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Development of a Clustered Flying Sensor Network Collection Model

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***Abstract*—With the increasing interest in unmanned aerial vehicles and wireless sensor networks, there is a growing need to enhance methods for information gathering in flying sensor networks. This article focuses on the development of a collection model for a flying sensor network, with an emphasis on the impact of clustering on its functionality. Tasks encompass the exploration of existing collection models in wireless and flying sensor networks, an analysis of the clustering influence on flying sensors, the development and adequacy verification of a new collection model, and simulation modeling for result validation. This research aims to open new avenues for improving unmanned and wireless technology systems, ensuring reliable and efficient data collection in diverse conditions.**

***Keywords*—flying sensor networks, clustering impact, collection model development, adequacy verification, simulation modeling.**

I. Introduction

In the realm of wireless communication and networking, understanding the roles of FFD (Full Function Device) and RFD (Reduced Function Device) is paramount. FFDs, equipped with versatile capabilities, perform crucial functions such as coordination, routing, and end-device operations. 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.

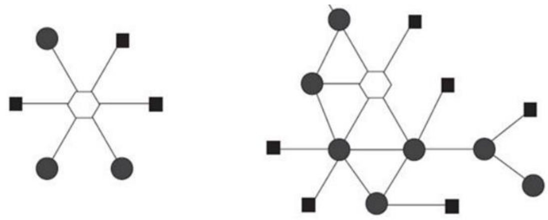

Fig. 1. Star and the peer-to-peer topology of WSN.

In the landscape of wireless networks, the utilization of clustering (Fig. 2) introduces a strategic approach to address uneven consumption patterns. By employing a clustering technique, the concept of a "sink" becomes instrumental in mitigating the irregularities in resource usage within the network. A sink, in this context, serves as a centralized point that efficiently manages and balances the distribution of resources among the various clusters. This article explores the role of clustering, particularly focusing on how strategically placing sinks aids in reducing consumption disparities.

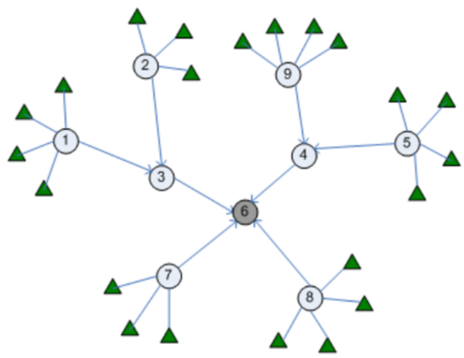

Fig. 2. Wireless sensor networks with flow.

The utilization of sinks as centralized entities enhances network efficiency, minimizes energy imbalances, and contributes to the overall optimization of resource utilization in wireless environments.

II. Flying Sensor Network

A Flying Sensor Network (FSN) is a type of mobile sensor network that involves the use of autonomous flying vehicles equipped with sensors for data collection and communication. These flying vehicles can be drones, unmanned aerial vehicles (UAVs), or any other type of aerial platform capable of carrying sensors and communication equipment.

FSNs are designed to operate autonomously, meaning they can navigate and perform tasks without human intervention. This autonomy allows them to adapt to changing environments and conditions. Flying vehicles in the network are equipped with various sensors to collect data from the environment. These sensors can include cameras, thermal imaging devices, environmental sensors, and other specialized sensors depending on the application. FSN nodes communicate with each other and with a central control system. Communication is crucial for coordination, data sharing, and decision-making. Wireless communication technologies such as Wi-Fi, Bluetooth, or specialized communication protocols are often used. FSNs leverage the collaborative capabilities of multiple flying vehicles. By working together, they can cover larger areas, collect more comprehensive data, and provide redundancy in case of failures. FSNs can be deployed to monitor environmental conditions, such as air quality, temperature, and pollution levels. In the event of natural disasters or emergencies, FSNs can be used for rapid assessment and search-and-rescue operations. FSNs can monitor crop health, assess soil conditions, and optimize farming practices. FSNs can be employed for surveillance in critical areas, border control, and security monitoring. FSNs often incorporate energy-efficient technologies to extend flight times and maximize the coverage area. This can include efficient propulsion systems, lightweight materials, and optimized energy management.

