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A Multi-Objective Optimization for enhancing the efficiency of Service in Flying Ad-Hoc Network Environment

Hayder A.Nahi[1], F. Al-dolaimy[2], Fatima Hashim Abbas[3], Mohammed Almohamadi[4], Mustafa Asaad Hasan[5], Mohammed Ayad Alkhafaji[6], Muhammet Tahir Güneşer[7]

[1]Computer Center ,Al Qasim Green University, Babil, Iraq, haider.satar@uoqasim.edu.iq
[2]College of Medical and Health Technologies, Al-Zahraa University for Women, Karbala, Iraq. firasabedi@alzahraa.edu.iq
[3] Medical Laboratories Techniques Department, Al-Mustaqbal University College, 51001 Hillah, Babil, Iraq. fatimahashim@mustaqbal-college.edu.iq
[4] College of Information Technology, Imam Ja'afar Al-Sadiq University, Al-Muthanna 66002, Iraq. mohammed.a@sadiq.edu.iq
[5]University of Thi-Qar, Iraq, Mustafa.alkhafaji@utq.edu.iq
[6]Collage of Engineering, National University of Science and Technology, Dhi Qar, Iraq mohammed.alkhafaji@nust.edu.iq
[7]Karabuk University, Karabuk, Turkey, mtguneser@karabuk.edu.tr

Abstract

Flying Ad-hoc Network (FANET) is one among the emerging technology and it is used in the huge application of the intelligent communication system. FANETs are combined with multiple Unmanned Aerial Vehicles (UAVs) to control the complex environment. Due to high mobility in FANETs the computation overhead and computation delay of the network is greatly increased that reflects in the reduction of the performance of FANETs. So it becomes very essential to provide effective routing and optimization in FANETs to maintain the stable communication. For that purpose, in this paper Multi-Objective Hybrid Optimization for Quality of Service (QoS) Assisted Flying Ad-Hoc Network (MOHOQ-FANET) approach is proposed with the combination of Ant colony optimization (ACO) and particle swarm optimization (PSO). To achieve effective routing in FANETs, reliability of ad-hoc that depend on demand vector routing (RAODV). In order to perform initial shortest path selection in FANETs, ACO algorithm is utilized. The PSO optimization is applied in FANETs to achieve the best optimal solution between the flying nodes during the time of communication between them. The MOHOQ-FANET technique is implemented using NS2 as the platform. As well as being compared to earlier studies like CSPO-FANET and OSNP-FANET, the performance of the FANETs is assessed using metrics like ratio of packet delivery, host-to-host delay, routing overhead, and network throughput. The outcomes have illustrated, as compared to earlier systems, the proposed MOHOQ-FANET approach delivers high packet delivery ratio and throughput as well as reduced host-to-host delay and routing overhead.

Keywords: Flying Ad-hoc Network, Quality of Service, Ant colony optimization, particle swarm optimization, Adhoc On demand vector.

