Survey on FANET Routing Protocols

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Abstract- *Flying Ad Hoc Network (FANET) are made up of a number of Unmanned Air Vehicles (UAVs) that are connected in an ad hoc manner. It is widely employed in both the civil and martial areas due to its distinct merits such as very low cost flexibility and adaptability. This network has emerged as as an essential network in recent years with the growth of UAV communication. These networks are characterized by recurrent changing topology, high degree of mobility and node moving in three-dimensional space, all of which causes networking problems. Selecting good routing protocols are necessary to confirm proper connectivity among the UAVs in order to resolve suchproblems.To enhance the quality of communication in FANET, various kinds of routing methods are proposed by various researchers. However, each one has its own setbacks. In this paper, an attempt has been made to examine several routing protocols used to assess FANET along with performance analysis.*

Keywords- FANET, Routing Protocol, UAV,Wireless Communication

I. INTRODUCTION

FANETs [1] is considered to be a new class of ad-hoc which is made up of flying agents (UAVs or Drones) that can be effectively reach out with one another and their surroundings in order to collect data using modules such as sensors. It is beneficial for circumstances like flood regions, monitoring of forest fires, hurricanes, disasters, and many others. UAVs, also known as drones [2] [3] are aircraft that can fly on their own and be controlled remotely without human interaction. Due to their numerous benefits, such as their simplicity, adaptability, lower operating costs, quicker data acquisition, and versatility, UAVs are now widely used in a large number of real-time scenarios, including those in the agriculture, law enforcement, 3D mapping, disaster relief and product delivery. Current research and application focuses on multiple-UAV systems. Communication amongst UAVs in a multi UAV system is considered to be a main issue in FANET [4].

Routing protocol is one among the main research areas for UAV network communication. Routing heavily influences network performance, and the transmission pathway is often a multi-hop path. Consequently, creating a top-notch
routing system for UAV network communications is crucial [5] [6]. In this paper, different categories of routing protocols for FANETs are examined. In addition, the drawbacks also discussed.

The remaining parts of this paper is ordered in the following manner. The following part is describing about the brief overview of the different categories of routing protocols. Section III describes the different types of routing schemes for each category. In section IV, the protocols are compared. Finally, a summary of this study is given in the last section.

II. ROUTING PROTOCOLS

FANETS have unique operating properties and are required to function in a variety of conditions. Transfer of information by UAVs is a challenging problem Therefore, specific routing strategies are required for data transmission in FANETs. Compared to MANETs and VANETs, choosing an effective routing mechanism is crucial for forwarding data packets and preventing any kind of data loss. It's crucial to create a system for routing which has to deliver reliable and efficient data transfer among the nodes.

In this section, the routing mechanisms that are available for FANETS communication are discussed. Numerous protocols have been put forth by various researchers for FANETS in an effort to improvise packet delivery ratio, delay, and throughput.The six main classes into which these routing protocols divided are listed here [7]:

Static Routing Protocols*:* For this type, a route table is created initially and implemented onto UAVs prior to flight and is not changeable while the aircraft is in flight. Nodes has a fixed topology in this sort of networking model. Each node has a communication channel with other nodes or ground stations, and it solely retains their data. It is vital to wait until the finish of the flying if there is a failure. They are not suitable for dynamic situations and fault tolerant.

Proactive Routing Protocols*:* In this, the routing tables are modified and distributed among the nodes on a periodic basis and it guarantees the availability of transmission paths inside the network. However, there are two significant issues. Firstly, these protocols cannot effectively utilize the bandwidth because they need a number of message exchanges between nodes.

***Reactive Routing Protocols**:* When there is no established routing paths across the nodes, this protocol is used to discover a path between them. Finding the path only when data has to be transferred results in a reduction in traffic and minimal routing overhead. A source node generates and sends route request messages to the network via flooding, and the target node responds by using a reply message. But the process of discovering routes can be time-consuming, thus significant latency may be experienced while it is being done and also faces security threats.

