FANET:-Communication Architecture and Routing Protocols A Review

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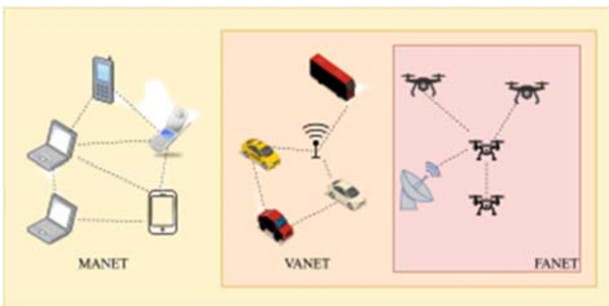
Abstract
FANET (Flying ad-hoc network) is a self-adjusting wireless network that enables easy to deploy flying nodes, inexpensive, flexible such as UAV in the absence of fixed network infrastructure they communicate amoung themselves. Past few decades FANET is only the emerging networks with it's huge range of next-generation applications.FANET is a sub-set of MANET's(Mobile Ad-hoc Network) and UAV networks are known as FANET.Routing enables the flying nodes to establish routes to radio access infrastructure specifically FANET and among themselves coordinate and collaborate.This paper presents a review on existing proposed communication architecture and routing protocols for FANETS.In addition open issues and challenges are summarized in tabular form with proposed solution.Our goal is to provide a general idea to the researchers about different topics to be addressed in future.
Keywords:
Rouitng,UAV,FANET,protocols,Ad-hoc networks

1. Introduction

Flying Ad-hoc Networks (FANETs) have quickly spread, where they are utilized in numerous applications, for example, common security, and military sectors. FANETs can be given an undertaking to such an extent that they can be in the field to work alongside individuals to perform basic errands and make activities simpler to accomplish. The organization comprises of various unmanned aerial vehicles (UAV) hubs that convey utilizing remote correspondence. Utilizing a solitary UAV rather than numerous ones can restrict the quantity of utilizations. While it very well may be plausible and has less intricacy in network availability, it doesn't have an enormous inclusion contrasted with the different UAVs framework. In addition , single detached UAVs take additional time to finish given under taking, since they work independently Consequently ,FANETs can be very supportive in time-basic circumstances where they work quicker and take less an ideal opportunity to complete a given under taking. Furthermore, they are viable with wide scope of utilizations. IN case they additionally may have complex network geography just as force utilization restrictions. Quite possible the most widely recognized applications in FANETs are utilized for are military and common applications. They are generally utilized in looking what's more, safeguard activities, as they can work quicker since they have enormous inclusion territory, which makes the undertaking of discovering possible targets, easier. Moreover, respectful applications additionally incorporate reconnaissance also respectful security. These applications rely upon outrageous security, where any interference may make significant harm the public.

FANETs known for their dynamic nature in which robots are flying with various rates and now and again in various ways. In these kinds of geographies, it is exceptionally difficult to execute the traditional routing protocols. To implement the conventional routing protocols is very challenging in these types of topologies.The routing protocols are vital in FANETs to build up the UAV-TO-UAV correspondence and tracking down an ultimate routing protocols which has the most reduced directing overhead while giving a solid end-to-end transmission of the information stays a functioning space of research [5].As of now ,analysts are exploring the viability of the routing protocols utilized in the (MANETs) Mobile Ad-hoc Network what's more , those carried out in the Vehicle Ad-hoc Network(VANETs).With the brought into the world of UAV's communication,[6]FANETs is a sub-field of MANETs network. Consequently, FANETs share a portion of the MANETs highlights, for example; working in an ad-hoc way, having a self-organizing topology and the less central control. These are the features which contribute towards broadening the range of communication and growing the network in an less structure area. Moreover, FANETs have some features of VANETs, like dynamic geography and portability aspects.



While designing a communication system for ad-hoc network crucial role play by the computational power.

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Two main factors affect protocol simulation first one is mobility model and second one is communicating traffic pattern, among others. Before effective use of network many problems need to be addressed.
Hence forth , the main point of the study is to follow the most recent turn of events in the network communication architectures and routing protocols that are planned in the literature for FANETs.

