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A Survey on QoS in Flying Ad Hoc Network based on Fuzzy Inference Based Routing Protocol

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Abstract— Flying ad hoc networks (FANETs) are showing promise in a variety of unmanned aerial vehicle application situations, such as urban surveillance or search as well as rescue operations. These networks, however, provide a unique set of communication challenges. This has led to several studies looking at how they function in a simulated environment. Even while various models of mobile node behavior in an ad-hoc network exist, most of them cannot be relied upon to accurately imitate the movements of unmanned aerial vehicles unless they are properly modeled. Small unmanned aerial vehicles (UAVs) may be used to create flexible, low-cost, and fast-to-deploy FANETs. Because of this, they are a highly sought-after technology for both civilian as well as military use. Recent years have seen a fast evolution in UAV capabilities and functions, and their widespread use in both the military and civilian sectors as a consequence of technological advancements in robotic systems like processors, sensors, and communications. Costs for the development and maintenance of UAVs are falling as technology advances. The employment of a single big UAV is being phased out in favor of many UAVs working together in teams to accomplish higher-level objectives. Because of the great mobility of UAVs in a fleet, new networking models must be developed that can be deployed on these mobile nodes. Any two nodes in the communication range of such networking models may connect directly, or indirectly via a no. of relay nodes, such as UAVs. Establishing an ad-hoc network between flying UAVs is a difficult task, and the requirements might vary from those of conventional networks, MANETs, including VANETs in terms of node mobility, connection, message routing, service quality, wide applications, & so on.

Keywords—FANET, Flight Autonomy, Quality of Experience, Routing Protocols (RPs), Fuzzy System

I. INTRODUCTION

Wireless networks are divided into 2 types: infrastructure networks & infrastructure lab (ad-hoc) networks. Infrastructure networks are a common kind of wireless network[1,2]. Infrastructural networks are made up of two types of networks: fixed & backbone networks. A new class of networks known as FANETs [1,2] has evolved, consisting only of airborne components that may communicate among UAVs &another ground-based UAV-to-ground device [3] UAVs are available in a variety of sizes (large and small). In missions, large UAVs may be employed alone, whilst tiny UAVs can be deployed in swarms or formations to complete tasks. When compared to big unmanned aerial vehicles, the latter is proven to be particularly beneficial in civilian applications because of several benefits, including lower purchase prices, lower maintenance & repair costs, plus greater maneuverability. In the arena of FANETs, problems have emerged that are distinct from the traditional infrastructure as well as cable challenges:

(1) positioning UAVs in the taken method to monitor areas while minimizing costs as well as maximizing network performance; (2) mitigating the negative properties of UAVs' higher mobility; as well as (3) traditional RPs are not adept of managing, in an effective way, flying networks, particularly FANETs, owing to characteristics e.g. higher nodal density. Communications between UAVs or network performance might be compromised as a result of this. As a result, it is critical to develop a plan to provide effective communication

under these circumstances, while also offering resources that assure satisfying and intelligent performance to lessen the specified issues [5].

A. *Need and Motivation*

When it comes to data transmission in each application, dependable communiqué or what is known as a routing protocol among UAVs is a fundamental structure piece of the whole system. Accordingly, an appropriately constructed networking model must be developed, that enables unmanned aerial vehicles to interact with one another as well as to self- organize into a network, known as the FANET [6], [7]. Even though FANET as well as its sub-classes are comparable to both MANET & also its sub-classes, FANET goes further in its idea to be capable of forwarding packets, gathering data, & communicating data. Despite this, many challenging characteristics of UAV behavior have been identified, which should be taken into consideration. These characteristics include their higher capacity, unexpected movements, as well as non-uniform circulation across the network, which also outcomes infrequent route discovery but also makes system design of FANET RPs a difficult task.

B. *Key contribution of this paper*

- This extensive analysis examines the dynamic environment of Flying Ad-Hoc Networks (FANETs), encompassing their architectural design, routing protocols, and the critical contribution of fuzzy logic to the improvement of Quality of Service (QoS).

