SECURE AND ENHANCED GPMOR PROTOCOL USING FIREFLY ALGORITHM TO MANAGE LOAD BALANCING SCHEME IN FANETS

Thesis Submitted for the Award of the Degree of

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Computer Science and Engineering

By

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DECLARATION

I declare that the thesis entitled “Secure and Enhanced GPMOR Protocol Using Firefly Algorithm to Manage Load Balancing Scheme in FANETs” has been prepared by me under the guidance of Dr. Deepak Prashar, Associate Professor, Department of Computer Science and Engineering, Lovely Professional University, India. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

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CERTIFICATE

This is to certify that the thesis entitled “Secure and Enhanced GPMOR Protocol Using Firefly Algorithm to Manage Load Balancing Scheme in FANETs”, which is being submitted by Ms. Manjit Kaur for the award of the degree of Doctor of Philosophy in Computer Science and Engineering from the School of Computer Science and Engineering, Lovely Professional University, Punjab, India, is entirely based on the work carried out by her under my supervision and guidance. The work reported embodies the original work of the candidate and has not been submitted to any other university or institution for the award of any degree or diploma to the best of my knowledge.

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ABSTRACT

Flying Ad-hoc Network (FANET) is a new form of Mobile Ad-hoc Network (MANET). FANETs are usually formed by Unmanned Aerial Vehicles (UAVs). UAVs are small autonomous drones. UAVs can be controlled remotely. UAVs have been used in many fields such as militaries, agriculture, medical, photography, environmental applications, and many more. In the beginning, UAVs have been used by the military only for surveillance and rescue operations. Nowadays, with the advancement of technology, UAVs have been extremely used in every field for different activities such as goods shipping and delivery, soil analysis, crop monitoring, etc. The primary concerns of such ad-hoc networks are bandwidth, highly dynamic topology due to node mobility, computational power, power consumption, and radio propagation model.

The thesis focuses on a particular type of ad-hoc network: Flying Ad-hoc Networks (FANETs). These networks consist of multiple UAVs. FANET is a special case of the traditional peer-to-peer ad-hoc network. It is the sub-category of Mobile Ad-hoc Network. FANET is only valid for multiple UAVs, but not all multiple UAVs are FANETs. The combination of UAVs and ground base station is called FANET. UAVs are the component of an unmanned aircraft system, which include a UAV, a ground-based controller, and a system of communication between both. FANET completed its work with driverless aircraft. UAV is a type of air vehicle that does not have a person on a platform, is driven by a jet or rotary engine, and can be commanded remotely or trained to fly independently using pre-determined flight data. In just the last few years, the implementation strategy for UAVs has shifted from particular military purposes to the civilian realm. An ad-hoc system is an integration without a communication system that each node is dynamic and therefore can move from one location to another within the network’s communication range. UAV networks have progressively gained popularity UAV networks are now getting evaluated as futuristic wireless technologies due to their instant implementation and versatility. The main

cause for this is the relatively inexpensive and widespread accessibility of UAV gadgets. Due to the extreme continuous development of innovative products like Internet - Connected devices, sensor systems, integrated computing devices, reduced Wi-Fi broadcast connections, and global navigation systems, UAVs can be utilized in a variety of defense and commercial applications. Earlier, UAVs were limited to their use for military purposes only however, they have pretty recently been used to optimize the performance of wireless sensor networks in a variety of applications, including surveillance, traffic-related network monitoring, forest fires management, geospatial, agriculture, rescue operations, disaster response, and route optimization

Here, the communication between these entities should be done in an ad-hoc manner. FANETs expand their applications in various domains such as soil monitoring, crop monitoring, water, underwater, mountain inspection, air quality monitoring in environment sectors, spying, surveillance at the border, missile launching, bomb-dropping, war-zone medical supply, combat aircraft in defense sectors, mining, delivery, agriculture, construction, photography, videography, surveillance, logistic, disaster management in civil sectors.

However, different levels of communications are used in the network. In FANET, different features are required for different applications. Several essential issues prevail in ad-hoc networks. Many aspects, including performance, energy efficiency, scalability, power consumption, and network topology, can influence the complexity of an ad-hoc network. Even in FANETs, load balancing is a critical issue. Load balancing is one of the most important concerns in such networks because most of the applications of ad-hoc networks depend upon knowing the location of flying nodes. For the good suit with distinctive characteristics of flying ad-hoc networks, some approaches estimate the location of flying nodes without measuring the distance directly. These approaches are categories as load balancing which is popular on the diversified domains of ad-hoc networks for its ease of applicability.

