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Exploring optimal resource allocation methods for improved efficiency in flying ad-hoc network environments: a survey

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Abstract
This survey explores optimal resource allocation methods to enhance the efficiency of flying ad-hoc networks (FANETs). Unmanned aerial vehicles (UAVs), commonly known as drones, are widely deployed in military and civilian applications, necessitating effective coordination and communication to overcome challenges. FANETs facilitate wireless communication among UAVs, improving coordination and information exchange in environments lacking traditional networks. The dynamic mobility of UAVs introduces unique considerations for network design and connectivity, distinguishing FANETs from conventional ad-hoc networks. This survey reviews various optimization techniques, including genetic algorithms, ant colony optimization, and artificial neural networks, which optimize resource allocation by considering mission requirements, network topology, and energy constraints. The paper also discusses the critical role of intelligent algorithms in enhancing network energy management, quality of service (QoS), maximizing resource allocation, and optimizing overall performance. The systematic literature review categorizes resource allocation strategies based on performance optimization criteria and summarizes their strengths, weaknesses, and applications. This survey highlights the potential of FANETs to revolutionize various industries and unlock new opportunities for UAV-based applications.

Author Keywords
Efficiency optimization; Flying ad-hoc network; Intelligent algorithms; Network performance; Resource allocation; Unmanned aerial vehicles

References

- Banafaa, M. K.
  A comprehensive survey on 5G-and-beyond networks with UAVs: applications, emerging technologies, regulatory aspects, research trends and challenges
  (2024) *IEEE Access*, 12, pp. 7786-7826.
- Arafat, M. Y., Moh, S.
  Routing protocols for unmanned aerial vehicle networks: a survey
  (2019) *IEEE Access*, 7, pp. 99694-99720.
- Chriki, A., Touati, H., Snoussi, H., Kamoun, F.
  FANET: communication, mobility models and security issues
  (2019) *Computer Networks*, 163.
- Saeed, M. M.
  Task reverse offloading with deep reinforcement learning in multi-access edge computing
  Proceedings of the 9th International Conference on Computer and Communication Engineering, ICCCE 2023, 2023, pp. 322-327.
- Bekmezci, I., Sahingoz, O. K., Temel, Ş.
  Flying ad-hoc networks (FANETs): a survey
  (2013) *Ad Hoc Networks*, 11 (3), pp. 1254-1270.

- Li, B., Fei, Z., Zhang, Y.
UAV communications for 5G and beyond: recent advances and future trends
(2019) *IEEE Internet of Things Journal*, 6 (2), pp. 2241-2263.

- Zeng, Y., Zhang, R., Lim, T. J.
Wireless communications with unmanned aerial vehicles: opportunities and challenges
(2016) *IEEE Communications Magazine*, 54 (5), pp. 36-42.

- Bekmezci, I., Sen, I., Erkalkan, E.
Flying ad-hoc networks (FANET) test bed implementation
(2015) *2015 7th International conference on recent advances in space technologies (RAST)*, pp. 665-668.

- Kapila, D., Ulloa, N., Anita, S., Subramanian, R. S., Kandewar, P., Sujatha, P.
Applications of drones in predictive analytics
(2023) *Predictive Analytics in Smart Agriculture*, pp. 250-274.

- Purohit, A., Mokaya, F., Zhang, P.
Collaborative indoor sensing with the SensorFly aerial sensor network
(2012) *IPSN'12 - Proceedings of the 11th International Conference on Information Processing in Sensor Networks*, pp. 145-146.

- Khan, M. F., Yau, K. L. A., Noor, R. M., Imran, M. A.
Routing schemes in FANETs: a survey
(2020) *Sensors (Switzerland)*, 20 (1).

- Ribeiro, A.
Optimal resource allocation in wireless communication and networking
(2012) *EURASIP Journal on Wireless Communications and Networking*, 2012 (1).

