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A Comprehensive Study of Flying Ad Hoc Network

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Abstract – MANET, VANET, FANET and SANET are the four types of ad hoc network. The full of these networks are Mobile Ad hoc NETwork, Vehicular Ad hoc NETwork, Flying Ad hoc NETwork, and Sea Ad hoc NETwork respectively. In this, FANET is a network which has flying node and comprises of a collection of small UAVs. It is an ad hoc network of flying nodes. Mobility, energy conservation, scalability, security, connectivity to the Internet, multi-hopping parameters are the basic features of FANET. This paper presents a study on characteristics as well as applications of flying network. In the first portion of this paper, a simple overview of the flying network, design consideration of FANET and basic classification of routing protocols of FANET has been presented. Lastly, open challenges and future scope of flying network have been discussed for future research advancements.

Keywords – MANET, VANET, FANET, SANET, routing protocols, UAV.

I. INTRODUCTION

A collection of dynamic nodes are presented in an ad hoc network where flying Ad hoc NETwork is a developing field amongst two networks that are MANET and VANET. In Flying Ad hoc NETwork, communication between multiple UAVs is reliant on change of topology and node mobility [1-3]. There is main role of UAV, which is an airborne vehicle that ensures not have a human on airborne panel, in other words, UAVs work without human help. In this type of network, one of the UAV is straight theme which connected to the infrastructure [4]. On the other hand, nowadays, UAV are being actually used in several applications, such as civil, military, environment etc. The particular UAV system is used very frequently; however, multiple aerial vehicles systems have specific limited challenges and issues.

A subclass of UAV can communicate with the satellite in flying ad hoc network. There are some main difference between traditional network and flying network. MANET and VANET are having less mobility degree than FANET. MANET and VANET are used by human beings whereas FANET are flying in the sky. In MANET and VANET, topology changes less

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frequently than FANET. It is due to high mobility of flying nodes and FANET requires peer to peer connections of UAV. MANET and VANET have less distance, but the distances among flying nodes are much than that [5]. FANET is a specialized form of mobile and vehicular network.

II. RELATED RESEARCH WORK

Previous research works by researchers have focused on different aspects of flying ad hoc network as shown in below. It shows a comparative study based on key points in detail.

Table 1: Surveys paper on FANET

S. No.	Authors Name	Surveys Reference	Description
1	Bekmezci et al. Jiang et al. Sahingoz et al. Oubbati et al. Mukherjee et al. Gupta et al.	[6-11]	Surveyed these papers and highlighted various design issues and considerations related to network, routing protocols, and mobility models and routing issues for FANET.
2	Singh et al.	[12]	Highlighted the classification of routing protocols, applications and future research insights of FANET.
3	Arafat et al.	[13]	Presented design issues of cluster based routing protocols for FANET.
4	Bashir et al.	[14]	Surveyed and discussed energy efficient layered protocol which can improved cycles, enhance the power consumption and focused traffic monitoring.
5	Bujari et al.	[15]	Compared position based routing protocols of FANET and highlighted the limitations.
6	Singh et al.	[16]	Described the concept of FANET with its challenges and applications.
7	Zhao et al.	[17]	Reviewed the different computational algorithms which are used for path planning.
8	Altawy et al.	[18]	Surveyed the main privacy and security

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S. No.	Authors Name	Surveys Reference	Description
			aspects of FANET.
9	Kanistras et al.	[19]	Discussed traffic monitoring management for UAV based systems.

In this paper, our investigation is organized as mentioned below:

In Division I, we introduce about FANET and Division II, about the review of literatures.

In Division III, we surveyed the research papers and deeply describe the total numbers of routing protocols of FANET.

In Division IV, we offer a classification of routing protocols of FANET with its advantages and disadvantages.

In Division V, we then provide the design considerations of FANET. Each design consideration is illustrated by an explanatory study.

In Division VI, we outline flying network as a specialized ad hoc network along with unique features of FANET.

In Division VII, we summarize the FANET applications and Division VIII, finally concludes this survey with additional viewpoints for further research.

III. SURVEY OF ROUTING PROTOCOLS

There are numerous previous and latest routing protocols are used by researchers. In [20], author surveyed the paper with 7 routing protocols and depicted the challenges of using UAV as mobile nodes in an ad hoc approach. In [6], 10 numbers of routing protocols are discussed with introduced the main design challenges of FANET. In [7], surveyed the paper and discussed the challenges and also discussed the open challenges. In [8], authors elaborated the issues of FANET along with 24 routing protocols. In [21], authors reviewed the architecture of FANET and discussed 4 routing protocols with cloud based algorithms.

In [22], surveyed the paper which having descriptions of 30 routing protocols and highlighted specific features of FANET. In [23], 14 numbers of routing protocols are discussed with communication architecture of FANET. In [24], authors discussed the FANET routing protocols which are 26 in total. In [25], authors compared the different ad hoc networks with its routing protocols which are 6 in total. In [9], total 16 routing protocols are mentioned in this paper and authors also compared with specific routing protocols. In [26], authors discussed the various challenges issues with 13 routing protocols. In [11], authors surveyed

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the most popular 15 routing protocols with its performance parameters. In [27], authors discussed 8 topology based routing protocols of FANET. In [10], authors highlighted communication methodologies with 9 routing protocols. In [28], authors included the review of VANET and FANET with 10 routing protocols. In [29], authors surveyed issues and mechanism of communication protocols of 3 routing protocols. In [30], authors surveyed the challenges and issues of FANET with 10 routing protocols. In [13], authors described 18 cluster based routing protocols of FANET with different routing issues.

