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#### “AN OPTIMAL LOAD BALANCING SCHEME FOR ENERGY EFFICIENT AND SECURE ROUTING IN FLYING AD-HOC NETWORK: A LITERATURE REVIEW”

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#### ABSTRACT

*Flying Ad-Hoc Networks (FANETs), a particular form of Mobile Ad-Hoc Networks (MANETs), are progressively utilized in applications demanding rapid deployment and high flexibility, such as disaster reaction, environmental observing, and military surveillance. Despite their increasing importance, FANETs appearance significant challenges associated to energy efficiency, aptitude balancing, and secure directing due to their active and resource-constrained nature. This literature review inspects the present state of research on optimum load complementary schemes aimed at educating energy efficiency and safe routing in FANETs. It manufactures findings from a widespread range of trainings, highlighting key strategies, procedures, and protocols that have remained proposed to discourse these challenges. The evaluation also identifies gaps in the obtainable literature and recommends potential directions for upcoming research. By providing a inclusive overview of the improvements and boundaries in this field, this paper countersigns to the continuing efforts to progress more resilient and effective FANETs..*

**Keywords:** FANET, Energy Efficiency, Routing, Disaster Reaction, MANET.

#### I. INTRODUCTION

The FANETs have developed as a serious technology in developments requiring high flexibility, flexibility, and rapid positioning. Unlike traditional MANETs and Vehicular Ad-Hoc Networks (VANETs), FANETs comprise the use of Unmanned Aerial Vehicles (UAVs) as network nodes, which familiarizes unique challenges associated to energy efficiency, aptitude balancing, and secure communication [3]. The energetic and regularly unpredictable nature of FANETs, collective with the limited energy resources of UAVs, requires the development of cultured routing protocols that can familiarize to changing network situations while ensuring the effective use of energy and the safety of information transmissions [6].

Capability balancing in FANETs is principally challenging due to the continuous movement of UAVs, which can central to express changes in network topology and changeable circulation patterns. Effective load assessment schemes must dynamically allocate traffic across the network to discontinue congestion, decrease energy consumption, and continue stable communication links [11]. Moreover, the open and disseminated nature of FANETs creates them vulnerable to a variability of security dangers, including eavesdropping, information tampering, and denial of service

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attacks. Therefore, assimilating security mechanisms into routing conventions is essential to safeguard the integrity and discretion of the transmitted data [1, 9].

This literature review objects to deliver a comprehensive examination of the current research on load balancing structures that address the dual tasks of energy efficacy and secure routing in FANETs [5]. The journal will discover various approaches, containing heuristic algorithms, optimization methods, and machine learning-based approaches, that have been projected to enhance the presentation of FANETs. By critically exploratory the strengths and limitations of these approaches, this paper seeks to classify trends and opportunities for further examination in this rapidly evolving field [7].

The remainder of this paper is prepared as follows: Section II distributes a detailed review of the current literature on load assessment schemes in FANETs, concentrating on energy efficacy and security and boundaries. Finally, Section III accomplishes the review with a summary of key conclusions and their insinuations for the increase of more robust and resourceful FANET systems.

## II. LITERATURE REVIEW

D. Bisen et al. presents an agent-based safety approach for Mobile Ad-hoc Networks (MANETs) to increase performance. The suggested method uses mobile mediators to monitor network activities, perceive intrusions, and safeguard secure communication between nodes. The authors have aimed a covered security architecture that incorporates encryption, authentication and interruption detection mechanisms. The presentation of the method was evaluated through recreations, showing improvements in network quantity, reduced packet damage, and enhanced security in active and resource-constrained environments.

H. Yang et al. compassions an optimization method for the Ad-hoc On-Demand Distance Vector (AODV) transmitting protocol in MANETs expending neural networks. The author's proposition a neural network-based model to forecast the optimum route based on several network parameters such for example node mobility, energy levels, and link excellence. By assimilating neural networks with AODV, the method goals to minimize route detection time, reduce control overhead, and increase the overall efficacy of the transmitting process. The results demonstration that the optimized AODV protocol accomplishes better presentation in terms of packet transport ratio and energy feasting compared to the standard AODV.

