Performance Evaluation of routing protocols in FANETs

Ali Ahammad
Department of Science and Technology
Universidade do Algarve
Gambelas Campus, Faro, Portugal
a81317@ualg.pt

***Abstract*— The growing interest on the production of small UAVs (Unmanned Air Vehicles) has becoming a key factor in several military, commercial and civilian applications with the augmented development of electronic, sensors and communication systems. A flying Ad hoc Networks (FANETs) facilitates such kind of networks to offer the interconnectivity among small UAVs in Ad-hoc manner which integrates high level goals for a team's achievement. FANET provides mobility, lack of central control, self-organizing and ad-hoc nature to the UAV nodes which helps to spread connectivity and communication in remote area. It is easy to deploy, flexible, self-configurable and relatively small operating expenses network. In this paper, routing protocols like AODV, DSDV and DSR will be investigating by simulating number of nodes and their performances based on various parameters like Total packet loss, Throughput, End to End delay over number of nodes will be compared in NS2.

Keywords—Flying Ad-Hoc Network, AODV, DSR, DSDV, NS2, Unmanned Aerial Vehicle.

I. INTRODUCTION

Our daily lives have been affected by the recent advancements in wireless technology, especially with the widespread availability of inexpensive Wi-Fi radio interfaces and other gadgets like GPS, sensors, micro-embedded computers, etc. The creation of miniature intelligent flying vehicles, such as Unmanned Aerial Vehicles (UAVs), has been made possible by all these inventive gadgets. The development of Flying Ad hoc Networks (FANETs), a brand-new type of network. Numerous military and civilian applications, including autonomous tracking, border supervision, and ground rescue team coordination, have been developed since FANET's launch. There are also a plethora of civilian uses, including filmmaking, oil field discovery, and monitoring of yards and agriculture. These kinds of applications demand the serious backing of multiple research fields, which calls for grabbing scientists' interest.

There are two types of uses for aerial nodes. Initially, there are applications involving a single aerial node (AN) situated at the core of a group of ground-based base stations. In order to communicate with base stations beyond of their communication ranges, the base stations can use the AN as a router or relay. Nonetheless, a number of problems exist, including AN's limited transmission range and the interference issue. The second application to address these issues is the deployment of an aerial node (AN) team, which offers numerous ways to address these issues and a range of applications known as multi-aerial-nodes applications.

The following succinctly describes the benefits of several aerial nodes over a single aerial node:

- When a node fails, multi-aerial nodes' fault tolerance is boosted.
- The cooperative missions' tasks can be parallelized, which significantly reduces the missions' duration.
- Aerial nodes have the ability to share computation and storage resources.

Common requirements across all FANET applications can only be met by aerial nodes—such as UAVs, aircraft, helicopters, etc.—through multi-hop communications. In the remainder of the poll, we are particularly interested in UAVs because both industry and academia have expressed a great deal of interest in them. Unmanned Aerial Vehicles (UAVs) are driverless aerial nodes that may be readily deployed throughout a network. Their movements are managed by algorithms, not by people. UAVs are recently entered the commercial market and consist of sensors and computing components.

As a result, UAVs are best suited for missions requiring multi-hop wireless communications, cooperation, and a more equitable work distribution. Creating routing methods becomes necessary and required in order to improve packet transfer between aerial nodes. However, the development of routing protocols specifically meant for FANET has proven to be extremely problematic due to a number of complex networking issues.

This is due to the fact that numerous factors, including the high level of mobility, uneven distributions of aerial nodes, and the rapid changes in the network topology, need to be taken into account. Among these limitations, the impact of aerial nodes' highly dynamic movements can result in a number of communication failures. Because of this, creating a routing strategy that ensures high reliability in the face of all these constraints gets increasingly difficult.

Furthermore, a low density of aerial nodes in the sky can result in a loss of communication between the nodes.

For FANETs to maintain the stability and functionality of their applications and services, routing is a critical component. Recently, a number of studies have only focused on integrating FANETs with other locally deployed networks, such VANETs. In fact, FANET nodes can be a good option to support extremely mobile networks like VANETs on the ground because of their regulated and flexible mobility. The many nodes that make up FANETs, like UAVs, may be quickly and easily deployed into various situations. This enables them to act as a backup network in the event that the networks on the ground are unable to transmit data packets between the nodes that are interacting. As a result, it is important to remember that understanding the various routing techniques used Many techniques and contributions have been offered in the previous few years, especially those that are focused on geographic situations.

This class of protocols was created to solve the issue of the nodes frequently disconnecting from one another due to their high mobility and their erratic behaviour. Certain solutions are only extensions of those suggested for Mobile Ad hoc Networks (MANETs), which are enhanced by the addition of new features to accommodate FANET-specific features. We do not disregard various topology-based routing protocols that have been suggested for FANETs that are only occasionally deployed and in which the nodes have a restricted number and move more slowly. Topology-based routing protocols, however, are not appropriate in situations with a large number of nodes and extremely dynamic movements. Since the great mobility of these protocols makes them susceptible to disruption, they rely on connection information that exists between the nodes. Moreover, their primary disadvantage is the increased energy and resource consumption brought on by the heavy reliance on memory (for example, routing table storage) and bandwidth (e.g., flooding process).

Furthermore, a number of thorough surveys that cover broad topics in many FANET study areas exist. They do not, however, offer specifics regarding routing systems, particularly those that rely on geographic locations. The restricted range between the UAVs and the ground base station is an additional problem. A UAV detaches itself if it is outside the coverage area of the ground station. An alternate method is needed in order to tackle the issues with the formation of an Ad-Hoc network among UAVs, known as FANETs. In FANETs, a subset of UAVs can establish a connection with a satellite or ground station, and all UAVs function as ad hoc networks. In this way, in addition to the ground station, the UAVs can converse with one another.

A. Main objective

1. To research various routing protocols and evaluate them according to various parameters.

2. To evaluate the effectiveness of various routing protocols.

3. To put in place a routing protocol to FANETs.

II. Related Work

This paper[2] examined and contrasted the AODV and DSDV routing protocols' performances within a FANET. The results show that there are minor variations between the selected protocols as well as good performances. When the nodes move at different speeds, a noticeable difference between them may be seen. Based on the findings, it is advised that the planned FANET (a four-node UAV network) employ the AODV routing protocol. The AODV, DSDV, and DSR routing protocols are examined in this paper[5] under various conditions, including packet delivery ratio in relation to mobile node speed, average throughput, and end-to-end delay.