- Wang, Z., Eisen, M., Ribeiro, A.
Learning decentralized wireless resource allocations with graph neural networks
(2022) *IEEE Transactions on Signal Processing*, 70, pp. 1850-1863.

- Fernando, X., Sultana, A., Hussain, S., Zhao, L.
Taxonomy for the resource allocation in CRNs
(2019) *Cooperative Spectrum Sensing and Resource Allocation Strategies in Cognitive Radio Networks*, pp. 41-58.

- Guan, X., Ma, Y.
Wireless network virtualization resource sharing considering dynamic resource allocation algorithm
Advances in Multimedia, 2022, p. 2022.

- Ahmed, Z. E., Hashim, A. A., Saeed, R. A., Saeed, M. M.
TinyML network applications for smart cities
(2024) *TinyML for Edge Intelligence in IoT and LPWAN Networks*, pp. 423-451.

- Guo, Z., Wang, Y., Sun, Y., Li, J., Fu, C., Zhong, J.
Resilience analysis of cooperative mission based on spatio–temporal network dynamics for flying ad hoc network
(2024) *IEEE Transactions on Reliability*, 73 (2), pp. 1034-1043.

- Liu, T., Bai, G., Tao, J., Zhang, Y. A., Fang, Y.
A multistate network approach for resilience analysis of UAV swarm considering information exchange capacity
Reliability Engineering and System Safety, 241, p. 2024.

- Phadke, A., Medrano, F. A.
Increasing operational resiliency of UAV swarms: an agent-focused search and

rescue framework
Aerospace Research Communications, 1, p. 2024.

- Hussein, S., Thasin, A., Sami, A., Banu, A. S.
Secure AI-based flying ad-hoc networks: trusted communication
International Conference on Innovative Computing and Communications: Proceedings of ICICC 2022, 2022, pp. 521-528.

- Haider, U., Shoukat, H., Ayub, M. Y., Tashfeen, M. T. A., Bhatia, T. K., Khan, I. U.
Cyber attack detection analysis using machine learning for IoT-based UAV network
(2024) *Cyber Security for Next-Generation Computing Technologies*, pp. 253-264.

- Alqahtani, H., Kumar, G.
Machine learning for enhancing transportation security: a comprehensive analysis of electric and flying vehicle systems
Engineering Applications of Artificial Intelligence, 129, p. 2024.

- Bharany, S., Sharma, S., Bhatia, S., Rahmani, M. K. I., Shuaib, M., Lashari, S. A.
Energy efficient clustering protocol for FANETS using moth flame optimization
(2022) *Sustainability (Switzerland)*, 14 (10).

- Thantharate, P., Thantharate, A., Kulkarni, A.
GREENSKY: a fair energy-aware optimization model for UAVs in next-generation wireless networks
Green Energy and Intelligent Transportation, 3 (1), p. 2024.

- Zhao, L., Bin Saif, M., Hawbani, A., Min, G., Peng, S., Lin, N.
A novel improved artificial bee colony and blockchain-based secure clustering routing scheme for FANET
(2021) *China Communications*, 18 (7), pp. 103-116.

- López Escobar, J. J., Ricardo, M., Campos, R., Gil-Castiñeira, F., Díaz Redondo, R. P.
Resource allocation for dataflow applications in FANETs using anypath routing
(2023) *Internet of Things (Netherlands)*, 22.

- Faraci, G., Rizzo, S. A., Schembra, G.
Green edge intelligence for smart management of a FANET in disaster-recovery scenarios
(2023) *IEEE Transactions on Vehicular Technology*, 72 (3), pp. 3819-3831.

- Chen, J.
Deep reinforcement learning based resource allocation in multi-UAV-aided MEC networks
(2023) *IEEE Transactions on Communications*, 71 (1), pp. 296-309.

- Raj, J. S.
A novel hybrid secure routing for flying ad-hoc networks
(2020) *Journal of Trends in Computer Science and Smart Technology*, 2 (3), pp. 155-164.

