and correct any unexpected problems that arise.

Anticipated Results

By the end of the semester, we will have a working system that tracks copperhead snakes living in the Powder Valley Nature Center. The system will consist of snake implants that send LoRa radio signals to three base stations located throughout the nature center. The base stations will be weatherized enclosures containing an Adafruit Feather MO powered by solar panels. They will add a time stamp to the signals and send them to the main base station. The main base station is similar to the others but includes a Raspberry Pi that runs a TDoA algorithm to determine the GPS coordinates of the implant devices. Finally, this location will be uploaded to a user dashboard and can be accessed by scientists studying the copperhead snakes.

Due to uncertainty in the algorithm this system provides a range for each location. To help Dr. Jellen pinpoint the snakes’ exact location we will additionally be creating a portable "dowsing rod” with the capability to receive signals from the snake and determine its exact location. In order to decrease power consumption this operational mode will only be active when Dr. Jellen enables it via the user dashboard.

We are working with another senior design group, Sierra Wang and Sethin Burrier, to accomplish our goal of creating a functioning system. Our group will be focusing on the base stations while the other group focuses on the implantable devices. The deliverables section of this proposal highlights the aspects of the system that we will be developing and then testing in collaboration with the other group.

Deliverables

Our group will complete the following deliverables by the end of the semester:

- **3 working base stations** that receive signals from tracking devices implanted in snakes and transmit these signals along with a timestamp to the main base station.
- A **main base station** consisting of a Adafruit Feather MO and a Raspberry Pi that receives data packets from the 3 base stations and runs an algorithm to determine the snake's locations within a minimal error range.
- **Weatherized enclosures** for all 4 stations including battery backup and solar panels.
- A **user dashboard** where the locational data of the snakes can be accessed.
- A **portable "dowsing rod"** with an additional operation mode that allows for the snake's exact location to be found when enabled and used in the field.
- A **final written report** detailing the creation of the above deliverables.
- A **final presentation** highlighting the results of the project

Timeline

Week	Tasks Completed	Tasks in Progress
02/21	• Hardware assembled • Algorithm coded and working	• Power calculations • Development of user dashboard • Establish LoRa communication between end node and base stations, and between base stations
02/28	• Order solar panels • Dowsing Rod Constructed	• Test LoRa packet communication • Dowsing Rod Code and Testing
03/07		• Test system before fully assembled • Enclosure design
03/14	• 3D print enclosure	
03/21	• Assemble enclosure	
03/28		• Test completed product
04/04		• Test at nature center?
04/11	• Complete all testing and refinement	
04/18	• User dashboard complete	
04/25		• Start working on reports
05/02		• Edit and continue working on reports
05/09	• Final Report • Website • Presentation	

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