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1. Introduction

An ad hoc network refers to a self-configuring, decentralized wireless network formed by a group of devices without the need for a fixed infrastructure or centralized control. In an ad hoc network, devices communicate directly with each other, dynamically establishing and maintaining network connections on-the-fly. These networks are highly flexible and adaptable, making them suitable for scenarios where traditional wired or infrastructure-based networks are impractical or unavailable. Ad hoc networks can be temporary or persistent, enabling communication and information sharing in a wide range of applications, including emergency response, military operations, mobile computing, and IoT deployments [1-9]. The absence of a central authority in ad hoc networks necessitates the use of distributed algorithms and protocols to enable routing, network discovery, and resource management among the participating devices. The decentralized nature of ad hoc networks offers advantages such as scalability, fault tolerance, and rapid deployment, but also poses challenges related to network stability, security, and efficient resource utilization. Overall, ad hoc networks provide a versatile and independent means of establishing wireless connectivity among devices, enabling dynamic and self-organizing communication in diverse settings [9],[10] Flying Ad-Hoc Network (FANET) are Unmanned Aerial Vehicles (UAVs) based network which is equipped with on-Board Units and GPS and that perform air to ground based communication and it is used in several real time applications such as military and civilian operation, agriculture and weather (disaster management) applications. Due to its characteristics FANETs are used in widespread applications. In general UAVs travel in the speed at the range of 50-200 km/hr. Through the expansion of UAV technology in FANETs it becomes a highly performing mobile self-organizing dynamic networks that carried out all the operation with the help of multiple UAVs. The communication modules which are performed by the UAVs are UAVs to UAVs and UAVs to ground level networks [10], [11]. To transmit the data between the source to the destination multi-hop communication is also performed and at the initial condition FANETs perform most reliable and cost effective communication. Increase of UAVs reduces the network utility and it reflects in the complex design. So it is very essential to provide an effective routing model to high accuracy in communication as well as optimal localization of UAVs to build stable network. Hence improper UAVs placement leads to ineffective communication [12], [13]. In earlier days several routing protocols and optimization techniques are used in FANETs to achieve effective performance but still it needs an improvement. For that purpose in the paper multi-objective hybrid optimization is proposed in FANETs. The contribution of the study is described.

The contribution of the study – To achieve effective communication in FANETs multi objective hybrid optimization is executed in FANETs with the ACO and PSO. At the initial stage reliability based routing is performed using the RAODV routing protocol. ACO algorithm is used to identify the first shortest path between the flying nodes and to obtain the best optimal solution. utilized PSO algorithm. Through this approach FANETs obtains high packet delivery ratio in addition to throughput. The remaining portions of the paper are structured as follows: Section II elaborated the earlier research study and FANETs and section III describes hybrid optimization-based path selection using ACO and PSO. Section V gives a detailed findings discussion on the suggested MOHOQ-FANET strategy and compares it to other researches like CSPO-FANET and OSNP-FANET. Section IV details the implementation results. Section VI concludes the research and the future direction is given.

2. Related work

In [14] the authors focus on a downlink cellular network assisted by multiple UAVs. This system has solved a user association, resource allocation, base station placement by using alternating optimization. This work has more energy consumption during the time of data transmission. In [15] the authors designed a novel approach to solve the relay selection problem in A2G VANETs and it uses unmanned aerial vehicle (UAVs) to improve the VANET communication and network performance. Through this network the state transition probability of communication interruption and transmission consumption is calculated. Here the STP and TC are combined to solve the relay selection problem but it fails to decrease the end to end delay. In [16] the authors proposed a method to select UAV and it is based on SNR value, authors propose two selection strategies and it is used for selecting UAV, they are best harmonic mean and best downlink SNR. Both strategies selection are based on outage probability, throughput, and coverage probability. In this technique gain at low SNR value, and failed to increase the network efficiency. In [17] the authors implemented an adaptive UAVs assisted geographic routing with Q-learning. The routing path is divided into two components, they are aerial component and ground component. In global routing path is selected based on fuzzy logic and depth-first-search algorithm. In ground component, vehicle maintains the Q-table method. The simulation result shows that throughput is low and host to hostdelay is high.

