ECE496 Final Proposal

Project Title: Bluetooth Low Energy (BLE) As Localization and Communication Solution for Drone Swarms

Project Number: 2022617

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Executive Summary

Swarm drones refer to a group of Unmanned Aerial Vehicles (UAVs) that operate together in order to complete tasks such as surveillance and mapping. There is constant room for further drone innovations such as increasing accuracy of drone localization, improving the reliability and robustness of drone-to-drone communication, and marginal costs. The team recognized that Bluetooth Low Energy (BLE) technology can provide an efficient solution to these areas, specifically for indoor swarm drones because the standard GPS technology has its limitations.

BLE technology can provide more accurate localization than the usual technologies such as GPS because it doesn't rely on satellite signals that have low signal strength and accuracy indoors. In addition, BLE can be used for drone communication as well, instead of having to rely on a separate module for that. These are the motivations for the project: to design and build drones that utilizes BLE technology for localization and communication. In order to generate designs for this project, the project scope, requirements, objectives and constraints have been specified in this document to ensure that these BLE drones can operate successfully for their intended indoor use. The scope of work is expressed in the systems diagram included in the document, highlighting the 3 subsystems that a solution needs to have: the drones with BLE modules, a ground control system (GCS) for the user, and a Bluetooth Angle of Arrival (AOA) array system required for detecting and sending packets from the drone to the ground station. A successful solution to the project will have this 3 subsystem structure and meet all the requirements specified in this document to effectively demonstrate that BLE technology can be applied in drone technology.

Motivation

State-of-the-art applications of drones include room mapping, search and rescue, surveillance, and infrastructure inspection. We discovered that these applications mainly rely on GPS and distance sensors such as LIDAR, RADAR, and ultrasonic for localization, with communication modules such as cellular and radio transceivers for communication. After further research, we found that Bluetooth Low Energy (BLE) can be used to locate signal origins using Angle of Arrival (AOA) or Angle of Departure (AOD) down to centimetre accuracy in addition to sending data packets [1]. Thus, it is clear that devising a drone swarm system that utilizes BLE AOA arrays as its communication and localization could help reduce the marginal costs down by replacing the standard localization and communication modules with one BLE module *(Figure 1)*. We also found that BLE in drones could have comparable accuracy to GPS modules, being able to locate the origin of a signal down to centimetre accuracy, while also being able to detect accurately indoors [2][3].

GPS System [7][8]: $49.00 (GPS module) + $9.15 (telemetry radio) = $**58.15**

BLE System[9]: $26.30 (BLE module) = **$26.30**

Figure 1 - Example of a representative marginal cost of adding one drone to the swarm on a BLE system vs a GPS system (in USD)

Problem Statement

Swarm drones for indoor use need a more accurate localization solution with lower marginal cost because GPS is limited only to outdoor use and is solely used for localization, therefore requiring a separate module on the drones for communication which makes costs higher.

Project Goal

The project goal is to develop a scalable swarm drone infrastructure that utilizes BLE AOA technology for both accurate indoor localization and communication between 2 or more drones.

Scope of Work

A solution that meets the project goal can be represented by the system structure shown in Figure 1. We divided the project into three subsystems: the Drone System (functioning drones, each with a BLE module), a BLE AOA Array (used for sending/receiving BLE messages, and detecting their angle of arrival which is used to localize the drones), and a Ground Control Station (GCS) used for controlling the drone(s) and tracking their information (*Figure 2)*. The minimum required components needed to achieve the project goal is indicated in red.

