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Development of a Model for Determining the Coordinates of Clustered Flying Sensor Network Nodes

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***Abstract*—This research explores the fundamental capability of determining the coordinates of individual objects within a network, presenting a compelling case for the attractiveness of such systems. The potential to determine coordinates becomes a key advantage, leading to cost reduction and diminished energy consumption of individual devices, notably by eliminating the need for GPS sensors. Additionally, the deployment of these networks is simplified, envisioning scenarios such as aerial dispersion of devices from aircraft. The adaptability of these sensor networks in challenging terrains further underscores their appeal. Although coordinate determination is integral to various wireless telecommunication networks, including cellular networks, the unique characteristics of each network necessitate distinct approaches to coordinate resolution, even when based on common principles such as geometric triangulation. Therefore, the task of determining coordinates for nodes in a clustered flying sensor network remains pertinent. The study discusses the contemporary relevance and significance of this challenge, emphasizing its potential to enhance the efficiency and applicability of wireless sensor networks, particularly in scenarios where conventional methods face limitations.**

Keywords—flying sensor networks, coordinate determination, clustered networks, energy-efficient devices, deployment optimization.

I. Introduction

In the ever-evolving landscape of wireless sensor networks, the integration of airborne sensors has emerged as a transformative paradigm, introducing unprecedented mobility, coverage, and data accuracy. Within this realm, the concept of Clustered Flying Sensor Networks (CFSNs) has gained considerable attention, promising enhanced efficiency and adaptability. One of the pivotal challenges in harnessing the full potential of CFSNs lies in the precise determination of the coordinates of individual nodes within the clustered architecture.

Traditional methods often rely on GPS sensors for geolocation, but the inherent limitations and associated costs have spurred a quest for alternative strategies. This article embarks on the exploration and development of a robust model specifically tailored for determining the coordinates of nodes in Clustered Flying Sensor Networks. By delving into the intricacies of coordinate determination within a clustered context, the research aims to contribute not only to the theoretical advancements in wireless sensor networks but also to the practical optimization of these networks for diverse applications.

As we delve into the intricacies of this model development, we unravel the complexities and nuances involved in achieving precise geolocation within a clustered airborne sensor network. The potential implications of such advancements are vast, ranging from cost-effective deployment strategies to increased energy efficiency in individual devices. This research seeks to bridge the gap between theoretical considerations and practical implementation, fostering a deeper understanding of the challenges and opportunities in the realm of clustered flying sensor networks.

On the other hand, RFDs, designed for more specific and streamlined tasks, operate with reduced functionality. This article delves into the dynamics of these two device types, exploring their roles and significance in wireless networks. Additionally, we will examine two fundamental topologies: the star topology, characterized by a central hub facilitating communication, and the peer-to-peer topology (Fig. 1), where devices communicate directly with one another, fostering decentralized and redundant structures. By unraveling the intricacies of FFDs, RFDs, and these topologies, we aim to provide valuable insights into the foundations of wireless networking, offering a comprehensive understanding that can inform the design and optimization of wireless communication systems.

In recent days, wireless sensor networks (WSN) are catching the spotlights in networking and other emerging fields like large data communication, artificial intelligence, automation systems etc [1]. Clustering, a machine learning technique, is an effective way to extend the lifecycle and reduce power consumption of wireless sensor networks [2]. In paper [3] descibed novel framework to realize efficient data collection from wireless sensor networks, where an unmanned aerial vehicle (UAV) is dispatched to collect the aggregated data from cluster heads and an unmanned ground vehicle carrying backup batteries moves along with the UAV to compensate for the shortage of UAV energy. The combination of a large number of nodes into a network, the requirements for minimizing the energy consumption of nodes and the network as a whole lead to the need for additional structural solutions when creating wireless sensor networks. The most important of these is network clustering, which also implies constant rotation of the cluster head node during the network life cycle [4]. Possible also optimise of structure the node for reducing energy consumption [5]. Test mockups or testbenches [6] can be used to study real networks [7]. Wireless sensor networks can effectively reduce complexity, weight, and costs of aerospace onboard communication systems [8]. However, it is necessary to optimize these networks in order to extend their autonomous lifetime[9] with power consumption [10].

Typically, the sensor network is important not only to detect or measure the value of an event parameter of interest, but also to correlate it to a specific point in space. As the location of sensors on the ground can be random in nature, there is a question of finding the coordinates of all nodes [11]. The possible idea is to expand the set of localizable nodes starting from the set of anchor nodes cluster by cluster rather than node by node [12]. Thus, the main tasks of the research can be reduced to:

- Perform a survey of flying sensor networks.
- Determine the structure of the flying sensor network.
- Consider the issue of network clustering.
- To develop the determination of the coordinates of the nodes of the clustered flying sensor network.
- Check the adequacy of the model.