FANET routing protocol performance has been examined in related studies. The studies are divided into four categories by us. No mobility models are specified by Group A [2–8]. Group B either employs one fixed mobility model or just one mobility model [9–18]. Several mobility models are employed by Group C [19–21]. Group D examined routing strategies using particular case studies [22, 23]. The relevant work is summarised in Table 1.

TABLE I. SUMMARY OF RELATED WORKS

	Reference	Routing Protocols	Mobility Models	Scenario
Group A	2	AODV, DSDV, OLSR		X
	3	AODV, DSR, LEPR		X
	4	AODV, DSDV		X
	5	AODV, DSDV, DSR, OLSR, AOMDV, HWMP		X
	6	AODV, OLSR	Fixed	X
	7	AODV, DSDV, OLSR		X
	8	AODV, LAR	Fixed	X
Group b	9	AODV, DSDV, DSR, AntHocNet	Randomwaypoint	X
	10	AODV, DSDV, DSR, BeeAdHoc	Randomwaypoint	X
	11-13	AODV, OLSR	Randomwaypoint	X
	14	AODV, DSDV	Randomwaypoint	X
	15	AODV, AOMDV, DSDV, OLSR, ZRP	Fixed, Random	X
	16	AODV, DC-OLSR, OLSR	Randomwaypoint	X
	17	DSR, AODV, GRP, OLSR, E-OLSR	Fixed	X
	18	BATMAN-ADV, BABEL, OLSR	Fixed, Horizontal flight	X
	19	OLSR	Randomwaypoint, Manhattan Grid, Reference Point Group, Pursue	x

Group C	**20**	**AODV, DSR, GRP, OLSR, TORA**	**Randomwaypoint, Manhattan Grid, Pursue, SRCM**	**x**
	21	**OLSR+, OLSR, G-OLSR**	**RandomWaypoint, Gauss–Markov**	**x**
	22	**EORB-TP, LADTR, GEOSAW, LEPR**	**Randomwaypoint**	**Reconnaissance**
Group D	**23**	**ODV, DSR, OLSR, ZRP**	**Group mobility, Ergodic waypoint**	**Disaster**
	My Paper	**AODV, DSDV, DSR**	**Randomwaypoint**	**Reconnaissance**

Routing protocols without mobility models were examined by Group A [2–8]. Garcia and colleagues, Leononov and colleagues, and Kumar and colleagues each looked at two protocols: AODV and DSDV [4], AODV and OLSR [6], and AODV and LAR [8]. Three procedures were examined by Singh et al. and Rabahi et al. [2, 7]: AODV, DSDV, and OLSR. In order to compare the AODV, DSR, and LEPR routing protocols, Li et al. devised the LEPR routing protocol, which is based on AODV [3]. Six routing protocols were compared and examined by Nayyar et al. [5]: AODV, DSDV, DSR, OLSR, AOMDV, and HWMP. Within this category, the majority of research works assessed exemplar ad hoc routing protocols, including DSDV, OLSR, and AODV. No studies, however, provided specific mobility models. It is essential to define and examine this data since different mobility models would result in different routing protocol performances.

Using a single mobility model, Group B examined routing techniques [9–18]. The random waypoint mobility model was employed in the majority of the investigations [9–17]. The effectiveness of the AODV and OLSR routing protocols was examined by Leonov et al. [11–13]. The BeeAdHoc protocol was first examined by Leonov et al. [10]. Maistrenko et al. examined AntHocNet, DSDV, DSR, and AODV. [9]. Two factors were taken into consideration when analysing routing protocols by Rahman et al. [14]: node speed and network size. Three types of routing protocols—proactive, reactive, and hybrid—were examined by Ema et al. [15].

DC-OLSR, a routing protocol suitable for heterogeneous dual-channel FANETs, was proposed by Zhang et al. [16]. Through parameter adjustments, Tuli et al. suggested an optimised E-OLSR and used simulation to compare its performance with current routing protocols [17]. In real-world scenarios, Guillen et al. examined the performance of routing protocols utilising WiFi networks operating at 2.4 GHz and 5 GHz [18]. The fact that the research solely employed one mobility model prevented them from showcasing various protocol performances using various mobility models. With a range of mobility models, Group C examined routing methods [19–21]. Singh et al. did not analyse multiple routing protocols, but instead attempted to optimise OLSR in FANETs [19].

AlKhatieb et al. used the Manhattan Grid, Pursue, SRCM, and random waypoint mobility models to analyse different routing algorithms [20]. A fuzzy logic-based routing technique known as OLSR+ was introduced by Rahmani et al. [21]; OLSR+ was then contrasted with OLSR and G-OLSR. The effectiveness of routing protocols was examined in those investigations. Though a number of elements contained in the usage scenarios affect the efficiency of FANET routing protocols, those studies did not take specific scenarios into account. Group D examined routing strategies using particular case studies [22, 23]. Their scenarios, meanwhile, are not the same as ours. Ahmed et al., for instance, assessed a disaster scenario [23].

Protocols were assessed by Sang et al. using data from combat reconnaissance missions [22]. Sang and colleagues concentrated on a particularly particular scenario in which every node is linked to the BeiDou satellite network. Although their approaches to scenario analysis align with ours, their findings did not take into account our areas of interest, what would make a good routing protocol, or a mobility model for a reconnaissance scenario. In contrast to them, we evaluate and compare the effectiveness of FANET routing protocols in a range of UAV-based reconnaissance scenarios using different mobility models.

III. Proposed system

A. Reconnaissance Scenarios

Finding an enemy in a designated area is the goal of a reconnaissance scenario. Our UAVs should be hard for the opponent to forecast where they will go. Consequently, rather than using a regular, plan-based route for reconnaissance, UAVs should choose an erratic one. Because of its simplicity, the Randomwaypoint model has been adopted as the default model [24].

According to the model, a UAV in the reconnaissance area creates a new destination at random and then takes off for it. A UAV repeats this procedure during a reconnaissance phase when it arrives at its objective. The Random Waypoint Model and Smooth RandomwayPoint (SRWP) function similarly. The distinction is that it takes the UAV's speed into account while calculating a smooth turn.

By comparing the performance of several routing protocols based on various characteristics, such as packet loss, end-to-end delay, throughput, etc., the optimal routing protocol is determined.

a. Performance Parameters:

The various routing protocols are compared using performance metrics.

Among the performance metrics are:

1. Total packets loss:

Packet loss=generated packets-received packets

2. End-to-End Delay:

Average amount of time taken by a packet to go from source to destination.

Delay=receiving time-sending time

Average delay=Delay/count

3. Throughput:

It is defined as total number of packets successfully received by the destination.

