Geolocation-based Routing Protocol for Flying Ad hoc Networks (FANETs)

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Abstract **—Unmanned Aerial Vehicles (UAVs), also called drones, are getting a lot of attention in various application scenarios such as search and rescue missions, infrastructure inspections, and delivery system. In addition, it is of increasing interest to researchers, which a group of drones are networked and coordinated to accomplish a mission delivered from Ground Control Station (GCS). To support those service scenarios, communication path should be maintained between GCS and the UAVs, and the UAVs should be able to exchange a message among themselves. However, communication range between GCS and the UAVs is bounded according to the transceiver power and its sensitivity. Hence, a multihop network approach need to be considered. In such multihop networks, routing protocol plays an important role. Accordingly, in this paper, we present a geolocation-based routing protocol for Flying Ad hoc Networks (FANETs) with multihop network communication. Our protocol shows robust and resilient performance to the dynamic multihop network topology. A network topology composed of UAVs is highly dynamic due to the high speed of UAVs while executing missions. In this circumstance, our protocol uses geolocation information of neighbors and then find the routing path to the destination by only considering the neighbor information, which in turn, results in low overhead and robustness to the dynamic network topology in FANETs. We also provide implementation of the proposed geolocation-based routing protocol and testbed environments.**

***Keywords*— Flying Ad hoc Networks (FANETs); Routing; Unmanned Aerial Vehicles (UAV); Unmanned Aircraft System Traffic Management (UTM)**

I. Introduction

Currently, unmanned aerial vehicles (UAVs) are getting a lot of attention because of their application in various service scenarios such as search and rescue mission, infrastructure inspection, and delivery system. Furthermore, to achieve mission efficiency, after receiving a command from Ground Control station (GCS), a group of UAVs can form a swarm and execute a mission through coordinating among themselves [1 - 6]. For that, multi-UAVs should exchange information about a mission and its status related information among UAVs. Based on that information, it is possible for UAVs to conduct more accurate task allocation and they can report mission execution results to the GCS.

In order to materialize the mentioned UAV application scenarios with multi-UAVs swarm, not only the communication path between UAVs and GCS but also inter-UAVs communication should be maintained and a message should be exchanged among themselves. However, due to the high mobility and dynamic topology formation of UAVs, communication path always changes. Therefore, it is impossible for the UAVs to maintain static communication path all the time. To tackle these problems, Mobile Ad hoc Networks (MANETs) is provided as one potential solution and in this regard, many research works have been conducted. However, concerning UAVs mobility issue, Flying Ad hoc Networks (FANETs) characterize more severe dynamic mobility of UAVs than in MANETs environment and mobile nodes also move in 3-dimensional space different from previous ground space case in MANETs [7, 8]. Therefore, more appropriate routing protocols for FANETs need to be investigated.

Several research works regarding the routing protocols aspect in MANETs have been proposed. In [9], Rosati, et al. presented an extended version of Optimized Link-State Routing (OLSR) in MANETs routing protocol called Predictive Optimized Link-State Routing (P-OLSR). P-OLSR shows better performance than the conventional OLSR protocol through utilizing approaches such as link quality estimation and considering the direction and relative speed between the UAVs. However, since P-OLSR is a proactive routing protocol which set up a routing table beforehand for finding next-hop node, its routing information could be useless when considering dynamic topology environments as in FANETs. From this perspective, geolocation (position) based routing protocol can be more suitable to support the dynamic topology in FANETs because a routing path is to be determined on demand when receiving a packet from neighbor node [10 – 12] Furthermore, as all UAVs have GPS-enabled navigation system, location information can always be utilized in FANETs environment.

In this paper, we propose a geolocation-based routing protocol for FANETs which utilizes location information to forward packets in a multihop path. As in previous research works, our protocol adopts greedy forwarding approach to select the next hop forwarder with the largest progress toward the destination. In this paper, we combined the link prediction with the greedy approach to determine the next hop forwarder to the destination. In addition to this, implementation of our proposed protocol is presented.

