Multi-hop Opportunistic Communication in Wireless Sensor Networks Using Unmanned Aerial Vehicle

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Abstract: The use of Unmanned Aerial Vehicles to collect data from the sensor nodes in wireless sensor network has attracted many researchers as this gives energy efficiency data gathering solution. The mobility of the UAV challenges the reliability of the network as the link connection time between the sensor and mobile UAV is less. Opportunistic routing offers to provide reliability in such scenarios. This paper proposes multi hop HVOR protocol which works along with ANOR protocol to provide reliable data transfer in the network. The proposed work has been compared with the existing single hop HVOR protocol based on the end to end delay, routing overhead, packet delivery ratio and throughput of the network. These parameters show an improved performance and validate the outperformance of the proposed system.

Keywords: Wireless Sensor Networks, Opportunistic Routing, UAV, HVOR, ANOR

I. INTRODUCTION

Wireless sensor networks (WSNs) are the network of structurally distributed sensors which gains information from the physical world. It is beneficial for monitoring environmental factors like temperature, pressure moisture etc. and send this data to the sink node or to the destination node. WSN has demonstrated advantageous in number of applications in the area of traffic surveillance, military application, weather forecasting, landslide detection, detection of fire etc. It is the pillar of the appearing technologies like Internet of Things (IoT), cyber physical system (CPS) etc. [1]. In wireless sensor networks signing unmanned aerial vehicle (UAV), UAV has been owned as an aerial sink to supply a real-time collection of data for the ground sensor networks. It is identified that effective communications are the key to a favorable response in the situation of emergency and disaster. This situation, although lifts many challenges when working with hundreds or thousands of wireless sensors on the ground [2]. The mobility of the UAV presents the challenge of achieving desired dependability in sensor network. Opportunistic routing is a new pattern in routing for wireless sensor network which selects the node closest to the fixed node for forwarding the data. The broadcasting nature of wireless sensor networks is used by them efficiency has been released. Opportunistic routing, throughput and reliability of sensor networks [1]. This paper presents the multi hop opportunistic communication between the sensor nodes and UAV that focuses to making the network more reliable. The proposed work uses the multi hop Highest Velocity Opportunistic Routing (HVOR) and also All Neighbors Opportunistic Routing (ANOR) to issue finer link for the sensor node to send data to the UAV.

This paper describes the related work in Section II and proposed methodology has been discussed in Section III. Finally the results have been discussed in Section IV.

II. RELATED WORK

This paper [3] examines the opportunistic routing (OR) in unmanned aerial vehicle (UAV) accommodated wireless sensor networks (WSNs). The authors examine the scenario where a UAV gathers data from randomly deployed mobile sensors that are moving with different velocities along a predefined route. This paper proposes the All Neighbors Opportunistic Routing (ANOR) and Highest Velocity Opportunistic Routing (HVOR) protocols. In essence, ANOR forwards packets to all neighbors and HVOR forwards them to one neighbor with highest velocity. HVOR helps the sensor which has little opportunity to communicate with the UAV to determine which sensor, among all the sensors that are within its range, is the forwarder. The selected node forwards the packet. As a result, in each hop, the packet moves to the sensor that has higher opportunity to communicate with the UAV. Through extensive simulations, they have shown that both HVOR and ANOR algorithms work better than DC. Moreover, the HVOR algorithm outperforms the other two algorithms in terms of the average overhead.

The research in [4] focuses on the experimental validation of the so-called Efficient Geometry-based Localization (EGL) technique, which provides a flexible, scalable, and distributed way to localize static sensor nodes on an experimental field. The mobile sink node will be carried by an UAV system with autonomous flight embedded with a low cost Global Navigation Satellite System (GNSS) receiver. Experimental results comparing localization with standalone GNSS and Real Time Kinematic (RTK) GNSS technique validate the EGL technique at the end.

This paper [5] presented an algorithm with this aim which makes hold of directional antenna for ground nodes together with a novel communication synchronization mechanism. The paper also presents the necessary assumptions related to directional antennas.

The authors in [6] 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 which leads 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. Their 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 demonstrate the superiority of the proposed approach and the designed algorithms via detailed performance results with analysis, comparisons, and insights.

In this paper [7], the authors proposed a protocol called A-OAloha (Adaptive-Opportunistic Aloha) for UAV-UAV-WSN system to guarantee its efficiency. This protocol is formed on a cross-layer design and is designed with the distribution of the successful sensors consideration, energy consumption and the transmission efficiency. For the successful sensors distribution, a mechanism is designed based on the priority to make the distribution more uniform and the priority could be adaptively changed. For the consideration of energy-efficiency they choose to use the method that make the sensors go into sleep when they do not need to send data until a beacon signal from the UAV is received for data transmission. For the transmission efficiency, a communication stage in every interval based on the O-Aloha scheme to enlarge the throughput under an acceptable system Bit Error Rate (BER) is added.