Throughput in Mbps=received data * 8/data transmission period.

B. FANETs

Compared to standard ad hoc networks, FANET routing protocols have various needs, such as rapid topology changes, high mobility, and low node density. Designing a FANET routing protocol with these features in mind is challenging. The goal of research was to create routing protocols appropriate for FANETs. They created new routing protocols [10, 25, 26] or expanded the current MANET and VANET routing protocols [27–29]. There are various methods to categorise these FANET routing protocols. In 2017, for instance, Oubbati et al. divided FANET routing methods into three groups: position-based, swarm-based, and topology-based protocols [30]. FANET routing protocols were categorised in 2019 into eight groups, including delay-tolerant networks and topology-based, secure, hierarchical, bio-inspired, energy- and heterogeneous-based, position-based, and heterogeneous-based protocols [31]. Since FANETs lack a central infrastructure, they are highly resilient to individual threats and network failure. These networks can also be simply deployed anyplace because they don't rely on outside help. These characteristics make FANETs the most practical solution for a number of activities, but they also create a challenging networking problem. Because of the UAVs' quick and erratic movements, a FANET's configuration might really vary greatly, and the node must adapt by updating its routing tables quickly.

Therefore, in FANETs, it is crucial to build a sensitive and dependable routing protocol. Four categories of routing protocols were identified by Lakew et al. [31]: topology-based, geographical, hybrid (geographic and topology-based), and bio-inspired protocols. Topology-based routing systems were divided into four groups by Wheeb et al. [32]: proactive, reactive, hybrid, and static protocols. We went over the fundamental topology-based routing protocols based on Wheeb et al. [32] in order to determine which protocols would work best for our reconnaissance scenario. Next, we choose the proactive and reactive routing protocols AODV, DSDV, and DSR.

C. Routing Protocols

A routing protocol is used if a packet needs to be sent via several network nodes. Every one of these protocols locates an appropriate path to send the packets to their intended location. The routing protocol's capacity affects FANET performance. Performance is centred on a number of factors, including power requirements, bandwidth overhead to enable proper routing, and convergence time following topology changes.

Routing protocols are divided into three categories: proactive, reactive, and hybrid protocols.

Proactive protocol: In these kinds of routing protocols, each node uses the routing tables, which are updated often when the network's topology changes, to store routing information about the other nodes in the network.

Destination Sequenced Distance Vector (DSDV), Fish Eye State Routing Protocol (FSR), Optimised Link State Routing Protocol (OLSR), Cluster Gateway Switch Routing Protocol (CGSR), Wireless Routing Protocol (WRP), Topology Dissemination Based on Reverse Path Forwarding (TBRPF), etc. are some examples of proactive protocols.

Reactive protocol: Routes are created as needed. The path is still valid as long as it leads to the destination or as long as it is needed. FANETs are the ideal application for this type of routing protocol; nevertheless, there is no routing protection and considerable latency associated with this type of routing.

Ad-Hoc ON Demand Distance Vector (AODV), Dynamic Source Routing Protocol (DSR), Temporally Ordered Routing Algorithm (TORA), Associativity Based Routing (ABR), and other protocols are examples of reactive protocols.

Hybrid protocol: The hybrid protocol is suggested as a solution to the high latency issue with reactive protocols and the routing overhead issue with proactive protocols.

Hybrid Wireless Mesh Protocol (HWMP), Temporally Ordered Routing Algorithm (TORA), Zone Routing Protocol (ZRP), Secured Hierarchical Anonymous Routing Protocol (SHARP), and other hybrid protocols are examples of the various varieties.

This research article discusses the performance analysis protocols listed below: AODV, DSDV, and DSR on metrics like throughput, packet loss, and end-to-end latency.

1. *Ad-Hoc On Demand Distance Vector (AODV)*

Reactive routing protocols like Ad-Hoc On Demand Distance Vector (AODV) are considered to be among the best because of their exceptional adaptability to quickly altering communication needs, low processing and memory overhead, minimal network usage, and effective determination of unicast routes from source node to destination node with loop avoidance.

The AODV routing protocol is divided into three stages.

(i) Route Discovery,

(ii) Packet Transmitting

(iii) Route Maintaining

In order to deliver a packet, a source UAV must first perform a route discovery operation to locate the intended recipient. Only then can the packet be sent via the designated route without going through a loop while being transmitted. In order to recover from connection failure, the route maintenance procedure is carried out.

2. *Destination Sequenced Distance Vector (DSDV)*

FANET routing will employ the DSDV routing protocol. Every aerial vehicle operating in the network under that protocol needs to be fully aware of every aspect about every other aerial vehicle. When there is a change in the topology, this protocol employs the sequence number assigned to the destination node to prevent looping and network congestion. Every UAV with a higher sequence number is more effective and faster than those with a lower number.

This protocol maintains a routing table with three parameters: destination, distance, and next hop. At predetermined intervals, neighbouring nodes and other nodes update the settings after each node transmits the routing table. Sequence number and damping are two additional route parameters that DSDV adds to the distance vector routing limitations.

3. *Dynamic Source Routing (DSR)*

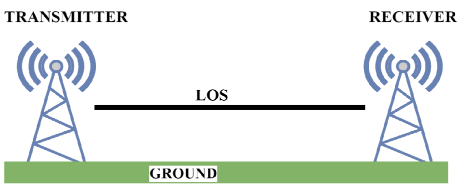
A reactive, wireless multi-hop routing technique called DSR is also utilised in FANETs to route data packets between UAVs. In order to avoid any form of congestion, UAV transmits the data packet using the Request ID via the following protocol. Every source node participating in DSR stores the path from its location in the data header to its destination, where any type of network issue, such as a connection failure, is handled to generate new paths.

D. Propagation Models

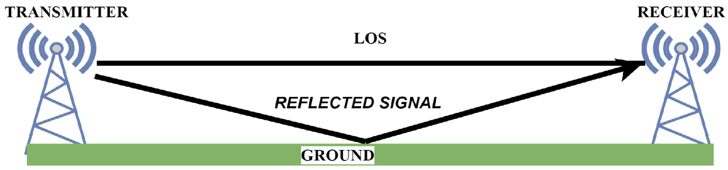
For the purpose of identifying channel parameters that are crucial for V2V and V2I communication, propagation models are required. Path loss and signal fading are two examples of propagation characteristics that have an impact on the signal strength as it travels over a wireless medium from source to destination. Four models are included for the study in this work: Two-Ray Ground (TR), Log-Distance path loss (LD), FRIIS (FS) route loss, and Nakagami (NK) fading models [33,34, 35]. Figures 3a and 3b, respectively, depict the visual representation of the Two-Ray Ground propagation model and the FRIIS.

