# SQUARE BASED PATH PLANNING ALGORITHM FOR UAV TO COLLECT DATA FROM SENSORS

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Abstract: The wireless sensor networks find their applications in agriculture, military, disaster prone area etc. The nodes in the network are run by smaller batteries which need to be utilized in a way that they can work for longer time duration. Unmanned aerial vehicles are used with such networks for data collection purposes to increase the network lifetime. The trajectory of the UAV needs to be optimized such that the network can give desired output. This paper proposes a modification to the existing spiral path planning algorithm and is based on the fact that UAV if moved along the square (inscribed in the circle) will have less trip distance. The performance of the network was compared based on trip time, tour length and remaining energy of the network. These parameters showed an improvement over the existing scheme.

Keywords: UAV, WSN, network lifetime, tour length, concave hull

## I. INTRODUCTION

Collaborative networks help resolving tasks that are relatively complex to be attained using a single network model. One of the collaborative networks can be formed using the unmanned aerial vehicles (UAVs) and the wireless sensor networks (WSNs). These networks can provide support in various applications concerning tracking and data acquisition problems. UAVs have tendency to fly autonomously and can collaborate with existing network to form a search, tracking, and data acquisition networks [1]. Further, these networks can be used to provide vast coverage and enhanced security in border areas [2]. These vehicles are capable of forming intermittent connections with the existing wireless networks to form fully reliable opportunistic networks that can sort issues like broadcast storm, network partitioning, and so forth [3]. With the tendency to organize and resolve the failure issues easily, these vehicles can be used to form self-sufficient networks that can withstand the sudden network changes and failures [4].

Collaborative network between the UAVs and the WSNs can provide an efficient solution to the routing loop problem in traditional sensor networks and can also enhance the lifetime of the sensors by optimal division of the load. However, these solutions are subjected to the formation of an optimal topology and a routing schema for utilization of the coordination between the UAVs and the WSNs. Also, the positioning of UAVs in sensor networks is an optimization problem that needs to be resolved for efficient deployment of such collaborative network models. This work focuses on the optimal path planning of the UAV to gather data from the sensor nodes.

This paper defines the existing techniques that work on improving the performance of wireless sensor network using UAV in Section II. The Section III describes the proposed path planning approach of UAV to gather data from sensor nodes. Section IV explains the results and paper has been concluded in the last section.

## II. LITERATURE REVIEW

This paper [5] mainly proposes a new path planning algorithm based on spiral decomposition, which is named as Spiral Path Planning (SPP) algorithm. Besides, the paper improves the existing FPPWR algorithm. Simulation proves SPP is more suitable for a UAV to collect data from sensors nodes evenly distributed in a circle area. Compared with FPPWR, the path SPP plans is shorter and runtime is less when number of sensors is small.

In this paper [6], the authors investigate an energy-effective data gathering approach in UAV-aided WSNs, where each sensor node (SN) dynamically chooses the transmission modes, i.e., (1) waiting, (2) conventional sink node transmission, (3) uploading to UAV, to transmit sensory data within a given time. By jointly considering the SN's transmission policy and UAV trajectory optimization, they aim to minimize the transmission energy consumption of the SNs and ensure all sensory data completed collected within the given time. They take a two-step iterative approach and decouple the SN's transmission design and UAV trajectory optimization process. First, the authors design the optimal SNs transmission mode policy with preplanned UAV trajectory. A dynamic programming (DP) algorithm is proposed to obtain the optimal transmission policy. Then, with the fixed transmission policy, they optimize the UAV's trajectory from the preplanned trace with recursive random search (RRS) algorithm. Numerical results show that the proposed scheme achieves significant energy savings gain over the benchmark schemes.

