A REVIEW OF ROUTING TECHNIQUES FOR UAV ASSISTED WSNs

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Abstract: The technology of unmanned aerial vehicles (UAVs) has gone through revolutionary improvements, which have led to highly advanced UAVs that come in numerous sizes, capabilities, and functions. These days the wireless sensor networks that consist of battery-limited nodes are using the UAVs for data gathering purposes. UAV helps significantly reduce the energy consumption used in data transmission, reduce radio frequency interference that can be caused with the hidden terminal and collision problems that are present in the multi hop data routing approach. UAV assisted WSN can have better network lifetime as the sensor nodes do not have to forward the data to the sink node. This also improves the QoS parameters of the network.

Keywords: UAV, WSN, network lifetime, energy consumption, QoS parameters

I. INTRODUCTION

In recent years, wireless sensor networks (WSNs) have received considerable attention, and many research efforts have been designed to address some critical issues in WSNs, such as routing [1, 2, 3], energy-efficient design [4, 5], MAC-layer protocols [6], coverage and connectivity issues [7, 8], etc. The development of modern sensing techniques and wireless communication technologies has greatly promoted wireless sensor development with both sensing and wireless communication abilities, which furthers the development of WSNs [9]. The objective of deploying a WSN is to keep the field-of-interest (FoI) under strict surveillance [10], and then forward the obtained information to a designated gateway/data sink. Accordingly, area coverage problem and target detection problem are two essential problems needed to be solved, and many research approaches have been proposed to cope with these two problems. For example, the authors in [11] analyzed the target detection problem in a WSN based on the geometric probability theory. Moreover, since the WSNs are always deployed in remote areas or hazardous environments, they could be very dangerous for human safety (e.g., battlefield, volcano, etc.). Thus, the manual/deterministic deployment strategies of WSNs may not be adopted [9]. In this case, deploying the unmanned aerial vehicle (UAV) with sensing equipment is a more pragmatic option, and is preferred for missions that are dangerous for humans. Meanwhile, compared with the traditional mobile sensor nodes, the UAV has a much faster moving speed, longer deployment range and relatively longer operating time. Consequently, the UAV can be considered as a perfect carrier for existing sensing equipment to form a UAV-based WSN (UWSN).

This paper defines the collaborative network formed by UAV and WSNs in Section II. Section III describes the previous research techniques that focus on achieving better network performance for collaborative networks. Finally paper has been concluded in the last section.

II. UAV assisted WSNs

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). UAVs have tendency to fly autonomously and can collaborate with existing network to form a search, tracking, and data acquisition networks [12]. Further, these networks can be used to provide vast coverage and enhanced security in border areas [13]. 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 [14]. 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 [15].

Motes in sensor network are static devices that operate over the battery and provide highly sensitive applications in data acquisitions [16, 17]. WSNs can be used in remote areas where direct data acquisition is not in the reach of humans. Excessive consumption of energy and optimal route selection in WSNs are still an open issue that requires an optimal solution to form an efficient WSN [18–20].

The collaboration between the UAVs and the WSNs can provide a vast range of applications such as sensor flocking, border surveillance, area monitoring, remote data gathering, and obstacle avoidance [17, 20–22]. 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. 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.

III. LITERATURE REVIEW

This paper [23] 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 work [24], the authors study the age-optimal trajectory planning problem in UAV-enabled wireless sensor networks, where a UAV is dispatched to collect data from the ground sensor nodes (SNs). The age of information (AoI) collected from each SN is characterized by the data uploading time and the time elapsed since the UAV leaves this SN. They attempt to design two age-optimal trajectories, referred to as the Max-AoI-optimal and Ave-AoI-optimal trajectories, respectively. The Max-AoI-optimal trajectory planning is to minimize the age of the 'oldest' sensed information among the SNs. The Ave-AoI-optimal trajectory planning is to minimize the average AoI of all the SNs. Then, they show that each age-optimal flight trajectory corresponds to a shortest Hamiltonian path in the wireless sensor network where the distance between any two SNs represents the amount of inter-visit time. The dynamic programming (DP) method and genetic algorithm (GA) are adopted to find the two different age-optimal trajectories. Simulation results validate the effectiveness of the proposed methods, and show how the UAV's trajectory is affected by the two AoI metrics.

In this paper [25], the authors first acquire data sensing points from the entire sensor field, in which UAV communicates with sensors to obtain sensor data, then we determine the best flight path between neighboring acquisition points. Using the proposed joint Genetic Algorithm (GA) and Ant Colony Optimization (ACO) from possible UAV flight paths, an optimal one is selected in accordance with sensing, energy, time and risk utilities. The simulation results show that our method can obtain dynamic environmental additivity and high utility in various practical situations.