The objective of the thesis work is to propose an algorithm to evaluate the optimal route for sending data from various sources of multiple UAVs. To implement the proposed optimization technique for load balancing. To design a secure approach for the detection of malicious UAVs in FANETs. It is desirable for an ad-hoc network that the process of load balancing should deliberate and effective distribution of

network or application traffic among multi-UAVs so that the overall network lifetime can be improved. Moreover, another concern with such a load balancing process is to potentially secure the useful flying nodes by applying adequate security services. It is performed with the combination of the firefly algorithm and radio propagation model. To provide the optimal path and to improve the data communication of different nodes, two-ray and shadow fading models is used, which secured the multiple UAVs in some high-level applications. The performance analysis of the proposed efficient optimization technique is compared in terms of packet loss, throughput, end-to-end delay, and routing overhead.

The mobility and geographical layout of UAVs are also critical factors in selecting communication pathways. These pathways are frequently modified as a result of the movement so that the UAVs' links may be maintained. This thesis proposes a specific routing protocol for FANETs called GPMOR, which utilizes the mobility level, received signal strength indicator, and, specifically, the flight independence of each UAV as dynamic measurements to guarantee network quality of administration and experience. Flight autonomy, mobility level, and signal strength are among the data points gathered. It is feasible to construct communication pathways that will remain operational for a longer amount of time-based on this information. Severe shadowing, traffic load balancing, multipath propagations, mobility congestion, and high error rates are all issues with FANET. The major security criteria for determining if an ad-hoc connection is protected are confidentiality (C), integrity (I), availability (A), authenticity (A), authorization (A), anonymity (A), and nonrepudiation (N). FANET networks are intrinsically unsafe, necessitating strong security solutions that take into account the network's unique properties, as these qualities are the primary sources of its vulnerability to assaults. This thesis suggests the use of the two-ray approach and shadowing effects for securing flying nodes in FANETs. The goal is to find routes with longer service life, fewer topology changes, and better data transmission conditions.

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Date: April 13, 2022 Manjit Kaur

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CHAPTER 1

Introduction

1.1 Introduction

Flying Ad-hoc Networks (FANETs) is a type of mobile ad-hoc network. FANET is an acronym for “Federation of Unmanned Aerial Vehicles” (UAVs). UAVs are part of an unmanned aircraft system, which includes a UAV, a ground-based controller, and a communication system between the two. FANET completed its work with driverless aircraft. UAVs are aircraft that do not have a human on board, are powered by a jet or rotary engine, and can be controlled remotely or trained to fly independently using pre-programmed flight data [1][2]. In just a few years, the deployment strategy for UAVs has switched from military to civilian applications. UAVs provide a less stressful environment. UAVs are more efficient, less expensive, versatile, long-lasting, and dependable. FANET has sensors, a Global Positioning System (GPS), and a camera. FANETs employ a variety of UAVs to carry out diverse tasks. Problematic dynamic automation systems that are flexible and responsive in execution can be used to operate UAVs. UAVs are simple to set up. An ad-hoc framework is a coordination without a correspondence framework in which every node is dynamic and can move to start with one area then onto the next inside the correspondence scope of the organization. UAV networks have filled in popularity over a lot of efforts. Because of their quick implementation and versatility, UAV networks are already being regarded as prospective wireless technologies [3][4]. The vital reason for this is that UAVs are generally reasonable and broadly accessible. UAVs can be utilized in the scope of guard and business applications because of the fast advancement of inventive items, for example, web associated gadgets, sensor frameworks, coordinated PC gadgets, diminished Wi-Fi broadcast associations, and overall route frameworks. Beforehand, UAVs were just utilized for military purposes, yet they are currently being utilized to work on the exhibition of remote sensor networks in an assortment of uses, including reconnaissance, traffic-related organization observing, woodland fire the executives, geospatial, agribusiness, salvage tasks, disaster reaction, and path reorganization [5][6].

Mobile Ad-hoc Networks (MANETs) and Vehicular Ad-hoc Networks (VANETs) are examples of FANETs. FANETs use driverless aircraft, also known as UAVs, to carry out a variety of functions. These are simple to install in non-deterministic environments.

