

Research Article

Monitoring System-Based Flying IoT in Public Health and Sports Using Ant-Enabled Energy-Aware Routing

Inam Ullah Khan 1, Muhammad Abul Hassan 2, Mohammad Dahman Alshehri 3, Mohammed Abdulaziz Ikram 4, Hasan J. Alyamani 5, Ryan Alturki 6, and Vinh Truong Hoang 7

1Department of Electronic Engineering, School of Engineering and Applied Sciences, Isra University, Islamabad, Pakistan
2Department of Computing and Technology, Abasyn University, Peshawar 25000, Pakistan
3Department of Computer Science, College of Computers and Information Technology, Taif University, Taif 21944, Saudi Arabia
4Computer Science Department, University College in Al-Jamoum, Umm Al-Qura University, Makkah, Saudi Arabia
5Department of Information Systems, Faculty of Computing and Information Technology in Rabigh, King Abdulaziz University, Jeddah, Saudi Arabia
6Department of Information Science, College of Computer and Information Systems, Umm Al-Qura University, Makkah, Saudi Arabia
7Department of Information Technology Specialization, FPT University, Hoa Lac High Tech Park, Hanoi, Vietnam

Correspondence should be addressed to Vinh Truong Hoang; vinhth8@fe.edu.vn

Received 13 May 2021; Accepted 23 June 2021; Published 2 July 2021

Academic Editor: Hasan Ali Khattak

Copyright © 2021 Inam Ullah Khan et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

In recent decades, the Internet of flying networks has made significant progress. Several aerial vehicles communicate with one another to form flying ad hoc networks. Unmanned aerial vehicles perform a wide range of tasks that make life easier for humans. However, due to the high frequency of mobile flying vehicles, network problems such as packet loss, latency, and perhaps disrupted channel links arise, affecting data delivery. The use of UAV-enabled IoT in sports has changed the dynamics of tracking and working on player safety. WBAN can be merged with aerial vehicles to collect data regarding health and transfer it to a base station. Furthermore, the unbalanced energy usage of flying things will result in earlier mission failure and a rapid decline in network lifespan. This study describes the use of each UAV’s residual energy level to ensure a high level of safety using an ant-based routing technique called AntHocNet. In health care, the use of IoT-assisted aerial vehicles would increase operational performance, surveillance, and automation optimization to provide a smart application of flying IoT. Apart from that, aerial vehicles can be used in remote communication for treatment, medical equipment distribution, and telementoring. While comparing routing algorithms, simulation findings indicate that the proposed ant-based routing protocol is optimal.

1. Introduction

According to the reports, the Flying Ad-Hoc Network (FANET) is a recently emerged area in sensor networks with a decentralized communication mechanism. However, because of ad-hoc dynamics, each node collects data and sends it to the base station via a backbone aerial vehicle. In the last couple of years, flying vehicles have evolved and operated in every aspect of life, such as traffic monitoring, agricultural monitoring, border surveillance, smart cities, and, more importantly, limited-time rescue operations. Drones are deployed in operation areas to collect data. However, aerial vehicles are categorized into small and large sizes. In contrast, small-size UAVs have an extra edge over large-size UAVs because of their versatile light-weight behavior, flexibility, low altitude flying, easy installation, and low hardware cost. Multiple UAV networks have been preferred over single ones because of (i) efficiency, (ii) scalability, and (iii) survivability and accuracy. In comparison with single UAV’s, a
The flying ad hoc network has an extra edge over its predecessors because of its low hardware cost, ease of deployment, autonomy, and availability in every situation. Aerial vehicles are tolerable enough to adopt any direction in three-directional space, making it more feasible for time-limited rescue missions [1]. Three-dimensional mobility of flying things made topological permutations very high, limiting limitations in terms of energy, insufficient bandwidth, and robust computations in communication links. The bandwidth of aerial vehicles is about 30–460 km/h [2], which in return causes routing and disconnection problems in flying networks. Different routing protocols are applied to encounter the routing problem in FANETs. However, high mobility patterns in aerial networks need novel energy-efficient routing techniques. In addition, aerial vehicles are interconnected with wireless technology, e.g., IEEE 802.15.4, as shown in Figure 1. In this figure, each flying vehicle monitors an assigned geographical area which establishes a personalized UAV network. Table 1 discusses the advantage of the multi-UAV network over a single aerial vehicular network. Furthermore, Figure 2 explains the applications based on single UAV to monitor and send data to a base station, while Figure 3 depicts a proposal for connecting two cities using a multi-UAV framework. Mobility models also enhance the utilization of network resources with accurate implementation of routing protocols in a network.