In this paper [8], the authors study UAVs supported data collection for WSN. Firstly, the entire region is divided into multiple cells. Secondly, the flight paths for single UAV and multiple UAVs are designed to cover all cells. The per-node capacity of sensor is derived, which is a function of the number of cells, the height of UAV, the number of sensors and the energy capacity of UAV. It is found that the per-node capacity with multiple UAVs is much larger than that with single UAVs. Then the optimal number of cells is derived to maximize the per-node capacity of WSN. Finally, they provide simulation results to verify the analysis. The discoveries in this paper may provide guideline for the UAVs assisted data collection in WSN.

III. PROPOSED METHOD

In the proposed scenario, the UAV is considered to be flying at given height and speed to collect data from sensor nodes that are moving along a predefined path at the same direction as UAV. Each sensor node will forward data to the UAV by exploring three options:

It can directly forward data to UAV if it is in the range of UAV. Or it can exercise ANOR and HVOR Algorithm in tandem. According to ANOR, the source nodes create routes with all the neighbor nodes that are within its communication range and relay packets to them. After that, HVOR algorithm is executed in which the selection of the node depends on the position of the node with respect to UAV.

- For the nodes which are behind the UAV, they will build connections with the one that has the highest velocity among its neighbors.
- For the nodes which are away from the UAV, they will build connections with the one that has the least velocity among its neighbors.

This will give ample time for UAV to reach closer to the nodes. Another modification proposed to the opportunistic routing is that even after choosing the lowest or highest velocity neighbor if the UAV is still far away from the chosen node, the chosen node can again opt for the ANOR and HVOR algorithm until the node reaches in the range where direct communication can be carried out between the node and UAV.

IV. RESULTS

The proposed system as well as the existing system was implemented in network simulator 2.35. In this study, we have taken parameters such as packet delivery ratio, throughput, end to end delay and routing overhead to check the reliability of the network.

Parameter	**Value**
Channel	Wireless
Mac	802.11
Propagation	Two Ray Ground
Queue	Drop Tail
Antenna	Omni Directional
Number of nodes	20
Network area	3000 *100 sq. meters
Initial Energy	50 Joules

Table 4.1: Simulation parameters

The above table shows the simulation parameters that have been used to create the network in NS2.35.

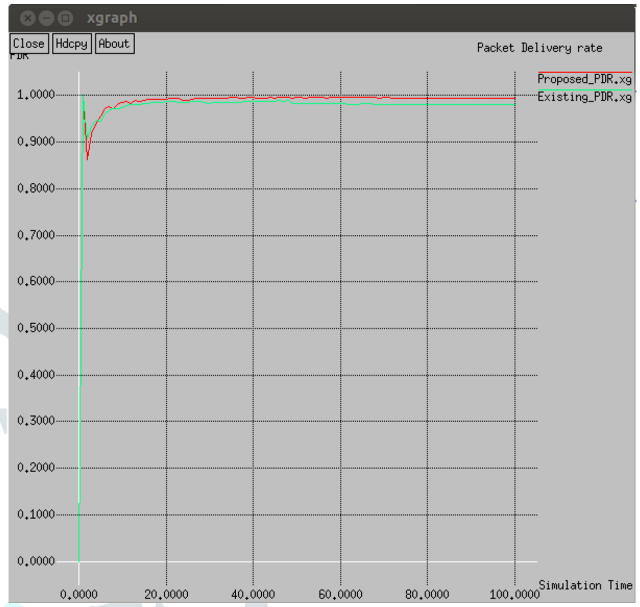

Figure 4.1: PDR Comparison

The graphs shows the comparison of the packet delivery ratio values obtained for both the schemes. The value of PDR obtained is 99.47 for the proposed scheme and 98.16 for the existing scheme. This means that less packets are dropped when we execute the proposed scheme in the network and better PDR shows better network performance.

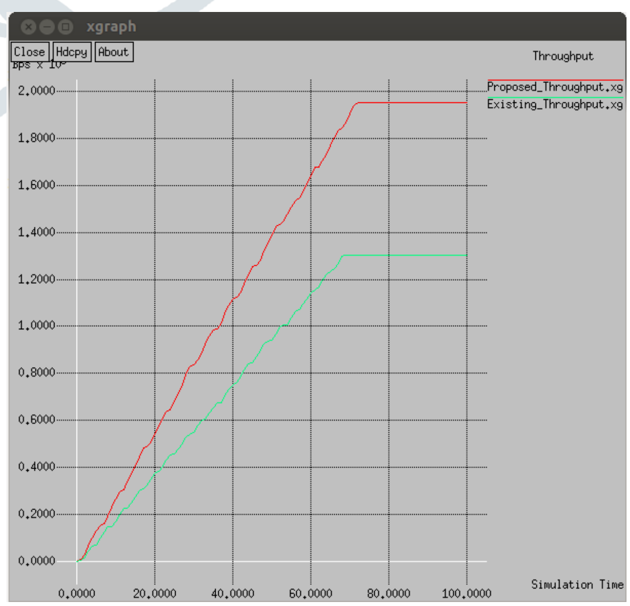

Figure 4.2: Throughput Comparison

The graphs shows the comparison of the throughput values obtained for both the schemes. The value of throughput obtained is 1951*10^3 Bytes per second for the proposed scheme and 1300*10^3 Bytes per second for the existing scheme. This means that UAV received more amount of data from the sensor nodes.