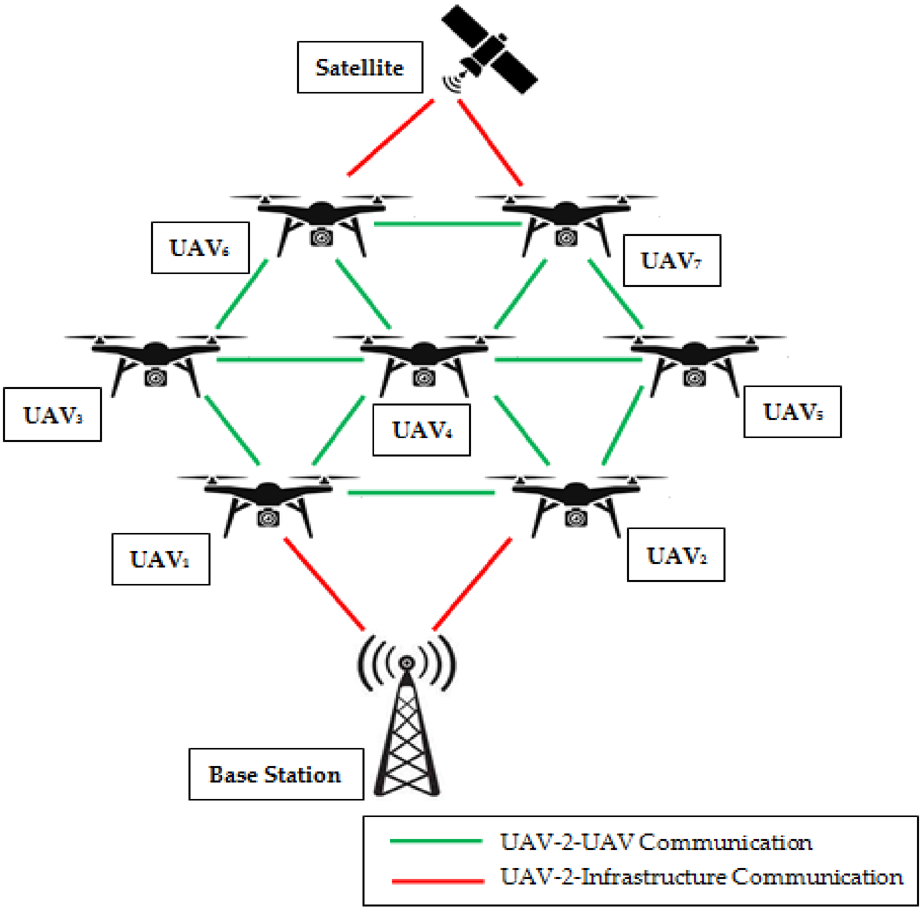


Figure 1.1: The architecture of FANETs

FANETs are used for a variety of purposes, including traffic monitoring, search and rescue operations, patrolling, remote data collection [7][8][9][10], environmental sensing, and agricultural management [11][12][13][14]. UAV-2-UAV communication and UAV-2-Infrastructure communication are the two types of communications in FANET. The UAV-2-UAV can be used for both short-range and long-range communication, depending on the rate of data transfer (indicated as a green line). UAV-2-Infrastructure communication, on the other hand, can be used to transmit and receive data (shown as a red line) on a variety of operations (either from a base station or from a satellite), as illustrated in Figure 1.1.

The different major design restrictions are described further in this chapter. One of the most important factors in the construction of multiple UAVs is communication. Another important factor is the battery’s limited energy [15][16]. Other key difficulties that must be addressed in this network include flight trajectory selection, energy limitations, adaptive routing protocols, power constraints, and so forth. The fundamental problem with FANETs is high mobility [17][18][19]. An irregular change in the structure of the nodes in the given network is another challenge. To tackle these network problems, several academicians have developed a variety of strategies and algorithms [20][21][22][23][24]. We explore how to address these issues in this thesis work, including how to employ minimum routing overhead, low computational cost, and maximum throughput parameters for load balancing in the network. The comparison between MANET, VANET and FANET are described in Table 1.1:

Table 1.1: Comparison of MANET, VANET and FANET

Characteristics	MANET	VANET	FANET
Node Mobility	The mobility of nodes in MANETs is lower. Figure 1.2 depict the MANET layout.	The mobility of nodes in VANETs is relatively faster than in MANETs. Figure 1.3 depict the VANET layout.	Node mobility is critical in air communication [25]. Figure 1.4 depict the FANET layout.

Characteristics	**MANET**	**VANET**	**FANET**
Node Density	The node density in MANETs is lower.	The node density in VANETs is medium-high.	The distance between nodes for UAVs is noticeable all around and the ground stays more noteworthy, representing a critical offensive.
Energy Life	The energy life in MANETs is medium.	The energy life in VANETs is low.	FANET hardware does not consume the same amount of power as MANET, VANET hardware.
Computing Power	It is limited in MANET.	It is average in VANET.	It is very high instead of MANET and VANET [26].
Localization	GPS is utilized to recover the estimations of endpoint gadgets.	GPS, AGPS and DGPS are used in VANET.	GPS, IMU, AGPS and DGPS are used in FANET [27].

MANET, a subset of ad-hoc network technologies such as VANET and FANET [28][29][30][31], is widely used. VANET is an automotive and vehicle-to-vehicle network. The basic goals of VANETs are to improve operational efficiency and productivity while reducing congestion, to obtain access to news and media to prevent accidents and to provide entertainment while driving. The FANET is a flexible version of the MANET. FANETs are typically UAVs in the context of unmanned aerial systems. There are numerous routing protocols, and some of them are incompatible with the FANET [32][33].