The authors in [7] propose the utilization of unmanned aerial vehicles (UAVs) to collect data in dense wireless sensor networks using projection-based compressive data gathering (CDG) as a novel solution methodology. CDG is utilized to aggregate data en-route from a large set of sensor nodes to selected projection nodes acting as cluster heads (CHs) in order to reduce the number of needed transmissions leading to notable energy savings and extended network lifetime. The UAV transfers the gathered data from the CHs to a remote sink node, e.g., a 5G cellular base station, which avoids the need for long range transmissions or multihop communications among the sensors. The problem definition aims at clustering the sensors, constructing an optimized forwarding tree per cluster, and gathering the data from selected CH nodes based on projection-based CDG with minimized UAV trajectory distance. They formulate a joint optimization problem and divide it into four complementary sub-problems to generate close-to-optimal results with lower complexity. Moreover, the authors propose a set of effective algorithms to generate solutions for relatively large-scale network scenarios. They demonstrate the superiority of the proposed approach and the designed algorithms via detailed performance results with analysis, comparisons, and insights.

This study [8] investigates a novel unmanned aerial vehicle (UAV)-based wireless sensor network, where the UAV acts as a flying base station to serve multiple wireless sensor nodes (SNs). The authors' goal is to maximize the system energy efficiency of the UAV while satisfying the fairness among SNs by jointly optimizing the UAV trajectory and UAV time allocation. The formulated problem is shown to be a non-convex fractional optimization problem, which is hard to tackle. To this end, they decompose the original problem into two sub-problems, and the block coordinate descent method and successive convex optimization technique are employed to solve these two sub-problems iteratively. Specifically, in the first sub-problem, the optimal UAV time allocation is obtained by maximizing the minimum achievable rate of SNs with given UAV trajectory constraints. In the second sub-problem, the UAV trajectory is achieved by minimizing the energy consumption of the UAV with the given UAV time allocation. Subsequently, an iterative algorithm is proposed to optimize the time allocation and UAV trajectory alternately. Furthermore, the convergence and complexity of their proposed algorithm are provided. Numerical results show that the proposed scheme outperforms the existing benchmark strategies in terms of energy efficiency.

This paper [9] studies an unmanned aerial vehicles (UAV) based data aggregation of wireless sensor networks (WSNs). The authors propose a topology-aware data aggregation (TADA) protocol, which preserves the advantages of CS-based schemes while alleviating the aforementioned issues. Extensive performance comparisons demonstrate that the data reconstruction error rate of TADA is much lower than other CS-based schemes under test. More important, for most WSN applications, since the underlying physical layer prefers frames with small payloads, the proposed TADA utilizes less transmissions from sensors to UAV in each round of data aggregation, and thus can yields a lower energy consumption.

This paper [10] considers an unmanned aerial vehicle (UAV)-enabled wireless sensor network (WSN) in urban areas, where a UAV is deployed to collect data from distributed sensor nodes (SNs) within a given duration. To characterize the occasional building blockage between the UAV and SNs, the authors construct the probabilistic line-of-sight (LoS) channel model for a Manhattan-type city by using the combined simulation and data regression method, which is shown in the form of a generalized logistic function of the UAV-SN elevation angle. They formulate a new rate maximization problem by jointly optimizing the UAV three-dimensional (3D) trajectory and transmission scheduling of SNs. They propose a novel and general design method, called hybrid offline-online optimization, to obtain a suboptimal solution to it, by leveraging both the statistical and real-time CSI. Essentially, the proposed method decouples the joint design of UAV trajectory and communication scheduling into two phases: namely, an offline phase that determines the UAV path prior to its flight based on the probabilistic LoS channel model, followed by an online phase that adaptively adjusts the UAV flying speeds along the offline optimized path as well as communication scheduling based on the instantaneous UAV-SNs CSI and SNs' individual amounts of data received accumulatively.

In this study [11], a crop health monitoring system is developed by using state of the art technologies including wireless sensors and Unmanned Aerial Vehicles (UAVs). The contribution of this paper is the formation of dynamic runtime clusters of field sensors by considering the above mentioned factors. Furthermore a mechanism (Bayesian classifier) is defined to select best node as cluster head. The proposed system is validated through simulation results, lab and infield experiments using concept devices. The obtained results are encouraging, especially in terms of deployment time, energy, efficiency, throughput and ease of use.

## III. PROPOSED WORK

The proposed work is based on theory that perimeter of the square inscribed in the circle is less than the circumference of the circle. Since the square has to be inscribed in the circle, therefore the proposed technique is required to be concave hull. Thus, when the nodes are deployed, first outer concave, middle concave and inner concave hull will be created.