In [18] the authors proposed a routing protocol; by considering both encounter probability and the persistent connection time between mobile nodes for each encounter in UAV VDTNs. In route selection we involve the persistent connection time, the proposed protocol finds more accurate of stability communication link in UAV VDTN environment. The disadvantage of this work is it produces more routing overhead during data transmission. In [19] the authors presented a new approach to enhance the spectrum efficiency and system capacity by using non-orthogonal multiple access in UAV assist. The k-means algorithm is utilize for deploy UAV based on the distance parameter. To maximize the probability by using cross layer relies on optimal power allocation. Also, the result shows improvement in the hit probability and more it fails to achieve low energy consumption. In [20] they offered random access routing protocol for V2I communication. In this proposed technique the collision is solved by using capture effect, provide SINR is large than a predetermined threshold. To maximize the network throughput the vehicle are optimized based on known density. In this technique vehicle using Markov chain and average system throughput. Disadvantage of the work is more energy consumption. In [21] the authors presented a novel approach to maximize the sum rate of the user equipment by using deep Q-network. In this work to maximize the sum rate of ground users, first we can get the value of path loss and find the location of UAVs. Using deep Q-network the UAVs location is adjusted. This method achieves moderate results but it fails to achieve low energy usage. In [22] they implemented two-wave with diffused power fading is derived based on bit error rate to improve the efficient communication system for ubiquitous coverage. The system considered source and designation which has single transmit and receive antenna, and other side have multiple transmit and receive antennas. This approach increased the network efficiency but fails to achieve low delay and overhead.

In [23] the authors developed UAVs assisted Flying Ad-Hoc Network (FANET) to achieve effective communication. This method is designed to solve the optimal virtual network function (VNF) placement problem in UAVs. The results are moderate but it is unsuccessful to achieve low latency and overhead. In [24] they proposed a ubiquitous connectivity among the heterogeneous devices to support complex missions. Through this method a mathematical optimization model is proposed that allows the Virtual Function (VF) placement and chaining process that's reflects in the decreasing of the energy usage in the network. But it fails to achieve high delivery rate and throughput. After analysis the earlier works it is understood that performance of FANETs needs to get improved and it is a current open research area. For that purpose in this paper to improve the network QoS, Multi-Objective Hybrid Optimization for QoS Assisted FANETs (MOHOQ-FANETs) is proposed and it is elaborated in the upcoming section.

3. Multi-Objective Hybrid Optimization For QoS Approach

The MOHOQ-FANET technique is suggested in order to enhance UAV communication. To achieve this, improved ACO and PSO hybrid optimization is presented. The PSO method is used to find the best solution for transferring data from the source to the destination, while the ACO algorithm is used for routing and initial path selection. The figure 1 depicts the FANET network design.

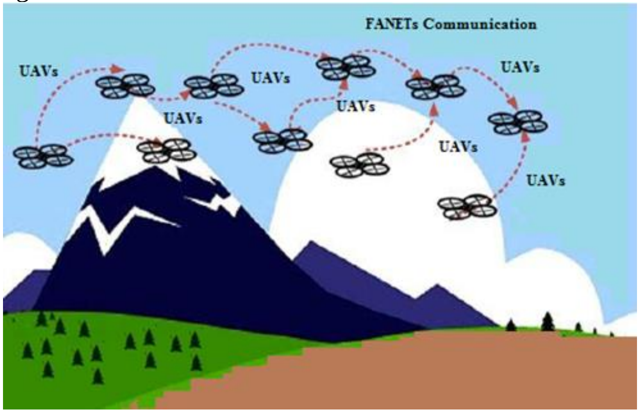

Figure 1. FANET network architecture

3.1 ACO based AODV routing in FANETs

An ACO with reliability based Adhoc On demand vector (RAODV) is used to perform effective routing in FANETs which establish the link between the source and the destination in a stable way. Whenever the flying nodes requires a link to perform communication then it broadcast a route request (RREQ) packets to its neighbors and the nodes that are present in the coverage area accepts the request to transmit the routing response (RREP) packets. Each routing path consists of certain number of intermediates that works to carry the data between the source to the destination. Here ACO is based particularly to find the routing path between the flying nodes which uses the dijsktra algorithm to find the reliable route to the destination. This process is mainly used to reduce the end to end delay and routing overhead of the FANETs.

