ECE496 Testing Document

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

Project Number: 2022617

Supervisor Name: Lacra Pavel

Team Members:

Mohammad Ahmed

Jun Ho Sung

Adam Pietrewicz

Natalia Sydorenko (Exception: Petitioned)

Executive Summary

This document outlines the testing requirements, description, plan, and procedure for this project's hardware and software components. The main requirements for testing this project include an assembled and functioning drone, the software for Bluetooth Low Energy Angle of Arrival (BLE AOA) localization and control system functioning as well. Most tests for this project prototype involve testing the built drone, therefore an open area of at least 5m x 5m x 3m (Width x Length x Height) with clear landing ground is a main requirement to complete the project testing.

The tests mainly consist of an exhaustive list of basic capabilities of the drone, GCS, and all software. This includes: successful communication between the Ground Control System (GCS) and drones, drones must not crash into each other, drones can perform their proper flight commands/movements, there is low latency between the drone and GCS, and the GCS computes accurate drone location using BLE AOA, all of which are Functional Requirements of the project. The setup for the tests include arranging the anchors (BLE AOA antennas) in the correct orientation and position for the drone's flight area. Various commands will be sent to the drone from the Ground Control Station (GCS) laptop using the terminal interface built for the project, and the tester must observe how the drone reacts/moves.

Since the project's main focus is to showcase the capabilities of BLE AOA localization for drones, there is no need to test for full drone flight functionality/specifications (for example measuring drone velocity), so aggressive maneuvers for stress-testing drones will not be conducted. As such, the main pass/fail criteria include satisfying the positional accuracy and latency requirements of the drone BLE system.

Requirements for Testing

Functional Requirement	Requirements for Testing
1. Successful communication between the Ground Control System (GCS) and drones	● A single drone and computer (GCS) running Windows 10 or 11. ● Clear space without obstructions between drone and computer (GSC)
2. The system should be able to detect out-of-bound commands	● A single drone and computer (GCS) running Windows 10 or 11. ● Clear room (at least 5m x 5m area of floor, at least 3m high ceiling) with clear ground available for drones to land safely.
3. Drones must not crash into each other	● 2 functioning drones and a computer (GCS) running Windows 10 or 11. ● Clear room (at least 5m x 5m area of floor, at least 3m high ceiling) or any indoor space without obstructions for flying drones.
4. Drone can perform proper commands/movements	● A single drone and computer (GCS) running Windows 10 or 11. ● Clear room (at least 5m x 5m area of floor, at least 3m high ceiling) or any indoor space without obstructions for flying drones.
5. Low latency between the drone and GCS	● A single drone and computer (GCS) running Windows 10 or 11. ● Clear room (at least 5m x 5m area of floor, at least 3m high ceiling) or any indoor space without obstructions for flying drones.
6. Accurate drone position received by the GCS	● A single drone and computer (GCS) running Windows 10 or 11. ● Clear room (at least 5m x 5m area of floor, at least 3m high ceiling) or any indoor space without obstructions for flying drones.
7. A drone must be a functioning quadcopter	● A single drone and computer (GCS) running Windows 10 or 11.
8. Drones must qualify in the “micro-drone” class under Canadian law	● Functioning electronic weight scale ● A single drone.

Table 1 – Requirements for Testing

Description of Testing:

1. **Successful communication between the Ground Control System (GCS) and drones**
    a. Setup GCS with laptop, and have a drone positioned close to it
    b. Check that drone sends heartbeat signals to GCS
    c. Check command signals sent from GCS, send commands one by one
    d. Check packets being received by the computer from the drones
    e. Check packets being received by the drones from the computer
    f. Compare the packets received by drone and sent by the GCS to confirm correct command has been received and processed by drone

2. **The system should be able to detect out-of-bound commands**
    a. Drone is placed in the middle of non-obstructed room, and connected to GCS
    b. Commands that provide the drone with coordinates outside of the room area boundary should be discarded
    c. The drone should land automatically if the drone ends up outside of the boundary (range for communication)

3. **Drones must not crash into each other**
    a. Two drones are tested simultaneously in the same space
    b. Commands that result in overlapping drone position should be discarded and not processed

4. **Drone can perform proper commands/movements**
    a. Drone should be able to:
        i. Arm, Disarm
        ii. Lift off, Land
        iii. Move left, Move right
        iv. Move forward, Move backward
        v. Move up, Move down

5. **Low latency between the drone and GCS**
    a. Person with fastest recorded reaction time (using online react tests) will measure latency
    b. The latency will be tested with a typical stopwatch, by hand
    c. The approximate latency will be calibrated using the average reaction time (after 6 tests)
    d. The latency should be approximately less than 1s, so testing by hand is sufficient