- Qian, L. P., Zhang, H., Wang, Q., Wu, Y., Lin, B.
Joint multi-domain resource allocation and trajectory optimization in UAV-assisted maritime IoT networks
(2023) *IEEE Internet of Things Journal*, 10 (1), pp. 539-552.

- You, W., Dong, C., Wu, Q., Qu, Y., Wu, Y., He, R.
Joint task scheduling, resource allocation, and UAV trajectory under clustering for FANETs
(2022) *China Communications*, 19 (1), pp. 104-118.

- Namdev, M., Goyal, S., Agarwal, R.
A method for improving efficiency and security of FANET using chaotic black hole

optimization-based routing (BHOR) technique
(2022) *Lecture Notes in Electrical Engineering*, 907, pp. 15-27.

- Mansour, H. S.
Cross-layer and energy-aware AODV routing protocol for flying ad-hoc networks
(2022) *Sustainability (Switzerland)*, 14 (15).

- Duan, R., Wang, J., Jiang, C., Ren, Y., Hanzo, L.
The transmit-energy vs computation-delay trade-off in gateway-selection for heterogenous cloud aided multi-UAV systems
(2019) *IEEE Transactions on Communications*, 67 (4), pp. 3026-3039.

- Liu, C. H., Ma, X., Gao, X., Tang, J.
Distributed energy-efficient multi-UAV navigation for long-term communication coverage by deep reinforcement learning
(2020) *IEEE Transactions on Mobile Computing*, 19 (6), pp. 1274-1285.

- Mohammed, N. A., Almutoki, S. M. M., Mansoor, R., Jaber, A. K., Al Ghzawi, B. A. H. K., Alsalamy, A. H.
Resource allocation with energy balancing for uavs assisted vanets based intelligent transportation system
(2023) *Al-Sadiq International Conference on Communication and Information Technology*, pp. 282-287.

- Priya, S. S., Mohanraj, M.
An energy-efficient clustering and fuzzy-based path selection for flying ad-hoc networks
(2023) *International Journal of Computational Intelligence and Applications*, 22 (1).

- He, C., Liu, S., Han, S.
A fuzzy logic reinforcement learning-based routing algorithm for flying ad-hoc networks
2020 International Conference on Computing, Networking and Communications, ICNC 2020, 2020, pp. 987-991.

- Grasso, C., Raftopoulos, R., Schembra, G.
Multi-agent deep reinforcement learning in flying ad-hoc networks for delay-constrained applications
(2022) *Procedia Computer Science*, 203, pp. 69-78.

- Yang, Z., Pan, C., Wang, K., Shikh-Bahaei, M.
Energy efficient resource allocation in UAV-enabled mobile edge computing networks
(2019) *IEEE Transactions on Wireless Communications*, 18 (9), pp. 4576-4589.

- Colajanni, G., Daniele, P., Galluccio, L., Grasso, C., Schembra, G.
Service chain placement optimization in 5G FANET-based network edge
(2022) *IEEE Communications Magazine*, 60 (11), pp. 60-65.

- Jailton, J., Carvalho, T., Araújo, J., Francês, R.
Relay positioning strategy for traffic data collection of multiple unmanned aerial vehicles using hybrid optimization systems: a FANET-based case study
(2017) *Wireless Communications and Mobile Computing*, 2017.

- Tong, X., Li, X., Ding, F. Z., Liu, Y.
Network consensus analysis and optimization of distributed FANETs based on multi-agent consensus theory
Eurasip Journal on Wireless Communications and Networking, 2023 (1), p. 2023.

- Pasandideh, F., Rodriguez Cesen, F. E., Henrique Morgan Pereira, P., Esteve Rothenberg, C., Pignaton de Freitas, E.

An improved particle swarm optimization algorithm for UAV base station placement
(2023) *Wireless Personal Communications*, 130 (2), pp. 1343-1370.