2. Literature Review

This paper carlos , Tassio, presents as demand of the internet access from different devices increasing rapidly that provide new challenges for companies. To support the increasing flow of the network as a possible solution with low latency and scalable infrastructure MANET(Mobile ad-hoc network) applying in UAV technology and develop FANETs (Flying ad-hoc networks) with the leading characteristics of high mobility and wireless scale –ability. Due to this it’s difficult to guarantee efficiency in all cases . Two simulators were develop to analyze the scenario in which FANETs with different protocols during video and data transmission .Result show that the proactive protocols in scenario more efficient that communicate with an onshore server.
This paper sara , aisha discuss the popularity of the unmanned aerial vehicles(UAV). A new idea for a routing mechanism which is effective and efficient implementation for FANETs.
This paper M fahad ,Ali Imran present review on the flying ad hoc network limited work on routing which possess unique characteristics that make it different from the old manet and vanet. Many routing metrics, like link expiration time, residual energy, mobility metrics,geographical location are used to select routes.Due to limited focus on the FANETs characteristics future work with large amount remains.
This paper presents a systematic review of RPL-based routing protocols. every year more topics being covered that RPL is gaining interest. RPL as the routing protocol accepted by many researchers. More focus on industrial uses of RPL ,Security enabled and cross-layer design.To find a single adoption and declare it as the ultimate routing for RPL is not easy. A huge number of RPL adaption in the review to improve the performance but in the original standard a change is required to make it incompatible with each other.
This paper discuss FANETs network in certain unique scenarios composed of UAV nodes and ,can be used to implement data transfer. Survey about state of art about routing protocols ,comparative analysis of different protocols on their characteristics and proposed solution to the unsoved problems using research direction on FANETs.
This paper present about UAV devices problems of small duration of flights, due to limited battery power unproductive routing and high mobility will be bridge with the use of hybrid KFFOCA. The KFFOCA shows good efficient performance than ECRNET, CACONET, GWOCNET and CLPSO on the basis of Cluster building time, number of cluster, PDR, consumed energy, through put,cluster head life time and end-to-end delay.
In this paper the authors presents UAV mobile networks challenges and opportunities. The future work and challenges in the usage of UAVs as mobile nodes.
In this paper four communication architectures introduces for UAVs networks. Some standard for UAV communication applied in military communications.

In this paper zeng et al. present three use cases accordingly on the UAV aided wireless communication:- UAV aided relaying, UAV aided ubiquitous coverage, UAV aided information dissemination.
This paper Bekmezci et al. present review on the opportunities and challenges of UAV networks. Analyze FANET security limitation.Also discussed open issues and research areas.

This paper Maxa et al present characteristics of FANET and literature review on the applied routing protocols is given. Also analyze their security features e.g potential threats , security exigencies and counter measures.

Table1. MANET and VANET link types comparision in FANET.
‘Y’ is for the presence and ‘N’ is for not.
‘H’ is for high, ‘L’ for Low , ‘M’ for medium

Category		***MANETs***	***VANETs***	***FANETs***
Link Types	AD hoc	✓	✓	✓
	Satellite	×	×	✓
	Direct link	✓	✓	✓
	cellular	×	✓	✓
Characteristics	Mobility models	Random way point	Prediction based	Realistic, SRCM
Characteristics	Energy constraint	H	L	M
Characteristics	Mobility degree	L	M	H
Characteristics	Localization method	GPS	Differential-GPS Assisted-GPS	Inertia measurement unit
Characteristics	Node density	H	M	L
Characteristics	Radio propagation model	NLOS	NLOS	LOS

3. UAV(Unmanned Air Vehicle)

UAV can be further categories into two categories:- Rotatory wing and fixed wing,each with its features.

Fixed wing:-heavy payload and have high speed.

Rotatory wing UAVs:- Payload and despite their limited mobility principally depend on UAVs choice and application.

According to range they are classified as close,short,and mid range).

Low cost : In term of large UAV maintenance and acquisition small UAVs is cheaper

Low missions completion time: Mission like search ,rescue and surveillance can be more faster.

Scalability:- In the new operation simply added new UAVs,System dynamically re.ordered its network structure.

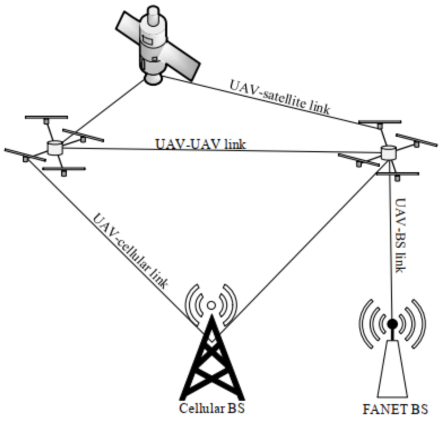
4. Communication in FANET

To overcome the communication designs issues areliable architecture is essential to proposed.

4.1 Unmanned Air Vehicle

The communication architecture tell us the flow of information between one UAVs or multiple UAVs and GCS. For UAVs networks four basic architecture of communications are introduced and displays in the fig. Namely UAV direct communication, UAV communication via satellite networks, UAV communication via cellular networks and UAV communication via ad-hoc networks.

Fig2.Types of links in FANETs.



UAV communication via cellular network:- Nowadays the maximum used form of communique is the mobile community as describe in fig. Centralized topology based on this generation includes reducing a territory into zone (cells), every of that's served via way of means of a base station (the imperative factor). Each communication need to undergo this imperative factor which has the position of routing them to their destinations.Communications via cellular is the inspiration of cellular cellphone technology including UMTS, GSM, LTE, GPRS, and Wi-Fi statistics communication including Wi-Max and Wi-Fi. Since they provide intense freedom for nomadic consumers.

