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Bluetooth-Localized Drones

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Background

Drones are becoming a versatile and powerful tool to technological systems both outdoors and indoors.

Currently, technologies such as GPS are used for localization of drones that provide accuracies within 400 cm. However, GPS uses satellite signals which are weak indoors and can't penetrate through buildings. Ultrasonic beacons are an example of Indoor Positioning technology, which improve location accuracy to 1-100 cm.

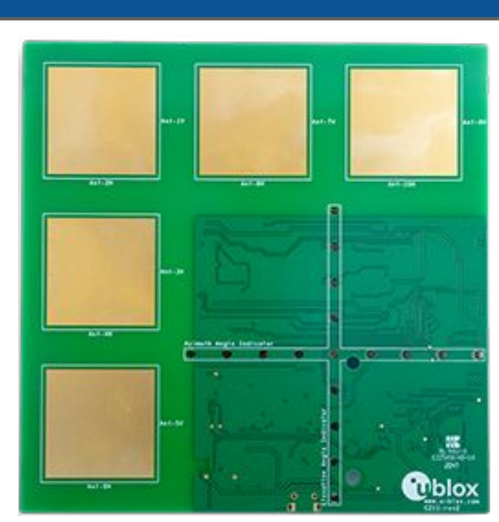
Our team has proposed to use Bluetooth Low Energy (BLE) Technology for drone localization because BLE Angle of Arrival (AOA) technology has capability of object localization accuracy within 1 - 50cm.

Goal, Requirements, and Objectives

Our project goal is to develop a scalable drone infrastructure that utilizes Bluetooth Low Energy Angle of Arrival technology (BLE AOA) for accurate indoor localization of drones. To accomplish this, our Project Requirements and Objectives include:

- Locate drones using BLE signals
- Drone location accuracy within 20cm
- Detect out of bounds drone commands
- Scalability: support multiple drones with minimum marginal cost