- Manogaran, G., Ngangmeni, J., Stewart, J., Rawat, D. B., Nguyen, T. N.
Deep learning-based concurrent resource allocation for enhancing service response in secure 6G network-in-box users using IIoT
(2023) *IEEE Internet of Things Journal*, 10 (4), pp. 3130-3137.
Feb

- Rovira-Sugranes, A., Razi, A., Afghah, F., Chakareski, J.
A review of AI-enabled routing protocols for UAV networks: Trends, challenges, and future outlook
Ad Hoc Networks, 130, p. 2022.

- Wang, H.
Joint resource allocation on slot, space and power towards concurrent transmissions in UAV ad-hoc networks
(2022) *IEEE Transactions on Wireless Communications*, 21 (10), pp. 8698-8712.

- Liu, J., Huo, S., Wang, Y.
Throughput optimization for flying ad hoc network based on position control using genetic algorithm
(2020) *International Journal of Metrology and Quality Engineering*, 11.

- Saeed, M. M., Saeed, R. A., Ahmed, Z. E.
TinyML for 5G networks
(2024) *TinyML for Edge Intelligence in IoT and LPWAN Networks*, pp. 167-229.

- Galluccio, L.
Reinforcement learning for resource planning in drone-based softwarized networks
2022 20th Mediterranean Communication and Computer Networking Conference, MedComNet 2022, 2022, pp. 200-207.

- Li, T., Leng, S., Wang, Z., Zhang, K., Zhou, L.
Intelligent resource allocation schemes for UAV-swarm-based cooperative sensing
(2022) *IEEE Internet of Things Journal*, 9 (21), pp. 21570-21582.

- Bayerlein, H., De Kerret, P., Gesbert, D.
Trajectory optimization for autonomous flying base station via reinforcement learning
(2018) *IEEE Workshop on Signal Processing Advances in Wireless Communications, SPAWC*, 2018, pp. 1-5.
June

- Ren, S., Li, D., Hu, Q., Liu, Y., Liu, J.
An improved security OLSR protocol against black hole attack based on FANET
(2022) *ASCC 2022 - 2022 13th Asian Control Conference, Proceedings*, pp. 383-388.

- Xu, Y. H., Li, J. H., Zhou, W., Chen, C.
Learning-empowered resource allocation for air slicing in UAV-assisted cellular V2X communications
(2023) *IEEE Systems Journal*, 17 (1), pp. 1008-1011.

- Hosseinzadeh, M.
A Q-learning-based smart clustering routing method in flying ad hoc networks
(2024) *Journal of King Saud University - Computer and Information Sciences*, 36 (1).

- Wang, Q., Liu, J., Liu, C., Huang, J., He, C., Xu, Y.
MPRdeep: multi-objective joint optimal node positioning and resource allocation for FANETs with deep reinforcement learning

(2021) *Proceedings - Conference on Local Computer Networks, LCN*, 2021, pp. 315-318. Octob

- Zhang, R., Tang, R., Xu, Y., Shen, X.
  Resource allocation for UAV-assisted NOMA systems with dual connectivity
  (2023) *IEEE Wireless Communications Letters*, 12 (2), pp. 341-345.

- Nahi, H. A.
  A multi-objective optimization for enhancing the efficiency of service in flying ad-hoc network environment
  (2023) *EAI Endorsed Transactions on Scalable Information Systems*, 10 (5), pp. 1-9.

- Li, S.
  Maximizing network throughput in heterogeneous UAV networks
  (2024) *IEEE/ACM Transactions on Networking*, 32 (3), pp. 2128-2142.

- Karthik, K., Balasubramanian, C.
  Improved green anaconda optimization algorithm-based coverage path planning mechanism for heterogeneous unmanned aerial vehicles
  Sustainable Computing: Informatics and Systems, 42, p. 2024.

- Yang, S., Li, T. L., Wu, D., Hu, T., Deng, W., Gong, H.
  Bio-inspired multi-hop clustering algorithm for FANET
  Ad Hoc Networks, 154, p. 2024.