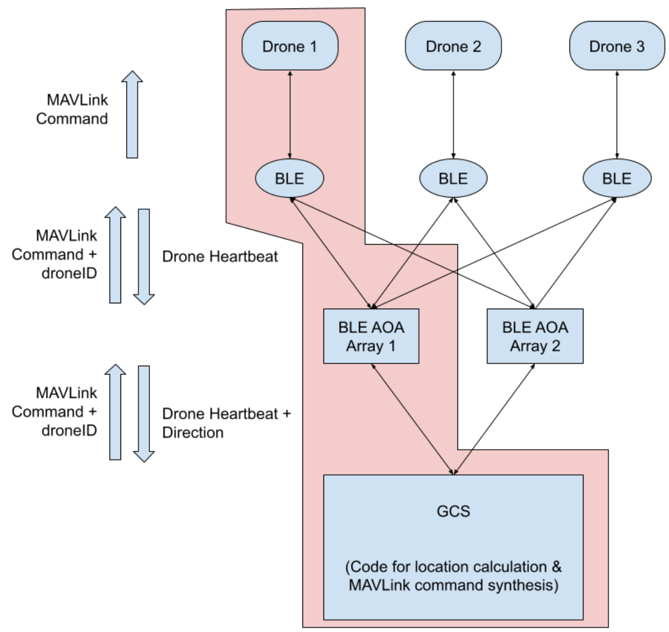

Figure 2 - Representation of the desired system, with the minimum system required highlighted in red

The first step in the project is to design the drone (the Drone System). The team will use off-the-shelf drone parts (airframe, motors, propellers, flight controller, etc) and a Bluetooth module to create a custom drone for this project. The total weight of the drone must not exceed 250 grams; this is to ensure the drones are classified as micro-drones allowing us to operate them without a license. Our next step would be to design a system which allows MAVLink commands to be sent using Bluetooth from the ground control system (GCS) to each drone, using the PyMAVLink library in Python [4]. MAVLink is a serial protocol used to send data and commands between drones and a ground control system. The GCS will be the backbone of the system as it is responsible for controlling and monitoring the movement of each drone. It is in the project scope to create this custom GCS using open source communication libraries and protocols as mentioned. The BLE AOA array will be constructed using existing BLE AOA modules.

With respect to control systems, motion planning and collision avoidance is a problem that has many existing solutions [5]. These algorithms require accurate location data to ensure that the drones will perform their functions correctly. The BLE AOA data is inconsistent and does not match the true location perfectly [6], therefore the location accuracy can be improved using algorithms, using more BLE arrays, and converting the location to Cartesian coordinates so it can be used in the control system. Thus any necessary control system used in this project will be outsourced and not implemented from scratch.

Testing will also be a part of our project scope since it must be done throughout the project lifetime. A useful tool to use during our design process is Gazebo, a multi-drone simulation application for simulating the motion control of drones. Then, as the 3 subsystems will be physically assembled, they will be tested separately as well as a whole to ensure a successful system's integration. Separate subsystem testing would include: running the drones manually to ensure they function according to the requirements. Integration testing would include measuring the latency between the drones and GCS.

Requirement Specification

Functions:

- Should be able to broadcast commands to drones and receive information about each drone's heartbeat
    - Heartbeat: signal, drone ID number, acknowledgment of received commands
- The system should be able to detect out-of-bound commands
    - Reject commands that lead to drone motion outside of the signal perimeter
    - Flip a kill switch (land immediately) if a drone manages to leave the signal range
- Drones must not crash into each other
- Each drone must be able to complete the following commands: arm (ready to start), disarm, liftoff, land, left, right, forwards, backwards, up, down

Constraints:

- The system must have a latency no greater than 1s between the drone and GCS
- Should be able to determine the location of each drone within an accuracy of 20cm
- A drone must be a quadcopter equipped with a BLE module and a flight controller with embedded electronic speed controllers
- Each drone must weigh less than 250g to qualify within the "micro-drone" class under Canadian law

Objectives:

- The system should be able to accommodate at least 2 drones
- The system should be able to correct any drone's drift up to a 20cm radius at any given time

Conclusion

With drone technology and application on the rise, this project provides an effective contribution to improving indoor drone localization and communication while improving marginal costs for larger drone swarms (larger than what will be built for the project). A solution to this project will showcase an exciting alternative technical drone design that utilizes BLE technology instead of the standard GPS.

References

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