Flying Ad-Hoc Networks (FANETs): Review of Communications, Challenges, Applications, Future direction and Open Research Topics

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Abstract Advancements in the fields of electronics, sensors, and communication systems has enabled the development of small unmanned aerial vehicles (UAVs) for various military, commercial, and civilian purposes. Nevertheless, the capacity of a solitary and diminutive UAV is insufficient. The utilization of several unmanned aerial vehicles (UAVs) can surpass the constraints imposed by a single small UAV, hence creating a more advanced system. A flying ad hoc network (FANET) is a network composed of a collection of small unmanned aerial vehicles (UAVs) that are interconnected in an ad hoc manner. These UAVs work together as a team to accomplish complex objectives. FANETs are characterized by their mobility, lack of centralized control, and self-organization, and an ad hoc nature among UAVs. These traits enable FANETs to enhance connections, extend communication range in areas without infrastructure. On the other hand, FANETs can be utilized in situations where regular communication infrastructure is unavailable, offering a swiftly deployable, adaptable, self-configurable, and cost-effective network. However, connecting aerial vehicles (UAVs) in a spontaneous network poses a significant challenge. To ensure resilient communication it is crucial to have the communication framework and routing protocols that can adapt to the constant movement of these flying nodes. This essay aims to offer an understanding of the communication technologies by exploring aspects, like Data rate, the spectrum type, coverage, and latency are the key factors to consider. Furthermore, this paper investigates the practicality and feasibility of enabling technologies. Additionally, it addresses the problems, unexplored territories, and future directions to enhance the research work.

1 Introduction

Unmanned Aerial Vehicles (UAVs), also known as drones, are being extensively utilized for wireless communication purposes. Either a person on the ground or on-board

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computers can operate these drones autonomously. Unmanned Aerial Vehicles (UAVs) are utilized for a wide array of missions, encompassing both military operations and agricultural uses. A flying ad hoc network (FANET) of UAVs can be established by utilizing a cluster of airborne UAVs [6]. FANET refers to a group of mobile drones that continuously modify their network structure without relying on any permanent infrastructure. These drones communicate with a central base station from various altitudes, as illustrated in Figure 1 [2]. The categorization of UAVs used in different FANET scenarios can be determined by various factors, including size, range weight, endurance, altitude, application, flying mechanism, ownership, airspace class, level of control (autonomy), and type of engine [6]. In order to establish communication between drones, it is necessary to utilize an IEEE 802.11 wireless adapter capable of transmitting on many frequencies, including the 2.4 GHz, 5 GHz, and 6 GHz frequency bands. The Wireless Fidelity (WiFi) Alliance employed a numbering system to designate different generations of WiFi protocols, namely 802.11b, 802.11a, 802.11g, 802.11n, 802.11ac, and 802.11ax. Some of these versions have the capability to operate on both the 2.4 GHz and 5 GHz frequency bands simultaneously [1].

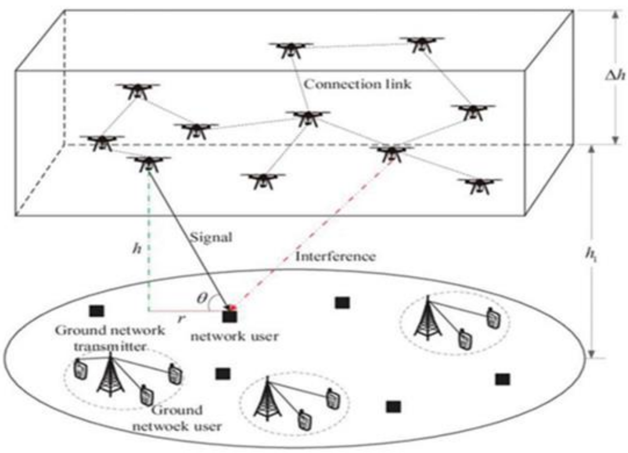

Fig.1 Flying ad hoc networks.