Thus, the task of determining the coordinates of nodes for a clustered flying sensor network is relevant.

II. Methods of Determining Coordinates

The main methods of determining coordinates include:

- Trilateration method (Fig.1).
- Multilateration method (Fig.2).
- Triangulation method (Fig.3).

Trilateration relies on distance measurements from three or more known points to determine the coordinates of an unknown point. It is commonly used in wireless communication and indoor positioning systems, often utilizing signal strength or time-of-flight measurements.

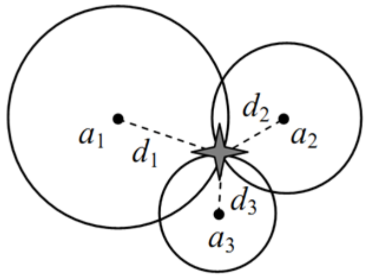

Fig. 1. Trilateration method.

Similar to trilateration, multilateration determines position by measuring the time difference of arrival (TDOA) or phase difference of signals from multiple known locations. This method is often used in radar systems and air traffic control. (Fig. 2).

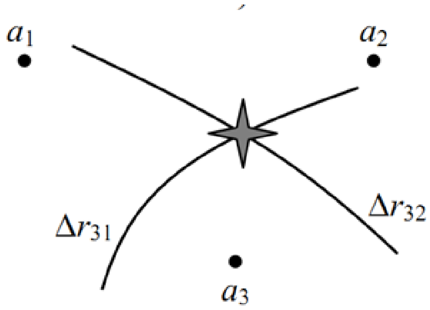

Fig. 2. Multilateration method.

Triangulation method involves measuring the angles between a known baseline and the lines to the target from two or more points. By using trigonometry, the coordinates of the target can be determined. Triangulation is commonly used in surveying and navigation.

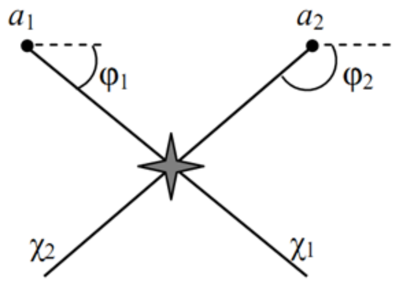

Fig. 3. Triangulation method.

The choice of method depends on the specific application, environmental conditions [13-18], and the level of accuracy required for the task at hand.

III. Symmetrical Double-Sided Two Way Ranging

A Flying Symmetric two-way ranging (SDS-TWR) [14] is a ranging method that uses two delays that naturally occur during signal transmission to determine the range between two nodes: repeaters (Fig.4):

- Signal propagation delay between two wireless devices.

- Confirmation processing delay in the wireless device.

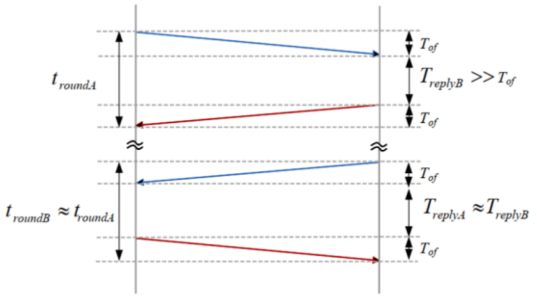

Fig. 4. SDS-TWR.

This method is called symmetric bilateral because: It is symmetric because the measurement from station A to station B is a mirror image of the measurement from station B to station A (ABA to BAB). It is two-way because only two stations are used to measure the range, station A and station B. It is two-way because it uses a data packet (called a test packet) and an ACK packet. Conditions for using the method. The absence of strict requirements for synchronization (characteristic of TOF and TDOA) with high accuracy of state estimation between nodes (much higher than that of RSSI) allows considering this method as the main method of radio ranging in the development of a method of spatial positioning.

IV. Proposed Model

To account for the lack of responses from nodes in our model, we propose introducing a specific function, referred to as a penalty function, to calculate the computation costs of estimates. This function should lead to an increase in the value of the minimized expression for those points, denoted as "I," situated in the vicinity of antenna locations through which signals from nodes were not received.

V. Conclusion

In this article, we explored a model for determining coordinates in clustered flying sensor networks. The proposed model incorporates a penalty function to account for nodes that do not provide responses, thereby enhancing the accuracy and efficiency of coordinate determination. Simulation results affirm the model's effectiveness in real-world scenarios. The introduction of the penalty function proves to be a promising approach for optimizing computations within network nodes, especially in locations where signal reception was challenging.

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