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A Review and Classification of Flying Ad-Hoc Network (FANET) Routing Strategies

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ABSTRACT

MANETs (Mobile Ad-hoc Networks) applications in various walks of life in the last two decades have resulted in introduction of its sub technologies such as VANETs (Vehicular Ad-hoc Network). In this paper, we focus on new ad hoc networking technology called FANET (Flying Ad-hoc Network). FANET introduces the ad hoc networking of flying UAVs to allow real time communication between them and control stations. Flying drones can also form FANET to establish real time communication to achieve their mission. FANET will help in handling of the circumstances like crisis, natural disaster, military combat zones, and package delivery. Efficient real-time routing is a major challenge in FANET because of the very high mobility which results in unpredictable dynamic topology. Routing along with medium access control is a major hurdle in their real time implementation. In this paper, we have first have first highlighted major research issues and challenges in FANET. Then we have performed an investigative review of suitability of using existing ad hoc routing protocols for FANETs. Then, we propose five categories of FANET routing protocols: static, reactive, proactive, hybrid and hierarchical. Finally, we present a comparison of routing strategies based on certain criteria's.
KEYWORDS— MANET, VANET, FANET, Routing protocols, UAV_S, Sensor nodes

I. INTRODUCTION

A mobile ad-hoc network (MANET) is a mobile network of autonomous wireless devices with no backbone or infrastructure but exhibits self-configuring characteristics. MANETs have many application areas such as, disaster relief, military communication, urgent business meetings, etc. The main advantage of MANETs is their portability or mobility. The wide spread applications of MANETs has enabled sub categories of ad-hoc networking technologies, such as Vehicular Ad hoc Networks (VANETs) and Flying Ad hoc Networks (FANETs). Usually, these networks have high mobility with rapid topology changes as compared to a typical MANETs, because in both VANET and FANET, most of the nodes are vehicles and UAVs (Unmanned Ariel Vehicles), respectively. VANETs are the networks in which vehicle to vehicle (V2V) and vehicle to pre-installed infrastructure communication is supported. The main objectives of VANETs are to improve, traffic efficiency and traffic congestion, access to information and news to avoid accidents, and for entertainment purpose while driving. Flying Ad-hoc Network (FANET) is a special type of MANET with support of very high mobility. In FANETs, the nodes are normally Unmanned Aerial Vehicles (UAVs) in Unmanned Ariel Systems (UASs) environment. These networks are aimed to construct self-organizing networks with flying aircrafts in the sky [1]. UAVs are involved in both military and civilian applications. The examples of applications of UAVs are, agricultural aviation governing [28], surveillance, patrolling the border area, traffic management, pipe-line monitoring, seismic events, volcano monitoring [4], environmental monitoring, etc. Single UAVs frameworks have been utilized for quite a long time. Although single UAV systems are very often in use, but adding multiple UAVs is a very fruitful idea due to its advantages over single UAV system. Therefore, these types of systems called multi-UAVs system. In single UAV architectures, the UAVs are connected to either base station located in the ground or connected with a satellite station for communication in star topology manners. In contrast to single UAV system, multi-UAVs systems have more than one UAV, therefore, multi-UAV can work in multi-hop scenario, and there is no need of all the UAVs to connect directly to the earth station or satellite station.

Besides this, certain advantages and challenges are associated with Multi-UAVs systems. Some of the advantages over single UAV system are given below:

Economical: The maintenance and installation cost of large UAVs, is much higher than that of a small UAV (used in single UAV system) [1].

Scalability: The coverage area of single UAV system is small as compared to multi-UAVs, hence, coverage rate is low [2] while, multi-UAVs systems have the ability to adapt to a situation easily.

Stability: One of the major drawbacks of single UAV system is the single point of failure i.e. if a UAV fails to complete its task then the task will not be completed until another UAV is sent. While in multi-UAVs if one UAV fails then the task can be

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done other UAVs through different routes.

Timewise efficient: It is obvious that as compare to one UAV, multiple UAVs work faster to complete a task [3].

Sustainability: Multi UAV systems are more sustainable than single UAV systems.

Some challenges are also associated with Multi UAV systems which are given below:

Cost of the equipment: The cost of the complex hardware used for communication with either the ground station or satellite station is very expensive.