The remainder of this paper is organized as follows. In the following section, we provide description of the working logic and structure of the proposed geolocation-based routing for FANETs. Section III presents implementation of our geolocation-based routing protocol and evaluation of its working model. Finally, conclusion and future works are described.

II. GEOLOCATION-BASED ROUTING PROTOCOL

In this section, we provide description of our geolocation-based routing protocol, the working logic and implementation structure of the protocol which could be applied to the multi UAV swarm service scenarios.

A. Geolocation-based Routing

In circumstances where UAVs are operated, the geolocation, speed, and direction of UAVs are broadcasted for the anti-collision between UAVs, tracking and controlling UAVs at the Ground Control Station (GCS). Our geolocation-based routing protocol utilizes this information for routing and it does not maintain table about end to end routing path as in proactive state-based routing schemes. Therefore, it can be adaptive to the dynamic topology changes because it selects a next hop node on demand and does not store the state information, which in turn, results in minimizing the overhead.

Geolocation-based routing works as follows. Each UAV node broadcasts its routing control information with a certain period of time. UAVs that receive this routing control information records the node ID, navigation information (geolocation, speed, direction), and time in the neighbor node table. To support routing, the state information is minimized to the neighbor node table, and when the data packet is transmitted, it is forwarded to the neighbor node closest to the destination node in a greedy manner. In addition to this, when selecting the next hop node, the geolocation of neighbor nodes is predicted based on the speed, direction, and time information of UAVs as shown in Equation (1). Therefore, through selecting the next hop based on the predicted location, the high-speed mobility of the UAVs is reflected in the process of routing.

$$LOC_{curr} = LOC_{prev} + (t_{curr} - t_{prev}) \times V_{direction} \quad (1)$$

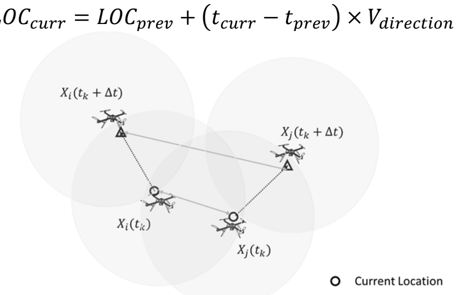

Fig. 1: Predicted location according to the UAVs movement

As per the type of mission scenario, UAVs' speed, mobility, and path are to be differently operated. Moreover, geolocation-based routing protocol uses this navigation information to acquire the latest information about neighbors, which impacts the performance of the routing protocol. Considering this condition, geolocation-based routing protocol adjusts the broadcast period of the routing control information based on the mobility of the UAVs. Initially, a broadcast period is set from the GCS, after that, each UAV adaptively adjusts the broadcast period of routing control information according to their speed while they are moving.

B. Avoiding Local Minima

In order to greedily select the next hop node, at least one neighbor node should be located closer to the destination so that data packet can be forwarded to the next hop. If there is no nearest neighbor node towards the destination direction, packet forwarding fails, and this is called local minima problem. Therefore, to adopt the greedy location-based routing, it is needed to have an algorithm which avoids these local minima problem. Generally, to avoid such a local minimum in 2-dimensional space, first, a planar graph is created and then a corresponding bypass path is searched. However, it is known that it is difficult to find a bypass path by plotting a corresponding plane graph in a 3-dimensinal space [13].

In geolocation-based routing protocol, when a node encounters the local minima situation, a route search message is utilized to discover a node closer to the destination than itself. In addition to this, for the sake of reducing the control message overhead, a region in the direction of the destination node is set. The route search message includes the current node location, the destination node position, and the broadcast area information. If the node that receives this message is closer to the destination node location than the current node position, it can respond the search message. The node which sent the route search message waits for a response message and then forwards the data to the discovered route.

III. IMPLEMENTATION

In this section, we have presented the implementation architecture of geolocation-based routing protocol for FANETs, which is operated over the traditional IP layer protocol. As seen from Fig. 2, to support geolocation-based routing in FANETs, geolocation routing header has been designed. The header format consists of 4bytes fixed header (type, length, number of destination) and variable size header (which includes list of destination node ID and location information).