Figure 1.2: Layout of MANET

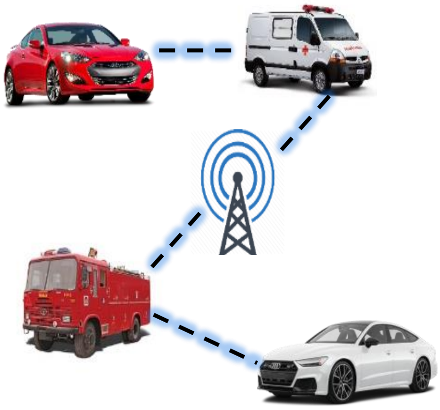


Figure 1.3: Layout of VANET


Figure 1.4: Layout of FANET

1.2 State of the Art

Sensor networks, military services, location-aware services, and disaster management have all used flying ad hoc networks. A sensor network is built and deployed to perform a variety of information processing tasks, including detection, object tracking, and multi-object classification. False misses, classification mistakes, and tracking quality are all examples of measurements that can be used to scale the performance of these activities. Ad-hoc network applications are many, and their range varies based on application needs, deployment modes such as sensing modalities, power supply, ad-hoc or fixed environment, and so on. Some examples of such applications are:

a) **Environment Sectors:** soil monitoring, crop monitoring, water, underwater, mountain inspection, air quality monitoring, etc.

b) **Defense Sectors:** spying, surveillance at the border, missile launching, bomb-dropping, war-zone medical supply, combat aircraft, etc [34].

c) **Civil Sectors:** mining, delivery, agriculture, construction, photography, videography, surveillance, logistic, disaster management, etc.

Table 1.2: Comparison of methods of remote sensing

Network	Mode of Operation	Resolution	Degree of availability	Operating cost
UAV	Autonomous or Remote control	cm to meters	High	Low
Helicopter	Human pilot	100 meters	High	Medium
Airborne	Human pilot	up to 50 meters	Moderate	High
Satellite	Autonomous	10 meters to 1 Km	Poor	Too high

Source: ref. [35]

FANET has also been utilized for security and search-and-rescue missions. As shown in Table 1.2, there are a variety of remote sensing techniques: Traditional UAV technologies have a gap in terms of flying capability, maintaining low and high speeds, low altitudes, and much higher spatial and temporal imaging resolution. Because of the increased usage of UAVs in technological challenges, aviation interference, liability, privacy, safety and security, and government rules and regulations, UAVs face several challenges [36][37].

a) **Technological Challenges:** When it comes to payload and flight time, there is always a trade-off. Payload and endurance are the primary concerns. In the network, some design standards need to be enhanced.

b) **Aviation Interference:** The user must keep the drone in sight. GPS and a jammer can be used by users.

c) **Liability:** For both public and private damages, there is no clear guideline. As a result, governing entities should enact certain laws and regulations.

d) **Privacy:** Both public and private properties are subject to legal action. Nonetheless, necessary guidelines and regulations are not explicitly stated.

e) **Safety and security:** Each flyer and the owner should be assigned a unique identification number, and a license must be issued.

f) **Government rules and regulations:** The most important thing is to have a policy for balancing rules. The government should establish an air traffic control board for UAVs or drones.

In addition, some parameters in FANET perform better, such as mobility, line of sight, localization, nodal density, and so on. The developing utilization of MANET, VANET, and remote sensor networks has prompted the advancement of new devices fit for independent development and flight, bringing about more convoluted frameworks. The devices are referred to as UAVs in FANET. By setting up another kind of organization worldview known as FANETs, the use of UAVs has grown better approaches for operating creative applications.

1.3 Research Motivation

Because of the increased mobility of UAVs, their better association, and advancement in application regions, the organizations differ from their conventional prototypes (MANETs for this situation). Because of the capacity of the robots to fly independently in three-dimensional space, FANETs might sum up and extrapolate geographies from 2D to 3D utilizing a free-movement approach. Specialists, researchers, and organizations have been attracted to this new setting, which is additionally giving the main thrust to real-world applications.

FANETs are commonly used to offer connectivity to hard-to-reach locations in disaster-stricken areas, as well as for military applications. Moreover, UAVs may be equipped with cameras and different sensors and devices to give a continuous aerial view, assisting rescue workers and firefighters in saving lives.

At times, it may be impractical to establish direct contact from the UAVs to the ground-based base station in large coverage regions. This challenge, however, can be solved by using UAV-2-UAV communication, which necessitates the usage of a routing protocol to determine the optimum route/path from the source to the final destination [38]. Due to the high mobility of UAVs, network topology might vary over time, making route discovery and maintenance one of the most important issues to handle [39]. As a result, the main goal of this thesis is to develop a FANET protocol that can handle this task more efficiently.

Routing protocols are in charge of locating, creating and maintaining communication routes between two nodes. The overhead and bandwidth consumption of these protocols should be kept to a minimum.

Due to various characteristics of FANETs, such as their dynamic topology algorithm, mutual interference, limited power, and the limited resources available in the UAVs, routing algorithms for FANETs are more difficult than fixed network protocols. Given the mobility of UAVs in a FANET, impossible that single aircraft will not be close enough to communicate with another, forcing it to use routing information to take another route. Communication between a few UAVs can be refined through the joint effort of middle nodes; that is, communication isn't restricted to the range of activity of every device independently, yet rather to the completion of all devices span of activity.