Reliability: The reliability of the communication is a big concern in multi-UAV system due to their high mobility. Very high mobility in multi-UAV system causes the communication links to make-and-break rapidly. Therefore, it will affect the reliability of the data.

Coverage Area: Coverage area is the transmission range of a UAV (in meter unit) in which it can remain connected with the ground station.

To cope all these challenges, the introduction of ad-hoc network is the alternate solution. This ad-hoc network is called FANET. FANET has the capability to solve this problem of communication between UAVs.

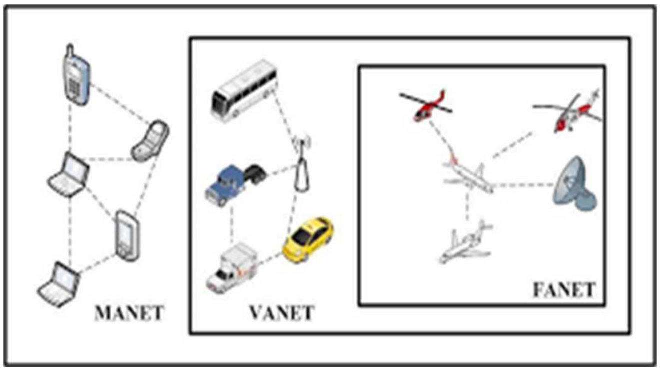

Figure 1. **MANET, VANET and FANET [1]**

Multi UAV systems may use star topology to connect to the base station. Some of the nodes (UAVs) correspond with base station, which is situated somewhere at ground, and other nodes can correspond with space station which may be a satellite. UAV-to-UAV communication using the infrastructure has some inherited design problem. UAVs must be outfitted with costly and entangled equipment to correspond with ground and satellite stations. Reliability of the communication in this highly dynamic environmental is a real challenge.

The rest of the paper is organized as follows. Section II, presents the major research issues and challenges of FANET. We presents our review and classification of FANET routing protocol in Section III. In section IV, we present a comparative study. Finally, in section V we presents our conclusion and highlight future work.

II. RESEARCH ISSUES AND CAHALLENGES

Considering few similarities between FANET, MANET and VANET; FANET inherits some of the issues and challenges from MANET and VANET. However, due to additional characteristics, such as, very high speed of UAVs in FANET, the routing protocols require major review and investigation. So, the data routing between UAVs undergoes a serious challenge. The routing communications protocol must be able to update routing table or cache dynamically according to modification in the topology. Previous protocol does not provide a reliable communication. So, there is a need of new communication protocol to provide a flexible and reliable communication.

There are also various issues related to transmission like, security overheads, loss of data packets, and use of energy. To some extent, a FANET is not quite the same as customary MANETs and VANETs; but the main idea is the same: having dynamic nodes in an ad hoc manner. Consequently, in a FANET, a few difficulties are substantial as in a VANET while confronting with extra difficulties. Many inquiries have been performed to build the productivity of system with flying nodes, there are as yet numerous unsolved issues, which ought to be investigated.

A. **Routing:**

In a FANET, routing of data between UAVs is a serious challenge, which is not same as the MANETs with low portability mobility conditions. As indicated by topology changes, routing tables must be updated dynamically. Most of existing routing algorithms' metric calculations are neglected in FANET to give a dependable correspondence between UAVs. Reliability of routes is also a real challenge due to the very high mobility in FANET. Authors in [22] have suggested reliable routing protocol, however suitability of such routing techniques in FANET is required. Along these lines, there is a need of new research direction to calculate routing metrics and develop efficient routing algorithms and network models for developing an adaptable and responsive ad hoc model.

B. **Path Planning:**

In a large scale mission territory and multi-UAV operations, participation and coordination between UAVs are one of the most important factors to increase the efficiency of a FANET. In such cases, each UAV needs to change its pathway, and new ones ought to be re-computed progressively. Accordingly, new methods/algorithms are required to arrange the FANET nodes for organizing the clusters of UAVs.