- Grasso, C., Raftopoulos, R., Schembra, G.
  (2022) *Comparison of deep reinforcement learning approaches for FANET optimization*,

- Li, Q., Ding, M., Ma, C., Liu, C., Lin, Z., Liang, Y. C.
  A reinforcement learning based user association algorithm for UAV networ
  (2018) *2018 28th International Telecommunication Networks and Applications Conference, ITNAC 2018*,

- Chen, M., Saad, W., Yin, C.
  Liquid state machine learning for resource and cache management in LTE-U unmanned aerial vehicle (UAV) networks
  (2019) *IEEE Transactions on Wireless Communications*, 18 (3), pp. 1504-1517.

- Yadav, A., Shastri, A., Verma, S.
  Experimental analysis of ACO with modified firefly and modified genetic algorithm for routing in FANETs
  (2023) *Lecture Notes in Electrical Engineering*, 892, pp. 81-87.

- Wang, Z.
  Learning to routing in UAV swarm network: a multi-agent reinforcement learning approach
  (2023) *IEEE Transactions on Vehicular Technology*, 72 (5), pp. 6611-6624.

- Albu-Salih, A. T., Khudhair, H. A.
  ASR-FANET: an adaptive SDN-based routing framework for FANET
  (2021) *International Journal of Electrical and Computer Engineering*, 11 (5), pp. 4403-4412.

- Khurshid, T., Ahmed, W., Rehan, M., Ahmad, R., Alam, M. M., Radwan, A.
  A DRL strategy for optimal resource allocation along with 3D trajectory dynamics in UAV-MEC network
  (2023) *IEEE Access*, 11, pp. 54664-54678.

- Saeed, R. A., Saeed, M. M., Ahmed, Z. E., Hashim, A. H. A.
  Enhancing medical services through machine learning and UAV technology:

applications and benefits
(2024) *Applications of Machine Learning in UAV Networks*, pp. 307-343.

- Ren, Z., Hussain, K., Faheem, M.
K-means online-learning routing protocol (K-MORP) for unmanned aerial vehicles (UAV) adhoc networks
Ad Hoc Networks, 154, p. 2024.
others

- Ahmed, Z. E., Hashim, A. A., Saeed, R. A., Saeed, M. M.
Mobility management enhancement in smart cities using software defined networks
(2023) *Scientific African*, 22.

- Kelner, J. M., Burzynski, W., Stecz, W.
Modeling UAV swarm flight trajectories using rapidly-exploring random tree algorithm
(2024) *Journal of King Saud University - Computer and Information Sciences*, 36 (1).

- Hussain, S., Sami, A., Thasin, A., Saad, R. M. A.
AI-enabled ant-routing protocol to secure communication in flying networks
Applied Computational Intelligence and Soft Computing, 2022, p. 2022.

- Saeed, M. M., Saeed, R. A., Gaid, A. S. A., Mokhtar, R. A., Khalifa, O. O., Ahmed, Z. E.
Attacks detection in 6G wireless networks using machine learning
Proceedings of the 9th International Conference on Computer and Communication Engineering, ICCCE 2023, 2023, pp. 6-11.

- Hosseinzadeh, M.
A novel Q-learning-based routing scheme using an intelligent filtering algorithm for flying ad hoc networks (FANETs)
(2023) *Journal of King Saud University - Computer and Information Sciences*, 35 (10).

- Zheng, Z., Sangaiah, A. K., Wang, T.
Adaptive communication protocols in flying ad-hoc network
(2018) *IEEE Communications Magazine*, 56 (1), pp. 136-142.
Jan

- Zhang, M.
Adaptive routing design for flying ad hoc networks: a joint prediction approach
(2024) *IEEE Transactions on Vehicular Technology*, 73 (2), pp. 2593-2604.

- Huang, Q., Wang, W., Lu, W., Zhao, N., Nallanathan, A., Wang, X.
Resource allocation for multi-cluster NOMA-UAV networks
(2022) *IEEE Transactions on Communications*, 70 (12), pp. 8448-8459.

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