[a.] Sample of a Table footnote. (*Table footnote*)

Fig. 1. (a) FRIIS and (b) Two-Ray Ground Propagation



(a)



(b)

Two-Ray Ground Propagation Model: One of the most widely used models for multipath radio propagation in VANETs, this model is also well suited for a wide range of wireless applications. Because it takes into account both the direct path and the ground reflected direction, this model, as mentioned in [35], has more practical implications than FRIIS. With nodes arranged in a planar topology, it forecasts the route loss between the transmitter and reception antenna inside the Line-of-Sight (LOS).

$$P_r = \frac{(H_t^2 \times H_r^2)\ G_r P_t\ G_t}{L \times d^4}$$

The symbols P_r, H_t and H_r, and d, respectively, represent the reception power, the height of the transmitter and receiver antennas, and the distance over which the antennas receive and broadcast. L stands for system loss, and G_t and G_r represent the receiving and transmitting antenna gains, respectively. This model is not appropriate for shorter distances because the constructive and destructive combination of the beam induces an oscillation parameter.

Nakagami Fading Model: It is essentially a fading model that takes multi-path fading-related variations in signal strength into account. For improved performance, the model can be used in conjunction with other loss models, as it is not well suited as a path loss model for simulations. For the various contexts, including the gamma distribution, it has a continuous probability distribution [36].

$$p(x{:}\,m, \omega) = \frac{2m^{\mathrm{m}}}{\Gamma(\mathrm{m})\omega^m} x^{2\mathrm{m}-1}\, e^{-\frac{m}{\omega}x^2}$$

In this case, ω represents the average power received, while m indicates the fading depth. Through gamma distribution modifications, the probability density function (pdf) at a given distance is calculated. As a stochastic model with average power fading and severity with amplitude x >= 0, the signal has a gamma distribution. When m = 1, the Rayleigh model is replaced with the Nakagami.

IV. SIMULATION

A. *Simulation Platform*

In 1989, the University of California and Cornell University created the open-source discrete event simulating platform NS2. It is entirely based on object-oriented programming and utilises the C++ and OTCL languages for programming.

The NS-2.35 version is used to simulate and assess FANET routing protocol performance.

B. *Simulation Parameters*

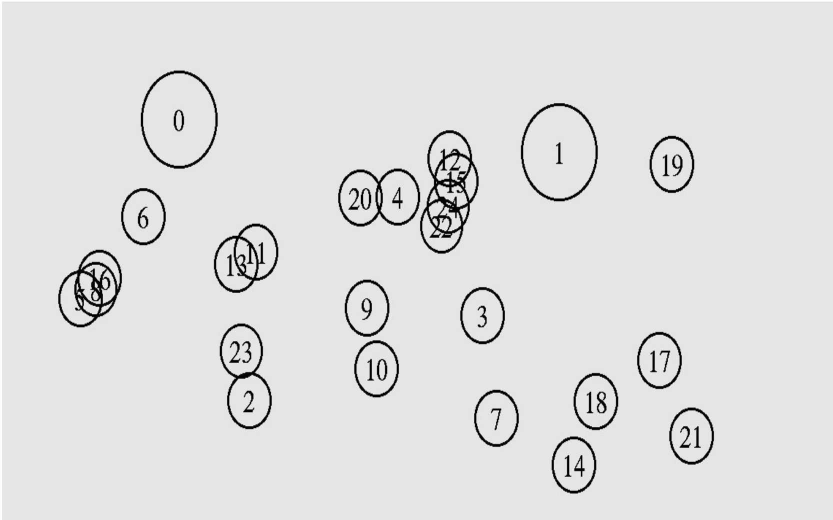
TABLE II. SUMMARY OF RELATED WORKS

Simulation parameters	**Values**
Simulator Version	Ns-all-in-one(version 2.35)
Channel Type	Wireless
Protocols Uses	AODV,DSDV,DSR
Number of UAVs	24
Type of Traffic	CBR
Mac Layer Protocol	802.11
Transport Protocol	TCP Reno

C. *Simulation Results*

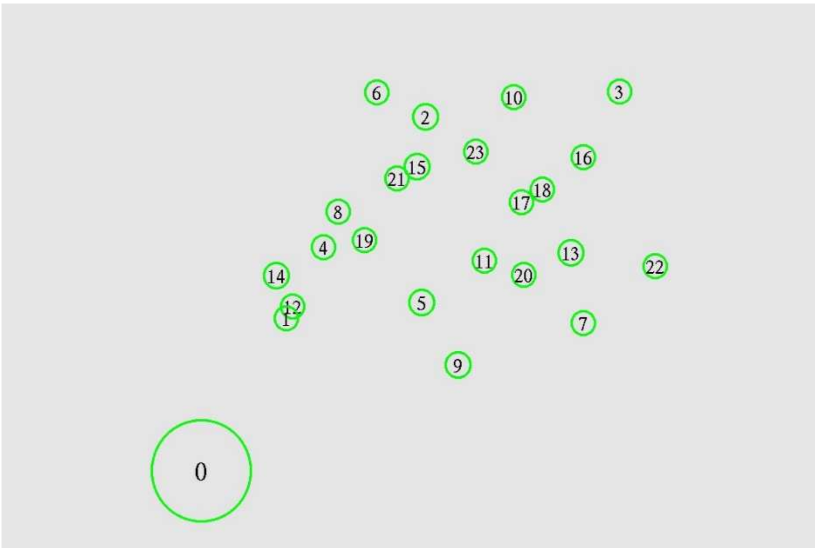
The output of Simulation of AODV in NS2 for 24 randomly placed nodes is shown below:

FIGURE 2. NAM SIMULATION OF AODV OF RANDOM PLACED NODES



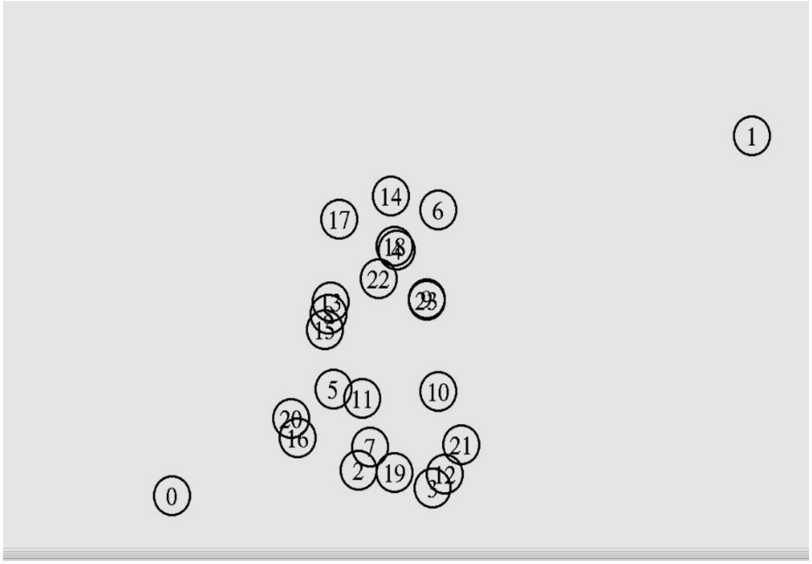
The output of simulation of DSDV in NS2 for 24 randomly placed nodes is shown below:

FIGURE 3. NAM SIMULATION OF DSDV OF RANDOM PLACED NODES



The output of simulation of DSR in NS2 for 24 randomly placed nodes is shown below:

FIGURE 4. NAM SIMULATION OF DSR OF RANDOM PLACED NODES



D. AWK results

AODV performance metrics:

Packet Delivery Ratio: 59.02%

Average End-to-End Delay: 5.23

Total throughput (bytes/sec): 5225022

Total packets sent: 29765

Total packets received: 17568

Total packets dropped: 3439

Total simulation time: 14.232667 seconds

Total bytes received: 2603072

Total bytes dropped: 349180

DSDV performance metrics:

Packet Delivery Ratio: 51.96%

Average End-to-End Delay: 49.02

Total throughput (bytes/sec): 39009172

Total packets sent: 71626

Total packets received: 37214

Total packets dropped: 860

Total simulation time: 99.976775 seconds

Total bytes received: 18986872

Total bytes dropped: 870276

DSR performance metrics:

Packet Delivery Ratio: 61.04%

Average End-to-End Delay: 77.99

Total throughput (bytes/sec): 43914492

Total packets sent: 80562

Total packets received: 49173

Total packets dropped: 1

Total simulation time: 140.000000 seconds

Total bytes received: 26661948

Total bytes dropped: 44

E. Graphs

AODV:

FIGURE 5. AODV END TO END DELAY WHERE X AXIS IS TIME(SECONDS) AND Y AXIS IS END TO END DELAY(S)

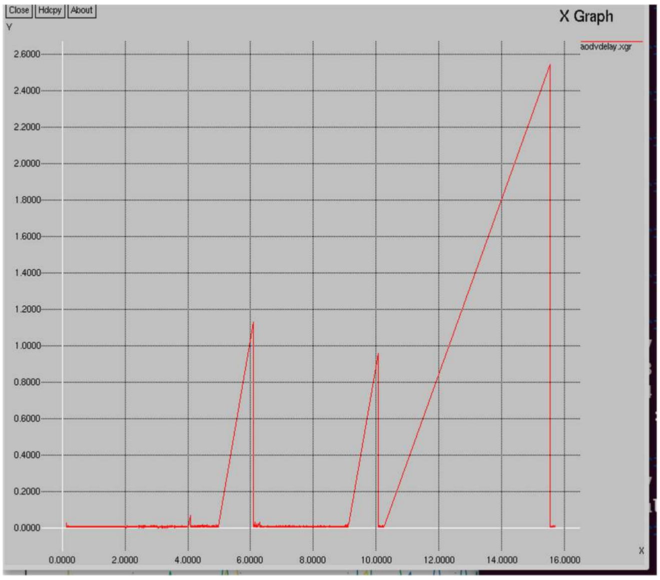


FIGURE 6. AODV PACKET DELIVERY RATIO WHERE X AXIS IS TIME(SECONDS) AND Y AXIS IS DROP RATIO

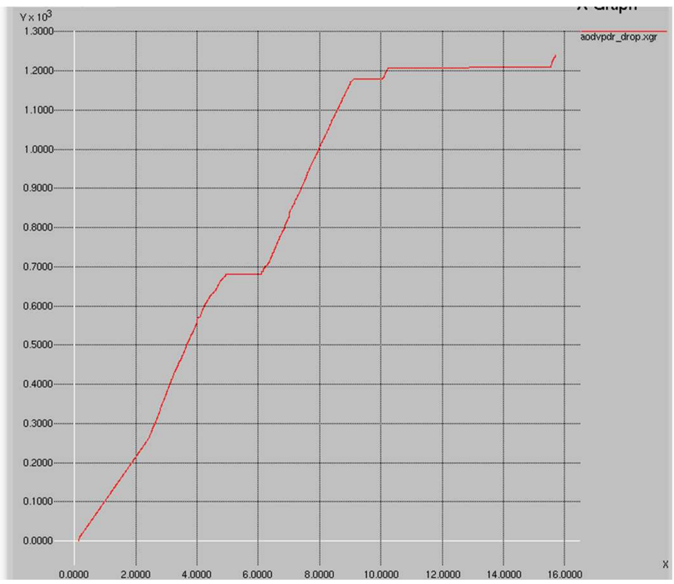
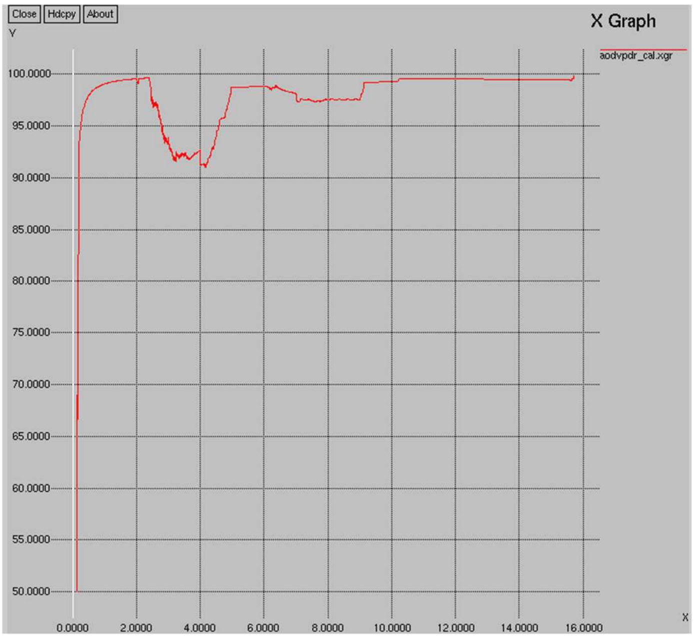