C. **Quality of Service (QoS):**

A FANET can be utilized for transporting various types of goods to the customer residences such as the delivery drones from Amazons. They incorporate GPS maps, streaming video/voice, images, straightforward instant messages etc. Provision of certain qualities to service [23] parameter such as delay, bandwidth and packet loss are essential for FANET applications. Characterizing an exhaustive system for QoS-empowered middleware is a serious challenge that ought to be overcome because of the exceedingly mobile and dynamic structure of FANET. Misbehaviors [24] of nodes in FANET could also affect the quality of services in their operations.

Coordination between UAVs and manned aircrafts: It is an inescapable fact that, later on with increased number of UAVs, the flights of UAVs must be coordinated with the manned aircraft. Similarly, in a military aspect, destruction of enemy aircraft may be achieved by utilizing a FANET or these UAVs can be utilized as electronic jammers. Furthermore, these UAVs can be used as surveillance in foe zones.

III. CLASSIFICATION OF FANET ROUTING STRATEGIES

In this section, we first review some major research that leads to the concepts of FANET. Then, we present classification of FANET routing protocols.

Remote (wireless) correspondence ability, available for small and mid-sized, less expensive UAVs, are currently provided commercially. Some of the UAVs are modified and are programmed, load with expensive equipment like cameras, storage, sensors and processors. They show a high level of stability in air. Some are equipped with just essential control units [6].

The engineering of an ordinary UAV having systems like, control, monitoring, data processing and landing. The inner system gives an extensive variety and capabilities, from routing to performing information exchange to ground stations. The UAV market is yet developing, and UAVs are being utilized as part of new activities and in taking care of new issues each day. Numerous organization are concerned with creating low cost UAV systems of related services [18].

Since FANETs nodes are mobile and ad hoc in nature, they imposes difficulties on the protocols used to help their wireless correspondence. In the UAVs communication system, the behavior and speed of UAVs are considered as advantageous. There are additionally advantages when UAVs utilize wireless network system. Some are as under:

- Because of line-of-sight propagation, UAVs provide on demand, excellent quality of unguided communication.
- UAVs can be distinguishing, or detecting the information nodes everywhere throughout the wireless network system which are powerfully and dynamically placed in the network system.
- UAVs can refresh their routes to improve the better execution of wireless system structure.
- UAVs have capability to carry and forward large amount of data.

A. FANET NETWORKING PROTOCOLS

The main purpose of routing protocols is to find appropriate path for data transmission. There are wide range of protocols for different applications in wireless networks, like pre-computed routing protocols, dynamic source routing protocols, on demand routing protocols, flooding, cluster based routing protocols. FANET and VANET are the sub-set of MANET networks [2]. FANET protocols are divided into the following categories.

- Static Protocols
- Proactive Protocols
- Reactive Protocols
- Hybrid Protocols

Static Routing Protocols

A routing table of static routing protocol must be computed and loaded before the operation of UAV nodes and cannot be change until the operation ends. Every node communicates with other nodes (UAVs) or with station on the ground, and stores its own information [10]. It is necessary to wait until mission ends in case of failure of updating the table that is why these protocols are not fault tolerant.

Load Carry and Delivery Routing (LCDR): Load Carry and Delivery Routing (LCDR) is the first routing protocol in FANET. UAV carry data from a ground node, and it may be a video or image, fly and carry it through to the destination ground node which can be a ground control station or military team.

Data Centric Routing (DCR): Data Centric Routing (DCR) is a routing protocol in FANET in which the receiving node, either a ground node or a UAV, scatters queries with a specific end goal to gather specific information from a particular zone. Data aggregation algorithm may use for energy efficient data dissemination. This model involves minimum assistance, when small numbers of UAVs are on the path. DCR allow three scopes in decoupling.

- Space decoupling: communication nodes can be anywhere.
- Time decoupling: Subscriber's node transmitted data instantly or may be transmitted later.
- Flow decoupling: Delivery can be accomplished constantly.