UAV direct communication:-

A direct communique link [33,37] may be used among the GCS and every UAV ,as proven in fig. This is the most effective structure, wherein the primary node is GCS which connect all UAVs. The direct UAV to UAV communique however due to centralized scheme isn't viable .This structure for dynamic environment and for NLOS (Non-Line-Of-Sight) communique can't be carried out.

UAV communication via Satelite networks:-

For communication between two very distant points in an area without fixed infrastructure, the best solution is satellite communication. Every aircraft can communicate with GCS via satellite in a system with multiple UAVs. In fact in some missions , buildings or tree may become obstacles to the signal exchange between the UAV and its relay satellite.

UAV communication via Ad-hoc network:-

In order to deal with the drawback of the communication network architectures mentioned above, The FANET community is proposed for a swarm of UAVs , as proven in fig. This community structure is part of the MANET wherin nodes talk among them without the want for a vital infrastructure.Each UAV is taken into consideration as an given up system.

The ad-hoc architecture lends itself well to the constantly changing topology of UAV networks resulting from the high mobility of the UAV .In FANET , as a regular end node function performed by GCS, which can have static or dynamic geographical location .Commnuication with the nearest UAV as a front door.

Thus FANET consider two types of communication:- UAV to GCS communication and UAV to UAV communication.

UAV - GCS communication:-

To offers information services for different user in the world wide network UAV used fixed infrastructure to communicate.A few of the topics of interest is navigation and communications,with the goal of investigating operator solutions to ensure safe control of UAVs BVLoS.

UAV -UAV communication:-

With one another UAVs communicate to complete basic missions like route planning or co-operative target tracking .In this kind of communication could be either direct or multi-hop in nature. Distances can be long or short in which UAVs can be communicate over. In FANET communication data rate and range increasing the efficiency.

Even through the FANET network's numerous advantages, routing remains a difficult problem, due to the dynamic change of the network topology and the imprecision of the available information. For FANET network a few routing protocols are being applied to meet these requirements. We present FANET routing protocols in the next subsection.

5. Routing Protocols:

Quite few routing protocols for Ad-hoc have been proposed in the literature, including flooding, dynamic source routing, on demand routing, cluster based routing and pre-computed routing. Because FANET is a subclass of MANET and VANET, researchers first tested protocols used in those networks for potential use in UAV networks. However due to unique characteristics of a node in FANET including energy shortage, speed, rapid changes in links between them. To fulfill the FANET requirements it's important to modify these protocols.The classification of adapted and proposed ones into five main categories: proactive routing protocols, static routing protocols,on-demand routing protocols, hybrid routing protocols and geographic routing protocols. These categories to be discus in next subsection.