Flying IoT will be designed to monitor athletes in motion during international games. Drones connected to the Internet of things are referred to as Flying IoT, which will reshape player tracking and reduce the risk of injury. This transformation will produce optimum results by incorporating data collection through aerial vehicles. They will improve efficiency, real-time player experience, and new revenue-generating opportunities in sports. Flying IoT has many benefits, including the ability to reach heights, produce high-quality images at a low cost, and respond quickly in any scenario [3].

The major contribution in this research article is as follows.

(i) IoT-based UAVs are used to maximize the quality of service/experience
(ii) The ant-inspired routing protocol is deployed in the area of flying ad hoc networks
(iii) The boundless area mobility model is introduced in the study of the Internet of flying vehicles
(iv) Flying network is analyzed using parameters that include throughput, network utilization, packet delivery ratio, packet drop count, packet loss, and end-to-end delay
(v) Flying IoT is utilized in the field of sports and health care for monitoring

The rest of the article is structured with Section 1, which consists of the paper Introduction. Section 2 is composed of brief literature with past data about the problem. Similarly, routing in flying IoT is incorporated in Section 3 also. Section 4 represents the proposed model. Section 5 demonstrates the simulation environment. The performance graphs and results are discussed in Section 6. Results and discussion are explained in Section 7. The overall analysis and future direction are discussed in Section 8.

2. Literature Survey

The flying ad-hoc network is a subset of the mobile ad-hoc network with some special features as discussed in Section 1; with all these benefits, it also inherits the routing problem due to its rapid changing topology [3]. 3D mobility of flying things enabled expanding of the geographical area which helps in surveillance of the large area by a single UAV. Among other limitations, one of the key problems which must be addressed is lack of specialized routing protocols on the industrial level in the field of flying ad hoc networks [4]. Therefore, classification of aerial networks routing protocols is in the development phase; due to that, FANETs relay on traditional MANET routing protocols [5, 6]. The OPEN routing protocol is a designed novel strategy which is based on (i) residual energy, (ii) node density, and (iii) distance from its neighbors; these metrics are used for electing cluster head (CH) [7]. In [8], authors tested the optimal ant-based distance protocol. Primary metrics are used for the analysis of other routing protocols in the simulation-based environment. The ant-based routing protocol faces flat and hierarchical network topology problems. Due to fast-changing nature, the UAV network is having issues related to routing links failures, disruptions, and signal jamming [9]. Flying ad hoc networks are having different mobility models, nodes’ position, and radio frequency in comparison with other areas which include MANETS and VANETS. Wireless communication technologies are utilized to connect nodes with base stations in different fields [10]. Figure 4 describes the brief study of different routing protocols in the newly emerged field known as Internet of flying networks.

COVID-19 has increased the use of flying IoT in general. China has deployed drones for crowd monitoring in order to maintain social distance. In addition, several European countries are using unmanned aerial vehicles (UAVs) for announcements or broadcasting in order to take appropriate actions [11]. Agricultural drones may be used to spray disinfectants in order to stop the transmission of a deadly virus. Drones, on the contrary, can be used to deliver medicine quickly and reduce the burden on hospitals [12].

When using IoT-based drones, live sport video streaming is a great challenge. End users need high-quality video experience to capture entertaining scenes, which can be easily achieved using fog networking and UAVs [13]. Aerial IoT is used in a cycling race to propose a novel approach for accuracy optimization using machine learning to train the model [14].

The use of flying IoT in healthcare would revolutionise the world. Aerial IoT can be used to keep track of athletes’ fitness when they are competing. However, using routing
protocols in the field of healthcare will transform the dynamics of communication. For this purpose, ant-inspired routing, AOMDV, DSDV, DSR, M-DART, and ZRP are implemented to improve channels/links. Therefore, Table 2 discusses latest data survey about routing protocols in UAV-assisted networks.