- This study investigates the FANET architecture, which consists of ground-based stations and airborne UAVs, specifically highlighting the unique difficulties presented by dynamic positioning, UAV mobility, and the constraints of traditional routing protocols.

A. The review classifies established routing protocols, providing insights into their applications and considerations, including Topology Aware RPs such *Fanet Communication*

Every network node (i.e., UAVs, GBS, & satellites) may operate as an end system, as previously mentioned [15]. In contrast, there are several restrictions on connecting two distant nodes, including unexpected disconnections, packet losses, as well as the permanent fragmentation of the network, among other things. All of these nodes may thus collaborate & arrange themselves as relays to deal well with the network conditions modification [15]. As a result, there are three ways of communicating to take into consideration in FANETs: (i) U2U communication; (ii) U2G communication; and (iii) Satellite communication.

II. ROUTING PROTOCOLS

As noted previously, FANET should build their routing algorithms because of their distinct features as well as the environment wherein they function. This study primarily covers routing protocols developed in recent past decades, which are particularly built for FANETs. According to the theories underlying each of the preceding techniques as well as methodologies, FANET RPs are largely split into 5 classifications shows in figure 1.

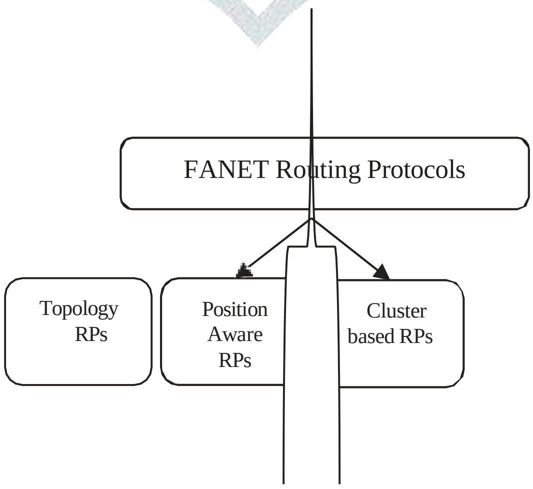

Fig. 1. Routing classification for FANET.

A. Topology Aware RPs

The fast migration of FANET nodes causes abrupt changes in the network structure. To address this issue, numerous routing methods built on topology awareness have been suggested to address the dynamic changes including asymmetric aspects of topology architecture that may easily cause network disruption. Although various RPs aimed at topology modifications are offered based on standard MANET, e.g. by simply adding GPS locating capabilities, many of these protocols are then applied straight to the FANET situation. There are still a great number of elements to take into consideration. In this section, we have included various RPs that are useful in resolving topology challenges, particularly in the FANET environment. Nodes may get data[16], about changes in surrounding structures over time, as well as several RPs can be integrated according to task needs to adapt to complicated circumstances.

1) Position Aware RPs

When using this type of RPs, each node may utilize GPS to identify geographical locations[17][18][19]as well as broadcast the position and speed at which they are moving to their neighbors. Therefore, it is suited for a broad variety of high-speed mobile networks since nodes may make local choices without having to consider the condition of the whole network. The benefit is that it eliminates the issue of frequent disconnection among network nodes caused by the unexpected movement of network nodes.

2) Cluster-Based RPs

The FANET's resource scarcity may be alleviated in part by the use of clustering theory, which divides nodes with identical geographic neighborhood features into several groups. It improves network adaptability, reduces routing overhead, as well as maximizes throughput, conserving the power of UAVs.

3) Beaconless Opportunistic RP

When a node moves, it creates an opportunity network that does not essential a full route among source & destination nodes. The network communicates by making use of encounter possibilities created by the movement of nodes. Traditional multi-hop wireless networks, including MANETs, wireless sensor networks, as well as wireless mesh networks, generally lack a unique method to cope with network connection interruptions in tough situations, which is especially true for wireless mesh networks. Consequently, when a link is lost, network performance suffers considerably, perhaps leading to the failure of the network itself. When it comes to real applications, the topological structure might alter at any moment, and the connection between nodes is often not ensured. As a result, we must investigate the routing protocol to determine the most efficient data transmission method to assure the effectiveness of task completion. The benefit of beaconless chance routing is that it is capable of sustaining and maintaining network connectivity in the presence of significant delays and intermittent connections.