6. **Accurate drone position received by the GCS**
    a. Drone position will be measured/tested by commanding the drone to fly and land in set locations on the ground, confirming that it lands in the expected location by comparing the GCS calculated location and the measured location on the ground
    b. Height position accuracy will be tested/measured using a measuring meter on the wall

7. **A drone must be a quadcopter**
    a. Drone must properly function as a 4-propeller multi-copter
    b. Each DC motor must be tested individually, to confirm it is operating properly
    c. Each motor must be able to ramp up to 100% capacity and back to 0%
    d. Each motor should be calibrated to have similar levels of thrust

8. **Drones must qualify in the “micro-drone” class under Canadian law**
    a. The drone will be weighed on a scale to confirm it is not too heavy

Test Plan

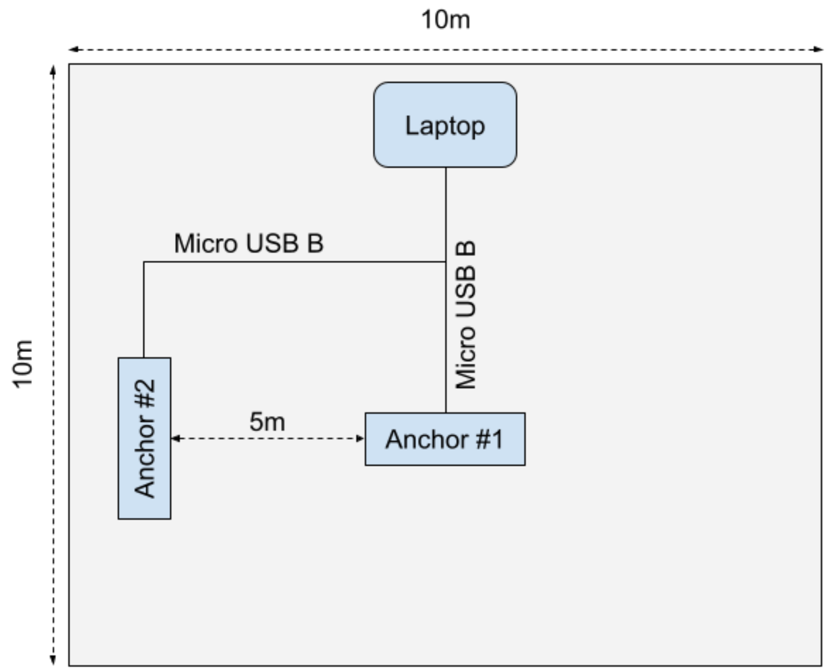

Figure 1 – Top-down view of testing setup

To set the testing environment:

a) First clear a room of at least 5m x 5m area (optimally about 10m x 10m) of the floor and at least a ceiling height of 3 meters
b) Ensure that clear ground is available within the above specified range for drones to land safely
c) Place the laptop running the GCS program in the location seen in Figure 1
d) Using masking tape, mark down a rectangular perimeter of the 10m x 10m (or 5m x 5m) space cleared out
    i) These are the bounds to conduct the tests when operating the drones
e) Place the AOA anchors orthogonal to each other
    i) The first anchor should be placed 5m in front of the laptop running the GCS program
    ii) The second anchor should be facing towards the first anchor positioned at a height of 2m off the ground and placed 5m to the left

Test Method

To conduct the following tests, a test environment must be set so each test can be accurately and consistently completed. These instructions are detailed in the section above.

The environment is now successfully set for the following 8 tests to be conducted:

1) **Verify the GCS successfully communicates with drone**
   a) Connect a 3.7V 1200 mah Li-Polymer battery to the drone
   b) Open the GCS program on a laptop device running on Windows 10/11
   c) Drone will start sending heartbeat signals
   d) GCS program should be outputting the location of the drone on the terminal
   e) A command to arm itself will be sent to the drone
   f) The drone should slowly spin the motors to show that it is armed

2) **Verify the system detects out-of-bound commands**
   a) Connect a 3.7V 1200 mah Li-Polymer battery to the drone
   b) Open the GCS program on a laptop device running on Windows 10/11
   c) Send the drone a lift off command to arm the drone
   d) Send the drone a move-up command to elevate the drone by 1m
   e) Send the drone a move-right command by 10.5 meters
   f) GCS must inform that this command is not possible, since drone will go out of bounds
   g) The drone does not accept the move-right command, stays put

3) **Drones must not crash into each other**
   a) Equip two operational drones; *drone one* and *drone two*
   b) Connect a 3.7V 1200 mah Li-Polymer battery to each drone
   c) Open the GCS program on a laptop device that is running on Windows 10/11
   d) Send *drone one* the two following commands:
      i) Lift off command to arm the drone
      ii) Send the drone a move up command to elevate the drone by 1m
      iii) Wait for *drone one* to respond to the move up command
      iv) Once first command has been received by drone, send a new command to move the drone right 1 m
   e) Now that *drone one* is stationary in position, send the following two commands to *drone two*
      i) Lift off command to arm the drone
      ii) Send the drone a move up command to elevate the drone by 1m
      iii) Wait for *drone two* to respond to the move up command
      iv) Once first command has been received, send a new command to move the drone right 1m
   f) Observe/confirm that *drone two* does not complete the second command, it stays stationary. Command is abandoned .