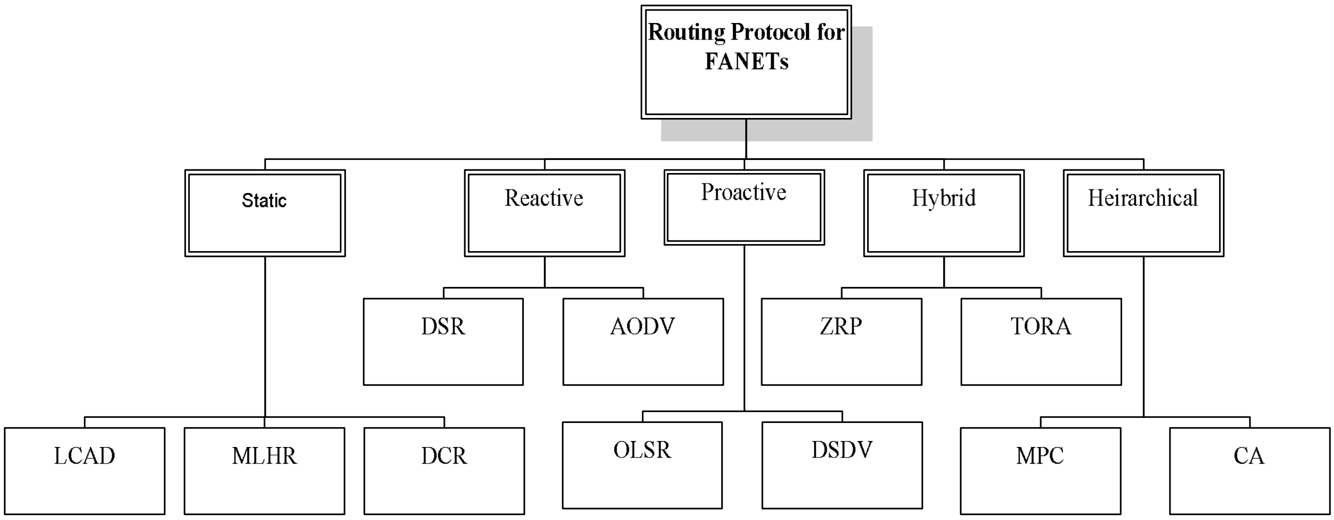

Figure 2. **Routing Protocols in FANET**

Figure 3. **A FANET scenery of multi-UAV systems.**

Proactive Routing Protocols

Proactive routing protocols manage all the tables of specific area and also gather routing information in a network. In FANET, there are different driven protocols which are not similar to each other. Nodes updates routing tables according to the change in topology. The routing protocol carries the latest information of nodes that is why there is no need to wait and select the path between sender and receiver. When the bandwidth is not used effectively (a lot of traffic between nodes) then this will not be recommended for large communication networks. Other than that the protocol seems to be slow when topology is changed, or failure occurs.

Destination Sequenced Distance Vector (DSDV): In Destination Sequenced Distance Vector (DSDV) routing protocol, every node behaves like a router. It is a proactive routing protocol with table driven approach, where every node can maintain its routing table and contains sequence number for each node. There updating mechanism works when network topology changes. For dynamic networks this protocol is not suitable because of the rapid changes in topology and does not support multipath routing.

Optimized Link State Routing Protocol (OLSR): In OLSR routing protocol use two types of messages for network that are "hello" and "topology control message". In the communication range "hello" message is use for finding the neighbor nodes to generate neighbor node list for each node and broadcasted to one hop neighbor [9]. Whereas "topology control message" is used in the network to maintain the topology information. Each node refreshes or recalculates its routing table because these messages periodically refresh the topology information. There is large amount of overheads in this protocols because of its periodic flooding nature. Multi point relay (MPR) is used for reducing these overheads [10].

Reactive Routing Protocols

In Reactive routing protocols, unless there is communication between the two nodes, there is no need to figure out a route between them; that is the reason Reactive routing protocols are the also called on demand routing protocols. This mechanism reduces the overhead problem of Proactive Routing Protocols. The utilization of bandwidth in (RRP) is good as there is no periodic messaging.

Dynamic Source Routing (DSR): It is a reactive protocol and designed for wireless mesh network. Sender determined the route from source to destination node. Sender node sends request to its neighbor nodes, there may be several route request messages in the network. Sender node send a unique request id to avoid the mixing of the sender node. Every node of the network must be related with route caches in which every one of the routes are available. The principle issue in this is to keep up and refresh the route caches.