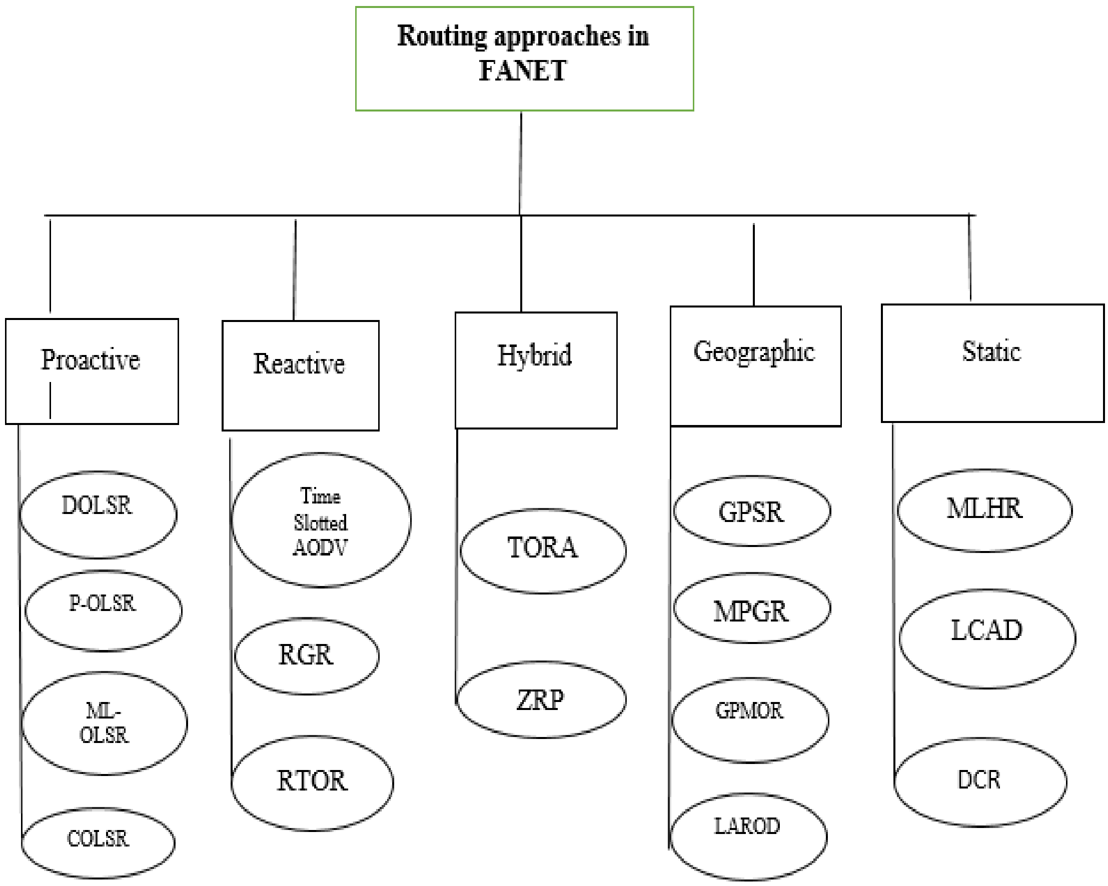


Fig3.Routing approaches classification in FANET.

5.1 Proactive Protocols

These protocols at fixed time intervals update their routing tables. Nodes in the network already know the change in routes that feature make faster transmission. The major drawback is to make constant update they need greater bandwidth.

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Following two types of proactive protocols:-

i) optimized link state routing (OLSR)

A protocols standard meant for ad-hoc sites. The purpose is to stop the stableness of link state criteria. In ad-hoc system it carry out authentic link state. In high, powerfull and dense system is suitable for routing process. To select some node that act as a relays called multipoint relay (MPR) is the main characteristic of OSLR.

ii) Destination-sequenced distance vector (DSDV)

According to the change in network topology the sequence of number in the routing table also change itself. To avoid nodes from occurring loops these numbers keep updated and send to all nodes in the network.

5.2Reactive protocols:

The communication establish when the node in the network send request.By using this feature the routing tables are always updated. when the packet is going to be sent it's important to check the best route. Following proposed protocols for use in FANETs.

i) Ad hoc on demand:-

In AODV when packet is important to send they first find the routes ,add it into the table right after the packet is transfer to the receiver. In other features because its mobile network protocols connection interruption, update and maintain routes in tables.

ii) Dynamic source routing (DSR)

This protocols used in multi-hop wireless networks, in addition node source keep details in about the entire route to its destination.

5.3 Hybrid

A protocol is a combination of reactive and proactive protocols. To overcome the weakness od reactive and proactive protocols hybrid is a proposed solution. In proactive overhead of control messages can be reduced by using this protocols. First route discovery process latency can be decreased in reactive protocols. This protocols is based on two zones concept, intra zone routing used by proactive protocols, and inter zone routing by reactive protocols.

The following categories of hybrid:-

i) Temporarily ordered routing algorithm (TORA):-

Basically it uses reactive routing protocols but with the addition of some proactive protocols. Node in the network only maintain the information about it neighbor node and update the routes. Some time it use shortest path and long route mostly used to reduce overhead network.

i) Zone routing protocols(ZRP):-

Protocol depend on the concept on zones. Different zone for each node.A set of nodes with minimum distance and pre-defined radius is know as a zone.The zone inside the network is intra-zone routing with the use of proactive protocols. Communication is done only when both source and destination are in the same zone.Inter zone routing is used in a case where packet is to be sent outside the zone with the use of reactive method.

5.4 Geographic routing:-

In this routing method geographical location of each node with pre-knowledge assumed.To find the best routing path between the source and destination it uses nodes locations.

Following strategies used for geographical routing in case of wireless.

i) Greedy perimeter stateless routing for wireless (GPSR):-

Each node periodically collect location of its neighbor node to send data greedily to its destination.

ii) Mobility Prediction Geographic Routing(MPGR)

Route path decide on the base of UAVs geographical positions. In addition of this method with GPSR working enhances.

UAV search mission protocols (USMP) and GPMOR (Geographic Postion Mobility Oriented Routing) are other approaches based on the GPSR.

iii) LAROD(Location Aware Routing for Opportunistic Delay tolerant network)

Mobility modules introduces which give permission to the each UAV to predict the movement of its next neighboring node.

5.5 Static Routing:

These protocols are when the task start they computed and loaded the static routing table. During an transmission there is no need to find and update the routing tables. Few numbers of flying node communicate with each UAV that store their own information. It's important for the protocols finish the previous first in order to start a new transmission. For dynamically changing scenarios they are not feasible as they are not fault tolerant.

Some static routing are as followings:-

- *Data Centric Routing:-*

(DCR) This static routing protocol is chosen where the system have limited numbers of UAV on a fixed route which involves less assistance. It also work well with the cluster topologies where cluster head is responsible for all information disseminating to other node in the cluster.

- *Load Carry And Delivery:-*

(LCAD) In this routing model the data is carried from ground node by UAV then by flying it reached to its destination ground node. To increase security and throughput is its main objectives.It is a proposed solution for transfer latency insensitive bulk data and tolerant delay.

- *Multi-Level Hierarchical Routing:-*

(MLHR)UAV network organized hierarchically and there is a need of many cluster head that perform in different mission areas. This routing model is suitable where the mission area is large and UAV are controlled in changed swarms.