***Hybrid Routing Protocols**:* This protocol combines proactive and reactive protocols. These protocols reduce the overheads associated with route finding, in order to boost scalability. This is mostly accomplished by proactively managing the routes to close nodes and utilizing a route discovery approach to identify routes to the far away nodes. The proactive technique is used for intra-zone routing while the reactive strategy is considered for inner-zone. It is highly efficient for larger networks.

***Geographic/Position Based Routing Protocols**:* These protocols utilize geographic positions to establish the routing path across nodes. According to these protocols, information is sent directly from the origin UAV to the target UAVs without discovering routes since it is assumed that the originating UAV knows about the locations of the other communicating nodes. Typically, each UAV has a GPS module or another sort of position facility to identify its own location.

***Hierarchical Routing Protocols**:* It is largely governed by certain proactive planned routes, and at lower levels, reactive protocol assists the request from triggered nodes. The main limitations of this include its complexity and addressing system for responses to the requests. It has the capacity to select proactive or reactive methods based on the hierarchy of the system.

II. LITERATURE SURVEY

The routing solutions for the FANET under different classes of routing are considered here. The three protocols under static routing are Multilevel Hierarchical Routing (MLH), Load Carry And Deliver Routing (LCAD) and Data Centric Routing (DCR).

A. Multilevel Hierarchical Routing (MLH)

MLH protocol [8] mainly depends on the scalability of the network. In this type, the entire network is divided into small clusters that are established to numerous zones. The cluster has a cluster head (CH) and it has links to other clusters. The CH has direct connection range with the other nodes in a cluster and also it has either a direct or indirect connection to satellites or UAVs in the top layer.

B. Load Carry and Deliver Routing (LCAD)

UAV will transmit the stored important information by flying to the target ground node from the source ground node after collecting the data in LCAD [9] [10]. Although a single origin and single target scenario was first looked on the LCAD, establishing multiple origin multiple target situations is also properly doable if required. It enhances security and maximize throughput. The fundamental drawback of this protocol is that the transmission latency gets intolerably high and excessive once the distance between the communicating UAVs increases.

C. Data Centric Routing(DCR)

Instead of using source or target IDs, data is gathered in respect of the data metrics in DCR. In this, numerous UAVs will generate the request as well as on-demand techniques are utilized to share the data. For this type of approach, the publish-subscribe paradigm is often suitable [11] [12]. The publishers, which is the producers of data and subscribers which is the consumers of routing algorithm get connected automatically. The key advantage is that it may only notify subscribers of registered resources.

The Optimized Link State Routing(OLSR) and Destination Sequenced Distance Vector (DSDV) protocol comes under proactive routing which are explained below.

D. The Optimized Link State Routing (OLSR)

It is a classification of table-driven routing and it is created by enhancing the classical link state algorithm [13]. A routing information table is regularly updated and maintained by the protocol across the other nodes in the network. By interacting with periodic HELLO packets, the OLSR protocol creates a database of information about local link and the nearby area. Finally, based on the whole network topology formed by the Topology Control(TC) packet, Multi Point Relay(MPR)-based route computation and maintenance are carried out. [14]. This method reduces the routing overheads and the latency can be enhanced.

E. Destination Sequenced Distance Vector (DSDV)

According to this technique [15], every aerial vehicle that operates within the network should be fully aware of all other aerial vehicles. When any type of topology change takes place, this protocol employs a sequence number assigned by the target node to prevent looping and overload in the network

Examples of on demand routing are Ad Hoc On Demand Distance Vector (AODV), Time slotted AODV, Dynamic Source Routing (DSR), and Ad Hoc On-Demand Multipath Distance Vector Routing (AOMDV) Protocol

F.The Ad Hoc On Demand Distance Vector (AODV) Protocol

In this AODV protocol, path maintenance between each node is not required constantly, instead, it will make a communication link request when it needs to communicate. Through HELLO messages, the nodes just need to keep track of the information about their neighbor nodes. The main advantage is that a significant amount of energy overhead can be saved if only active nodes that are involved in communication has to maintain the channels. The dynamic nature of the AODV routing algorithm enables fast moving nodes to swiftly discover destinations and establish routes [16] [17].