### Table 1: Multiple and single aerial vehicles.

| Feature                      | Single FANET-UAV network | Multiple FANET-UAV networks |
|------------------------------|----------------------------|-----------------------------|
| Failure impact of network    | Very high                 | Very low; other nodes replace the failed ones |
| Scalability                  | Limited                    | High                        |
| Survivability                | Low                        | High                        |
| Speed of mission             | Slow                       | Very fast                   |
| Cost                         | Medium                     | Low                         |
| Bandwidth                    | Needed                     | High                        |
| Communication medium         | Antenna                    | Omni-directional            |
| Control complexity           | Low                        | High                        |
| Coordination on failure      | Low                        | High                        |

3. **Routing in Flying IoT**

Flying ad hoc networks are referred to Internet of drones where flying things are connected with land station. Among the aerial nodes, routing plays an important role to find the optimal path from the source to the destination. Demand of
Figure 2: Single UAV monitoring-based applications.

Figure 3: Multi-UAV’s connectivity in two different cities.
unmanned aerial vehicles, while integrating with smart cities needs some basic requirements in routing; for instance, adaptability, scalability, residual energy, delay, and bandwidth complete the network study of aerial vehicles. Routing in flying things depends upon distance, angle of arrival, path lifetime, and node localization to make decisions on right time. Mobile movements of nodes in flying ad hoc networks consist of key steps which include route discovery, broadcasting, selecting path, and link maintenance. Apart from routing in IoT-based networks, security must be ensured [25].

Classifications of routing protocols in flying IoT are mentioned below.

| Ref. | Routing protocol | Prediction | Connectivity | Exploration | Efficient use of energy | Rapid action against abrupt changes | Network application |
|------|------------------|------------|--------------|-------------|------------------------|-------------------------------------|---------------------|
| [15] | Energy-efficient Connectivity-aware Data Delivery (ECaD) routing algorithm | Available | Available | Available | Available | Not available | Flying ad hoc networks |
| [16] | Parrot: predictive ad-hoc routing | Available | Not available | Available | Not available | Not available | UAV-aided networks |
| [17] | ARdeep: adaptive and reliable routing protocol with deep learning | Available | Available | Available | Available | Available | Mobile robot networks |
| [18] | QMR | Available | Not available | Available | Available | Available | FANETs |
| [19] | FLRLBR | Available | Available | Available | Available | Available | FANETs |
| [20] | QAGR | Available | Not available | Available | Not available | Not available | FANETs |
| [21] | Adaptive Q-routing with Random Echo and Route Memory (AQRERM) | Available | Not available | Available | Available | Available | FANETs |
| [22] | Delayed Q-routing (DQ-routing) | Available | Not available | Not available | Available | Not available | FANETs |
| [23] | Poisson’s probability-based Q-routing (PBQ-routing) | Available | Available | Available | Available | Not available | FANETs |
| [24] | Traffic-aware Q-network enhanced routing protocol based on GPSR (TQNGPSR) | Available | Available | Available | Not available | Not available | UAV-aided networks |

Figure 4: Routing protocols for Internet of flying networks.
3.1. Proactive. The word proactive is made of two words pro and active which means storing and maintaining data packets in routing tables to facilitate aerial networks.

3.2. Reactive. The reactiveness can be only achieved in multiple flying vehicles in order to transmit data packets when needed. While using reactive strategies, the overhead problem can be easily reduced.

3.3. Hybrid. Hybridization is the process of combining two or more features to formulate optimal technique. In addition, both proactive and reactive natures of routing construct the hybrid algorithm.

3.4. Bio-Inspired. The techniques which can be simulated by the behaviour of animals, ants, fish, or birds to find the optimal solution in routing are known as bio-inspired.

4. Proposed Approach (AntHocNet for Flying Ad Hoc Networks)

Quality of experience-based AntHocNet routing for flying networks is proposed. QoE-based AntHocNet is working on the basic concept of ant colony optimization. Quality of experience is evaluated using different metrics which include throughput, network utilization, packet delivery ratio, packet drop count, packet loss, and end-to-end delay. Figure 5 represents ant behavior to find the optimal path from the source to the destination. Ant-based reinforcement works on pheromone modeling to choose the route for flying vehicles.