III. Fuzzy Logic Role In The Improvement Of QOS

IV. The fuzzy rules for increasing the routing performance of FANET are described in detail below. Eight principles must be followed to determine the degree of available bandwidth. The channel usage, buffer utilization, and latency data are used to determine the rules. There are several causes for data loss in a network; thus, concentrate on the reasons that have been identified and assess the impact of each of them on the network. The following are the primary areas of emphasis: Increases the dependability of data reception while reducing the amount of data lost. Reduces the amount of energy used as well as the lifespan of the prologue network. Assign a priority to data based on the relevance of the information. Packet drops are most often caused by communication that occurs in a high mobility environment or by a shortage of available routes. Given that dynamic protocols (whether proactive or reactive) seek to savethe latter kind of drop (no route) to a bare minimum by being attentive to topological modifications, the maximum load in network dropouts has become the most essential aspect to evaluate when calculating relative bandwidth use. The effectiveness of the routing protocol (calculated based on control overhead in bytes) affects the number of network congestion experienced by a provided data traffic load since both routing control packets, as well as data packets, share the same channel capacity or buffers. Table 1 lists some of the reasons for dropping out, as well as conditions and fuzzy criteria for doing so. Communication Protocols for Fanets

FANET is a subclass of VANET as well as MANET; as a result, normal MANET routing protocols are recommended as well as validated for FANET at the beginning. Because of UAV-specific difficulties, including such fast variations in connection quality, the majority of these protocols are not immediately related to the FANET environment. As a result, to enforce this novel networking paradigm, several specialized ad-hoc networking protocols have been developed, as well as some existing protocols that have been changed in the literature. This group of protocols may be divided into four primary categories.

A. *Static RPs:*

Static RP is defined as a routing table that is constructed & loaded onto UAV nodes before a flight & that can't be changed thruthe mission; as a consequence, it is referred to as static RP. Static RP is defined as follows: In this type of networking technology, unmanned aerial vehicles (UAVs) frequently have an ongoing or unchanging topology. A node could only interface with a restricted number of UAVs or ground control stations at a time because it only stores data that is replace d among the two entities. In the event of a failure (of a UAV or a ground station), it is required to wait for the tables to be updated before continuing.

B. *Proactive RPs:*

To store all routing paths for EVERY other's node or nodes in a specified section of the network, PRP makes use of table storage. In FANET, a variety of table-driven protocols may be employed, each of that differs in a method in which the routing table is updated as a topology of network changes. Because proactive routing has the most up-to-date data on routes, it is modest to pick a path from of transmitter to the recipient and there is no need to wait for the data to be updated. Nevertheless, there are several obvious drawbacks to this approach. First and foremost, since PRPs need a significant number of message exchanges between nodes, they are unable to properly use bandwidth, which would be a restricted communication resource in FANET; as a result, PRPs are not ideal for extremely maneuverable and/or bigger networks. Second, when the topology is modified or a failure occurs, it exhibits a delayed response time to the change. When it comes to VANETs, two primary protocols are frequently used: OLSR protocol &DSDV protocol.

C. *Reactive RPs:*

It is referred to as the "on-demand RP" because it does not need the storage (or the attempted storage) of a route among two nodes if there is no communication between those. There are 2 types of messages in this routing model: Route Request communications as well as RR messages, which are interchangeable. RR communications are generated and sent to the network by source node by flooding network, as well as destination node responds to this message with a RR message. The communications process starts when a Route Reply message is received.

D. *Hybrid RPs:*

HRP is a mixture of earlier protocols that have been developed to address the limitations of the previous protocols. Reactive routing systems' high initial route discovery time and proactive routing techniques' control message overhead may both be reduced via the usage of HRP. If you have a network that has been divided into many zones, they may use proactive and reactive techniques to route traffic across the zones, making it ideal for large networks with many zones.