Key Components

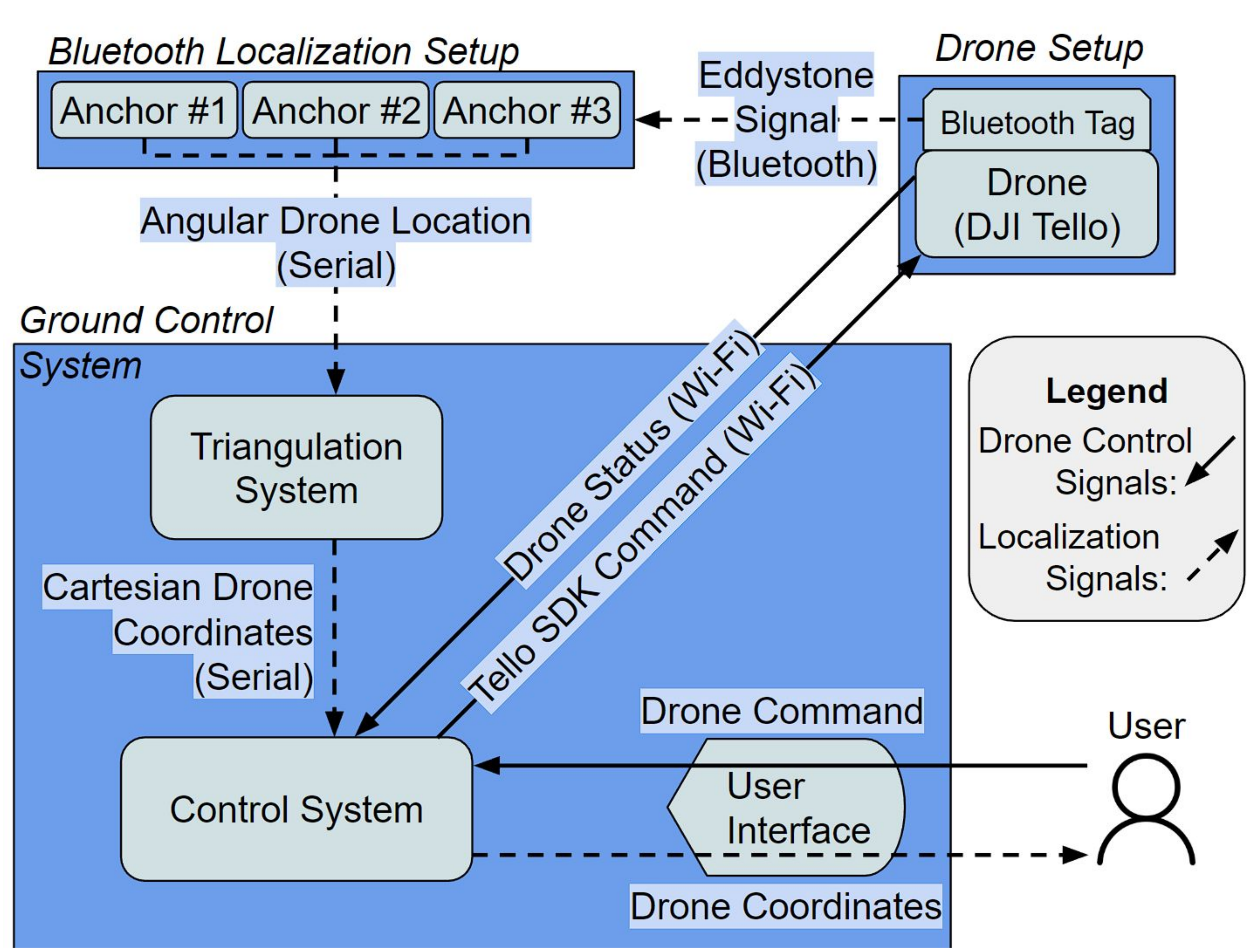


BLE AOA Anchors: *uBlox XPLR-AOA-1 C211*
This module intercepts Bluetooth Eddystone signals from a BLE tag and calculates its angles of arrival.