1.4 Researcher's Contribution

The following section depicts the researcher's contribution in this area and summarises it as follows:

1.4.1 Mobility of UAVs

The mobility and geographical layout of UAVs are also critical factors in selecting communication pathways. These pathways are frequently modified as a result of the movement so that the UAVs' links may be maintained. As a result, routing must be done dynamically by enhancing the autonomy of the UAVs and minimizing the data delivery time between source and destination nodes [40].

1.4.2 Uses of Geographic Position Mobility Oriented Routing Protocol (GPMOR) with Firefly algorithm for load balancing

Another significant contribution of this thesis is the execution of another communication network model for giving availability in hard-to-arrive regions (particularly after calamitous events). FANETs are easy to set up and move to a different location.

The frequent update of control information can assure more accurate information; nevertheless, this requires more energy consumption, which limits the nodes' autonomy.

1.4.3 Secured flying nodes in the FANETs

Severe shadowing, traffic load balancing, multipath propagations, mobility congestion, and high error rates are all issues with FANET. As a contribution, this thesis suggests the use of the two-ray approach and shadowing effects for securing flying nodes in FANETs. The goal is to find routes with longer service life, fewer topology changes, and better data transmission conditions. As a result, this thesis conducts a cross-layer assessment including the network and application levels to validate it using various criteria such as packet delivery ratio, packet loss, throughput, overhead routing, and so on.

1.5 Organization of the Thesis

The thesis is divided into seven sections. The following is a brief outline of the chapters:

Chapter 1 presents the concept of ad-hoc networks, as well as the fundamental information and operation of ad-hoc networks. It emphasizes some of the most important issues in this field and provides a brief overview of FANET application development. The contribution of the authors is also recognized in this chapter.

Chapter 2 shows the most recent research effort in this field by various researchers. The uses of ad-hoc networks are first examined in detail. Secondly, as per the author's objective, the literature review work has been discussed in this chapter. Various research works related to these categories are analyzed.

Chapter 3 presents a detailed discussion of the load balancing process. The different categorization of routing protocols has also been shown.

Chapter 4 proposes a hybrid algorithm of firefly algorithm in FANETs using its two different properties. Along with the proposed algorithm, the network model is also discussed. The simulation of the firefly algorithm and the results are thoroughly analyzed.

Chapter 5 shows the comparison of different position-based routing protocols. Along with the proposed algorithm, the load balancing of different flying nodes has been discussed. The simulation of the load balancing concept and the results are thoroughly analyzed.

Chapter 6 proposes a secure technique using the two-ray model and shadowing effect to find the malicious flying node in the network. The two-ray model has been widely utilized to examine the performance of an ad-hoc network as a propagation model. In this study, a more realistic model called the shadowing propagation model applied. In a shadowing propagation model, a mobile node may receive a packet with a signal level below the needed threshold level. This low signal level has an impact on a network’s routing protocol as well as its medium access control protocol. Results of the simulation are also analyzed in the chapter.

Chapter 7 concludes the thesis highlighting the prime outcomes of the current research of the author and significant contribution of the thesis and also notifying about the scope for future research in this area.

CHAPTER 2

Review of Literature

2.1 Introduction

A Flying Ad-hoc Network (FANET) is a flying platform that manages the self-directed active movement of a large number of Unmanned Aerial Vehicles (UAVs), a.k.a. drones. Modern communications solutions that link numerous UAVs to a FANET system, on the other hand, can enhance more. It can be swiftly organized to useful FANETs in difficult situations that are in great demand currently. A precise blend of communication technologies, security systems, and energy conversion methods is required to deliver robust and reliable communication networks with extended flight durations and low communication delays for diverse practical uses. The literature review work has been discussed in this chapter, as per the objectives. Various research studies about these categories are examined.

2.2 Literature Review

This section discusses the summary of reviews.

The Gauss Markov mobility model was combined with the Geographic Position Mobility Oriented Routing by Lin, et. al. [41]. It's been used in the context of high-speed UAVs. The best next-hop finding property has been used. It will, however, be possible for high-traffic applications in the network. If that is the case, then load balancing must be considered.

The Smooth turn mobility model suggested by Wan, et. al. [42] has been applied for Air Borne (AN) networks. In highly random networks, the model is simple enough for tractable analysis. The vehicle's trajectory is predicted using correlated speed and acceleration data that is straight and smooth during curves. The validation of the model using UAV flight data, on the other hand, will be covered. In the future, complete coverage and the amount of time required will be critical. Future research will focus on the performance of routing protocols and designs with more advanced connectivity features (such as path and link duration).

An adaptive hybrid communication protocol was proposed by Zheng, et. al. [43]. It has been demonstrated that data transport with low delay is possible. It has developed communication operations for flying UAVs. These protocols are resilient and dependable, resulting in a decentralized autonomous connection for FANETs. More flying UAV mobility concepts, on the other hand, can be considered. It will also be utilized to improve the flexibility of routing protocols by optimizing their calculating performance. In future research, the size of the FANET can be increased (in terms of more nodes).