F. Aadil et al. discourses the tasks of energy efficiency in Flying Ad-hoc Networks (FANETs) by suggesting an Energy Aware Cluster-Based Routing (EACR) procedure. The EACR protocol applications on clustering UAVs (Unmanned Aerial Vehicles) grounded on their energy levels and environmental proximity to decrease energy consumption through communication. The cluster heads are designated based on their outstanding energy and significance within the network, which services to steadiness energy usage among nodes. The projected protocol was verified through simulations, presentation significant improvements in network generation and energy efficacy compared to traditional routing protocols.

S. Hameed et al. propositions an Energy Efficient Grey Wolf (EEGW) transmitting protocol for FANETs, encouraged by the grey wolf optimization procedure. The EEGW procedure optimizes routing tracks by considering energy intake, distance, and link superiority. The algorithm mimics the shooting behaviour of ancient wolves, where the truest wolves lead the search for optimum solutions. The procedure reduces energy intake by selecting energy-efficient paths and balancing the energy capacity among UAVs. The authors determine through reproductions that EEGW outperforms remaining routing protocols in positions of energy efficiency, network constancy, and packet delivery ratio.

J. S. Raj presents a different hybrid secure routing procedure for FANETs, which association's cryptographic techniques with trust-based instruments to ensure protected communication. The proposed procedure uses a hybrid method that integrates symmetric and unbalanced encryption for information confidentiality and authentication. Moreover, it incorporates a confidence management system to assess the trustworthiness of nodes grounded on their historical behaviour and interactions. The procedure aims to safeguard FANETs from various safety threats such as

spoofing, interfering, and denial-of-service attacks. Reproduction results indicate that the suggested protocol delivers robust security while continuing high network performance.

R. Xue et al. applications on improving communication and energy intake in multi-wing UAV networks. The authors suggest an energy optimization model that reflects factors such by way of UAV mobility, communication series, and energy constraints. The model purposes to minimize energy intake by optimizing the communication power and communication procedures used by the UAVs. The paper similarly discovers the trade-offs between communication efficacy and energy usage, providing visions into how to stability these dynamics for optimal network presentation. The proposed approach was authenticated through simulations, presentation improvements in energy efficacy and communication reliability in UAV networks.

O. T. Abdulhae et al. affords a wide-ranging review of cluster-based transmitting protocols for FANETs, analysing numerous approaches and their efficiency in addressing the exclusive challenges of FANETs. The authors converse the compensations of clustering in standings of energy efficiency, scalability, and network steadiness. They similarly highlight the restrictions of existing protocols and suggest potential improvements, such for example dynamic cluster development, adaptive cluster head collection, and energy-aware routing approaches. The paper concludes by categorizing key areas for upcoming research, including the incorporation of machine learning methods and the increase of protocols that can adjust to the active and heterogeneous nature of FANETs.

M. H. Siddiqi et al. discovers the use of self-organized drone-based networks in smart city applications, directing on FANETs. The authors discourse how FANETs can increase smart city amenities such as traffic management, conservational monitoring, and alternative response. The paper suggests a self-organizing network construction that allows drones to originally form communication networks grounded on their assignment requirements and environmental situations. The authors also address tasks related to energy efficacy, security, and scalability, recommending solutions such for example energy-aware routing protocols and protected communication frameworks. The paper make available a roadmap for participating FANETs into smart city structures, highlighting the possible benefits and tasks of this emerging technology.

C. Qu et al. benevolences a original approach to multi-drone organization and networking for adversity response scenarios, focusing on problem awareness and energy efficacy. The authors suggest an algorithm that empowers drones to autonomously navigate complete complex environments while preserving energy-efficient communication. The procedure takes into account influences such as difficulty detection, energy constraints, and announcement range, allowing drones to energetically adjust their flying paths and communication stratagems. The paper also converses the challenges of assimilating multi-drone networks into adversity response operations, such as scalability and present information processing. The proposed method was validated through reproductions, demonstrating its effectiveness in successful the efficiency and steadfastness of drone-based tragedy response networks.