To start the tour, UAV will first visit the nearest node in the outer concave hull. After collecting data from this node, UAV will move to next nearest node. At each step, the node at which UAV is visiting will act as parent node, and all the neighbors in its range will act as child node.

In the proposed Sq-PP algorithm, after visiting each parent node, UAV will first visit each child node in its communication range. The first child visitor will be the one that is closest to the parent node. The last child visitor will be the one that is farthest from it. Once UAV visits entire nodes, then it will move to next parent node. This will make sure that none of the child node remains unvisited.

## IV. RESULTS

In this work, wireless sensor network along with UAV has been considered that collects data from the sensor nodes. The proposed square concave hull based path planning as well as spiral convex hull based path planning algorithm were implemented in network simulator 2.35. In order to analyze the performance of the network, tour time, tour length and remaining energy of the network.

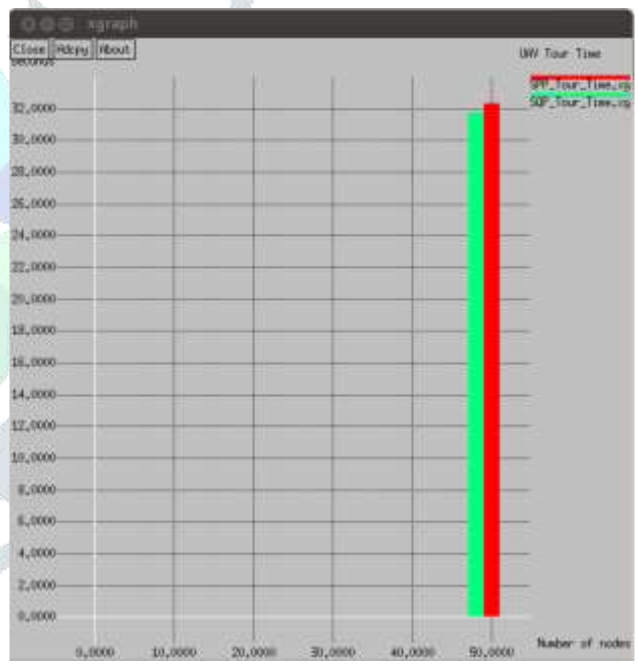


Figure 4.1: Tour Time Comparison

The above graph displays the comparison of the time taken by UAV to collect data from the sensors using both the schemes. The time taken with the existing scheme was 32.32 seconds and with the proposed scheme was 31.72 seconds.

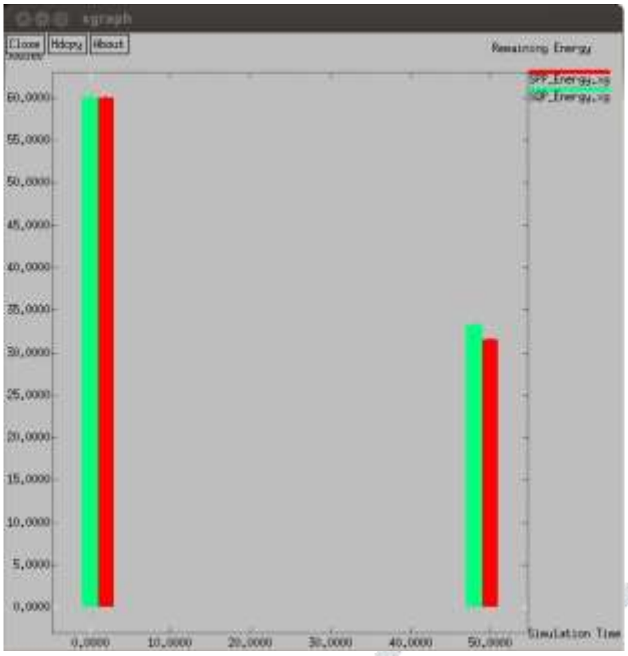


Figure 4.2: Remaining Energy Comparison

The above graph displays the comparison of the remaining energy for both the schemes. The remaining energy of the network with the existing scheme was 31.55 Joules and with the proposed scheme was 33.16 Joules.