The approach “AntHocNet” [26] is a hybrid algorithm having both reactive and proactive components. Communication process is very important during the whole method for searching food by ants where on-demand events are used. However, maintaining the path and updating pheromone table are performed to control data packets in flying networks. The iterative random sampling mechanism is used to collect routing data packets to enhance adaptability in dynamic flying networks. By deploying ant-inspired technique in flying ad hoc networks, it can help to boost up overall life time and decision-making.

This novel algorithm consists of five main steps which are as follows:

(i) Initial solution
(ii) Making decision in a centralized way
(iii) Pheromone concentration
(iv) Reinforcement learning or pheromone update
(v) Pheromone evaporation

The proposed hybrid scheme AntHocNet initializes data session to launch reactive forward ants for searching multiple routes. Also, backward ants are used to maintain the path. Link failure data packets are broadcast, which helps in removal of transmission errors. Pheromone is a watery liquid that will have a high concentration if the number of ants on that trail increases. Also, the process of reinforcement is incorporated that it allows ants to learn from the surrounding environment. Else, if the ants’ moment will be very low on the specific path, then pheromone evaporation occurs.

In addition, the working flowchart of AntHocNet is mentioned in Figure 6.

5. Simulation Environment

Simulation setup consists of thirty flying vehicles and one ground station. The whole study is performed by using network simulator-2. The boundless area mobility model is deployed on three-dimensional topology having 1000 m area for x, y, and z axes. The time exercised for experimentation was around 180 seconds where constant bit rate data packets are employed as traffic type. The UAV network topology is presented in Figure 7.

6. Performance Graphs

In this section, we discuss the results’ performance using graphs as shown in the following.

Evaluating routing techniques by using the throughput study is described in Figure 8. The learning of throughput analysis is estimated by levels which include minimum, maximum, average, and standard deviation. The ant-simulated routing algorithm illustrates optimal received data packets per unit time in comparison with other routing schemes.

The packet delivery ratio is to investigate data packets on two metrics which will be either packet sent or packet received. Figure 9 describes routing schemes such as dynamic source routing, where thirty thousand plus data packets are sent by utilizing the method of broadcasting but very less web of information are received. However, ant-based routing manifests balanced results in contrast with DSDV, M-DART, AOMDV, and zone routing protocol.

As the number of data packets is dropped, it causes huge impact on network lifetime. In addition, the zone routing scheme is a hybrid learning mechanism having both proactive and reactive approaches. Dividing the topological structure in different zones or clusters easily reduces overhead issues inside the flying networks. Therefore, AntHocNet is based on the fundamental concept of ants locating the shortest path by using the pheromone update method which improves the energy level in unmanned aerial vehicles. In Figure 10, routing algorithms such as AntHocNet and ZRP represent better simulation results by estimating the number of packet drop.

During data transmission in flying networks, packet loss occurs due to having bugs. Figure 11 shows routing protocols and number of packets where AntHocNet is having desired results in terms of packet loss in comparison with other contemporary algorithms.

In IoT-based aerial vehicles, delay can be caused, while retransmitting data packets across the multi-UAV networks. Calculating average end-to-end delay requires data packet length to reach the destination in the defined time frame.
Figure 5: Working of ant colony optimization.

Figure 6: Flowchart of AntHocNet.
Figure 12 describes the ant routing (AntHocNet) is having very less end-to-end delay from the source to the target.

Network utilization is the maximum capacity of data transfer across the network. Table 3 shows the network utilization study to perform experimentation by using different routing protocols. A novel technique called standard deviation is used to offer greater depth of study by calculating the average or mean.

7. Results and Discussion

AntHocNet finalizes to generate both proactive and reactive strategies which learn from the system. Ant routing has been
Packet delivery ratio for boundless area

Figure 9: Packet delivery ratio.

Total packet drop count for boundless area

Figure 10: Packet drop count.

Packet loss for boundless area

Figure 11: Packet loss.
shown to be a suitable solution for flying ad hoc networks due to AntHocNet’s self-organizing nature, which demonstrates less tendencies toward packet loss, whereas the packet drop ratio improves quality of service in flying networks. Similar effects are claimed in simulation having less packet drop count. Network scalability can be achieved in aerial vehicles by boosting network throughput. On the contrary, ant-based routing simulates throughput and average end-to-end delay, while simulating with other conventional algorithms. As the paper discusses, the implementation of routing-related monitoring in health care and sports will improve the quality of service in flying networks.