G. Dynamic Source Routing (DSR)

DSR Protocol [18] is specifically made for Multi-Hop Wireless Networks, FANETs make use of DSR for data packet routing between UAVs. To prevent any kind of congestion, the UAV broadcasts data packets with Request ID. When a network problem, such as failure in links, maintenance task is performed to find new routes. Since there is frequent topology change and there might be UAV failures occasionally, DSR is not ideally suited for the FANETS network.

H. Time Slotted Ad-hoc on Demand Distance Vector routing

Here, time slotted set up is considered with the AODV to minimize collisions. The authors suggested a strategy to cut reduce intermediate node communication [19]. This strategy uses a time reservation system similar to Slotted ALOHA. Every node is given a time slot during which it can communicate information to its cluster head or master node and has better communication. The suggested technique improves packet delivery ratio while lowering collisions.

I. Ad Hoc On-Demand Multipath Distance Vector Routing (AOMDV) Protocol

On the backbone of the AODV, the AOMDV is developed and presented in order to address practically all of its drawbacks [20]. During route discovery, it calculates numerous pathways to ensure that in the event of a connection failure, paths can be constructed across transmitting nodes. In contrast to the AODV routing protocol, it eliminates all of the high latency and overhead restrictions. If a full link failure occurs during the overall process under AOMDV, the route discovery phase will be proceeded. For identifying many links and successfully carrying communication, it is a great routing mechanism for FANETs.

Zone Routing Protocol (ZRP), Temporarily Ordered Routing Algorithm (TORA) and Hybrid Wireless Mesh Protocol (HWMP) comes under the category of hybrid routing protocols which overcomes the disadvantages of proactive and reactive routing protocols.

J. Zone Routing Protocol (ZRP)

The Zone Routing Protocol employs proactive discovery inside a node's local neighborhood and a reactive protocol to communicate across these neighborhoods. Hence it brings together the benefits of proactive and reactive protocols in to a hybrid scheme [21]. Intra-zone routing is the term for the routing within a zone, which employs a proactive method to maintain the route. Sending data packets outside the zone is the responsibility of inter-zone routing. To maintain routes, it takes a reactive strategy.

K. Temporarily Ordered Routing Algorithm (TORA)

It is an extremely versatile on-demand routing technique that functions well in multi hop networks [22]. Each UAV simply updates route information of nearby UAVs in this routing method. The essential traits of this routing technique is that it is possible to reduce the control packets with which topological changes are addressed to in a highly dynamic setting. From the source to the destination UAV, a Directed Acyclic Graph(DAG) is created and updated. Data is sent in a top-down manner and it provides loop-free routing.

L. Hybrid Wireless Mesh Protocol (HWMP)

The HWMP [23] is a hybrid routing mechanism for wireless mesh networks that makes use of peer link management protocol to find nearby nodes. The protocol uses

PREQ (Path Request) packets to find the best route between transmitting nodes in a manner similar to AODV.

Greedy Perimeter Stateless Routing (GPSR), Geographic Routing Protocol(GRP), Geographic Position Mobility Oriented Routing(GPMOR), Robust and Reliable Predictive Routing (RARP), Adaptive Beacon Scheme for Geographic Routing (ABPP) and Jamming-Resilient Multipath Routing (JarmRout) are some of the geographic location based routing protocols for FANET.

M. Greedy Perimeter Stateless Routing (GPSR)

GPSR [24] outperforms proactive and reactive routing algorithms in terms of its performance. It was established that "greedy location-based forwarding " is appropriate for networks of densely distributed UAVs. But, in cases with sparse installations, reliability of networks might be a serious concern.

N. Geographic Routing Protocol(GRP)

It is a routing technique built on geographical information. GRP utilizes the next hop forwarding of data packets using the position based information [25] [26]. In GRP, the topology is segmented to several neighbor hoods to improve flooding and data forwarding. Every neighborhood is set up is in a hierarchical manner [44].When the system is developed initially, a node will instantly flood with necessary geographic information when it goes past a certain distance or exceeds the boundary of a neighborhood [27].

O. Geographic Position Mobility Oriented Routing(GPMOR)

The UAVs' location data is the only parameter used by traditional position-based systems. GPMOR [28] predicts how UAVs will move around, and it makes use of this information to determine the next hop. With regards to the packet delivery ratio and delay, it is looked at whether this routing methodology can effectively forward data. The cluster and cluster heads' stability is increased by the proposed technique.