V. USAGE OF FANETS

The following are some of the areas where FANET is put to use [20][21][22]:

- **In Military:** Military administrations benefit from the use of FANETs. It's quite difficult to establish a speedy communication link in a combat battleground. To communicate information between officers, troops, and military leadership, FANETs are used.
- **Tragedy Handling:** Whenever the present communication infrastructure is damaged by a disaster such as a fire, earthquakes, flooding, etc., FANET comes in handy.
- **In Search & Rescue Task:** FANET may be applied to provide a better means of doing investigations and tasks of recovery, for example, the recovery of prisoners.
- **In Sensor Networks:** There are a variety of sensor devices that may be used to gather data to do daily tasks like detecting terrestrial movement or predicting the weather.
- **Security Purpose:** Because of FANET's capacity to rapidly install and communicate. Furthermore, it may be used to collect data to ensure security[23].
- **Area Wise Services:** In the following services, FANETs may be used. Travelers may use it as a route-finding tool. 9 Calls might be sent to any other area the ability to perceive information relevant to a certain region.

VI. ADVANTAGES OF FANET

A few of the benefits of a network of multi-UAVs [22] are:

- **Cost:** The maintenance costs are also reduced.
- **Scalability:** By gradually adding additional UAVs to the network, it may increase the system's operational capabilities.
- **Survivability:** Failure of one UAV has little impact on the functioning of the FANETs since other UAVs take over and carry out the work constantly and without interruption[25].
- **Speed-up:** A high number of unmanned aerial vehicles (UAVs) can expedite the process. We can provide the desired service quicker than a single unmanned aerial vehicle (UAV).

VII. LITERATURE REVIEW

This section summarises FANET's prior efforts in the area of quality of service (QoS). The past work motivates the development of any new strategy for enhancing the network's routing effectiveness.

Nishat I. Mowla et al. [25] suggested for the first time a federated learning-based jamming attack detection technique for the FANET network. According to Dempster-Shafer's theory, the lower, as well as upper limits of the trust measure for each UAV client group, are associated with belief as well as plausibility [26]. It was so determined that the best UAV client groups might be identified using a UAV client group prioritizing approach. FANET jamming attacks may be detected efficiently on-device via federated learning, which decreases the amount of interaction with the centralized system.

Emerson A. Marconatoet al. [27], Autopilot, and wireless network interfaces were modeled in OMNeT++ for network communication simulations in this case study. Experimental findings provided above are meant to assess AVENS as a robotics simulator, not network efficiency or behavior. Simulating aircraft as well as network characteristics, as well as network activity, deprived of having to spend a lot of time in the field but without needing actual assets.

Jorge Souza et al. [28] The intrinsic capacity of a Gaussian fuzzifier to minimize the noise of input variables led to its selection. A value of 0.6 was determined to be good or exceptional after the simulated procedure had 100 encounters. Fuzzy sets may be part of fuzzy sets at the same time in certain cases (such as 0.55). When relevance algorithm is used, the metric that has the highest weight will be the one that determines the output set.

Shaojie Wen et al. [29] is an algorithm that utilizes local channel data from neighbors to find the most cost-effective solutions for smaller issues. Both the sub-gradient approach as well as the one-order derivative technique are used to speed up algorithmic convergence by providing updates for the dual parameter as well as for the primal solution, respectively. The final analysis includes proof of convergence of the optimization technique.

Muhammad Asghar Khan et al. [30]] FANETs were used to test different topology-based routing systems. We spoke about how they function, as well as their drawbacks. It is because of these characteristics that the flying ad-hoc networks have worse effectiveness.

One of the most difficult aspects of designing multi-UAV is communication. FANETs, the Adhoc networks between UAVs, are examined in this research. In this paper, researchers provide a formal description of FANET as well as examples of possible FANET use cases. In addition, the current FANET testbeds and simulations are highlighted. A flying ad hoc network family has never been studied before, to our knowledge, in this paper. Defining the multi-UAV ad hoc network challenge and encouraging other scientists to work on the open research topics stated in this study are our primary goals [31].