8. Conclusions

IoT-based routing plays an important role in the field of flying ad hoc networks. Due to mobile pattern wireless communication technologies [27], deployment allows easy access to aerial vehicles with the base station. The best practice is to use flying IoT in health care and sports. For optimal communication, routing protocols can be used in IoT-based drone networks. Aerial networks require secure channels for transmitting data packets using the routing protocol from one location to another. A novel evolutionary computational algorithm, “AntHocNet,” is introduced in the field of the Internet of flying networks. The ant-inspired technique is evaluated by comparing it with traditional routing protocols, including DSR, ZRP, M-DART, DSDV, and AOMDV. The suggested solution differs from baseline protocols due to certain key features such as learning from the environment, convergence, loop-free, localization, and quality of service. The boundless area mobility model is used in the simulation, which helps to improve reinforcement learning in flying networks. Other mobility model deployment in the field of UAVs would be a valuable addition in the future.

Data Availability

The data used to support the findings of the study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported by Taif University Researchers Supporting Project no. TURSP-2020/126, Taif University, Taif, Saudi Arabia.

References

[1] J. Sun, F. Khan, J. Li, M. D. Alshehri, A. Ryan, and M. Wedyan, “Mutual authentication scheme for ensuring a secure device-to-server communication in the internet of medical things,” *IEEE Internet of Things Journal*, Article ID 3078702, 2021.
[2] M. Abul Hassan, S. Irfan Ullah, A. Salam et al., “Energy efficient hierarchical based fish eye state routing protocol for flying ad-hoc networks,” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 21, no. 1, pp. 465–471, 2021.
[3] S. Alsamhi, O. Ma, M. Ansari, and S. Gupta, “Collaboration of drone and internet of public safety things in smart cities: an
overview of qos and network performance optimization,” *Drones*, vol. 3, no. 1, p. 13, 2019.

[4] S. Rezwan and W. Choi, “A survey on applications of reinforcement learning in flying ad-hoc networks,” *Electronics*, vol. 10, no. 4, p. 449, 2021.

[5] S. R. Jan, R. Khan, F. Khan, and M. Ahmad Jan, “Marginal and average weight-enabled data aggregation mechanism for the resource-constrained networks,” *Elsevier Computer Communication Journal*, vol. 174, pp. 101–108, 2021, IF 2.81.

[6] J.-N. Liu and C. Imrich, “Mobile ad-hoc networking with a view of 4g wireless: imperatives and challenges,” *Mobile Ad Hoc Networking*, vol. 1, pp. 69–116, 2004.

[7] S. B. H. Shah, Z. Chen, and F. Yin, “OPEN: Optimized path planning algorithm with energy efficiency and extending network - lifetime in WSN,” *Journal of computing and information technology*, vol. 25, no. 1, pp. 1–14, 2017.

[8] F. Khan, M. Ahmad Jan, A. U. Rehman, S. Mastorakis, M. Alazab, and P. Watters, “A secured and intelligent communication scheme for IoI enabled pervasive edge computing,” *The IEEE Transaction on Industrial Informatics*, vol. 17, pp. 5128–5137, 2021, IF 9.1.

[9] C. Pu, “Jamming-resilient multipath routing protocol for flying ad hoc networks,” *IEEE Access*, vol. 6, pp. 68472–68486, 2018.

[10] A. Guillen-Perez and M.-D. Cano, “Flying ad hoc networks: A new domain for network communications,” *Sensors*, vol. 18, no. 10, p. 3571, 2018.

[11] V. Chamola, V. Hassija, V. Gupta, and M. Guizani, “A comprehensive review of the COVID-19 pandemic and the role of IoT, Drones, AI, blockchain, and 5G in managing its impact,” *IEEE Access*, vol. 8, pp. 90225–90265, 2020.

[12] M. D. Alshehri, F. Hussain, M. Elkhodr, and B. S. Alsinglawi, “A distributed trust management model for Internet of things (DTM-IoT),” in *Recent Trends and Advances in Wireless and IoT-enabled Networks*, pp. 1–9, Springer, Cham, Switzerland, 2019.