Table2. FANETs Routing Protocols Limitation's.

Category	Protocols	Issues in application to FANET
Proactive	• P-OLSR [56] • COLSR [58] • DOLSR [55] • MILOSR [57]	-To keep table up-to-dates large overhead maintenance required. -essential bandwidth usage -Slow reaction to topology changes.
Reactive	• RGR [60] • Time slotted • RTORA [61] • AODV [59]	-Because of essential header size may increase larger network overhead. -High latency during path finding. -For hop by hop routing table must have intermediate node.
Hybrid	• GPSR [64] • TORA [62] • ZRP [63]	-Difficult to maintain for dynamic scenario.
Geographic	• MPGR [65] • GPMOR [67] • GPSR [64] • LAROD [68] • USMP [66]	Information about the node location sharing strategy in some application areas may be un-realistic.
Static	• MLHR [16] • DCR [16] • LCAD [51,52]	Not scalable and cannot handles any changes. For dynamic topology of FANET fixed tables not suitable.

6. Comparative Analysis:-

The table below describe the comparision of routing protocols on the base of some parameters and are PDR,E2E delay , throughput, Simulator , No.of Nodes.

Table 3:- Routing Table of comparision

Where the symbols '✓' shows the presence of technique and '×' shows the absence of the technique.

Papers Ref	Protocols	E2EDelay	PDR	Throughput	Simulator	No. of Nodes	Conclusions
[1]	DSDV	×	✓	✓	MATLAB	11	DSDV define by its modified approach
[2]	OLSR AODV DSDV	✓	✓	✓	NS-2	20	To optimize the FANETs performance OLSR can be used.
[3]	DSR AODV DSDV	×	✓	✓	NS-2	-	More prefer-ables protocols are Anti-Hoc-Net and DSR
[4]	RGR AODV GRP OLSR	✓	✓	✓	OPNET MODELER	30	GPR is worst whereas RGR is the best
[5]	DSR AODV DSDV	✓	✓	✓	NS-2	-	To enhance the FANETs performance in OLSR pursue mobility model can be used.

7. Issues, Challenges and Solutions:-

Table4.A summary of open Issues and their purposes, and their challenges, and proposed solution.

Sr. No	Open Issues	Purpose	Challenges	Proposed Solution
1	Multi-UAV swarm architecture use routing	Due to ultra-densification Managing massive amount of data	Low residual energy, High dynamicity, High cost	Next geographical location of UAV is pridcting
2	FANETs routing investigation enhancing mobility models	Mobility management	High cost, Low residual energy, high dynamicity	Based on real –life scenarios forming mobility models
3	To improve routing disconnect frequent link to reduce its effects	Minimizing the retransmission of packets and reconnect routes	High cost , high dynamicity	Predicting the further geographical location of a UAV in route selection

4	Through multiple-routing performance of network and survivability improved	Decrease network congestion and Increase utilization of resources.	High routing overhead	Approaches based on Artificial intelligence
5	Network coverage improve by utilizing high/low altitude UAVs	Minimizing the retransmission of packets and reconnect routes	High cost	Between high/low altitude platforms collaboration enabled.
6	Network performance improved by using AI	Optimize performance	High routing overhead, high cost	Network performance improve by using AI based approaches
7	Use of green energy minimize power consumption	Network partitioning decrease	Low residual energy, high cost	For extra energy backup solar panels are use.

8. Conclusion:-

During the past few decades ,the roles and capabilities of UAVs has been witnessed. Therefore ,FANET networks are rapidily growing in several operational domains of huge range of applications. Firstly we recalled the particular features of UAV,UAS, FANET networks. There are many routing protocols including AODV, DSR, Anti-hoc Net , DSDV,OLSR for data transmission in UAVs. Advantages and disadvantages for each protocols reviewed. A Comparative analysis of each routing protocols in tabular form.The goal of this paper is to motivated the researchers to proposed solutions for the open issues and challenges of FANET networks.

References

[1] K. Singh and A. K. Verma, "Experimental analysis of AODV, DSDV and OLSR routing protocol for flying adhoc networks (FANETs)," 2015 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), 2015

[2] Biomo, Jean-Daniel Medjo Me, et al. "Directional Antennas in FANETs: A Performance Analysis of Routing Protocols." 2017 International Conference on Selected Topics in Mobile and Wireless Networking (MoWNeT), 2017

[3] Simarjot Kaur, Arvinder Singh, "Experimental Analysis On Dsdv Protocol For Fanets," International Journal for Research in Applied Science & Engineering Technology (IJRASET) 2016

[4] K. Singh and A. K. Verma, "Applying OLSR routing in FANETs," 2014 IEEE International Conference on Advanced Communications, Control and Computing Technologies, 2014

[5] Maistrenko, Vasily A., et al. "Experimental Estimate of Using the Ant Colony Optimization Algorithm to Solve the Routing Problem in FANET." 2016 International Siberian Conference on Control and Communications (SIBCON), 2016.