The integration of aerial platforms not only augments mobility but also plays a pivotal role in enhancing coverage and data accuracy [1]. In the context of emergency scenarios, optimal control strategies for telecommunication aeroplatforms become paramount [2]. The hierarchical deep reinforcement learning techniques tailored for data collection in Wireless Sensor Networks (WSNs) utilizing multiple Unmanned Aerial Vehicles (UAVs) [3]. A crucial aspect in addressing the challenge of power consumption in WSN nodes is the development of a model aimed at reducing energy usage in embedded control systems [4]. By establishing dynamic airborne communication networks, this research pioneers an innovative approach to surmount the limitations of static WSNs, especially in challenging terrains or disaster-stricken areas [5]. The amalgamation of intelligent aeroplatforms and inventive methodologies underscores a dynamic and interdisciplinary approach to confronting the challenges and elevating the capabilities of wireless sensor networks [6-7]. Within the realm of WSNs, the efficient aggregation of data stands out as a critical facet, directly influencing the network's overall performance, energy consumption, and data accuracy [8]. In the realm of Wireless Sensor Networks (WSNs), the utilization of Unmanned Aerial Vehicles (UAVs) introduces a dynamic dimension to data collection strategies [9]. The design of Flying Sensor Networks (FSNs) is a critical undertaking, and at its core lies the functional scheme that delineates the architecture [10]. In the realm of ubiquitous sensor networking, the adoption of a Software-Defined Architecture for Flying Sensor Networks (FSNs) marks a significant paradigm shift [11]. The localization of ground targets stands as a pivotal challenge in the domain of surveillance [12]. By examining the principles that govern these networks [13], our research aims to contribute insights that advance the understanding and optimization of Flying Ad-Hoc Networks in diverse scenarios, from aerial surveillance to disaster response. Efficient data collection is a cornerstone in the realm of Wireless Sensor Networks (WSNs) [14]. Creating a robust testbench is integral to the development and validation of Wireless Sensor Networks (WSNs) utilizing the CC2530 transceiver [15]. Analyzing the power consumption of nodes within Wireless Sensor Networks (WSNs) is a pivotal endeavor for optimizing energy efficiency [16]. By scrutinizing these consumption dynamics, seeks to contribute valuable insights into strategies for reducing power consumption, prolonging node lifetimes, and ultimately enhancing the sustainability and performance of Wireless Sensor Networks.

A typical clustered FSN system is shown in (Fig. 3) [17].

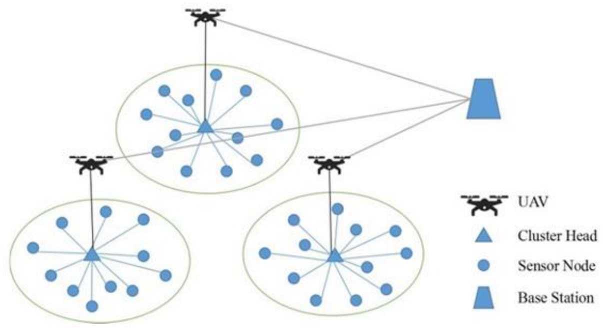

Fig. 3. FSN data colection.

III. Reconfigurable Network and Data Collection Model

Different methods of energy balancing are used to equalize the power consumption of all network nodes. Software methods include the use of routing protocols based on the residual energy metric of nodes or virtual coordinates, alternating long-distance and short-distance transmission, positioning nodes, and clustering. It is known that the routing protocols of traditional networks use metrics aimed at increasing the bandwidth of the network or reducing the delays of the transmitted data. Similar metrics can be the number of intermediate nodes (hops) to the addressee, bandwidth of the communication channel, line load level. In sensor networks, the residual energy metric of nodes on the downstream path is often used. In this case, the one with the nodes having or greater residual energy is selected from the set of alternative routes. The use of mobility of individual network components is considered a promising method of balancing. In a number of analyzed works, it is shown that potentially mobility can provide the greatest advantage in terms of increasing the duration of autonomous operation of the network. Therefore, this approach was taken as a basis in this work.