Table1. Shows the list of WIFI 802.11n standards

IEEE standard	Frequency/ medium	Speed	Transmission range
802.11	2.4 GHz RF	1-2 Mbps	20 feet
802.11a	5 GHz	Up to 54 Mbps	25—75 feet; range can be affected by building materials
802.11b	2.4 GHz	Up to 11 Mbps	Up to 150 feet; range can be affected by building materials
802.11g	2.4 GHz	Up to 54 Mbps	Up to 150 feet; range can be affected by building materials.
802 11n	2.4 GHz/5 GHz	Up to 600 Mbps	175+feet; range can be affected by building materials
802.11ac	5 GHz	Up to 600 Mbps	175+feet; range can be affected by building materials

Various forms of mobile networks exist, including ad hoc networks, mobile ad hoc networks (MANET), vehicular ad hoc networks (VANET), and flying ad hoc networks (FANET).

These networks employ distinct routing protocols to facilitate communication, given their frequent changes in topology. These networks exhibit high levels of mobility, a dynamic arrangement of connections, and a restricted range of communication. They differ from VANETs and MANETs in their ability to move in three dimensions [6]. Unmanned aerial vehicles UAVs are slowly becoming more popular and acknowledged for their multiple purposes in different sectors like surveillance, agriculture medicine traffic management inspections public security [2]. This paper is a review to provide the reader with an in-depth overview of FANET network communication, application and limitations trying to elucidate issues related to connecting many UAVs within ad hoc networks. Since FANETs are dynamic and decentralized in nature, their setting up requires a large level of coordination due to the complexity involved.

2 Background and Evolution of FANETs

2.1 Historical Development Of FANETs

Historical background of Flying Ad hoc Networks (FANETs) cannot be underestimated when discussing the scope of issues in the field of Ad-Hoc networks . 2010 Song and Huang published a brief overview of the key technologies and challenges in UAV Ad-Hoc networks, addressing advances made with communications networks for flying machines .Zhao Braun, A survey on Topology control They conveyed about the recent strategies related to connectivity, coverage and tasking in FANETs [4]. The features of FANETs are unique in that it is autonomously arranged, nodes communicate and collaborate with each other without a centralized infrastructure; instead the use of intermediary UAVS for multi-hop communication with ground controller. The Fountain-code based Greedy Position Assisted (FGPA) is a routing strategy that could enhance the dependability of communication in FANETs. In this scheme, UAVs are used as relay nodes hops of the data packet up to its destination base station. The proposed Greedy Position Assisted (FGPA) routing strategy based on the Fountain-code could be a solution for enhancing communication reliability and assurance of high reliable service delivery in terms of data. UAVs act as intermediaries in the context of FPGAs Field-Programmable Gate Arrays , they transmit recorded messages sequentially to subsequent most suitable Unmanned Aerial Vehicle until a designated destination base station receives successfully the data packet[5]. The evolution of FANETs in the history has been developed that entails conveying its weird communication requirements for future systems and coming out with better improvements on communicating reliability achievements within these networks[3].

2.2 Key Technological Advancements And Their Impact

Fountain code based Greedy Position Assisted (FGPA) routing is a proposal to enhance communication reliability and ensure data delivery in Flying Ad hoc Networks , FANETs have characteristics such as self organization , communication and cooperation between nodes without a centralized infrastructure and the usage of UAVs for multi hop communication with the ground controller however The development of FANETs has involved exploring networking problems key technologies and challenges in UAV Ad Hoc networks It has also included studying topology control and mobility strategies for connectivity , coverage and flocking in FANETs also The historical progress of FANETs has focused on addressing the communication needs of FANET applications while enhancing the reliability and efficiency of communication within these networks [5], Mobility models play a role in simulating FANETs and evaluating network performance prior to deployment ,

Existing mobility models for FANET simulations can be categorized into five classes include randomized, time path planned, group based and hybrid models moreover Trajectory optimization is an aspect of FANETs as it allows adjustment, to changing environments It involves planning of UAV trajectories to meet application requirements while optimizing network performance.
Many methods and algorithms have been suggested for both dynamic deployment scenarios in order to take into account factors like coverage , throughput , energy usage and UAVs with cache capabilities [4].