P. Robust and Reliable Predictive Routing (RARP)

To ensure the protocol's reliability, RARP [29] uses uni-cast and geolocation routing. It is based on the trajectory data and position of the node. It estimates three-dimensional and directional transmission for predicting the positions of relay nodes. It also keeps track of the changes in topology for network reliability. Additionally, speeding up connection rebuilding and service interruptions time to increase route lifespan and packet transmission performance.

Q. Adaptive Beacon Scheme for Geographic Routing (ABPP)

The main components of this technique [30] is

- *Location prediction (PP) approach coupled with linear regression and local weighting*
- *Adaptive Beacon (AB) scheme*

ABPP technology improves package delivery ratio while significantly lowering beacon overhead. However, this technique just examined the x- and y-planes of node behavior,
ignoring the stereoscopic characteristic of the network's configuration in FANET.

R.Jamming-Resilient Multipath Routing (JarmRout)

The protocol outlines the standards for evaluating the connection quality of neighboring nodes and offers solutions for link quality, traffic through the network and network environment [31]. To assess the physical separation between various pathways, the author developed a new distance calculation system and new distance metrics. Except for the source node and destination node, none of these two pathways has any other public nodes. However, it is challenging to identify numerous pathways if the destination node has just one neighbor.

The Hierarchical Routing Protocols include Mobility Prediction Clustering Algorithm (MPCA) and Clustering Algorithm.

S. Mobility Prediction Clustering Algorithm (MPCA)

Based on the characteristics of UAVs, the Mobility Prediction Clustering Algorithm has been proposed [32]. In order to address the challenges relating to the high mobility of the UAVs, it relies on the prediction algorithm and connection expiring time. Main benefit of this algorithm is that it enhances the clustering stability and performance of the network

T. Clustering Algorithm of UAV networking

Based on clustering algorithms, out-of-sight UAV management challenges can be resolved. To increase the stability and adaptability of nearby clusters, a multi-UAV system builds clusters on the ground before reconfiguring them in space [32]. Also in the dynamic routing of UAV nodes, this algorithm further lowers system cost and complexity.

IV. PERFORMANCE COMPARISON

Comparison of the six FANET routing protocols such as static, proactive, reactive, hybrid, geographic based and hierarchical protocols are discussed in the table I. The six parameters discussed here are route, size of the configuration, bandwidth efficiency, delay, failure rate and complexity of the network.

Parameters	**Static**	**Proactive**	**Reactive**	**Hybrid**	**Geographic**	**Hierarchical**
Route	Fixed	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
Network size	Small	Small	Large	Small/ Large	Large	Large
Bandwidth efficiency	High	Low	High	Average	Low	High
Delay	Low	Low	High	High	Low	High
Complexity	Low	Medium	Medium	Medium	High	High

In the static protocol, the route remains constant throughout the process and all other protocols have dynamic routes.Static protocols are appropriate for relatively small networks. For the proactive protocol, as the number of UAVs rises, so do the corresponding routing table entries. As a result, proactive protocols work best for small networks. In a larger network, position-based and hierarchical protocols are deployed.

The distance between the UAVs in static, proactive and geographic based protocols is minimal, which in turn offer low delay in communication. But distance between UAVs and ground stations is substantially greater in reactive, hybrid, and hierarchical protocols, they have higher delay.Only static protocols lack an approach when the path changes, resulting in a high mission failure rate in this routing protocol.

V. CONCLUSION

The routing information between flying agents in the sky is a rather complicated issue. Several protocols that employ different algorithms and techniques required to enable continuous routing to ensure that the transmission of data have been created. However, routing protocols in FANET also face certain difficulties when taking into account characteristic of easy interruption, which has a negative impact on the routing strategy's performance while carrying out tasks. One of the main problems with FANET is communications because of high mobility and frequent network modifications. Even though there has been a lot of work put forth towards enhancing UAV communication for a single system, there is always room for improvement. In this paper, a survey of the efforts is done to enhance FANET communication. The present routing protocols available for FANETs are examined using various performance metrics.

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