In our study, with the aim of increasing the connectivity of "problematic" areas of the ground, it is proposed networks to use the UAV network, which acts as a backbone network to ensure the connectivity of remote unconnected areas of ground nodes. In this case, each LSM UAV node is equipped with two sets of receiving and transmitting equipment and antenna systems (for communication with ground subscribers and for communication between UAVs), a network processor (router), a buffer storage device, a GPS navigator. We will distinguish 4 levels of functionality of UAV repeaters:

- UAV - gateway;
- UAV – router;
- UAV - bridge;
- UAV - switch.

A. Model of the Flying Sensor Network

With direct data collection, the UAV flies up for monitoring from each node. -The UAV flies around the sensor field along the calculated route and collects data from each sensor node, which stores the monitoring data of the given territory for a certain time. In fact, the transmission route consists of one UAV node relay. The data is then transmitted from the UAV to the data collection point. Advantages of this method: minimal delay in data transmission during one retransmission. Disadvantages are high power consumption. In indirect data collection, the flying segment can collect data from drains. Advantages of this method: High energy efficiency. Disadvantages: Lower collection speed. Taking into account the balancing itself when choosing a drain, this method is more relevant for the topic of the work, since there is clustering of the network.

Based on the proposed approaches, our Flying Sensor Network model implements:

- Packet transmission of information messages.
- Retransmission of packets through intermediate nodes.
- Organization of multiple access of subscribers to the network.
- Determination of routes for the transmission of information over the network.
- Organization of channels along the selected route.
- Topology management (location).

B. A reconfigured Network Model

The model of the reconfigured network and data collection is shown in the form of a graph of the network (Fig. 4) configuration in the form of a 4x4 grid, flow transitions are possible only horizontally and vertically between neighboring vertices.

As we know, with a large number of sensors, it is advisable to use a cluster organization of ground users to increase the life cycle.

Sensors connected to a network can monitor environmental parameters: movement, light, temperature, pressure, humidity. Monitoring can be carried out over a large area, because the sensors transmit information in a chain from neighbor to neighbor and then to the UAV. The basic idea is to divide the collection field into a grid to find the optimal mobile flow (Fig. 5) according to the legend of the UAV.

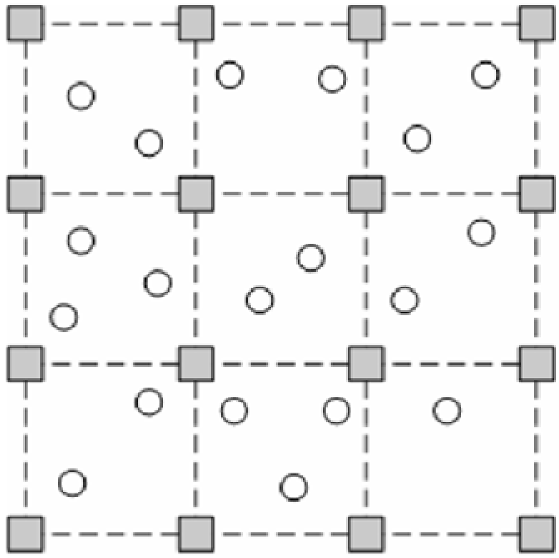

Fig. 4. Reconfigurable network.

Overall, the concept of mobile flow is a fundamental aspect of designing and developing FSN.