Li, et al. [44] explored the topology control of UAV ad-hoc networks to construct a wireless aerial backbone network for controlling the movement of UAV swarms. To evaluate the system's performance, an efficient scheme is required. Li, et al. [45] discussed four communications architectures that are suited for UAV communications and specify how information travels between UAVs. Data connection systems have been proposed in this chapter to facilitate communication in decentralized UAV networks. The main aspects of wireless communications were outlined by Sánchez-García, et. al. [46]. It has examined the primary evaluation techniques for Unmanned Aerial–Aquatic Vehicle (UAAV) networks. It will be beneficial as a starting point for the design of UAAV networks in the future.

In [47] concentrated on the positioning of base stations for the downlink system. A pattern generation framework was employed to reduce the Unmanned Aerial Vehicle-Radio Frequency (UAV-RF) of the network and achieve near-optimal performance. The number of UAV base stations, on the other hand, has a significant impact on the complexity. The effect of quick pattern creation on dynamic UAV-RF will be studied in the future. Zhao, et. al. [48] discussed the many sorts of habitats, including 2D and 3D basic environments. This is valuable for recognizing important outcomes from UAV path planning approaches. Computational intelligence approaches were employed in this case to select the appropriate time-domain based on real situations. During the UAV path planning, it was contributed to the space domain. This will, however, be utilized in more complicated situations such as caves and woods. As a result, 3D UAV path planning study will become the norm in the future.

In [49] suggested two deployment strategies, centralized and distributed, are employed to achieve on-demand coverage. It has been used to keep multiple UAVs connected at the same time. However, the centralized algorithm’s outputs may be better for the distributed algorithm’s decision-making to determine how many UAVs should be deployed to undertake autonomous searching and coverage. The results of the distributed algorithm can be applied to dynamic instances involving moving on-ground objects. Thammawichai, et. al. [50] developed a mixed-integer non-linear program formulation that used less energy. Validation on target tracking and mapping has made use of this, displaying the influence of various factors. It can, however, be extended to optimize the energy usage of different units. It will be utilized in the future to implement both centralized and distributed energy consumption.

The position-based routing utilized on 3D networks was explored by Bujari, et. al. [51]. It has been proven to work successfully in dense networks. All randomization-based techniques have been restored, and packet delivery and path dilation have improved slightly. It will need to be compared to other factors in the future, such as network density and network size. It will be used in conjunction with a targeted position adjustment technique in which nodes alter their positions on their own.

Belbachir, et. al. [52] developed a method for improving localization using a decision-making strategy. A model is built with planning and control methods for determining the most efficient forest fire localization using a rotorcraft UAV. It’s employed to keep the fire zone from being completely explored. In [53] emphasized the benefits of a multi-UAV network and four-layer network topology for civilian and military missions. It includes two distributed gateway-selection methods that are optimized for tiny multi-UAV networks. In the future study, it could be employed for massive multi-UAV networks. Rohde, et. al. [54] developed a Positioning of Aerial Relays method that finds suitable locations for UAVs. Without resource planning, this is utilized to derive key performance metrics and reduce interference between base stations and UAVs.

Wu, et. al. [55] looked into a novel sort of multi-UAV that allows wireless networks to maximize the minimum average rate for all users. It has the advantages of improved air-to-ground channels and flexibility, as well as increased base station throughput. It will be utilized in the future to alternately optimize the UAV trajectory and the joint optimization of user scheduling and power control. It’s suitable for both aerial and ground-based stations. Zeng, et. al. [56] proposed an energy-efficient UAV communication system based on trajectory optimization. It has been demonstrated that rate maximization and energy reduction designs cause energy efficiency to vanish. Based on non-linear state-space approximation and sequential optimization approaches, it will be used to maximize energy efficiency.

Fadlullah, et. al. [57] proposed a method for dynamically adjusting the UAVs’ center coordinates and radius. It has been utilized in UAV networks to improve communication performance. In the future, it will be utilized for relay communication between two UAVs. In [58] suggested a two-phase mathematical optimization approach for assessing power network degradation in two phases. It was utilized to determine the UAV pre-positioning locations, and an ideal solution was found in a reasonable amount of time. It can, however, be integrated into a single model and provide a cost-effective solution technique to improve computational performance.

For UAV networks, Dai, et. al. [59] proposed a quality-aware coverage and path planning approach. This system has successfully monitored difficult situations before the start of a mission. Multi-UAVs can use a variety of strategies to identify energy-efficient, deadline-aware path planning, and so on. It will, however, look at online adjustment mechanisms to ensure that sensing quality is maintained in unpredictable scenarios. To deliver satisfactory visual observations to end-users, effective communication channels will be required.

Lyu, et al. [60] proposed a time-complex strategy for achieving wireless connectivity while reducing the total number of required mounted mobile base stations.