FIGURE 7. AODV PACKET DELIVERY RATIO WHERE X AXIS IS TIME(SECONDS) AND Y AXIS IS DELIVERY RATIO



DSDV:

FIGURE 8. DSDV END TO END DELAY WHERE X AXIS IS TIME(SECONDS) AND Y AXIS IS END TO END DELAY(S)

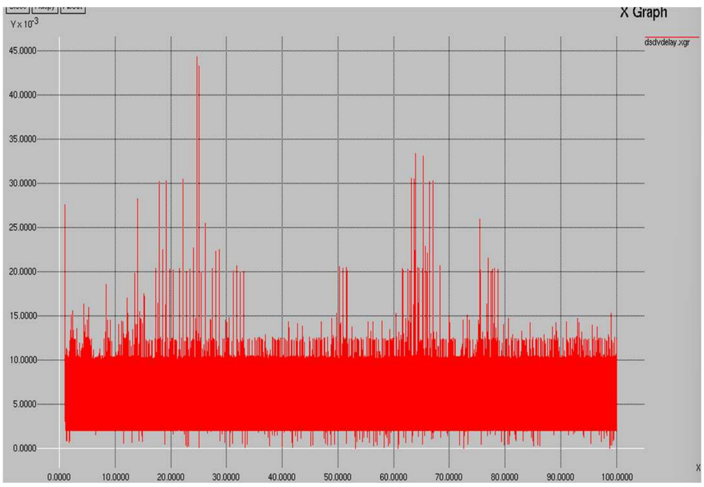


FIGURE 9. DSDV PACKET DELIVERY RATIO WHERE X AXIS IS TIME(SECONDS) AND Y AXIS IS DROP RATIO

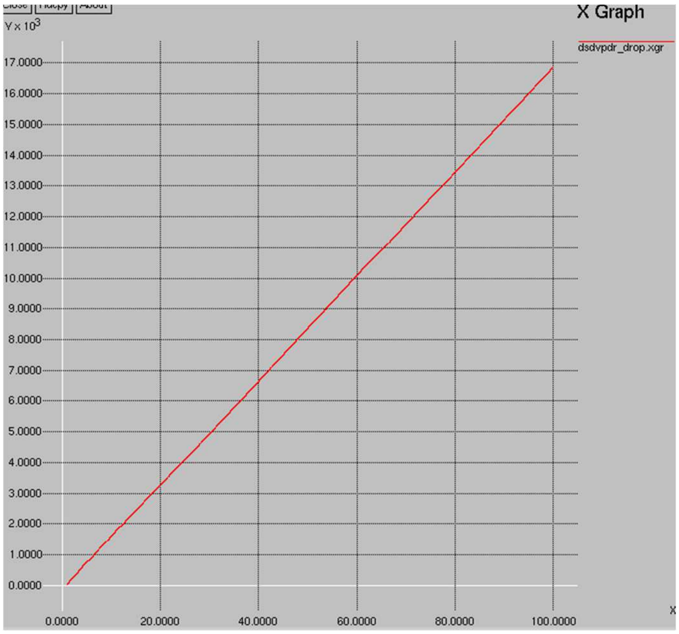
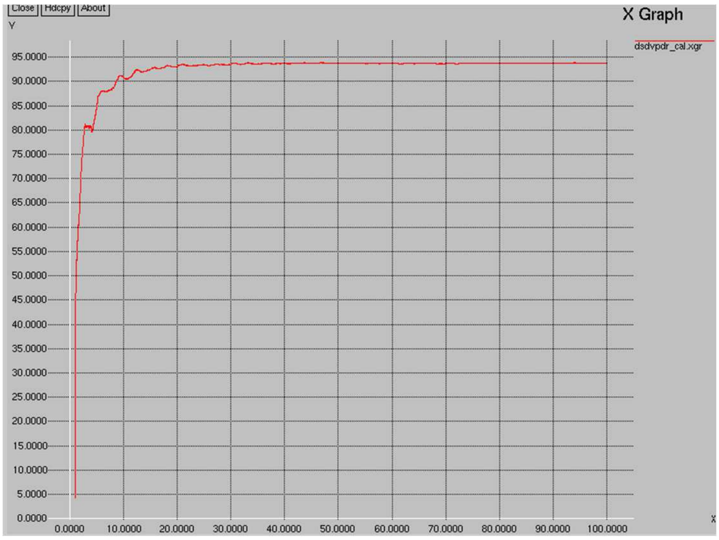


FIGURE 10. DSDV PACKET DELIVERY RATIO WHERE X AXIS IS TIME(SECONDS) AND Y AXIS IS DELIVERY RATIO



DSR:

FIGURE 11. DSR END TO END DELAY WHERE X AXIS IS TIME(SECONDS) AND Y AXIS IS END TO END DELAY(S)