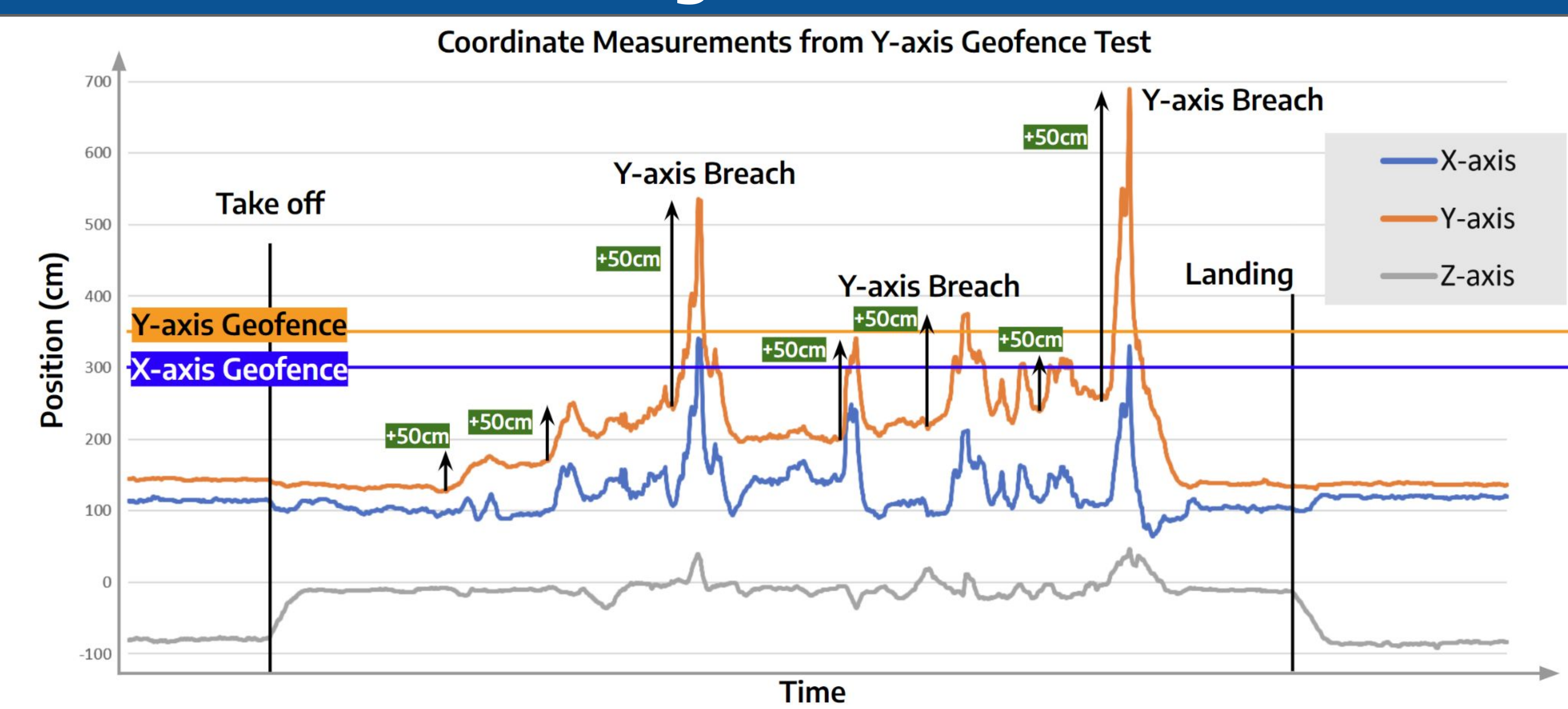
BLE Tag: uBlox *XPLR-AOA-1 C209*
Attached to the drone, advertises Bluetooth Eddystone signals for the anchors to intercept.