In [61] presented a new bat algorithm for UAV networks with connection constraints that incorporate several characteristics and dynamic variables. This task planning for bats allows them to look for and categorize various types of bugs. Bekmezci, et al. [62] suggested a multi-UAV task planning strategy that covered all target points in a short amount of time while also generating efficient assignments with no constraints. However, all target points will be efficiently covered and clear of obstructions.

Arafat, et. al. [63] compared traditional Delay-Tolerant Networking (DTN) routing techniques against location-assisted routing. It has suggested Location-Aided Delay Tolerant Routing (LADTR), a new routing system for UAV networks that might be used in disaster zones. It has helped to alleviate the issue of frequent link disconnection. It will be used to increase the resilience of location estimate systems in the future by looking for the best path. It will be utilized to improve the routing method for network traffic balancing. Oubbati, et. al. [64] detailed the design of FANETs and compared the various techniques using various criteria. The routing protocols have been characterized using a global taxonomy. In the future, it will be necessary to cope with network fragmentation and extremely dynamic topology to devise an effective routing protocol that can adapt to any situation.

Depending on the topology and route between nodes, the protocol [65] was designed to resolve the issues. The results revealed the importance of overheads in the network, throughput, channel usage, end-to-end delay, and packet delivery ratio characteristics in terms of network performance. Li et al. [66] introduced multi-cluster FANETs for effective network management, which lowered communication costs and improved network performance. It also took advantage of low power. There were two modes mentioned in this article: beaconless mode and beacon-activated mode. Alenazi et al. [67] provided a method for calculating multiple robust pathways between routing processes using Link-stability Estimation Pre-emptive Routing (LEPR). This approach also helped to limit the number of nodes that were damaged.

Kumar et al. [68] developed a way for defining simulation borders by using a 3D Gauss Markov mobility model to define a buffer zone. Get the enhanced data from the simulation bounds based on the outcomes. With the help of location and trajectory information, a predictive routing technique [69] was presented for geo-casting and unicasting routing. The results showed that FANET's performance had significantly improved. Oubbati et al. [70] proposed a location-oriented directional Media Access Control (MAC) technique that incorporated the estimation of neighbor node locations as well as the use of directional antennas. In FANET, the results revealed substantial information in terms of throughput, usage, and delay.

In [71] surveyed position-based routing protocols and presented a full explanation of these routing protocols, as well as their benefits and drawbacks, which are used in FANET. In [72] illustrated the firefly method, which is determined by several factors such as the attractiveness function and distance calculation. In [73] employed sophisticated method names such as classical FA (Firefly algorithm), which are generally acceptable for multi-modal optimization applications. The multi-modal test functions were explained in this research work.

Yang [74] discussed some of the implementations of classical FA for non-linear optimization problems, as well as continuous and combinatorial optimization. In [75] summarised and reviewed some nature-inspired metaheuristic algorithms. Several optimization approaches are compared here, including the Firefly Algorithm (FA), Cuckoo Search (CS), and Harmony Search (HS), among others. In [76] discussed the fundamentals of swarm intelligence algorithms as well as nature-inspired swarm intelligence algorithms. Bee’s mating [77], bats echolocation [78], bacterial foraging [79], bees foraging [80] are some of the most common examples. In this study, the author [81] reviewed several of the nature-inspired algorithms as well as their applications.

The modified Firefly Algorithm with several standard functions was proposed by Palit et al. [82], and the modified firefly algorithm outperformed its classical predecessor. Falcon et al. [83] discussed binary firefly methods that have been used to address specific groups of issues. In [84] highlighted the dynamic nature of traffic information and how it improves accuracy. Yang [85] proposed a new firefly algorithm that spreads all of the fireflies to obtain the desired outcomes using the mathematical function Gaussian Distribution (GD). The experimental results in this research revealed the improved performance and more accurate data. Yang [86] provided a technique in which levied flight travel in the Metaheuristic firefly algorithm, which indicated that the proposed strategy outperformed other algorithms in terms of success rate and efficiency. Swarm intelligence, the firefly algorithm, levy flights, and cuckoo search algorithms were all investigated by the author in [87]. In [88] presented approaches for improving the mobility of robust global optimization with attractiveness and light absorption coefficient. For difficulties involving unconstrained optimization problems based on conventional benchmark functions, Subutic et al. [89] presented the parallelized firefly technique. The findings on the parameters of speed and quality were displayed here. The modified firefly algorithm on the graphics processing unit was discussed by [90].

Various writers used hybrid firefly algorithms to show outcomes in some of the other research articles. For the cryptanalysis of monoalphabetic substitution ciphers, Luthra et al. [91] presented a hybrid FA approach. The authors defined the concept by using genetic algorithm operators (crossover and mutation). In [92] presented security measures based on execution time and compared alternative algorithms based on energy usage. The traditional firefly algorithm was presented using a search heuristic in [93]. This method was accurate to a mathematical concept known as graph 3-coloring. Batra et al. [94] presented a hybrid logical security paradigm to improve network functionality while reducing overhead. Abdullah et al. [95] described a hybrid evolutionary firefly algorithm.