3 Literature Review

This review consolidates various studies related to Flying Ad-Hoc Networks (FANETs), a dynamic and rapidly evolving area of research within wireless communication networks. FANETs are distinguished by their unique characteristics—high mobility, variable topology, and limited energy resources, which pose specific challenges in terms of communication and routing protocols. The studies featured in this review explore diverse approaches to optimizing routing algorithms, enhancing network performance, and integrating emerging technologies within FANETs. By examining the methodologies and findings of recent research, this review aims to highlight the advancements, pinpoint ongoing challenges, and identify future directions in the development and application of FANETs. The following table provides a summary of key studies, outlining their contributions and the focus areas they address.

Table 2. Related work

Author	Year	Key Insight	Methodology	Core Focus
[10]	2019	Examines FANET routing protocols highlighting dynamic topology and node mobility.	Literature Review	Routing Protocols, Mobility, Network Scalability
[9]	2023	Introduces GPSR+, enhancing adaptability and longevity by selecting stable UAVs for routing.	Simulation, Position Prediction	Routing Stability, Network Performance
[6]	2022	Proposes a particle swarm optimization-based algorithm for dynamic threat adaptation and connectivity maintenance.	Particle Swarm Optimization	Threat Management, Network Connectivity
[12]	2023	Reviews over 170 studies, integrating AI, VR, IoT technologies in FANETs, outlining challenges and ML solutions.	Systematic Review	Technology Integration, ML Solutions, Security
[8]	2021	Describes SPA, a new packet forwarding algorithm that improves various network performance metrics.	Simulation, Mathematical Modeling	Packet Forwarding, Network Performance Metrics
[13]	2022	Discusses routing protocol using LSTM models to optimize routes based on UAV traffic prediction.	Simulation, LSTM Models	Routing Optimization, Traffic Prediction
[1]	2021	Proposes an SDN-based routing framework to improve packet delivery and reduce delays.	Simulation, SDN	SDN, Routing Efficiency, Packet Delivery
[7]	2022	Surveys 21 cluster-based routing protocols assessing performance	Survey, Comparative Analysis	Cluster-Based Routing, Performance, Scalability

		and scalability in FANET environments.		
[4]	2019	Reviews communication challenges, mobility models, and security in FANETs, emphasizing robust systems for dynamic UAV interactions.	Literature Review	Communication Systems, Security, Mobility Models
[5]	2018	Explores characteristics distinguishing FANETs from other networks, focusing on mobility, topology changes, and energy needs.	Literature Review, Model Evaluation	Network Characteristics, Energy Efficiency
[3]	2013	Surveys the fundamentals of FANETs, highlighting rapid topology changes and communication protocol challenges.	Literature Review, Comparative Analysis	Design Challenges, Communication Protocols
[11]	2023	Discusses the adaptation of LoRa technology in FANETs for enhanced communication and mobility.	Systematic Literature Review	LoRa Technology, Energy Efficiency, MAC Protocols
[2]	2023	Analyzes bio-inspired routing algorithms' suitability for dynamic FANET environments.	Simulation, Position Prediction Strategy, Spherical Removal Technique	Routing, Data Transmission Reliability, Network Longevity, UAV Position Prediction

4 Technical Aspects of FANETs

4.1 Architecture And Design Of FANETs.

FANETs, Flying Ad Hoc Networks are widely recognized for their communication architectures these networks make use of vehicles (UAVs) to establish fast communication setups . There have been three proposed architectures, for FANETs, one of which includes a UAV ad hoc network layer. When designing FANETs it is crucial to consider factors like UAV mobility, frequent changes in network topology and three dimensional movement. To ensure communication among UAVs routing protocols such as Geographic Position Mobility Oriented Routing (GPMOR) and Multilevel Hierarchical Routing (MLH) play a role [5]. The architecture of FANETs allows for real time ad hoc communication without the reliance on infrastructure, which helps overcome communication range limitations. It proves valuable in scenarios where establishing infrastructure poses challenges. Given the connections and disconnections of UAVs ad hoc networks, within FANETs often serve as a solution.