Ad-hoc On-demand Distance Vector (AODV): AODV has the same on demand functions like DSR and the difference is maintaining the routing table [4], [10]. Every node in DSR can store different entries in the table for every destination and establish the path for data packet transfer from source to destination. Whereas in AODV it holds only one entry for each destination and stores next hop information to each data communication. AODV routing protocol consists of three phases: routing discovery, transmission of packet, and route maintenance. AODV routing messages type are route request, route reply, and route error.

Hybrid Routing Protocols:

Hybrid Routing Protocols (HRP) are used to overcome the limitations of proactive and reactive routing protocols as reactive protocols require more time to find routes and proactive protocols have control messages overhead. In Hybrid routing a network is divided into different regions, proactive protocol is used for intra region routing whereas reactive protocol is used for inter region routing.

Zone Routing Protocol (ZRP): ZRP works on the concept of zones. Each node has an alternate zone and zones are separated by predefined range called R. Where the neighboring nodes meet along the range lines. Proactive strategy is used for routing inside the zone and is called intra zone [10]. Information sends right away, when source and destination nodes are in the same zone. Reactive routing techniques are used when information is needed to be sent outside the zone.

Temporarily Ordered Routing Algorithm (TORA): TORA is a scalable, efficient and adaptive algorithm. It finds various routes among source and destination. Most likely, TORA is a complicated protocol and when any network system connect down the control messages propagates the purpose of failure. TORA works well on larger networks but has higher overhead for smaller networks.

Hierarchical Routing Protocols

Hierarchical routing is the routing which is mainly based on cluster based topology. One of the major issue in hierarchical routing is the formation of the cluster. Two clustering formation algorithms are discussed here:

Mobility prediction clustering (MPA): A cluster formation algorithm is proposed for FANET in [19] namely called Mobility prediction clustering. Due to high mobility scenario in FANET, the formation of clusters has rapidly updates, and this algorithm address this problem by predicting the updates regarding network topology. It forecast the structure of mobility of UAVs by using structure prediction algorithm [20] and link expiration time mobility model. It selects the UAV with highest weighted sum value of these models as cluster head (CH). The result showed that this CH selection scheme increases the clusters stability.

Clustering Algorithm: A clustering formation algorithm for UAV networking is proposed in [21]. In first, the cluster is constructed on ground for multi-UAV system and then updated during the flying operation. Then the clustering plan is calculated for selection of the CHs according to the geographical information. Once the UAVs deployed, then cluster structure is adjusted according to the mission information. Results showed that this algorithm can be used to increase the stability and guarantee the ability of dynamic networking.

IV. COMPARATIVE STUDY

As specified before, there exist four essential routing protocols for FANET. In this segment, we fundamentally break down and look at these essential FANET protocols. Table 1 introduces the relative study among these four FANET routing protocols which are static, proactive, reactive, and hybrid protocols. We clarify each of the examination criteria with more subtle elements in this area.

Table: 1 **Comparisons among the Basic Routing Protocols in FANET**

	Types of Protocols			
Criteria	**Static Protocols**	**Proactive Protocols**	**Reactive Protocols**	**Hybrid Protocols**
Main Idea	Static Table	Table Driven Protocol	On demand protocol	Combination of Proactive and Reactive protocols
Complexity	Less	Moderate	Average	Average
Route	Route is Static	Route is Dynamic	Route is Dynamic	Route is Dynamic
Topology Size	Small	Small	Large	Small and large
Memory Size	extensive	extensive	Least memory space	Medium memory space
Fault Tolerant	Missing	Missing	Missing	Mostly present
Bandwidth Utilization	Best possible	Least possible	Best possible	Moderate
Convergence Time	Quicker	Slower	Mostly fast	Medium
Signaling Overhead	Missing	Existing	Existing	Existing
Communication Latency	Less	Less	High	High
Mission Failure Rate	High	Low	Low	Very low
Popularity	Least popularity	Medium popularity	Medium popularity	Best popularity
Operation	Fixed mission	Dynamic mission	Dynamic mission	Dynamic mission

A. Main Idea

In Static protocol, the primary thought is that the routing information is unchangeable or fixed for a specific mission and is stacked into the UAV before the mission. Whereas, Proactive protocol holds the present route data into the table. Reactive protocol is on request/on demand protocol, at the point when the source requests destination route, it computes the route.