[6] Anuradha Chauhan, and Ms. Renu Singla. "A Detail Review on Unmanned Aeronautical Ad-Hoc Networks." International Journal of Science, Engineering and Technology Research (IJSETR), May 2016.

[7] Bekmezci, Ilker, et al. "Flying Ad-Hoc Networks (FANETs): A Survey." Ad Hoc Networks, vol. 11, no. 3, 2013, pp. 1254–1270., doi:10.1016/j.adhoc.2012.12.004

[8] Bani, Muneer, and "Nour Alhuda." "Flying Ad-Hoc Networks: Routing Protocols, Mobility Models, Issues." International Journal of Advanced Computer Science and Applications, vol. 7, no. 6, 2016.

[9] Cruz E. A comprehensive survey in towards future FANETs. IEEE Latin America Transactions. 2018;**16**(3):876-884

[10] S.K. Singh, A comprehensive survey on FANET: challenges and advancements, Int. J. Comput. Sci. Inf. Technol. 6 (3) (2015) 2010–2013.

[11] S. Hayat, E. Yanmaz, R. Muzaffar, Survey on unmanned aerial vehicle networks for civil applications: a communications viewpoint, IEEE Commun. Surv. Tutor. 18 (4) (2016) 2624–2661.

[12] I. Bekmezci, E. Sentrk, T. Trker, Security issues in flying Ad-Hoc networks (FANETs), J. Aeronaut. Space Technol. 9 (2) (2016) 13–21.

[13] G. Vipul, K. Mukesh, An effective review on important issues in unmanned aerial vehicles (UAVs) networks, Int. J. Innov. Res. Comput. Commun. Eng. 4 (6) (June 2016).

[14] M. Erdelj, M. Krl, E. Natalizio, Wireless sensor networks and multi-UAV systems for natural disaster management, Comput. Netw. 124 (2017) 72–86.

[15] J.-A. Maxa, M.-S.B. Mahmoud, N. Larrieu, Survey on UAANET routing protocols and network security challenges, Ad-Hoc Sens. Wirel. Netw. (2017).

[16] Mozaffari, M., Saad, W., Bennis, M., et al. A tutorial on UAVs for wireless networks: applications, challenges, and open problems. arXiv:1803.00680 2018.

[17] M.M. Azari, F. Rosas, S. Pollin, Cellular Connectivity for UAVs: network modeling, Perform. Anal. Des. Guidel. (2018) arXiv:1804.08121.

[18] Federal Aviation Administration (FAA), UAS Traffic Management Research Transition Team Plan, Federal Aviation Administration (FAA), January 2017 Technical report.

[19] M.T. Hyland, Performance Evaluation of Ad-Hoc Routing Protocols in a Swarm of Autonomous Unmanned Aerial Vehicles, Air Force Institute of Tech Wright–Patterson AFB Oh School of Engineering and Management, 2007.

[20] D.L. Gu, G. Pei, H. Ly, et al., UAV aided intelligent routing for Ad-Hoc wireless network in single-area theater, in: Proceedings of the Wireless Communications and Networking Confernce. WCNC, IEEE, 2000.

[21] A. Franchi, C. Secchi, M. Ryll, et al., Shared control: balancing autonomy and human assistance with a group of quadrotor UAVs, IEEE Robot. Autom. Mag. 19 (3) (2012) 57–68.

[22] C.-M. Cheng, P.-H. Hsiao, H.T. Kung, et al., Maximizing throughput of UAV-relaying networks with the load-carry-and-deliver paradigm, in: Proceedings of the IEEEWireless Communications and Networking Conference, IEEE, 2007, pp. 4417–4424.

[23] L.E. Michael, J.-S. Park, M. Gerla, UAV assisted disruption tolerant routing, in: Proceedings of the IEEE Military Communications Conference. MILCOM, IEEE, 2006, pp. 1–5.

[24] S. Mohseni, R. Hassan, A. Patel, et al., Comparative review study of reactive and proactive routing protocols in MANETs, in: Proceedings of the 4th IEEE International Conference on Digital Ecosystems and Technologies (DEST), IEEE, 2010, pp. 304–309.

[25] Clausen, T. et Jacquet, P. Optimized link state routing protocol (OLSR). 2003.
[55] A.I. Alshabtat, L. Dong, J. Li, et al., Low latency routing algorithm for unmanned aerial vehicles Ad-Hoc networks, Int. J. Electr. Comput. Eng. 6 (1) (2010) 48–54.

[26] S. Rosati, K. Kruzelecki, Louis Traynard, et al., Speed-aware routing for UAV Ad-Hoc networks, in: Proceedings of the IEEE Globecom Workshops (GC Wkshps), IEEE, 2013, pp. 1367–1373.

[27] Zheng, Y., Wang, Y., Li, Z., et al. A mobility and load aware OLSR routing protocol for UAV mobile Ad-Hoc networks. 2014. [58] L. Yan, L. Xiling, Cross layer optimization for cooperative mobile Ad-Hoc UAV network, Int. J. Digit. Content Technol. Appl. 6 (18) (2012) 367.