3.2 ACO based Initial Path Selection

ACO is one among the meta-heuristic algorithm that works using the principle of real ant colony structure which is mainly used to solve the issues created by centralized controlled mechanism. ACO performs the path selection process with the help of the set of complex set of iterations with real ant functionalities. Once if the path selection is initiated then the ant deposits the pheromone in the travelling path where the other ants follow the path that consists of higher pheromone concentration. The other operations which are performed in this process are pheromone update and evaporation. The mathematical function for calculating of pheromone deposition by the ants in the travelling path is given in the equation (1).

$$P_{N1,N2} = \frac{(C_1 * PC_{N1,N2})^2 * (C_2 * ED_{N1,N2})^2}{\sum (C_1 * PC_{N1,N2}) * (C_2 * ED_{N1,N2})} \quad (1)$$

From the equation (1) the terms C_1 *and* C_2 are the constant parameters used to control the real time operation of the ants, $PC_{N1,N2}$is the pheromone concentration between the edges N1and N2 as well as $ED_{N1,N2}$ is the effective desirability parameters of the path N1 and N2. Followed by this calculation the pheromone update is performed and it is mathematically explained in the equation (2).

$$PC_{N1,N2}(t) = [EV_{N1,N2} * PC_{N1,N2}(t-1)] + \Delta PC_{N1,N2} \quad (2)$$

From the equation (2) the terms $\Delta PC_{N1,N2}$implies the contribution of artificial ants in the network and $EV_{N1,N2}$ implies the evaporation value of the path. This pheromone deposition and updates are performed for each iteration and it is updated. This method greatly helps to find the path to reach the destination for the source. Hence FANETs maintain unpredictable high speed mobility the topology changes frequently to address that the path selection has to get optimized further. For the purpose to find the optimal solution for the FANET flying node PSO algorithm is initiated and it is elaborated in the next subsection.

3.3 PSO based Optimal Path Selection

PSO algorithm is one among the numerical optimal path selection algorithm and its works using the principle of index based cost function evaluation process. The principle of PSO algorithm is population initialization in random manner then fitness calculation. The mathematical expression for the calculation of population initialization with respect to the position is expressed in the equation (3).

$$PI_{pos} = P_{min} + (\alpha * (P_{max} - P_{min})) \quad (3)$$

From the equation (3) the terms P_{max}, P_{min} minimum and maximum distance of the particles and α is the experimental constant. Now the finest to find the optimal solution to transfer the data between the source and destination is mathematically expressed in the equation (4).

$$F_{N1,N2}(t) = \sum_{i=1}^{n} W_{fun}(Q_{max} - Q_{min})^2 + \sum_{i=1}^{n}(\beta * \gamma) \quad (4)$$

From the equation (4) the terms W_{fun}implies the weighted function, Q_{min} *and* Q_{max} are the minimum and maximum velocity of the particles, β *and* γ are the constraints and weights respectively. Using this equation (4) the best optimal solution among the source to the destination is found out that greatly helps to achieve effective communication for FANETs. The workflow for the proposed MOHOQ-FANET approach is given in the figure 2.