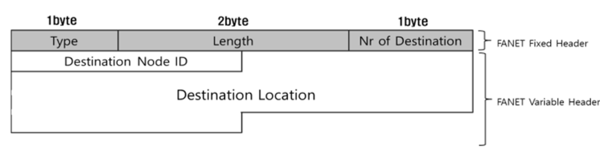

Fig. 2: Geolocation routing header format

Based on this header format, when a node wants to select the next hop forwarder, the destination information in the packet header can be checked and the neighbor node closest to the destination can be selected and then, the corresponding data packet can be delivered to the selected next hop neighbour node.

Fig. 3 shows the routing packet processing and routing flow of the geolocation-based routing protocol. The routing daemon implementation has been combined with the IP layer so that the routing daemon can utilize the geolocation routing header encapsulated in the transmitted data packet.

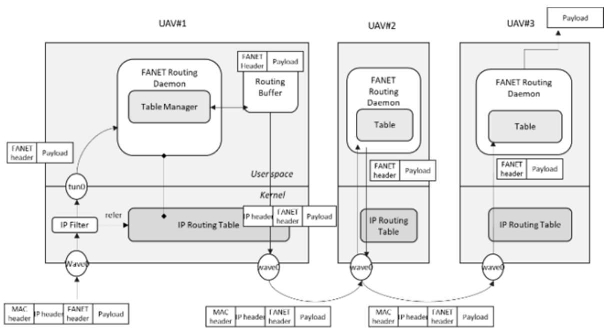

Fig. 3: Geolocation routing packet processing flow

When the packet is delivered to the routing daemon, the daemon checks the destination ID and location information in the data packet and determines the next hop based on the predicted neighbor location (computed as per Equation (1)) accessed from the neighbor table.

Geolocation-based routing testbed is shown in Fig. 4. As shown from Fig. 4, a group of UAVs exchange the status, attitude, and mission information between each other through utilizing multihop communication which is supported via geolocation routing protocol of the communication modem. The corresponding multi-UAVs have a mission payload, and the ground mission control station acts as a Ground Control Station (GCS) to transmit commands for mission execution and status monitoring information to multi-UAVs. The Data Logger system collects the status information of the UAVs and the communication modem. Based on the collected information, the Data Monitor can be used to visualize the operation and status information of the autonomous collaborative unmanned aerial vehicles.

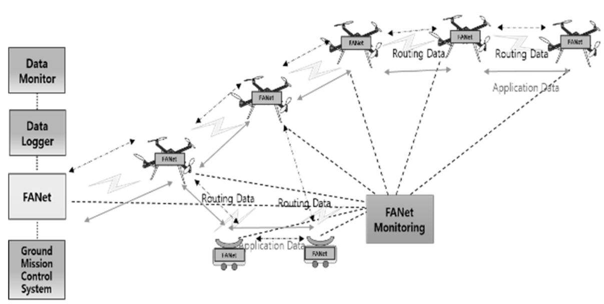

Fig. 4: Applying geolocation routing to multi-UAV system

IV. Conclusion

In this paper, we have proposed a geolocation-based routing protocol for Flying Ad hoc Networks (FANETs). We have also presented the implementation of our geolocation-based routing. Due to the high mobility of drones and availability of location information, geolocation-based routing protocol can be a potential candidate to support a stable multihop communication in FANETs environment. As a future work, we will evaluate the scalability performance of our geolocation-based routing protocol through applying it to multi-swarm UAV service scenarios.

Acknowledgement

This research was supported by Unmanned Vehicles Advanced Core Technology Research and Development Program through the National Research Foundation of Korea (NRF), Unmanned Vehicle Advanced Research Center (UVARC) funded by the Ministry of Science and ICT, the Republic of Korea (2017M1B3A1A02937507) and (2017M1B3A2A01049996).

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