Various communication architectures have been proposed for FANETs to cater to needs and applications. FANETs consist of UAVs and ground base stations (GBS), with selected UAVs acting as gateways to extend network coverage. The specific setup varies depending on types of communication, network organizations, and application-specific requirements. Figure 2 [4].

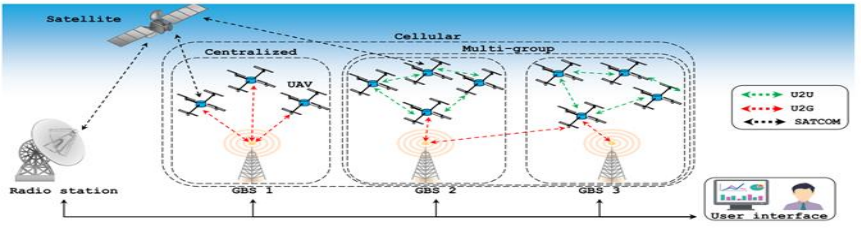

Fig. 2 FANET architecture.

4.2 Communication Used In FANETs

4.2.1 Routing Protocol

In the context of FANET (Flying Ad-Hoc Networks), various routing protocols on the network layer are defined, each tailored to specific network needs. The classification of FANET routing protocols is illustrated in Figure 2 [4] and further examined.
Position-based Routing (Figure 3, Box A): These protocols use GPS for geographical node information. Nodes calculate dynamic forwarding delay (DFD) using local position data and sequentially transmit packets. The node closest to the destination with the minimal DFD becomes the next forwarding node.
Topology-based Routing (Figure 3, Box B): This method involves hop-by-hop routing using network structure and link status information, like IP addresses. It includes static, proactive, reactive, or hybrid protocols, with the three primary DTN-based protocols for FANETs being deterministic, social, and random.
Delay Tolerant Network (DTN) Routing (Figure 3, Box C): DTN involves mobile nodes that connect sporadically. Due to high latency and low data rates, specific routing protocols are developed for DTN characteristics. The primary DTN-based protocols for FANETs are deterministic, social, and random.
Heterogeneous Routing (Figure 3, Box D): FANETs interact with various terrestrial networks like VANETs, MANETs, or fixed nodes. Heterogeneous routing protocols facilitate data exchange among mobile and fixed nodes, providing subnet support for land nodes and drones.
Cluster-based Routing (Figure 3, Box E): This technique groups nodes with similar properties into clusters, each led by a master node. Cluster-based routing in FANETs falls into probabilistic and deterministic classifications.
Swarm-based Routing (Figure 3, Box F): Inspired by the social behaviors of fish, birds, and insects, this method manages paths and topologies efficiently. The choice of routing protocol depends on factors like routing approach, mobile visualization, simulation, and performance evaluation tools.
Drone routing protocols are in their early development stages, with reactive and proactive approaches showing promise in dynamic FANETs [3]