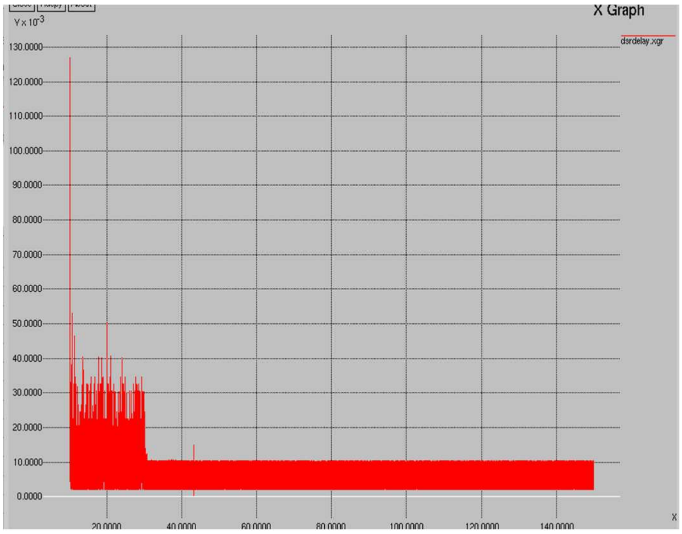


FIGURE 12. DSR PACKET DELIVERY RATIO WHERE X AXIS IS TIME(SECONDS) AND Y AXIS IS DROP RATIO

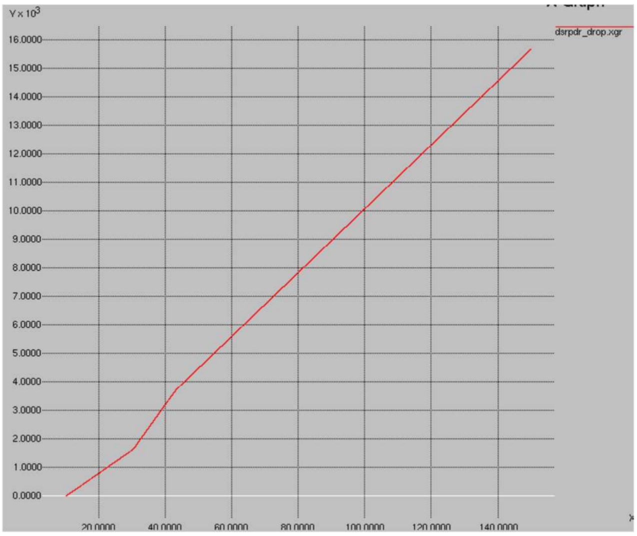
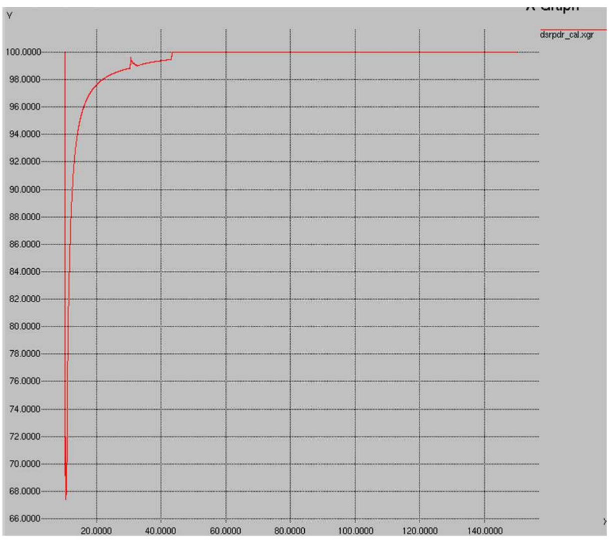


FIGURE 10. DSR PACKET DELIVERY RATIO WHERE X AXIS IS TIME(SECONDS) AND Y AXIS IS DELIVERY RATIO



V. CONCLUSION

For FANETs, to choose a best routing protocol, the performance is analysed over different routing protocols like AODV, DSDV and DSR on the bases of performance parameter like Total packet loss, End-to-End delay and Throughput. From overall results DSR has been recognized as best routing protocol among AODV, DSDV and DSR.

REFERENCES

[1] A. Nayyar, "Flying Adhoc Network (FANETs): Simulation Based Performance Comparison of Routing Protocols: AODV, DSDV, DSR, OLSR, AOMDV and HWMP," 2018 International Conference on Advances in Big Data, Computing and Data Communication Systems (icABCD), Durban, 2018, pp. 1-9.

[2] Singh, K.; Verma, A.K. Experimental analysis of AODV, DSDV and OLSR routing protocol for flying adhoc networks (FANETs). In Proceedings of the 2015 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT),Coimbatore, India, 5–7 March 2015; pp. 1–4.

[3] Li, X.; Yan, J. LEPR: Link stability estimation-based preemptive routing protocol for flying ad hoc networks. In Proceedings of the2017 IEEE symposium on computers and communications (ISCC), Heraklion, Greece, 3–6 July 2017; pp. 1079–1084.

[4] Garcia-Santiago, A.; Castaneda-Camacho, J.; Guerrero-Castellanos, J.F.; Mino-Aguilar, G. Evaluation of AODV and DSDV routing protocols for a FANET: Further results towards robotic vehicle networks. In Proceedings of the 2018 IEEE 9th Latin AmericanSymposium on Circuits & Systems (LASCAS), Puerto Vallarta, Mexico, 25–28 February 2018; pp. 1–4.R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[5] Nayyar, A. Flying adhoc network (FANETs): simulation based performance comparison of routing protocols: AODV, DSDV, DSR, OLSR, AOMDV and HWMP. In Proceedings of the 2018 International Conference on Advances in Big Data, Computing and DataCommunication Systems (icABCD), Durban, South Africa, 6–7 August 2018; pp. 1–9.

[6] Leonov, A.V.; Ryabchevsky, V.O. Performance evaluation of AODV and OLSR routing protocols in relaying networks in organization in mini-UAVs based FANET: Simulation-based study. In Proceedings of the 2018 Dynamics of Systems, Mechanisms and Machines (Dynamics), Omsk, Russia, 13–15 November 2018; pp. 1–6.

[7] Rabahi, F.Z.; Bemmoussat, C.; Benaissa, M. A comparison of different dynamic routing protocols in FANETs. In Proceedings of the 2018 International Conference on Applied Smart Systems (ICASS), Medea, Algeria, 24–25 November 2018; pp. 1–5.

[8] Kumar, S.; Bansal, A.; Raw, R.S. Analysis of effective routing protocols for flying ad hoc networks. Int. J. Smart Veh. Smart Transp. (IJSVST) 2020, 3, 1–18. [CrossRef]

[9] Maistrenko, V.A.; Alexey, L.V.; Danil, V.A. Experimental estimate of using the ant colony optimization algorithm to solve the routing problem in FANET. In Proceedings of the 2016 International Siberian Conference on Control and Communications (SIBCON), Moscow, Russia, 12–14 May 2016; pp. 1–10.

[10] Leonov, A.V. Application of bee colony algorithm for FANET routing. In Proceedings of the 2016 17th International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices (EDM), Erlagol, Russia, 30 June–4 July 2016; pp. 124–132.

[11] Leonov, A.V.; Litvinov, G.A. Applying AODV and OLSR routing protocols to air-to-air scenario in flying ad hoc networks formed by mini-UAVs. In Proceedings of the 2018 Systems of Signals Generating and Processing in the Field of on Board Communications, Moscow, Russia, 14–15 March 2018; pp. 1–10.

[12] Leonov, A.V.; Litvinov, G.A. Considering AODV and OLSR routing protocols to traffic monitoring scenario in FANET formed by mini-UAVs. In Proceedings of the 2018 XIV International Scientific-Technical Conference on Actual Problems of Electronics Instrument Engineering (APEIE), Novosibirsk, Russia, 2–6 October 2018; pp. 229–237.

[13] Leonov, A.V.; Litvinov, G.A. About applying AODV and OLSR routing protocols to relaying network scenario in FANET with mini-UAVs. In Proceedings of the 2018 XIV International Scientific-Technical Conference on Actual Problems of Electronics Instrument Engineering (APEIE), Novosibirsk, Russia, 2–6 October 2018; pp. 220–228.