[28] J.H. Forsmann, R.E. Hiromoto, J. Svoboda, A time-slotted on-demand routing protocol for mobile Ad-Hoc unmanned vehicle systems, in: Proceedings of the International Society for Optics and Photonics Unmanned Systems Technology IX, 2007, p. 65611P.

[29] R. Shirani, Reactive-greedy-reactive in unmanned aeronautical Ad-Hoc networks: a combinational routing mechanism, Carleton University, 2011.

[30] Z.Q. Zhai, J. Du, Y. Ren, The application and improvement of temporally ordered routing algorithm in swarm network with unmanned aerial vehicle nodes, in: Proceedings of the 9th IEEE International Conference on Wireless and Mobile Communications, Nice, France, 2013.

[31] Park, V. Temporally-ordered routing algorithm (TORA) version 1 functional specification. draft-ietf-manet-tora-spec-03. txt, 2000.

[32] Z.J. Haas, A hybrid framework for routing in Ad-Hoc networks, Ad-Hoc Networking, 2002.

[33] B. Karp, H.T. Kung, GPSR: greedy perimeter stateless routing for wireless networks, in: Proceedings of the 6th Annual International Conference on Mobile Computing and Networking, ACM, 2000, pp. 243–254.

[34] L. Lin, Q. Sun, S. Wang, et al., A geographic mobility prediction routing protocol for Ad-Hoc UAV network, in: IEEEGlobecom Workshops (GC Wkshps), IEEE, 2012, pp. 1597–1602.

[35] R.L. Lidowski, B.E. Mullins, R.O. Baldwin, A novel communications protocol using geographic routing for swarming uavs performing a search mission, in: Proceedings of the IEEE International Conference on Pervasive Computing and Communications, PerCom 2009, IEEE, 2009, pp. 1–7.

[36] Lin Lin, Qibo Sun, Jinglin Li, et al., A novel geographic position mobility oriented routing strategy for UAVs, J. Comput. Inf. Syst. 8 (2) (2012) 709–716.

[37] E. Kuiper, S. Nadjm-Tehrani, Geographical routing in intermittently connected Ad-Hoc networks, in: Proceedings of the 22nd International Conference on Advanced Information Networking and Applications-Workshops, AINAW 2008, IEEE, 2008, pp. 1690–1695.

[38] T. Brown, B. Argrow, C. Dixon, et al., Ad-Hoc UAV ground network (augnet), in: Proceedings of the AIAA 3rd Unmanned Unlimited Technical Conference, Workshop and Exhibit, 2004, p. 6321.

[39] T. Brown, S. Doshi, S. Jadhav, et al., Test bed for a wireless network on small UAVs, in: Proceedings of the AIAA 3rd Unmanned Unlimited Technical Conference, Workshop and Exhibit, 2004, p. 6480.

[40] M Faessler, F Fontana, C Forster, E Mueggler, M Pizzoli, D Scaramuzza, Autonomous, visionbased flight and live dense 3D mapping with a quadrotor microaerial vehicle, J. Field Robot. 33 (4) (2015) 431–450.

[41] F Fraundorfer, L Heng, D Honegger, H Lee G, L Meier, P Tanskanen, M Pollefeys, Vision-based autonomous mapping and exploration using a quadrotor MAV, in: Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), IEEE, 2012.

[42] C. Fu, R. Duan, D. Kircali, E. Kayacan, Onboard robust visual tracking for UAVs using a reliable global-local object model, Sensors 16 (9) (2016) 1406.

[43] E.W. Frew, T.X. Brown, Networking issues for small unmanned aircraft systems, J. Intell. Rob. Syst. 54 (1-3) (2009) 21–37.

[44] L. Song, T.L. Huang, A summary of key technologies of Ad- Hoc networks with UAV node, in: Proceedings of the International Conference on Intelligent Computing and Integrated Systems (ICISS), 944-, IEEE, 2010, p. 949.

[45] Z. Zhao, T. Braun, Topology control and mobility strategy for UAV Ad-Hoc networks: a survey, in: Proceedings of the Joint ERCIM eMobility and MobiSense Workshop, Citeseer, 2012, pp. 27–32.

[46] O.K. Sahingoz, Mobile networking with UAVs: opportunities and challenges, in: Proceedings of the International Conference onUnmanned Aircraft Systems (ICUAS), IEEE, 2013, pp. 933–941.

[47] J. Li, Y. Zhou, L. Lamont, Communication architectures and protocols for networking unmanned aerial vehicles, in: Proceedings

of the IEEE Globecom Workshops (GC Wkshps), IEEE, 2013, pp. 1415–1420.

[48] K. Namuduri, Y. Wan, M. Gomathisankaran, Mobile Ad-Hoc networks in the sky: state of the art, opportunities, and challenges, in: Proceedings of the Second ACM MobiHoc Workshop on Airborne Networks and Communications, ACM, 2013, p. 25.