Figure 4.3: Tour Length Comparison

The above graph displays the comparison of the tour length of the UAV for its data collection tour. The length traversed by UAV for the existing scheme was 1548.17 meters and with the proposed scheme was 1477.45 meters.

| Parameter\Scheme | Spiral Path Planning | Square Path Planning |
|---|---|---|
| Tour Length | 1548.17 meters | 1477.45 meters |
| Tour Time | 32.32 seconds | 31.72 seconds |
| Remaining Energy | 31.55 Joules | 33.16 Joules |

Table 4.1: Results Comparison

## V. CONCLUSION

The work was aimed at reducing the tour length for UAV to collect data from the sensor nodes in the network. The length traversed by UAV was less for the proposed scheme. In the proposed work, the UAV moves along with boundary of the square inscribed in the circle, so the length of the tour traversed by the UAV becomes shorter. This also reduces the data collection time for the UAV. Since the tour length of the UAV is shortened with the use of square concave hull based path planning algorithm, this also reduces the energy consumed by it to collect the data from the sensor nodes which increases the lifetime of the network as well. Therefore, the improved values for the proposed data collection scheme helps us to conclude that it has outperformed the existing scheme.

In future, some of the nodes can be grouped into clusters so that UAV should have to visit less number of the nodes in the network. This will eventually reduce the tour length as well tour time for the network.

References:

1. V. Sharma and R. Kumar, “A cooperative network framework for multi-UAV guided ground ad hoc networks,” Journal of Intelligent & Robotic Systems, vol. 77, no. 3-4, pp. 629–652, 2015.

2. S. Berrahal, J.-H. Kim, S. Rekhis, N. Boudriga, D. Wilkins, and J. Acevedo, “Unmanned aircraft vehicle assisted WSN-based border surveillance,” in Proceedings of the 23rd International Conference on Software, Telecommunications and Computer Networks (SoftCOM '15), pp. 132–137, IEEE, Split, Croatia, September 2015.

3. V. Sharma and R. Kumar, “An opportunistic cross layer design for efficient service dissemination over flying ad hoc networks (FANETs),” in Proceedings of the 2nd International Conference on Electronics and Communication Systems (ICECS '15), pp. 1551–1557, Coimbatore, India, February 2015.

4. V. Sharma, R. Kumar, and P. S. Rana, “Self-healing neural model for stabilization against failures over networked UAVs,” IEEE Communications Letters, vol. 19, no. 11, pp. 2013–2016, 2015.

5. Wu Yue, Zhu Jiang, “Path Planning for UAV to Collect Sensors Data Based on Spiral Decomposition”, 8th International Congress of Information and Communication Technology, Procedia Computer Science 131 (2018) 873–879.

6. Bin Liu and Hongbo Zhu, “Energy-Effective Data Gathering for UAV-Aided Wireless Sensor Networks”, Sensors 2019, *19*(11), 2506.

7. Dariush Ebrahimi, Sanaa Sharafeddine, Pin-Han Ho, Chadi Assi, “UAV-Aided Projection-Based Compressive Data Gathering in Wireless Sensor Networks”, IEEE Internet of Things Journal (Volume: 6 , Issue: 2, April 2019).

8. Luxi, Yang & Hua, Meng & Wang, Yi & Zhang, Zhengming & Li, Chunguo & Huang, Yongming. (2019). Energy-efficient optimization for UAV-aided wireless sensor networks. IET Communications.

9. Wang, X, Zhou, Q and Cheng, C 2019, 'A UAV-assisted topology-aware data aggregation protocol in WSN', Physical Communication, vol. 34, pp. 48-57.

10. Changsheng You, Rui Zhang, “Hybrid Offline-Online Design for UAV-Enabled Data Harvesting in Probabilistic LoS Channel”, arXiv:1907.06181, July 2019.

11. Mohammad Ammad Uddin, Ali Mansour, Denis Le Jeune, Mohammad Ayaz and El-Hadi M. Aggoune, “UAV-Assisted Dynamic Clustering of Wireless Sensor Networks for Crop Health Monitoring”, Sensors 2018, 18(2), 555.