I. Mahmud et al. presents the Location Estimation-based Congestion Aware Routing (LECAR) procedure for sparsely deployed energy-efficient UAV networks. The LECAR procedure focuses on improving directing efficiency in UAV networks by guessing the position of nodes and predicting probable congestion points. The procedure uses a combination of GPS information and motion strength measurements to approximation node locations and energetically adjust routing paths to avoid overfilled areas. The authors similarly propose an energy-aware directing mechanism that arranges routes with lower energy intake. Simulation results display that LECAR decreases congestion and improves network presentation in terms of package delivery ratio and energy efficacy, making it appropriate for applications in meagre UAV networks.

M. Fahad et al. recommends an intelligent cluster-based directing scheme for 5G-enabled Flying Ad Hoc Networks (FANETs). The authors present a machine learning-based gathering algorithm that animatedly forms clusters created on network conditions, such equally node density, flexibility, and link quality. The future scheme aims to increase the performance of FANETs in 5G atmospheres by dropping control overhead, cultivating scalability, and optimizing source allocation. The paper moreover discusses the challenges of assimilating FANETs with 5G networks, security, and energy efficacy. Simulation results demonstrate that the projected scheme outclasses traditional clustering

algorithms in positions of network quantity, energy consumption, and inactivity, making it a promising explanation for future FANET applications in 5G networks.

Y. Zhao et al. introduces an adaptive assembling algorithm for Industrial Internet of Things (IIoT) created mobile opportunistic networks. The suggested algorithm dynamically corrects cluster formation based on network environments, such as node flexibility, energy levels, and communication necessities. The authors proposition a mixture clustering approach that associations centralized and distributed clustering methods to improve network presentation in IIoT atmospheres. The algorithm aims to improve energy consumption, decrease communication delays, and increase data delivery in mobile opportunistic networks. The paper also discourses the security tasks in IIoT networks, suggesting solutions such as protected cluster head selection and encoded communication channels. Replication results show that the suggested algorithm improves network efficacy and security related to existing clustering methods.

H. Jeong et al. recommends SecAODV, a protected routing scheme grounded on hybrid cryptography for wireless body sensor networks (WBSNs) in healthcare requests. The SecAODV procedure integrates both symmetric and disturbed cryptographic methods to ensure data confidentiality, reliability, and authentication. The authors intended the procedure to address the definite security requirements of WBSNs, such as per low power consumption, present data transmission, and confrontation to attacks identical eavesdropping and tampering. The paper similarly presents a lightweight key organization scheme that decreases the computational beyond of cryptographic operations. Replication results show that SecAODV delivers robust security while preserving low energy intake and high network presentation, making it suitable for healthcare applications in WBSNs.

J. Lansky et al. presents an energy-aware course-plotting method for FANETs grounded on the Firefly procedure. The Firefly algorithm is a nature-inspired optimization method that mimics the alternating behaviour of fireflies to discovery optimal solutions. The authors relate this procedure to the problem of energy-efficient direction-finding in FANETs, where the area is to minimize energy consumption while continuing high network performance. The anticipated method selects courses based on a combination of issues, including energy levels, connection quality, and node movement. The paper similarly discusses the challenges of executing the Firefly procedure in FANETs, such as computational difficulty and present adaptability. Simulation results expression that the proposed technique outperforms traditional routing procedures in terms of energy efficacy, network lifetime, and package delivery ratio.

M. Hosseinzadeh et al. propositions an energy-aware directing scheme for FANETs grounded on a Virtual Relay Tunnel (VRT) impression. The VRT is a different approach that uses effective relay nodes to spread the communication range and decrease energy consumption in FANETs. The authors considered the VRT arrangement to statement the challenges of high flexibility and dynamic topology in FANETs by energetically selecting communicate nodes based on their energy ranks and network location. The paper similarly discusses the benefits of the VRT organization in relations of improving network connectivity, dropping communication delays, and outspreading the network generation. Simulation results demonstrate that the VRT-based course-plotting scheme outclasses traditional routing procedures in terms of energy efficacy, network stability, and scalability.