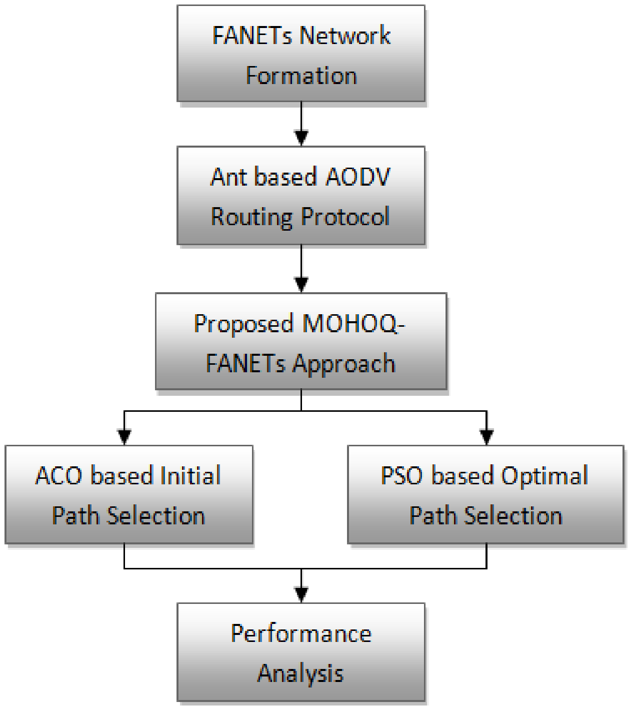

Figure 2. Workflow of the Proposed HBSPR Protocol

4. Performance Evolution and Results Analysis

In this section the measure of the techniques such as CSPO-FANET [23], OSNP-FANET [24] When compared to earlier techniques, the proposed MOHOQ-FANET achieves 7% to 13% higher packet delivery ratio, 16ms to 56ms less host to host delay, 338 packets to 510 packets less routing overhead, and 210 Kbps to 290 Kbps higher throughput. The idea of a cluster is utilized to integrate FANETs in the future to achieve improved energy efficiency. The major parameters which are considered for the implementation of the proposed method are given in the Table 1.

TABLE 1. Simulation Parameters

Parameters	Values
Simulation Time	100 ms
Network Coverage	1000m*1000m
No of Nodes	300 nodes
Antenna Type	Omni-directional Antenna
Propagation Model	Two Ray Ground Model
Queue Type	DropTail
Node Initial Energy	100 Joules
Network Traffic	CBR

Packet Size	1024 Bytes

4.1 Packet delivery ratio

In the below figure 3 plots the ratio of packet delivery methods such as CSPO-FANET, OSNP-FANET and proposed MOHOQ-FANET. During the time of communication, the count of packets transmitted from the source to the destination is known as the packet delivery ratio. From the below figure, that admitted the delivery ratio of the offered method (MOHOQ-FANET), is higher than the PDR of the following methods such as CSPO-FANET and OSNP-FANET. Using the concept of hybrid optimization in FANETs the proposed MOHOQ-FANET achieved high packet success rate.

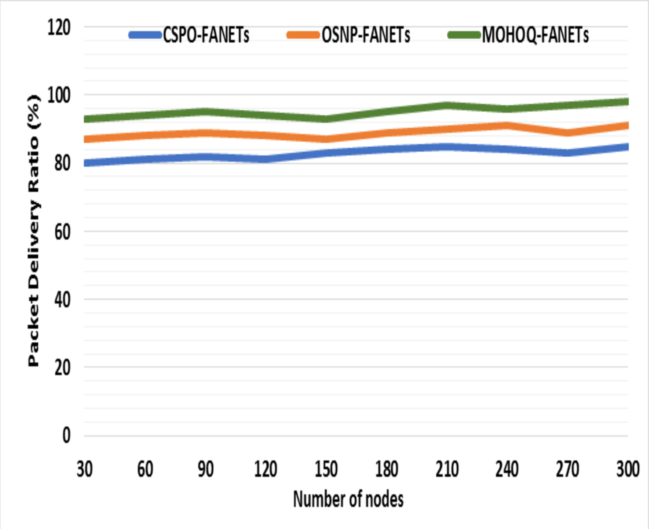

Figure 3. The ratio value of the packet delivery

4.2 End to End Delay

In the Figure 4, the plots are discussed about the host to host delay of the committed methods like CSPO-FANET and OSNP-FANET over the proposed method MOHOQ-FANET. The host to host delay is defined as the time consumption of the packets to get through the destination from the source. The below figure shows that the MOHOQ-FANET approach is far behind than the previous methods in terms of end to end delay performance. It becomes possible due to presence of hybrid optimization in FANETs. In this approach both initial path selection and optimal solution findings are performed separately to achieve more accuracy. So the end speed to increase that reflects in the reduction of the end to end delay during communication.