B. Complexity

Complexity is comparatively low in static protocol, when destination is fixed. If there should be an occurrence of topology change, route finding turns out to be more complicate in proactive convention.

C. Route

If there should be an occurrence of static protocol, route is settled all through the mission. Routes are dynamic for every other protocol.

D. Topology size

Best utilization for fixed topology mission is Static protocol. Subsequently, if the size of the topology measures extensive, then there is a possibility of change in topology. Thus, it is better to use Static protocol for small network systems. Proactive protocol is a table-driven protocol. If the event that the quantity of UAVs expands, their comparing routing table sections additionally increments. In this manner, proactive protocol is suitable for network with small number of nodes. For hybrid and intra zone routing mostly fixed and small network size is better.

E. Memory size

Before the mission starts, the entire information about routing is transferred into the UAV in Static protocol. Accordingly, this process requires large memory space. In the event that the number of nodes increases, the table size becomes bigger. In this manner, large memory space needed in Proactive protocol. Reactive protocols are mostly source driven protocol hence, when source requires to discover a route, the route discovery mechanism would be actuated, hence, requiring less memory. Position-based protocol stores the directions of each UAV, along these lines requiring large memory space.

F. Fault tolerant

Mission route or topology change in FANETs is a fundamental issue. Static protocol doesn't support this situation. In this way, fault tolerance is missing in this convention. Other routing mechanisms have some fault tolerance mechanism for finding alternate routes.

G. Bandwidth utilization

Static protocols are utilized as a part of small network system where topology is fixed, so there is almost no use of bandwidth utilization. Hello messages are sent periodically by Proactive protocols in the system. Thus, this protocol requires more information exchange or require more bandwidth. Less transmission capacity is required for Reactive protocols because they are source driven. For hybrid protocols, transmission capacity use is medium.

H. Convergence time

Destination is predefined in the static protocol. When a route is required, discovery time is minimum. After every change in the topology, proactive protocol looks through the destination node, resulting in bigger convergence time. Reactive protocol discovers the route quick, however this protocol takes additional time when topology changes. Whereas Hybrid protocols need average time to converge the network.

I. Signaling overhead

There are signaling overheads in Proactive, Reactive and Hybrid protocols; however, the Static protocols have no overhead. For example, in proactive protocol overhead of hello messages, whereas, route request and route reply message in Reactive and hybrid protocols.

J. **Popularity**

Static protocols are easy to understand; however, they are not blame tolerant. That is the reason, they are only used in static small networks. Other protocols are easy to configure and can handle mobile and dynamic networks, therefore, they are significantly well known.

K. **Communication latency**

Since the path distance in between the UAVs is less and also have low correspondence in the static and proactive protocols, there is low communication latency. The distance between the UAV to UAV and ground station to UAV is higher in reactive and hybrid protocols. Due to this Reactive and hybrid protocols holds much higher latency as compare to static and proactive protocol. Also reactive protocols need time for route discovery, therefore, the communication latency increases.

L. **Operation**

Static protocols are utilized as a part of missions where mission objective and topology are settled or fixed. Already, most of the protocols were utilized as a part of military operations. However, utilization of UAVs has expanded day by day. Therefore, numerous civilian operations are currently directed by multi- UAVs frameworks. Therefore, every protocol is being modified to handle mobility and ad hoc nature, so these protocols can also utilize in civilian and military operations.

V. CONCLUSION

UAVs have a promising part in a substantial operation zone with complex missions. UAVs require participation with each other and need a fast and simple data communication framework. Multi UAV framework reduces the operation achievement time and enhance the quality of the framework for airborne operations when contrasted with a single UAV framework. To apply organizing in non-Line of Sight (LOS), urban, forceful, and loud condition, multi-UAV framework is extremely viable and precise. Correspondence is a critical issues for multi-UAV frameworks. In this research paper, specially appointed systems among the UAVs, i.e. FANETs are studied alongside their main difficulties in contrast to the conventional ad hoc systems. The current steering conventions for FANETs are grouped into five noteworthy classifications which are then basically broke down and analyzed in view of different execution criteria. At last, we have listed a few open research issues concerned with FANET, which allow the research community to focus on.

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