Route discovery, as well as routing information, are the two key components of the proposed routing strategy. According to the direction of motion, residual energy of the nodes, connection quality as well as reliability, this score is determined. For the route selection process, they also use a fuzzy approach to pick fewer hops as well as routes with better fitness. The second stage consists of 2 steps: avoiding route failure to identify & change pathways when they reach the failure threshold, as well as rebuilding failed routes to recognize and swiftly replace routes that have been lost or damaged. NS2 is then used to test the proposed routing system's effectiveness and quality. Results from the simulations are contrasted to three routing algorithms, which are ECaD, LEPR as well as AODV. In terms of end-to-end timePDR, route stability, or energy consumption, the suggested routing approach beats conventional routing systems. Nonetheless, routing overhead has risen marginally as a result of this change [32]. Table 1 depicts an evaluation of RPs depending on factors such as nature, communications amongst UAVs, as well as feature selection.

TABLE I. COMPARISON AMONG FANETS RPS

RPs	Nature	Communication between UAVs	Feature
Load Carry and Deliver Routing (LCAD)	Static	No, just in the area among UAV & GB.	Secure
Multilevel Hierarchical Routing (MLH)	Static	The linkage between UAVs in each cluster is established. As well as the relationship among clusters & GB by CH.	Minimize overhead
Data-Centric Routing (DCR)	Static	The link is established among UAVs in each cluster. In addition, among clusters & GB via CH.	ID for UAV does not matter
Directional Optimized Link State Routing (DOLSR)	Proactive	Not all UAVs. Among UAV & MPR	Lower end to end delay
Time Slotted On-demand Routing (TSOR)	Reactive	YES	Prevent the collision

I. Research Gaps and challenges

The summary presented delineates a multitude of research endeavours pertaining to FANETs, specifically emphasising the enhancements in routing effectiveness and QoS. The summarised works encompass a variety of subjects, such as the detection of jamming attacks using federated learning, evaluations of topology-based routing systems, noise reduction using Gaussian fuzzifiers, and the utilisation of local channel data to implement cost-effective solutions. A study underscores the difficulties associated with communication in FANET scenarios involving multiple UAVs, emphasising the necessity for additional investigation and exploration in this field. The heuristic approach utilised by the proposed routing strategy takes into account various factors including node energy, connection quality, and reliability when determining the optimal route. The simulation outcomes demonstrate an enhanced level of performance in comparison to conventional routing algorithms, albeit with a marginal augmentation in routing overhead. Notwithstanding these progresses, the synopsis also implies that there are areas of research that have yet to be explored and refined, thus creating scope for additional inquiry and progress in the realm of FANETs.

II. Conclusion

Routing is regarded to be one of the most important components of FANETs since it is responsible for ensuring proper functioning as well as effective cooperative network operations. Approximately sixty methods have been suggested in the literature over the previous decade. In the first phase, we selected the bulk of the survey works as well as qualitatively contrasted them dependent on the most notable characteristics to demonstrate novelties of our survey.

Furthermore, in an innovative method, this study examines the architecture of FANETs by defining the many organizations that have been accepted, the various types of communications that are now in use, and their features. It is discussed in the second phase which strategies have been used by the FANET routing protocols and why. In the next section, a worldwide classification of these FANET RPs is presented, in that protocols are divided into eight major groups with ten subgroups, respectively. In this section, every group is detailed individually, accompanied by explanatory figures of its RPs, which are then evaluated with one another on basis of several criteria. As the last stage, we highlighted less-explored open research issues and needs for FANET RPs that have not yet been addressed. To summarise this research, we can state that FANET routing methods must cope with network division as well as the network's extremely dynamic structure. A novel network family, FANETs, is presented in this research to study ad-hoc networks connecting UAVs. Future developments in Flying Ad-Hoc Networks (FANETs) might involve improving communication between several UAVs in busy and unpredictable areas, using AI to make real-time routing decisions that adapt to conditions, and solving security problems using strong encryption and blockchain. In order to make UAVs last longer in the field, researchers should focus on developing energy-efficient routing algorithms. They should also look at advanced swarm intelligence techniques to help UAV swarms communicate and coordinate better. Improving FANETs in these areas will lead to more widespread use of the technology in a variety of contexts by increasing its scalability, security, and longevity.

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