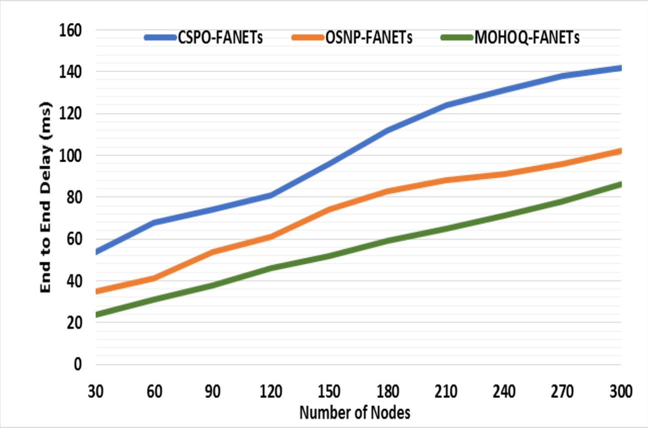

Figure 4. End to End Delay

4.3 Routing Overhead

Figure 5 compares the routing costs between the proposed technique MOHOQ-FANET and existing methods CSPO-FANET and OSNP-FANET. Meanwhile, within network communication the overhead is the calculated via the number of packets that are returned to the source without reaching the destination. As delay, the routing overhead is also inversely proportional to the performance of the network. The reduction of routing overhead in this suggested strategy leads to exceptionally effective data transfer in the network. Through efficient hybrid optimization, data is sent from source to destination in a very steady way, resulting in relatively few packets being sent, which lowers the network's routing expenses.

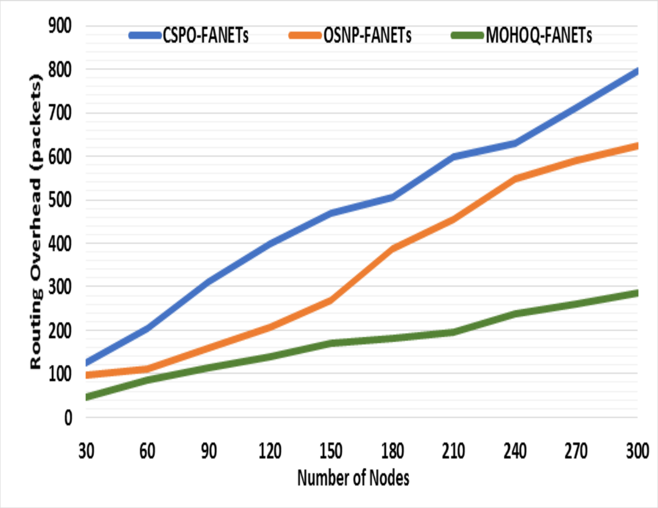

Figure 5. Routing Overhead

4.4 Routing Throughput

When compared to other approaches like CSPO-FANET and OSNP-FANET, the suggested method (MOHOQ-FANET) has a high throughput, as shown in figure 6. It may be considered as the ratio of data packets received via the target receiver and number of sent packet. In this calculation the proposed method possesses high network throughput when compared with the prior methods such as CSPO-FANET and OSNP-FANET. The proposed approach achieves low delay and overhead so that it leaves the path to transmit more number of data in all the transmission and that reflects in the raise of the throughput.