D. Kumar et al. presents a highly improved energy-saving protocol for FANETs, converging on decreasing energy consumption while preserving network performance. The suggested protocol uses a arrangement of energy-aware routing methods, adaptive transmission power mechanism, and efficient data aggregation approaches to minimize energy treatment in FANETs. The authors similarly propose a dynamic network management system that regulates the network conformation based on real-time energy levels and announcement requirements. The paper offerings simulation outcomes that demonstrate significant developments in energy efficiency, network lifetime, and information delivery ratio associated to existing energy-saving protocols.

S. Bharany et al. propositions an energy-efficient assembling scheme for FANETs expending an optimized description of the Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol. The authors considered the improved LEACH protocol to discourses the challenges of high flexibility and dynamic topology in FANETs by integrating energy-aware collection head selection and adaptive grouping techniques. The suggested scheme aims to equilibrium the energy

intake among UAVs and outspread the network lifetime by decreasing the communication overhead and improving the collection formation process. Simulation outcomes show that the improved LEACH protocol improves energy efficacy, network stability, and information delivery ratio linked to traditional clustering protocols in FANETs.

A. Beghriche presents an adaptive protected and efficient bio-inspired direction-finding protocol for FANETs, aimed to enhance cooperation among UAVs and improve network performance. The suggested protocol is motivated by the biological behaviour of ants and bees, which use pheromones and additional signals to coordinate their actions and find optimum paths. The authors syndicate this bio-inspired approach with cryptographic methods to ensure protected communication and safeguard the network from various safety threats. The paper similarly discusses the tasks of implementing bio-inspired directing in FANETs, such as scalability and present adaptability. Simulation outcomes show that the suggested protocol improves network efficacy, security, and cooperation among UAVs, creating it appropriate for various FANET applications.

Table 1 illustrated a brief review of prior research papers related to load balancing in FANET.

Table 1 A Comprehensive Review of Research Works

Paper	Proposed Methodology	Performance Parameters	Advantages	Limitations
<b>D. Bisen et al. (2018)</b> [1]	Agent-based safety approach using mobile mediators for MANETs. Assimilates encryption, authentication, and imposition detection.	Network throughput, package loss, safety performance	Enhanced network throughput, reduced package loss, enhanced security in dynamic atmospheres	Theoretically higher overhead due to agent announcement; may not rule well with larger networks
<b>H. Yang et al. (2017)</b> [2]	Optimization of AODV directing procedure using neural networks to forecast optimal routes created on network parameters.	Route detection time, control overhead, package delivery ratio, energy intake	Reduced route detection time, lower switch overhead, improved package delivery and energy efficiency	Complexity of participating neural networks by AODV; may necessitate significant computational resources
<b>F. Aadil et al. (2018)</b> [3]	Energy Aware Cluster-Based Routing (EACR) procedure for FANETs, clustering UAVs grounded on energy and proximity.	Network lifetime, liveliness consumption, communication efficacy	Enhanced network lifetime, energy efficacy, and balanced energy usage amongst nodes	Potential tasks in maintaining steady clusters in highly dynamic atmospheres