This work [26] discusses the problem of trajectory planning for WSN (Wireless Sensor Network) data retrieving deployed in remote areas with a cooperative system of UAVs (Unmanned Aerial Vehicles). Three different path planners are presented in order to autonomously guide the UAVs during the mission. The missions are given by a set of waypoints which define WSN collection zones and each UAV should pass through them to collect the data while avoiding passing over forbidden areas and collisions between UAVs. The proposed UAV trajectory planners are based on Genetics Algorithm (GA), RRT (Rapidly-exploring Random Trees) and RRT* (Optimal Rapidly-exploring Random Trees). Simulations and experiments have been carried out in the airfield of Utrera (Seville, Spain). These results are compared in order to measure the performance of the proposed planners.

In this paper [27], the authors explore various UAV mobility patterns that follow different paths to sweep the operation area in order to seek the best area coverage with the maximum number of covered nodes in the least amount of time needed by the mobile sink. They also introduce a new metric to formulate the tradeoff between maximizing the covered nodes and minimizing the operation time when choosing the appropriate mobility pattern. A realistic simulation environment is used in order to compare and evaluate the performance of the system. They present the performance results for the explored UAV mobility patterns. The results are very useful to present the tradeoff between maximizing the covered nodes and minimizing the operation time to choose the appropriate mobility pattern.

This paper [28] proposes a novel distributed range-free movement mechanism for mobility-assisted localization in WSNs when the mobile anchor's movement is limited. The designed movement is formed in real-time pattern using a fuzzy-logic approach based on the information received from the network and the nodes' deployment. Our proposed model, Fuzzy-Logic based Path Planning for mobile anchor-assisted Localization in WSNs (FLPPL), offers superior results in several metrics including both localization accuracy and localization ratio in comparison to other similar works.

The aim of the present paper [29] is to propose an agricultural environment monitoring server system utilizing a low-cost Wireless Sensor Network (WSN). Several sensor nodes are scattered in fields several kilometres in size, and the authors propose collection of the information stored in the nodes by a mobile node, or mule. To cover long distances in a short period of time, they use an unmanned aerial vehicle (UAV), which retrieves the data stored in the ground nodes. In addition, the UAV may be used to acquire additional information and to perform actions. Its elevated position allows observation of the field with a perspective that is useful for detecting changes affecting crops, such as pests, diseases, significant changes in soil moisture, drought or floods.

This paper [30] proposes a new quality-aware and energy-efficient UAV coverage and path planning scheme with the objective of sensing a geometrically complex target area with satisfactory spatial and temporal resolutions. An occlusion-aware waypoint generation algorithm is first designed to find the best set of waypoints for taking pictures in a target area to satisfy the spatial resolution requirement. The selected waypoints are then assigned to multiple UAVs by solving a vehicle routing problem (VRP) such that all the waypoints are visited within a global deadline to satisfy the temporal resolution requirement. The vehicle routing problem is formulated to minimize the maximum energy for the UAVs to travel through the waypoints within the deadline. A Min-Max energy path planning algorithm is designed to solve this problem in two steps: first, a mixed integer linear programming problem (MILP) is solved to calculate the minimum energy for a UAV to go from one waypoint to other; then, a genetic algorithm is devised to plan the paths for all the UAVs. Evaluation results show that the proposed coverage and path planning scheme results in better coverage and energy consumption than traditional coverage and path planning techniques for UAVs.

In this paper [31], a method is proposed to optimize parameters which affect performance of the PSO algorithm by using Rauch-Tung-Striebel (RTS) smoother. Moreover the Metropolis Criterion is applied as acceptance policy, which can prevent the PSO algorithm from falling into local minimums in the proposed method. The RTS smoother is applied to eliminate the irregular error of the PSO updated position, and to smooth the produced path. Experimental results show the proposed method which is based on the fusion of the PSO, Metropolis Criterion and RTS performs better than the existing methods in terms of solution's quality and robustness in the path planning problem for UAVs.

IV. CONCLUSION

This paper describes the collaborative networks formed using unmanned aerial vehicles and wireless sensor networks. These collaborative network have improved network lifetime as equated to normal sensor networks. In these networks, the QoS parameters such as end to end delay or throughput depends on how efficiently data has been gathered by UAV. Therefore, path planning for UAV in such networks is of prime importance. One of such algorithm is spiral path planning algorithm that proposed UAV to visit the nodes in the spiral trajectory. In future, the spiral path can be optimized in a way which reduces the path length for UAV trajectory and improve network's performance.

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