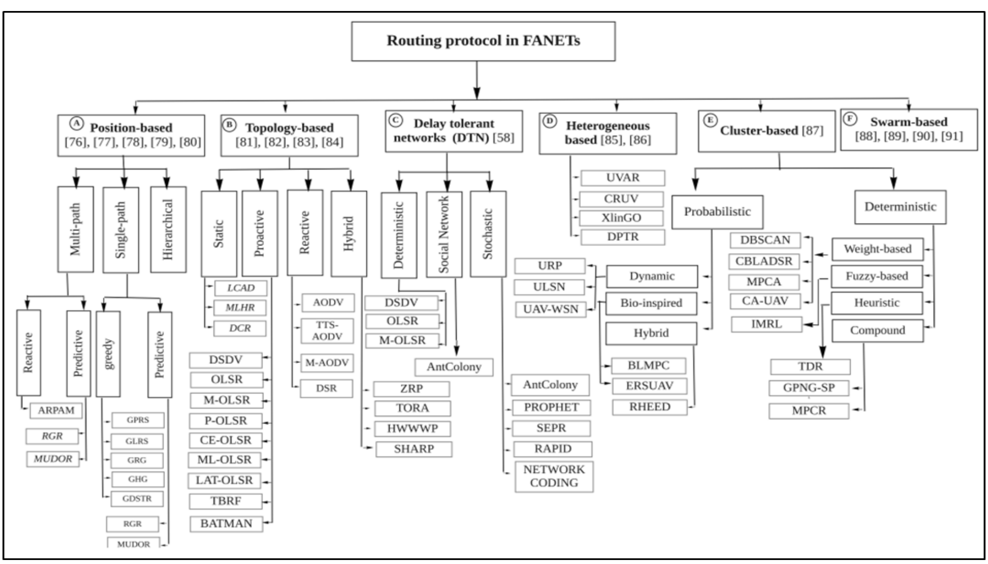

Fig3 FANET Routing Protocols

4.2.2 Communication Protocol

Communication protocols in Flying Ad-Hoc Networks (FANETs) play a crucial role in ensuring efficient and reliable data transmission. These protocols are characterized as follows:
Changes to Routing Protocols: Protocols from Mobile Ad-hoc Networks (MANETs) and Vehicular Ad-hoc Networks (VANETs) have been changed to work with FANETs because UAVs have unique features like quick changes in link quality and fast 3D movement that make using MANET and VANET protocols directly inappropriate.
Classification of Protocols [3]: FANET protocols are categorized into several types: static protocols with fixed routing tables, proactive protocols with periodically updated tables, reactive or on-demand protocols, hybrid (proactive-reactive) protocols, position/geographic-based protocols, and hierarchical protocols.
Communication Technologies [4]: Depending on application needs, various wireless technologies are used, such as IEEE 802.11 (Wi-Fi), IEEE 802.15.4, infrared, LTE, advanced LTE, CDMA, TDMA, GPRS, GSM, and IEEE 802.16 (WiMAX) OFDMA, particularly for communication with cellular infrastructure.
Networking Technologies (Noor et al., 2020): Wi-Fi (IEEE 802.11), ZigBee (IEEE 802.15.4), and Bluetooth (IEEE 802.15.1) are used independently to establish FANET systems, especially in areas without existing networks or where installation is challenging.
Communication Architecture [4]: This includes UAV communication architectures, routing and MAC protocols, mission-oriented communication, considerations for frequency and technology in the network, and defining information flow between Ground Control Stations (GCS) and UAVs. Finding solutions for the challenges and limitations in designing routing protocol for FANETs is an area of research where Researchers are actively working on addressing these issues and constraints [2], When it comes to choosing a communication protocol for FANETs in scenarios such as sensing or wildfire management there are factors that need to be considered. These factors include support for mobility, latency, data rate, transmission range and UAV capacity. All of these factors play a role, in the decision-making process.

4.3 Comparing FANET with other unstructured networks

FANETs possess qualities that differentiate them from other network types such as MANETs and VANETs , MANET or Mobile Ad hoc Network refers to a network where mobile devices communicate with each other without relying on an infrastructure on the other hand VANETs or Vehicular ad hoc networks represent a type of MANET where the mobile nodes are vehicles and communication occurs between vehicles as well as between vehicles and roadside units (RSUs) However VANETs are considered state of the art technology that aims to enhance safety and convenience for drivers on the road [3],[6] FANETs display characteristics that distinguish them from other networks. These distinctions can be outlined in aspects:
1. Mobility and Spatial Freedom; FANET nodes and unmanned aerial vehicles (UAVs) have mobility levels and 3D spatial freedom compared to the 2D mobility observed in MANETs and VANETS. The distinctive movement patterns of UAVs in FANETS lead to topology changes that differ from those seen in MANETS or VANETS.
2. Energy and Computing Power; In MANETS nodes primarily rely on battery power, with computing capabilities. On the hand FANET unmanned aerial vehicles utilize their energy sources to enhance their communication abilities resulting in computing capabilities.
When comparing MANETs, to VANETs and FANETs it is generally observed that both VANETs and FANETs support devices with functionalities.