4) **Drone can perform proper commands/movements**
   a) Connect a 3.7V 1200 mah Li-Polymer battery to the drone
   b) Open the GCS program on a laptop device that is running on Windows 10/11
   c) Send the drone the following commands:
      i) Arm
      ii) Take off

iii) Move 1m up and hover
iv) Move 1m left
v) Move 1m forward
vi) Move 1m right
vii) Move 1m backward
viii) Land
ix) Disarm

d) Observe that the drone responds and completes the commands

5) Measure the low latency of the system (between drone and GCS)

a) Use an online reaction time test (i.e: Human Benchmark web application [1]) to measure the timer's reaction time. Person with the lowest reaction time will conduct the procedure.
b) Connect a 3.7V 1200 mah Li-Polymer battery to the drone
c) Open the GCS program on a laptop device that is running on Windows 10/11
d) Send a lift-off command through the computer terminal to arm the drone
e) Instantaneously activate a stopwatch as the command is sent
f) Closely observe the drone's propellers
g) Once the drone's motors/propellers slowly start to spin, stop the timer on the stopwatch. Record this measured time.
h) Add the recorded time on the stopwatch with the timer's reaction time test result. Record this result.
i) Send a land command to the drone. Drone must land safely. Next, send a disarm command. Immediately (10 seconds later), send an arm command to the drone.
j) Repeat steps d) to i) 9 more times, for a total of 10 times. Record all timing results and compute the average of all 10 iterations.

6) Measure the accuracy of the received location of the drone (form GCS)

a) Connect a 3.7V 1200 mah Li-Polymer battery to the drone
b) If test environment is not already setup, place the AOA anchors orthogonal to each other, 5m apart, with one faced up on the floor 5m in front of the GCS laptop, and the other 2m off the ground (on a desk or chair) and facing towards the first anchor
c) Open the GCS program on a laptop connected to the two anchors
d) Place and hold the drone (by hand) in locations within a 5m radius of the floor anchor. Measure this location on the ground using a measuring meter.
e) Record and compare the location the GCS program reports on the laptop and the location the drone was placed.
f) Now place the drone on the ground, and send the following commands: Arm, take off, move 1m up and hover, move 1m left, land, disarm.
g) Record and compare the location the GCS program reports on the laptop and the location the drone has landed, must be equal.

7) Check to see if the drone qualifies as quadcopter

a) Connect a 3.7V 1200 mah Li-Polymer battery to the drone
b) Run a tester program flashed on the flight controller
c) Check that each motor runs periodically while running step b)
d) Observe if each motor has a similar speed while running step b)
e) Toggle tester program to 100% throttle (max speed)
f) After 0.5s, toggle tester program to 0% throttle
g) Observe and confirm that all 4 motors/propellers functioned properly

8) **Measure the drone's total weight, must qualify in the "micro-drone" class under Canadian law**
    a) Place the drone on an electronic weight scale
    b) Record the weight displayed on the scale. Verify the total weight is less than 250 grams

Success Criteria

Functional Requirement	PASS/FAIL
1. Successful communication between the Ground Control System (GCS) and drones	Each communication signal should be properly sent and received by the drone and GCS and the acknowledgement should be shown on the computer terminal.
2. The system should be able to detect out-of-bound commands	A successful test would cause the drone to move 10 meters to the right and then halt within the marked perimeter. The drone should not obey the full command (moving 10.5 meters to the right) as this would cause the drone to go out of bounds.
3. Drones must not crash into each other	*Drone two* should not obey the second command sent to it (move right 1m). A successful test would result in the drone remaining 1m up in the air from its original position, as accepting the move right command would cause a crash to occur with *drone one*.
4. Drone can perform proper commands/movements	Each drone command should be observed.
5. Low latency between the drone and GCS	The measured latency should be less than 1 second + the timer's reaction speed.
6. Accurate drone position received by the GCS	The drone should land within a 20 cm radius of the expected lading position.
7. A drone must be a quadcopter	The drone must have 4 DC motors functioning at a similar level and must take off at 100% throttle.
8. Drones must qualify in the "micro-drone" class under Canadian law	A single drone weighs < 250g

Table 2 – Success Criteria for conducted tests

References

[1] *Human benchmark*. [Online]. Available: https://humanbenchmark.com/tests/reactiontime. [Accessed: 26-Jan-2023].