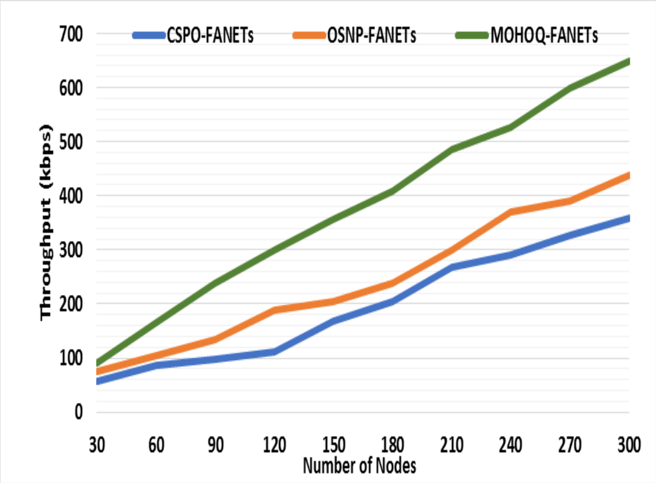

Figure 5. Network Throughput

5. Results and Discussion

As measured by the ratio of packet delivery, host to host latency, routing overhead, and network performance, solutions including CSPO-FANET, OSNP-FANET, and the proposed MOHOQ-FANET methodology are addressed in this section. The ultimate results of various procedures are displayed in Table 2.

TABLE 2**.** Results Analysis and Measurements

Parameters / Methods	CSPO-FANET	OSNP-FANET	MOHOQ-FANET
Delivery Ratio	85%	91%	98%
End to End Delay	142ms	102ms	86ms
Routing Overhead	796 packets	624 packets	286 packets
Network Throughput	358 Kbps	438 Kbps	648 Kbps

The ratio of the packet delivery is completed with the aid of using the proposed MOHOQ-FANET method is 98% whilst in comparison with the previous strategies such CSPO-FANET and OSNP-FANET it reaches as much as 85% and 91% respectively. So, the illustrated of packet delivery ratio MOHOQ-FANET method is 7% better than OSNP-FANET and 13% better than CSPO-FANET. The host to host delay proposed via way of means of the proposed MOHOQ-FANET approach is 86ms in which as for the sooner techniques such OSNP-FANET and CSPO-FANET it reaches as much as 102ms and 142ms respectively. So, the host to host delay of the proposed MOHOQ-FANET approach is 16ms less than OSNP-FANET and 56ms less than CSPO-FANET. The MOHOQ-FANET approach's anticipated routing overhead is 286 packets, compared to the preceding OSNP-FANET and CSPO-FANET approaches' proposed routing overheads of up to 796 and 624 packets, respectively. So, the routing overhead of the proposed MOHOQ-FANET approach is 338 packets lower than OSNP-FANET and 510 packets lower than CSPO-FANET. The throughput executed with the aid of using the proposed MOHOQ-FANET technique is 648 Kbps in which as for the sooner techniques such as OSNP-FANET and CSPO-FANET it is reaches up to 438 Kbps and 358 Kbps respectively. So, the throughput of the proposed MOHOQ-FANET approach is 210 Kbps better than OSNP-FANET and 290 Kbps better than CSPO-FANET. It is clear from the computation of these parameters that the hybrid technique for optimization, which combines RAODV, ACO, and PSO optimization, helped the suggested MOHOQ-FANET approach attain the overall best performance.

CONCLUSION

In this paper the Flying Ad-hoc Network (FANET) are combined with multiple Unmanned Aerial Vehicles (UAVs) to achieve effective communication. Currently the FANETs consist of huge number of UAVs so that it becomes indispensable to provide routing and optimization for FANETs. Hence Multi-Objective Hybrid Optimization for Quality of Service (QoS) Assisted Flying Ad-Hoc Network (MOHOQ-FANET) approach is proposed. The main segments which are present in this approach are ACO based AODV routing in FANETs, ACO based Initial Path Selection and PSO based Optimal Path Section. Through this method UAVs are highly optimized that greatly increased the packets success ratio and throughput achievement in FANETs. The simulation is carried out in NS2 and the parameters such as packet delivery ratio, end to end delay, routing overhead and network throughput as well as it is compared with the earlier researches such as CSPO-FANET and OSNP-FANET. From the results it is proven that When compared to earlier techniques, the proposed MOHOQ-FANET achieves 7% to 13% higher packet delivery ratio, 16ms to 56ms less host to host delay, 338 packets to 510 packets less routing overhead, and 210 Kbps to 290 Kbps higher throughput. The idea of a cluster is utilized to integrate FANETs in the future to achieve improved energy efficiency.

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