In terms of density and radio propagation FANETs typically have a density of nodes covering a wider spatial area. They heavily rely on line of sight (LoS) communication, which's different from the line of sight (NLoS) propagation commonly seen in MANETs and VANETs.
Security and routing protocols pose challenges in FANETs due to their nature. Designing protocols that can effectively differentiate between link failures and malicious activities becomes crucial due to the mobility. Sparse node density. Additionally, there may be variations in deployment costs and ease of implementing security mechanisms.
Accurate localization is crucial in FANETs due to their mobility and the models used to predict signal propagation losses differ in FANETs compared to MANETs or VANETs because of the line of sight conditions encountered during UAV operations also resource Quality of Service (QoS) poses challenges in FANETs due to their dynamic 3D mobility patterns and limited energy resources however routing schemes commonly employed in MANETs or VANETs can still be applicable Furthermore managing resources while considering the sensors used by UAVs and meeting their quality of service (QoS) requirements presents challenges for network scheduling and administration in FANETs.

Table 3. Compression of (FANET, VANET, MANET)

Criteria	FANET	VANET	MANET
Node Mobility	High compactness	Medium compactness	Low compactness
Mobility Model	Usually predetermined but special models for independent multi-UAV systems	Steady	Arbitrary
Node Density	Low thickness	Medium thickness	Low thickness
Topology Change	Rapid and speedy	Average speed	Slow and steady
Radio Propagation Model	High above the ground level, LoS accessible for most cases	Close to ground, LoS not always accessible	Very close to ground, LoS not accessible
Power Consumption	Needed for mini UAVs, not for small UAVs	-	Need of energy efficient protocols
Computational Power	Very big	Average	Limited
Localization	GPS, AGPS, DGPS, IMU	GPS, AGPS, DGPS	GPS

5 Applications of FANETs

Flying Ad Hoc Networks (FANETs) are being increasingly used in fields offering advantages and facing specific challenges in each application [1].
Military Operations: FANETs enhance communication in crisis management, border surveillance, and search and destroy missions. They provide a communication network when traditional infrastructure is compromised, FANETs can be quickly Self-configured to connect with rescue teams during disaster management.
Environmental Monitoring: FANETs play a role in applications such as wildfire management and wind estimation by enabling real-time data collection and sharing due to their mobility and flexibility make it easier to cover areas efficiently and improving environmental monitoring processes and decision-making.
Disaster management plays a role, in dealing with crisis situations. In scenarios, search and rescue operations and the use of damaged network systems (FANETs) are vital moreover they not enable real time data sharing and situational awareness. Also assist in making critical decisions during emergencies [6].
FANETs also have applications in traffic monitoring, Unmanned aerial vehicles (UAVs) within FANETs contribute by providing observations of crop conditions and aiding in traffic

analysis for flow management. However it's important to note that effectively operating and maintaining UAVs over areas is essential for these applications. When it comes to search and rescue operations FANETs prove their worth by facilitating target detection efforts and aiding in rescue missions. Ensuring a connection for real time communication is the challenge that needs to be addressed. Additionally FANETs find applications, in healthcare, traffic control and public safety fields. They have the ability to quickly adapt to changing needs within these domains. However, there are challenges associated with ensuring network stability and coverage across environments.