IV. CLASSIFICATION OF ROUTING PROTOCOLS

Generally, MANET and VANET's routing protocols are inappropriate directly for FANET. So, some of the former ad hoc routing protocols have been improved and some innovative has been suggested for flying ad hoc network routing. As shown in below table i.e. the classification of six routing protocols:

Table 2: Classification of FANET Routing Protocols

Protocols	Description	Advantages	Disadvantages
Static Routing Protocols [31]	-These protocols have a routing table. -It has not modified in network. -There are three sub-categories of static routing protocols: DCR, LCAD, and MLHR.	-Increased efficiency -multi activities processed all together -more secure -high throughput	-redundancy available -no unique ID in network -high bandwidth -longer delay in delivery
Proactive Routing Protocols [32]	-These protocols contain a routing table which has been modified at any time. -There are four sub-categories of proactive routing protocols: DOLSR, P-DOLSR, ML-OLSR, and COLSR.	-reduced redundancy -increased throughput -easy implementation -maintain the shortest distance	-more space required -not suitable for all devices -large bandwidth -unnecessary broadcasting

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Protocols	Description	Advantages	Disadvantages
Reactive Routing Protocols [33]	-This protocol fills the routing tables at the required time. -There are three sub-categories of reactive routing protocols: time slotted AODV, RGR, and RTORA.	-save storage capacity (required small space) -preserve bandwidth -reduce the delay time	-more time taken for route setup -delay in actual transmission -fail in high mobility
Hybrid Routing Protocols [34]	-This protocol is a mixture of reactive and proactive routing protocols. -There are two sub-categories of hybrid routing protocols: TORA, and ZRP.	-preserve bandwidth -required less time for setup -less space required	-fail in high mobility -battery problem
Geographic/Position Based Routing Protocols [35]	-These protocol calculates its own location with various services. -There are five sub-categories of geographic routing protocols: GPSR, MPGR, USMP, GPMOR, and LAROD.	-secure than others -no control required -no loop hole in routing -low failure chances	-exact location may not identified easily -increases of implementation cost -more computation power required
Hierarchical Routing Protocols [36]	-This protocol is dived into smaller layers of network. -There are three sub-categories of	-all nodes covered during process. -preserved energy -increases of message size	-may network fail due to halting -energy bandwidth issue -required more

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Protocols	Description	Advantages	Disadvantages
	hierarchical routing protocols: MPC, LANMAR, and DREAM.	-avoid replication of data -efficient use of battery	processing time -data may collide in network

V. DESIGN CONSIDERATIONS OF FLYING AD HOC NETWORK

There are some different design considerations for flying ad hoc network, which has been mentioned below in table 3:

Table 3: FANET design considerations

S. No.	Design Considerations	Explanation
1	Adaptiveness	-If the high levels of changes are in network, adaptiveness is always preferred. -Flying ad hoc networks need adaptive layer protocols.
2	Latency	-Real-life monitoring is the example of latency. -Delayed transfer of data packets could make harmful problems.
3	Scalability	Flying ad hoc network permits multiple UAVs to connect together with nominal overhead. For collective task completion, a flexible network and scalable network is constantly chosen.
4	Mobility	With high degree of mobility, there are many probabilities of failure because of any kind of faults (either hardware fault or software fault).
5	Bandwidth	Delay constraints during search and rescue operations. Multiple UAVs needs significant amount of bandwidth in different cases such as UAV speed, communication, security to broadcast communication etc.
6	Deployment of hardware	It needs the deployment of hardware on the multiple UAVs. Sometimes, space for the

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S. No.	Design Considerations	Explanation
		installation of hardware could be restricted.

VI. FEATURES OF FANET

There are several features of flying ad hoc network as mentioned below: -

1. **Mobility model:** It is fixed for predetermined paths in FANET, but some of the models are using random speed.
2. **Node mobility:** The degree of node mobility is very high in FANET. The speed of UAV is round about 460 kilometer per hour.
3. **Topology change:** It is fast as compared to MANET and VANET. The communication link of the UAVs has broken normally. It is due to either high speed or out of range of UAV.
4. **Power consumption:** It is not required for small UAV but energy efficiency problem stills in mini UAVs.
5. **Computational power:** It is very high as compared to MANET and VANET.
6. **Localization:** It is available with GPS, AGPS, DGPS and IMU, which determining the location for each UAV.
7. **Radio propagation model:** In FANET, light of sight is available for majority of the cases. It is depend on the surrounding environment.
8. **Node density:** It is very low as compared to mobile and vehicular networks. It is according to nature of the flying nodes.

VII. APPLICATIONS OF FANET

There are various applications of flying ad hoc network as mentioned below: -

1. **Military Services: -** The main parameter of FANET is communication. The use of communication in military service is very difficult.
2. **Search operation and Rescue Operation: -** It is used as a rescue operation of criminals, where flying ad hoc network offers a better way to do find criminals and rescue in their area.
3. **Security: -** It is used to provide the information in safe mode, in which security is very essential part.
4. **Localization: -** FANET can be used to detect information about specific location. It can be also used to forwarding calls.

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5. **Environmental Management: -** There are some natural disasters such as fire, flood, tsunami, and earthquake. So, when the current system is damaged due to these cases, then flying ad hoc network is useful.

There are some other applications of FANET like emergency services and calamity recovery, real estate and urban planning, architecture and engineering, media and communications, agriculture and aquaculture, business and commerce, recreation and entertainment etc [37-38].

VIII. CONCLUSION AND FUTURE SCOPE

This paper explains the concept of FANET and this study shows that the evolution, its challenges, design considerations, features and various applications of FANET. Various routing protocols of FANET are also discussed with their advantages and disadvantages. FANET routing protocols are more interesting for researchers. In this paper, study of almost all number of protocols of FANET is discussed. There is a requirement to search more efficient routing protocols in detail. Additionally, we will further work on a well-organized routing protocol that can be improved to all situations in future.

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