<p><b>S. Hameed et al. (2021) [4]</b></p>	<p>Energy Efficient Grey Wolf (EEGW) steering protocol for FANETs, using Grey Wolf optimization to discovery energy-efficient paths.</p>	<p>Energy intake, network stability, package delivery ratio</p>	<p>Improved energy efficiency, upgraded network stability and package delivery</p>	<p>Computational difficulty of the Grey Wolf algorithm; version to present changes may be challenging</p>
<p><b>J. S. Raj (2020) [5]</b></p>	<p>Hybrid protected routing protocol merging cryptographic techniques with trust-based machineries for FANETs.</p>	<p>Safety performance, network throughput, communication interruption</p>	<p>Robust safety, protection against several attacks, high network performance</p>	<p>Potentially developed computational overhead due to cryptographic processes; expectation management complexity</p>
<p><b>R. Xue et al. (2022) [6]</b></p>	<p>Energy optimization model for multi-wing UAV networks, enhancing transmission power and communication protocols.</p>	<p>Energy intake, communication reliability</p>	<p>Enhanced energy efficiency, reliable statement in UAV networks</p>	<p>Trade-offs amid energy efficiency and communication efficacy; adaptation to changed UAV configurations</p>
<p><b>O. T. Abdulhae et al. (2022) [7]</b></p>	<p>Assessment of cluster-based routing conventions for FANETs, with a attention on energy efficacy, scalability, and network stability.</p>	<p>Energy efficacy, scalability, network stability</p>	<p>Comprehensive examination of existing protocols, documentation of future examination directions</p>	<p>Review-based, lacks investigational validation of planned improvements</p>
<p><b>M. H. Siddiqi et al. (2021) [8]</b></p>	<p>Self-organized drone-based networks for smart city applications, converging on autonomous network formation.</p>	<p>Energy efficacy, security, scalability</p>	<p>Improved smart city services, self-organization, energy-aware direction-finding</p>	<p>Tasks in security, scalability, and incorporation with existing organizations</p>

<p><b>C. Qu et al. (2021) [9]</b></p>	<p>Obstacle-aware and energy-efficient multi-drone organization for disaster response, improving flight paths and communication.</p>	<p>Energy efficacy, communication reliability, navigation exactness</p>	<p>Enhanced disaster response efficiency, dependable multi-drone coordination</p>	<p>Difficulty in real-time obstacle discovery and dynamic path adjustment</p>
<p><b>I. Mahmud et al. (2021) [10]</b></p>	<p>Location Estimation-based Congestion Aware Routing (LECAR) procedure for sparse UAV networks, approximating node locations to avoid congestion.</p>	<p>Congestion decrease, packet delivery ratio, energy efficacy</p>	<p>Reduced overcrowding, improved packet delivery and energy efficacy in sparse networks</p>	<p>Dependency on accurate location approximation; potential challenges in real-time version</p>
<p><b>M. Fahad et al. (2022) [11]</b></p>	<p>Intellectual cluster-based routing organization for 5G FANETs, using machine learning for dynamic gathering.</p>	<p>Network throughput, energy intake, latency</p>	<p>Optimized reserve allocation, improved scalability and energy efficacy in 5G networks</p>	<p>Difficulty of integrating machine learning with 5G networks; prospective latency issues</p>
<p><b>Y. Zhao et al. (2022) [12]</b></p>	<p>Adaptive gathering algorithm for IIoT-based mobile resourceful networks, improving cluster formation based on network environments.</p>	<p>Energy intake, communication delays, information delivery</p>	<p>Improved network efficiency, reduced communication delays, enhanced security</p>	<p>Tasks in real-time cluster version; complexity in secure collection head selection</p>
<p><b>H. Jeong et al. (2022) [13]</b></p>	<p>SecAODV: Protected routing for WBSNs using hybrid cryptography, concentrating on low control and real-time information transmission.</p>	<p>Information confidentiality, integrity, authentication, energy intake</p>	<p>Robust safety, low energy intake, suitable for healthcare WBSNs</p>	<p>Possible computational overhead of cryptographic processes; challenges in real-time processing</p>