6 Challenges And Open Issues

The study of FANETs is still in its early stages. A UAV network, functioning as a flying platform, has the potential to enhance and provide additional services. Below are some open research topics that provide additional suggestions for further study.
Aerial blockchain is a promising trend for enhancing privacy In UAV communication networks, which are enabled by 5G, B5G and 6G technologies [2]. Assurance of data collected by UAVs can be achieved by the implementation of an aerial blockchain methodology. This method guarantees the preservation of data accuracy and protection against weaknesses in cybersecurity. Utilizing blockchain technology, the process of software development for unmanned aerial vehicles (UAVs) can be made more adaptable, responsive, and capable of making real-time decisions. Although there has been significant research conducted on blockchain technology in UAV networks, the exploration of blockchain-enabled network softwarization has not been undertaken by researchers thus far..
Deep Reinforcement learning that involves complex and intricate processes Cellular technology plays a crucial role in enabling high-speed data transmission services for to the swarm of UAVs in the sky [2]. However, it also presents obstacles, such as the need to support mobility Deep reinforcement learning methods can be employed to dynamically improve handover decisions in order to maintain stable communication. Furthermore, deep-reinforcement learning techniques can be employed to determine the most optimal approach for evading collisions during real-time course planning and navigation.
Technologies for the extraction of energy the restricted battery capacity and weight limitations, along with the short length of flight for unmanned aerial vehicles (UAVs), continue to be significant obstacles inhibiting the widespread use of Flying Ad-Hoc Networks (FANETs) in various applications.Utilizing energy collecting devices to charge UAVs can effectively address the issue of limited flight endurance.
Integrating Unmanned Aerial Vehicles (UAVs) into 5G Networks involves virtualization, allowing them to access cloud computing, web technologies, and service-oriented infrastructures available on the Internet. This integration would facilitate the creation of sophisticated Internet of Things (IoT) applications. UAV resources can be virtualized and integrated into a Interconnected environment with additional network resources using same configurations. Therefore, it is crucial to develop efficient methods for virtualizing UAV-enabled 5G networks.
Implementing FANET networks for practical civil applications encounters numerous obstacles and concerns. UAV networks exhibit distinctions from conventional Ad-Hoc networks such as MANETs and VANETs, however they nevertheless adhere to the fundamental concept of mobile nodes networking in an Ad-Hoc fashion. There are unresolved problems in communication, security, and mobility models that still need to be addressed in order to enhance efficiency [3].

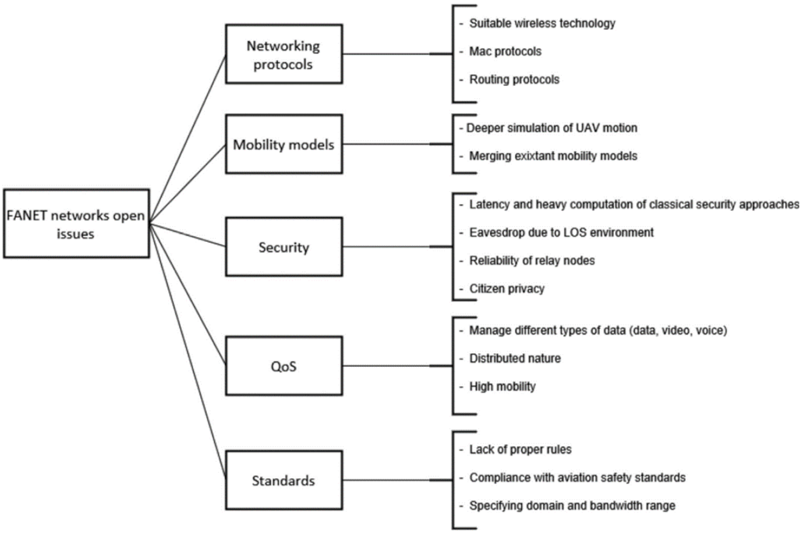

Fig. 4 FANET Open Issues.

Selecting the appropriate networking protocol is a crucial concern in FANET, as it relies on the characteristics of application domains, the size of the area, and the density of UAVs. In order to develop effective networking protocols, it is advisable to do more research by modifying existing protocols for UAV networks through the utilization of Cognitive Radio technology. (CR)[4].

It is possible to enhance mobility models by incorporating seamless characteristics to represent particular flight behaviors or integrating them with current models to replicate the movement of unmanned aerial vehicles (UAVs) in a realistic setting. The significance of data sharing and security arises from the presence of latencies and intensive calculations, as well as the distinct attributes of UAV networks, which have a higher susceptibility to eavesdropping compared to MANET or VANET. The security of FANET is directly impacted by the dependability of relay nodes, thus necessitating the establishment of a way to authenticate their reliability.