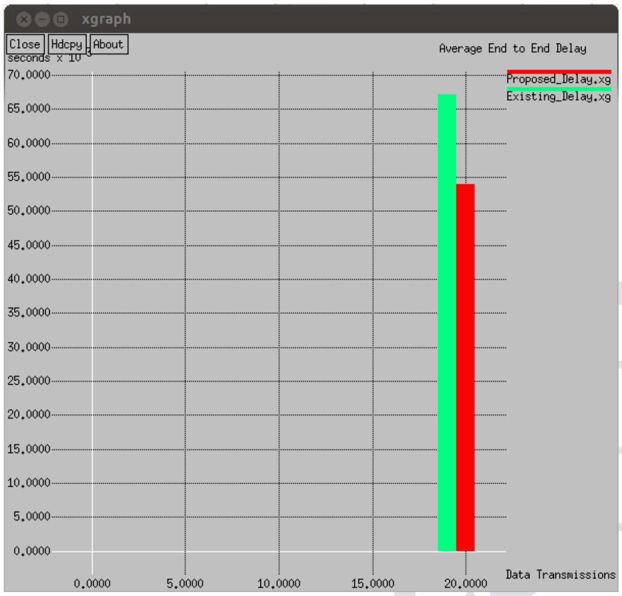

Figure 4.3: End to End Delay Comparison

The graphs shows the comparison of the average value of end to end delay obtained for both the schemes. The value of delay obtained is 0.053 seconds for the proposed scheme and 0.067 seconds for the existing scheme. This means that the UAV receives packets earlier when the packets are sent using modified multi hop HVOR.

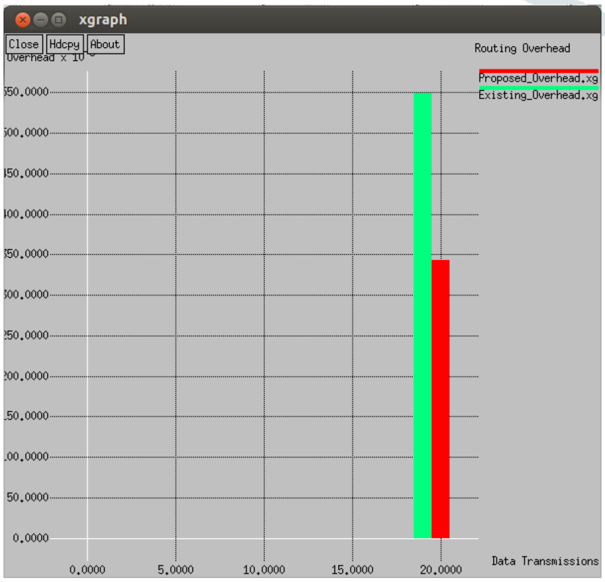

Figure 4.4: Routing Overhead Comparison

The graphs shows the comparison of the routing overhead obtained for both the schemes. The value of overhead obtained is 0.34 for the proposed scheme and 0.55 for the existing scheme. This means that lesser link breakage happens in the proposed scheme as lesser control packets are sent in the network.

Parameter	**Proposed Scheme**	**Existing Scheme**
PDR	99.47	98.16
Throughput	1951*10^3 Bytes per second	1300*10^3 Bytes per second
Average End to End Delay	0.053 seconds	0.067 seconds
Overhead	0.34	0.55

Table 4.2 Performance parameters comparison

V. CONCLUSION

The proposed method was aimed at improving the HVOR communication scenario among the moving sensor nodes and the unmanned aerial vehicle. In the proposed scheme the sensor nodes would repeatedly execute the HVOR and ANOR until a node is found that is in direct communication range with the UAV. Moreover, the node chosen can be higher velocity node or it can be lower velocity node depending on the position of the sensor nodes and UAV. This leads to short range communication among the selected vehicle and UAV which further leads to better quality of the link made among them. The parameter which indicates the better link quality was routing overhead which indicates the number of control packets sent in the network for route maintenance or link maintenance. The lesser value of routing overhead for the proposed scheme shows better link quality. Furthermore, the better quality of the link increases the throughput as well as packet delivery ratio for the proposed scheme. Since the multi hop HVOR enables the direct communication with the UAV, the lesser communication distance also leads to lesser end to end delay.

In the future, some of the source nodes can be grouped into clusters such that only cluster head executes the HVOR or AVOR or DC as desired. This can lead to lesser routing in the network. Furthermore, while selecting the cluster head optimization techniques such as PSO or GA can also be considered for better network performance.

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