[14] Rahman, A.; Mou, J.R. A Comparative Analysis of Routing Protocols using 3D Graph for Flying Ad hoc Networks. In Proceedings of the 2019 4th International Conference on Electrical Information and Communication Technology (EICT), Khulna, Bangladesh, 20–22 December 2019; pp. 1–6.

[15] Ema, R.R.; Anik, A.; Nahar, N.; Rahman, M.A.; Eti, K.P.; Islam, T. Simulation Based Performance Analysis of Proactive, Reactive and Hybrid Routing Protocols in Wireless Sensor Network. In Proceedings of the 2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Kharagpur, India, 1–3 July 2020; pp. 1–6.

[16] Zhang, W.; Peng, W.; Wang, P. A Heterogeneous Dual-Channel Routing Protocol Based on OLSR for FANETs. In Proceedings of the 2021 2nd International Conference on Electronics, Communications and Information Technology (CECIT), Sanya, China, 27–29 December 2021; pp. 57–64.

[17] Tuli, E.A.; Golam, M.; Kim, D.S.; Lee, J.M. Performance Enhancement of Optimized Link State Routing Protocol by Parameter Configuration for UANET. Drones 2022, 6, 22. [CrossRef]

[18] Guillen-Perez, A.; Montoya, A.M.; Sanchez-Aarnoutse, J.C.; Cano, M.D. A comparative performance evaluation of routing protocols for flying Ad-Hoc networks in real conditions. Appl. Sci. 2021, 11, 4363. [CrossRef]

[19] Singh, K.; Verma, A.K. Applying OLSR routing in FANETs. In Proceedings of the 2014 IEEE International Conference on Advanced Communications, Control and Computing Technologies, Ramanathapuram, India, 8–10 May 2014; pp. 1212–1215.

[20] AlKhatieb, A.; Felemban, E.; Naseer, A. Performance evaluation of ad hoc routing protocols in (FANETs). In Proceedings of the 2020 IEEE Wireless Communications and Networking Conference Workshops (WCNCW), Seoul, Reoublic of Korea, 6–9 April 2020; pp. 1–6.

[21] Rahmani, A.M.; Ali, S.; Yousefpoor, E.; Yousefpoor, M.S.; Javaheri, D.; Lalbakhsh, P.; Ahmed, O.H.; Hosseinzadeh, M.; Lee, S.W. OLSR+: A new routing method based on fuzzy logic in flying ad hoc networks (FANETs). Veh. Commun. 2022, 36, 100489. [CrossRef]

[22] Sang, Q.; Wu, H.; Xing, L.; Ma, H.; Xie, P. An energy-efficient opportunistic routing protocol based on trajectory prediction for FANETs. IEEE Access 2020, 8, 192009–192020. [CrossRef]

[23] Ahmed, S.B.M.; Hussain, S.A.; Latiff, L.A.; Ahmad, N.; Sam, S.M. Performance Evaluation of FANET Routing Protocols in Disaster Scenarios. In Proceedings of the 2021 IEEE Symposium On Future Telecommunication Technologies (SOFTT), Bandung, Indonesia, 6–7 December 2021; pp. 46–51.

[24] Broch, J. Dynamic source routing in ad hoc wireless networks. IETF Internet Draft, draft-ietf-manet-dsr-00. txt 1998.

[25] Iordanakis, M.; Yannis, D.; Karras, K.; Bogdos, G.; Dilintas, G.; Amirfeiz, M.; Colangelo, G.; Baiotti, S. Ad-hoc routing protocol for aeronautical mobile ad hoc networks. In Proceedings of the Fifth International Symposium on Communication Systems, Networks and Digital Signal Processing (CSNDSP), Patras, Greece, 19–21 July 2006; pp. 1–5.

[26] Le, M.; Park, J.S.; Gerla, M. UAV assisted disruption tolerant routing. In Proceedings of the MILCOM 2006-2006 IEEE Military Communications Conference, Washington, DC, USA, 23–25 October 2006; pp. 1–5.

[27] Bahloul, N.E.H.; Boudjit, S.; Abdennebi, M.; Boubiche, D.E. Bio-inspired on demand routing protocol for unmanned aerial vehicles. In Proceedings of the 2017 26th International Conference on Computer Communication and Networks (ICCCN), Vancouver, BC, Canada, 31 July–3 August 2017; pp. 1–6.

[28] Rosati, S.; Kru ˙zelecki, K.; Traynard, L.; Mobile, B.R. Speed-aware routing for UAV ad hoc networks. In Proceedings of the 2013 IEEE globecom workshops (GC Wkshps), Atlanta, GA, USA, 9–13 December 2013; pp. 1367–1373.

[29] Oubbati, O.S.; Lakas, A.; Zhou, F.; Güne¸s, M.; Yagoubi, M.B. A survey on position-based routing protocols for Flying Ad hoc Networks (FANETs). Veh. Commun. 2017, 10, 29–56. [CrossRef]

[30] Oubbati, O.S.; Atiquzzaman, M.; Lorenz, P.; Tareque, M.H.; Hossain, M.S. Routing in flying ad hoc networks: Survey, constraints, and future challenge perspectives. IEEE Access 2019, 7, 81057–81105. [CrossRef]

[31] Lakew, D.S.; Sa'ad, U.; Dao, N.N.; Na, W.; Cho, S. Routing in flying ad hoc networks: A comprehensive survey. IEEE Commun.Surv. Tutor. 2020, 22, 1071–1120. [CrossRef]

[32] Wheeb, A.H.; Nordin, R.; Samah, A.; Alsharif, M.H.; Khan, M.A. Topology-based routing protocols and mobility models for flying ad hoc networks: A contemporary review and future research directions. Drones 2021, 6, 9. [CrossRe]

[33] Mathuranathan. Free Space Propagation Model. 2013. Available online: https://www.Gaussianwaves.Com/2013/09/Friss-Free-Space-Propagation-Model/ (accessed on 22 November 2021).

[34] Martinez, J.F.; Toh, K.C.; Cano, C.J.; Calafate, T.C.; Manzoni, P. Realistic Radio Propagation Models (RPMs) for VANET Simulations. In Proceedings of the IEEE Wireless Communications and Networking Conference, Budapest, Hungary, 5–8 April 2009; Volume 5, pp. 1–6. [Google Scholar]

[35] Rappaport, S.T. Wireless Communications, Principles and Practice; Prentice Hall: Hoboken, NJ, USA, 1996. [Google Scholar]

[36] Nakagami, M. The m-distribution—A general formula of intensity distribution of rapid fading. In Statistical Methods in Radio Wave Propagation; Elsevier: Pergamon, Turkey, 1960; pp. 3–36. [Google Scholar]