Before granting UAVs access to national airspace, it is crucial to address the matter of safeguarding citizen privacy. Prior to commercializing unmanned aerial vehicles (UAVs) for civilian tasks, it is imperative to safeguard individuals' privacy. Ensuring high Quality of Service (QoS) is a crucial concern in FANET due to the transportation of many types of data, including simple data, video, and time-sensitive data such as real-time audio. Establishing a complete framework to support Quality of Service (QoS) is challenging because of the decentralized structure of FANET and its significant mobility. The absence of adequate norms and regulations for UAVs is a critical obstacle to their commercialization for civilian applications. Aviation safety standards must comply with FANET standards, and organizations like ISO/TC 20/SC 16, ANSI, ASTM International, EUROCONTROL, and JAA aim to standardize FANET. Figure 4 provides a concise overview of the several unresolved matters related to FANET networks.

7 Future Research Directions

Based on the comprehensive review of existing literature on Flying Ad-Hoc Networks (FANETs), several key areas have been identified where further research could significantly advance the field. These include:

Advanced Routing Protocols: Future studies should focus on developing adaptive, scalable routing protocols that leverage machine learning techniques. Such protocols would ideally predict and dynamically adjust to changes, enhancing resilience in high-mobility environments characteristic of FANETs.
Technology Integration: There is a critical need for frameworks that integrate FANETs with emerging technologies such as the Internet of Things (IoT), artificial intelligence (AI), and machine learning (ML). These integrated frameworks could potentially enhance network efficiency and support sophisticated applications like disaster management and urban planning.
Security Improvements: As FANET applications expand into critical areas, addressing security and privacy concerns becomes increasingly important. Future research should aim to develop robust security protocols that ensure data integrity and confidentiality across complex multi-layer networks.
Energy Efficiency: Given the limited energy resources available to UAVs, enhancing energy efficiency is crucial. Future directions should include the development of energy-efficient routing protocols and the exploration of renewable energy sources to extend the operational lifespan of UAVs within FANETs.
Standards and Interoperability: Establishing standards for interoperability is essential to ensure seamless communication and integration between different UAV systems and other types of networks. Future studies should focus on developing universal communication protocols and hardware interfaces.
Empirical Research: Transitioning from theoretical and simulation-based studies to empirical, real-world testing is necessary to validate models and gather practical insights that could lead to more robust FANET designs.
Network Management: There is an opportunity to explore advanced network management systems capable of efficiently handling large numbers of UAVs in diverse operational scenarios. Such systems are essential for maintaining robust performance in FANETs.
Each of these areas represents a significant opportunity for research that builds upon the existing knowledge base, addressing the gaps and challenges identified in the reviewed studies. By focusing on these directions, researchers can contribute to the development of more practical, efficient, and secure FANETs.

8 Conclusion

In recent years, there has been a noticeable observation of the evolving roles and capacities of UAVs. Therefore, FANET networks are gaining significance and assuming an increasingly crucial role in several operational domains, including a wide array of applications and complex missions. Hence, establishing a reliable connection between the UAVs and the Ground Control Station (GCS) as well as other users poses a significant challenge. Undoubtedly, communication is a vital design concern for FANET networks, encompassing routing protocols, QoS, and mission-oriented requirements. Aside from communication challenges, there are several other issues that must be resolved in FANET. These include the need for accurate mobility models to simulate the UAVs' environment realistically, addressing security concerns to ensure the secure sharing of data among all FANET members, and the absence of standardized protocols in FANET. This study addresses all the aforementioned concerns. Initially, we reviewed the distinct attributes of UAV, and FANET networks. An overview of the current FANET surveys is conducted. The communication challenges and requirements are resolved, as well as the potential security mechanisms employed in FANET. Lastly, unresolved matters and difficulties are presented. To ensure effective and secure communication networks with lengthy Optimal flight durations and lowest transmission delays for different real-time applications, it is necessary to achieve a precise combination of communication technologies, security systems, and energy harvesting methods. Hence, The paper extensively investigated key facilitating technologies, applications, obstacles, and areas of research that remain to be explored.

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