Drone: *DJI Tello*
Off-the-shelf drone with useful Python SDK commands to use in our control system and UI.

System Diagram



Testing & Evaluation

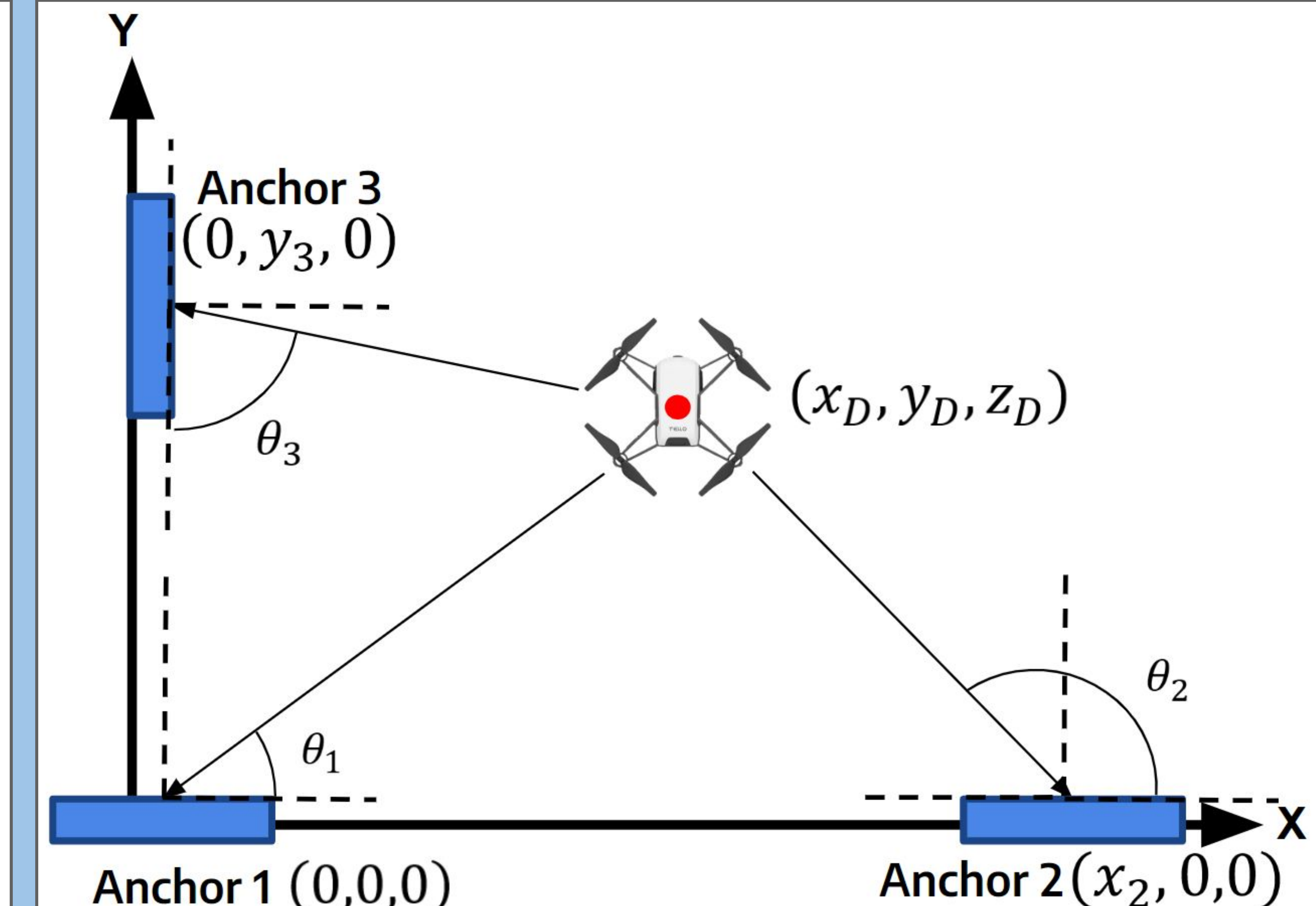


Shown above is the drone's position during a Y-Axis Geofence test, where if the drone oversteps the Y-axis geofence bounds, it will automatically move back in. The drone takes off (moving up the Z-axis) then takes steps of +50cm in the Y-axis, then lands back down.

The Z-coordinate calculation is very stable and accurate to the drones takeoff and landing movement. However, the X and Y axis coordinates have a lot of inaccuracy when the drone performs its Y-axis steps, especially when moving further from the anchors. The X position jolts when moving in the Y-axis. The Y position does show the 50cm steps but with much noise.

Testing videos can be found here through this QR Code! →

Bluetooth Localization Setup



Triangulation

	Anchor 1&2	Anchor 1&3	Anchor 2&3
X_D	$\frac{x_2 \tan(\theta_2)}{\tan(\theta_2) - \tan(\theta_1)}$	$\frac{-y_3 \tan(\theta_3)}{\tan(\theta_3) - \tan(\theta_1 + 90°)}$	$x_2 - Y_D \tan(\theta_2 + 90°)$
Y_D	$\frac{x_2 \tan(\theta_2) \tan(\theta_1)}{\tan(\theta_2) - \tan(\theta_1)}$	$y_3 - \frac{-y_3 - \tan(\theta_3)}{\tan(\theta_1 + 90°) - \tan(\theta_3)}$	$\frac{y_3 - x_2 \tan(90° - \theta_3)}{1 - \tan(\theta_2 + 90°) \tan(90° - \theta_3)}$
Z_D	$\frac{\sqrt{X_D^2 - Y_D^2}}{\tan(90° - elevation°)}$	$\frac{\sqrt{X_D^2 - Y_D^2}}{\tan(90° - elevation°)}$	$\frac{\sqrt{X_D^2 - Y_D^2}}{\tan(90° - elevation°)}$

1. Every AOA anchor calculates the angle at which the drone's BLE signal is received.
2. Each pair of anchors calculates the X, Y, Z coordinates of the drone using the triangulation equations above.
3. The final X, Y, Z coordinates of the drone are calculated by taking the average of all 3 anchor pairs.
4. To improve the triangulated drone location, the system calculates the rolling average of the X, Y, Z coordinates every N samples.

Future Work

Overall, BLE technology is currently too unreliable to be used for drone localization due to accuracy limitation of BLE modules. However, with sufficiently powerful averaging algorithms and support from machine learning models, a system of Bluetooth-localized drones may be feasible in the future at satisfactory accuracy.
We expect computer vision camera systems become more prevalent for indoor drone localization in the near future.

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