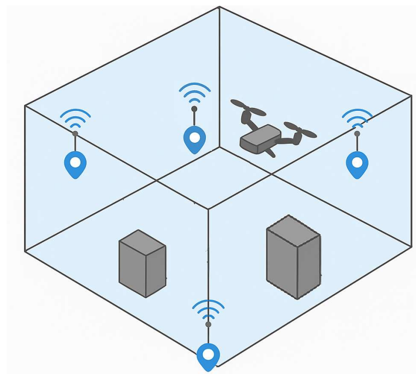
GNSS-Free Positioning Using Communication Systems

Global Navigation Satellite Systems (GNSS) are widely used for positioning; however, due to the low signal power at the receiver, they are highly vulnerable to interference, spoofing, and jamming. This creates critical risks in applications where secure and reliable positioning is essential, ranging from civil to defense domains.

The objective of this project is to develop an alternative self-positioning solution that does not rely on GNSS. The designed system must leverage existing communication systems resilient to interference and disruptions. A mobile object will estimate its position by communicating with *anchor nodes,* which are fixed-location terminals, and extracting spatial information from the received signals.

Several features can be utilized for this purpose, including (but not limited to):

- Received signal strength from anchor nodes
- Time of Arrival (ToA) from anchor nodes
- Time Difference of Arrival (TDoA)
- Angle of Arrival (AoA) and triangulation
- Channel State Information (CSI)
- Multipath characteristics and channel delay spread



Simple positioning techniques may suffer from significant limitations. For example, their performance can degrade considerably in non-line-of-sight (NLoS) environments. Furthermore, unfavorable anchor geometries (e.g., all anchors being at similar altitudes) can result in large estimation errors, particularly along the vertical (z) axis. The designed system should tackle these issues.

The project involves exploring enhanced positioning techniques through both simulation and hardware implementation in outdoor test environments (e.g., Devrim Stadium, a parking lot).

- The communication system should use modern modulation techniques (e.g., OFDM). A synchronization preamble can be utilized to provide coarse time and frequency alignment for the frame.
- 3D positioning should be performed within a region of 20m × 20m × 10m using N = 4 anchor nodes placed at known fixed positions.
- The performance should be evaluated using both Root Mean Square Error (RMSE) and bias metrics, and for various cases when all anchor nodes are at the same altitudes as well as at different altitudes.
- For both cases, the positioning accuracy within the area enclosed by the anchor nodes must satisfy RMSE ≤ 1 m in the x-y plane, and RMSE ≤ 2 m along the z-axis. In regions not enclosed by the anchor configuration, the accuracy should meet RMSE ≤ 1.5 m in the x-y plane and RMSE ≤ 2.5 m along the z-axis.
- Position update period must be less than 1 second.
- Improving the positioning accuracy along the z -axis is particularly challenging when all anchor nodes are at the same altitude, and may necessitate the use of advanced signal processing techniques.
- The signal-to-noise ratio (SNR) will depend on the relative positions of the anchor nodes and the mobile object.

- Algorithms must be developed to optimize the placement of N = 4 anchor nodes to maximize the positioning accuracy via simulation.
- Hardware demonstration should be performed to characterize the positioning accuracy for various anchor geometries using a proper platform such as software defined radios (SDRs).
- An interface for position visualization is expected for demo purposes.

Extra Features (Optional)

- Comparative study of different positioning techniques.
- Performance analysis with increased number of anchor nodes.
- Real-time position tracking with a specialized tracking algorithm