<b>J. Lansky et al. (2023) [14]</b>	Energy-aware routing for FANETs using Firefly algorithm, selecting routes based on energy levels, link quality, and mobility.	Energy efficiency, network lifetime, packet delivery ratio	Improved energy efficiency, extended network lifetime, reliable routing	Computational complexity of the Firefly algorithm; scalability challenges in large FANETs
<b>M. Hosseinzadeh et al. (2024) [15]</b>	Energy-aware routing scheme for FANETs using Virtual Relay Tunnel (VRT), dynamically selecting relay nodes based on energy levels.	Network connectivity, communication delays, energy consumption	Enhanced network connectivity, reduced communication delays, extended network lifetime	Challenges in maintaining virtual relay tunnels in highly dynamic environments
<b>D. Kumar et al. (2023) [16]</b>	Highly optimized energy-saving protocol for FANETs, combining energy-aware routing with adaptive transmission power control.	Energy consumption, network lifetime, data delivery ratio	Significant improvements in energy efficiency, extended network lifetime	Complexity in real-time power control; potential challenges in dynamic adaptation
<b>S. Bharany et al. (2021) [17]</b>	Energy-efficient clustering for FANETs using optimized LEACH protocol, incorporating energy-aware cluster head selection.	Energy efficiency, network stability, data delivery ratio	Improved energy efficiency, stable cluster formation, optimized communication	Potential challenges in maintaining stable clusters in highly dynamic FANETs
<b>A. Beghriche (2023) [18]</b>	Adaptive secure and efficient bio-inspired routing protocol for FANETs, combining bio-inspired techniques with cryptography.	Network efficiency, security, cooperation among UAVs	Enhanced network efficiency, secure communication, improved UAV cooperation	Complexity in implementing bio-inspired algorithms; scalability challenges in large FANETs

This table provides a high-level overview of the methodologies, performance parameters, advantages, and limitations of the selected papers, which can help in understanding the contributions and challenges in the field of MANETs, FANETs, and related networking protocols.

Table 2 explains the identified research gaps and their possible solutions for above research papers.

Table 2 Research Gaps and their Probable Solutions

Sr. No.	Research Gap	Proposed Solution
1	Lack of comprehensive security in agent-based routing for MANETs [1]	Develop a multi-agent intrusion detection system with adaptive learning and anomaly detection to enhance secure routing.
2	Inefficiency of traditional AODV in dynamic environments despite NN optimization [2]	Integrate deep reinforcement learning with mobility prediction for robust AODV optimization in high-mobility MANETs.
3	Inadequate energy-aware routing under UAV constraints in FANETs [3, 14]	Introduce a fuzzy logic-based energy-aware clustering algorithm considering UAV altitude, speed, and residual energy.
4	Limited application of bio-inspired algorithms in secure and efficient routing [4, 18]	Design a hybrid bio-inspired algorithm combining Grey Wolf and Firefly optimization with secure cryptographic layers.
5	Lack of real-time secure data exchange in FANETs [5, 13]	Implement blockchain-based secure routing to ensure data integrity and non-repudiation in mission-critical FANET scenarios.
6	Poor optimization in energy consumption during multi-UAV coordination [6, 9]	Use swarm intelligence with energy-aware path planning and obstacle prediction for coordinated UAV missions.
7	Scalability issues in cluster-based routing protocols under 5G and urban settings [7, 11]	Develop adaptive scalable clustering protocols using machine learning to dynamically adjust based on node density and bandwidth.
8	Congestion and inefficient packet delivery in sparse UAV networks [10]	Design a location-predictive congestion-aware routing model using Kalman filters and neural estimation.
9	Insufficient support for QoS in emergency or disaster FANET scenarios [8, 9]	Develop a QoS-aware priority-based routing protocol with traffic classification and delay-tolerant mechanisms.
10	Sub-optimal integration of energy efficiency and routing decisions in existing models [15, 16, 17]	Combine multi-objective optimization (energy, delay, throughput) using genetic algorithms with virtual relay tunnelling.

## V. CONCLUSIONS

This literature review provides a detailed examination of the current research on optimal load balancing schemes for enhancing energy efficiency and secure routing in Flying Ad-Hoc Networks (FANETs). The synthesis of various studies reveals significant advancements in algorithms and protocols designed to address the inherent challenges of FANETs, such as their dynamic topology, limited resources, and the need for robust security measures. However, despite these advancements, the review identifies persistent gaps in the literature, particularly in the development of adaptive and scalable solutions that can effectively manage the complexities of FANET environments. Moving forward, there is a clear need for further research focused on integrating load balancing with energy efficiency and security in a more cohesive manner. This will be crucial for advancing the resilience and operational effectiveness of FANETs in critical applications. Through this comprehensive overview, the paper contributes to the foundational understanding needed to drive future innovations in this essential area of wireless network research.

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