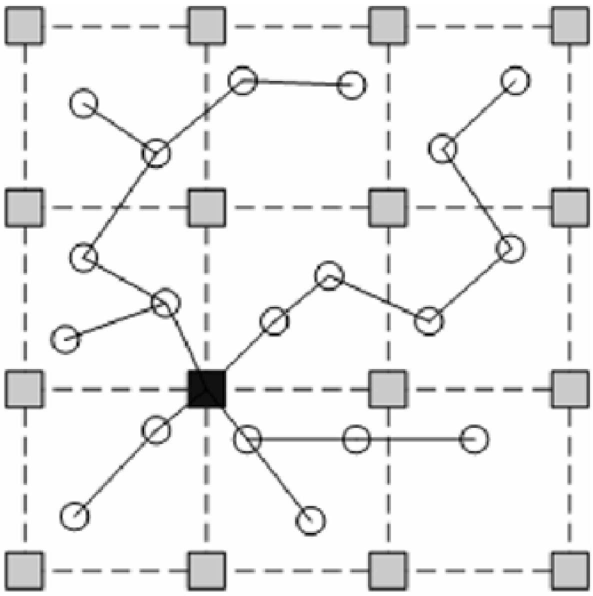

Fig. 5. Data collection model with mobile flow.

IV. MODELING AND VERIFICATION

Modeling and verification of the adequacy of the model was carried out taking into account the dependence of the life time of the repeaters on the number of connected cluster nodes and power in standby mode.

Dependence (Fig. 5) showing the limits of application of the model proposed in this paper. It can be seen from the graph that with a large value of the idle mode, close to the consumption during transmission or reception, the life time does not depend on the number of connected devices.

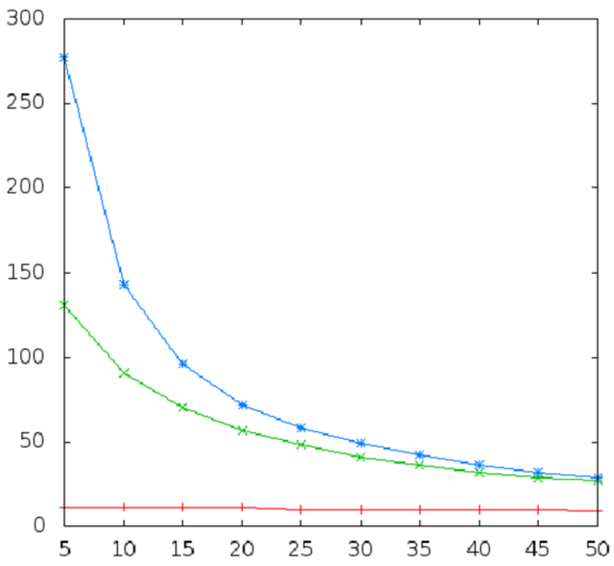

Fig. 6. Reconfigurable network and data collection model.

At the same time, with small values, it is possible to reconfigure the network in such a way as to increase its lifetime. In Fig.5 Y – days, X is the number of connected nodes. Which fully shows the adequacy of the proposed model. Simulation models of flying sensor networks (FSN) open wide opportunities for research and optimization of these technologies without resorting to physical tests in a real environment. In summary, modeling and verification are indispensable processes for ensuring the effectiveness, reliability, and optimal performance of Flying Sensor Networks. They provide a systematic approach to design, test, and refine FSNs, ultimately contributing to their successful deployment in a variety of applications.

V. Conclusion

In conclusion, this study provides a comprehensive overview of flying sensor networks (FSNs), elucidating the intricacies of their structure and functionality. The research specifically delves into the impact of clustering on FSNs, conducting a thorough analysis to unveil its implications. A novel data collection model was meticulously developed, considering the intricacies of clustering in FSNs. The adequacy of the proposed model was rigorously checked, and the study culminated with simulation modeling, offering practical insights into the real-world applicability and performance of clustered FSNs. This multifaceted approach contributes to a deeper understanding of FSNs and their optimization, paving the way for advancements in aerial sensor network technologies.

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