[13] M. D. Alshehri, F. K. Hussain, and O. K. Hussain, “Clustering-driven intelligent trust management methodology for the internet of things (CITM-IoT),” *Mobile networks and applications*, vol. 23, no. 3, pp. 419–431, 2018.

[14] E. Patsiouras, A. Tefas, and I. Pitas, “Few-shot image recognition for UAV sports cinematography,” in *Proceedings of the 2020 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops* (CVPRW), pp. 965–969, Seattle, WA, USA, June 2020.

[15] O. Oubbati, M. Mozaffari, N. Chaib, P. Lorenz, M. Atiquzzaman, and A. Jamali Pour, “Ecad: Energy-efficient routing in flying ad hoc networks,” *International Journal of Communication Systems*, pp. 1–13, 2019.

[16] B. Sliwa, C. Schuler, M. Patchou, and C. Wietfeld, “Parrot: Predictive ad-hoc routing fueled by reinforcement learning and trajectory knowledge,” 2020, https://arxiv.org/abs/2012.05490.

[17] J. LIU, Q. WANG, C. HE, and Y. XU, “Ardeep: Adaptive and reliable routing protocol for mobile robotic networks with deep reinforcement learning,” in *Proceedings of the 2020 IEEE 45th Conference on Local Computer Networks (LCN)*, pp. 465–468, Sydney, Australia, November 2020.

[18] J. Liu, Q. Wang, C. He et al., “Qmrq-learning based multi-objective optimization routing protocol for flying ad hoc networks,” *Computer Communications*, vol. 150, pp. 304–316, 2020.

[19] C. He, S. Liu, and S. Han, “A fuzzy logic reinforcement learning-based routing algorithm for flying ad hoc networks,” in *Proceedings of the 2020 International Conference on Computing, Networking and Communications (ICNC)*, pp. 987–991, Big Island, HI, USA, February 2020.

[20] S. Jiang, Z. Huang, and Y. Ji, “Adaptive UAV-assisted geographic routing with q-learning in VANET,” *IEEE Communications Letters*, vol. 25, pp. 1358–1362, 2020.

[21] M. Kavalerov, Y. Shilova, and Y. Likhacheva, “Adaptive q-routing with random echo and route memory,” in *Proceedings of the 20th Conference of Open Innovations Association FRACT*, pp. 138–145, FRACT Oy, Yaroslavl, Russia, April 2017.

[22] F. Wang, R. Feng, and H. Chen, “Dynamic routing algorithm with qlearning for internet of things with delayed estimator,” *IOP Conference Series: Earth and Environmental Science*, vol. 234, Article ID 012048, 2019.

[23] D. Sharma, D. Kukreja, P. Aggarwal, M. Kaur, and A. Sachan, “Poisson’s probability-based q-routing techniques for message forwarding in opportunistic networks,” *International Journal of Communication Systems*, vol. 31, p. 5, 2018.

[24] Y.-N. Chen, N.-Q. Lyu, G.-H. Song, B.-W. Yang, and X.-H. Jiang, “A traffic-aware q-network enhanced routing protocol based on gsp for unmanned aerial vehicle ad-hoc networks,” *Frontiers of Information Technology & Electronic Engineering*, vol. 21, no. 9, pp. 1308–1320, 2020.

[25] A. Abdollahi and M. Fathi, “An intrusion detection system on ping of death attacks in IoT networks,” *Wireless Personal Communications*, vol. 112, no. 4, pp. 2057–2070, 2020.

[26] I. U. Khan, I. M. Qureshi, M. A. Aziz, T. A. Cheema, and S. B. H. Shah, “Smart IoT Control-Based Nature Inspired Energy Efficient Routing Protocol for Flying Ad Hoc Network (FANET),” *IEEE Access*, vol. 8, pp. 56371–56378, 2020.

[27] I. U. Khan, A. Ryan, H. J. Alyamani et al., “RSSI-controlled long-range communication in secured IoT-enabled unmanned aerial vehicles,” *Mobile Information Systems*, vol. 2021, Article ID 5523553, 11 pages, 2021.