[49] S.K. Singh, A comprehensive survey on FANET: challenges and advancements, Int. J. Comput. Sci. Inf. Technol. 6 (3) (2015) 2010–2013.

[50] S. Hayat, E. Yanmaz, R. Muzaffar, Survey on unmanned aerial vehicle networks for civil applications: a communications viewpoint, IEEE Commun. Surv. Tutor. 18 (4) (2016) 2624–2661.

[51] I. Bekmezci, E. Sentrk, T. Trker, Security issues in flying Ad-Hoc networks (FANETs), J. Aeronaut. Space Technol. 9 (2) (2016) 13–21.

[52] G. Vipul, K. Mukesh, An effective review on important issues in unmanned aerial vehicles (UAVs) networks, Int. J. Innov. Res. Comput. Commun. Eng. 4 (6) (June 2016).

[53] M. Erdelj, M. Krl, E. Natalizio, Wireless sensor networks and multi-UAV systems for natural disaster management, Comput. Netw. 124 (2017) 72–86.

[54] J.-A. Maxa, M.-S.B. Mahmoud, N. Larrieu, Survey on UAANET routing protocols and network security challenges, Ad-Hoc Sens. Wirel. Netw. (2017).

[55] Mozaffari, M., Saad, W., Bennis, M., et al. A tutorial on UAVs for wireless networks: applications, challenges, and open problems. arXiv:1803.00680 2018.

[56] M.M. Azari, F. Rosas, S. Pollin, Cellular Connectivity for UAVs: network modeling, Perform. Anal. Des. Guidel. (2018) arXiv:1804.08121.

[57] Federal Aviation Administration (FAA), UAS Traffic Management Research Transition Team Plan, Federal Aviation Administration (FAA), January 2017 Technical report

[58] Azari, M.M., Rosas, F., et Pollin, S. Reshaping cellular networks for the sky: the major factors and feasibility. arXiv:1710.11404 2017.

[59] R.I. Bor-Yaliniz, A. El-Keyi, H. Yanikomeroglu, Efficient 3-D placement of an aerial base station in next generation cellular networks, in: Proceedings of the IEEE International Conference on Communications (ICC), IEEE, 2016, pp. 1–5.

[60] E. Kalantari, H. Yanikomeroglu, A. Yon- Gacoglu, On the number and 3D placement of drone base stations in wireless cellular networks, in: Proceedings of the IEEE 84th Vehicular Technology Conference (VTC-Fall), IEEE, 2016, pp. 1–6.

[61] J. Lyu, Y. Zeng, R. Zhang, et al., Placement optimization of UAV-mounted mobile base stations, IEEE Commun. Lett. 21 (3) (2016) 604–607.

[62] M. Alzenad, A. El-Keyi, H. Yanikomeroglu, 3-D placement of an unmanned aerial vehicle base station for maximum coverage of users with different QoS requirements, IEEE Wirel. Commun. Lett. 7 (1) (2018) 38–41.

[63] M. Mozaffari, W. Saad, M. Bennis, et al., Wireless communication using unmanned aerial vehicles (UAVs): Optimal transport theory for hover time optimization, IEEE Trans. Wirel. Commun. 16 (12) (2017) 8052–8066.

[64] S. Rohde, M. Putzke, C. Wietfeld, Ad hoc self-healing of OFDMA networks using UAV-based relays, Ad Hoc Netw. 11 (7) (2013) 1893–1906.

[65] E. Koyuncu, Power-efficient deployment of UAVs as relays, in: Proceedings of the IEEE 19th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC), IEEE, 2018, pp. 1–5.

[66] M.M. Azari, Y. Murillo, O. Amin, et al., Coverage maximization for a poisson field of drone cells, in: Proceedings of the IEEE 28th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC), IEEE, 2017, pp. 1–6.

[67] M. Chen, M. Mozaffari, W. Saad, et al., Caching in the sky: proactive deployment of cache-enabled unmanned aerial vehicles for optimized quality-of-experience, IEEE J. Sel. Areas Commun. 35 (5) (2017) 1046–1061.

[68] H. Wang, G. Ding, F. Gao, et al., Power control in UAV-supported ultra dense networks: communications, caching, and energy transfer, IEEE Commun. Mag.56 (6) (2018) 28–34.

[69] J.-S. Marier, C.A. Rabbath, N. Lchevin, Health-aware coverage control with application to a team of small UAVs, IEEE Trans. Control Syst. Technol. 21 (5)(2012) 1719–1730.

[70] Y. Zeng, R. Zhang, Energy-efficient UAV communication with trajectory optimization, IEEE Trans. Wireless Commun. 16 (6) (2017) 3747–3760.

[71] M. Mozaffari, W. Saad, M. Bennis, et al., Unmanned aerial vehicle with underlaid device-to-device communications: Performance and tradeoffs, IEEE Trans. Wirel. Commun. 15 (6) (2016) 3949–3963