FANET is a sub-domain of MANET and VANET and is another type of ad-hoc network. It is not permitted to use MANET and VANET's distinguishing features directly. However, new or modified methodologies that take into account the particular characteristics of a UAV are necessary. Table 2.1 shows a comparison of parameters that must be addressed in the common of extant studies in the literature as well as our suggested work.

Mahjri et al. [96] developed a simple model to depict collisions in flying nodes based on two input parameters: UAVs with accurate detection and avoidance capabilities and UAVs without precise detection and avoidance capabilities. The key restrictions of this stochastic model in the case of real-world UAV nodes are adequacy and accuracy. For the deterministic situation, Belkhouche et al. [97] employed kinematic equations, which they also used to calculate the probability of a collision between cars. This strategy does not guarantee that the collision risk will not be underestimated, resulting in security requirements being violated.

To overcome the Reinforcement Learning (RL) problem, Hung et al. [98] developed a framework and method. In a non-stationary stochastic environment, this paradigm is employed for fixed-wing UAVs. By applying function approximation approaches, this formulation can be used for better exploration strategies to speed up the learning process. A 3D distributed and straight-line conflict identification and alerting technique were proposed by [99]. For the ideal environment, this technique is solely used for packet loss and uncertainty information at the state level. In [100] suggested a 3D UAV relative localization framework and demonstrated performance based on the precision of the UAVs' localization. This framework is currently only used for MDS-based methods, but it may be expanded to include additional types of relative localization in the future.

Table 2.1: Characteristics of flying ad-hoc network

Work	Packet Loss	Through-put	End-to-End Delay	Routing Overhead	Collision Risk Assessment	Two_ray Effects (Secure vs Insecure)	Shadowing Effects (Secure vs Insecure)
Mahjri et al. [96]	✓	×	×	×	✓	×	×
Belkhouche et al. [96]	×	×	×	✓	✓	×	×
Hung et al. [98]	×	×	✓	×	✓	×	×
Mahjri et al. [99]	✓	×	×	×	✓	×	×
Liu et al. [100]	✓	×	✓	×	×	×	×
Tang et al. [101]	×	×	✓	✓	×	×	×
Temel et al. [102]	✓	✓	✓	×	✓	×	×
Khabbaz et al. [103]	×	✓	×	×	×	×	×
Tang et al. [104]	✓	✓	×	×	×	×	×
Wen et al. [105]	×	✓	×	×	×	×	×
Rosati et al. [106]	×	×	×	✓	×	×	×
Proposed work	✓	✓	✓	✓	✓	✓	✓

Tang et al. [101] used a 6G intelligent network to investigate and prove machine learning technologies in the network. This research looked at the unique issues that each network faces. In a 6G intelligent network, proactive security approaches can be implemented. Temel et al. [102] introduced a unique directional MAC protocol Location Oriented Directional MAC (LODMAC) that improved spatial reprocess and overall network size in the existing network's 3D environment. The scope of this research is limited to FANET MAC protocols.

Khabbaz et al. [103] examined ways to improve data communication performance by adjusting several characteristics such as network speed and density. In [104] uses Location-Based Social Networks (LBSNs) to compute data in the cloud. The authors demonstrated the mechanism for the effectiveness of a UAV-mounted, cloudlet-assisted network with accurate throughput and reduced packet delay in this paper. A distributed optimization approach for flying nodes in networks was presented by Wen et al. [105]. They demonstrated the simulation work by demonstrating increased network speed, reduced End-to-End delay (EED), and reduced co-channel interference. Rosati et al. [106] examined the two alternative routing algorithms in FANETs and demonstrated the performance of Predictive – Optimized Link State Routing (P-OLSR) and Optimized Link State Routing (OLSR).

Table 2.2: Main findings (Research gap and objectives) of literature review

Journal/Book Details	Indexing of journal	Research Gap and Objectives
Liu et al., IEEE Transactions on Vehicular Technology (2020) [100]	Scopus	This framework is currently only used for Multidimensional scaling (MDS) based algorithms. Research Gap: It has not been extended to other relative localization applications in the future. Objective: To make a solution for localization

Journal/Book Details	Indexing of journal	Research Gap and Objectives
		application in FANETs and find the suitable or best path of different flying nodes.
Wen et al., Ad-hoc Networks, (2020) [105]	Scopus	More effort will be made in the future to incorporate the issues and appropriate solutions into the optimization framework and transmission strategy. The objective may be to find pathways for the movement of nodes so that the UAVs' links may be maintained.
Oubatti et al., IEEE Access, (2019) [64]	Scopus	In the future, it will be necessary to cope with network fragmentation and extremely dynamic topology to devise an effective routing protocol that can adapt to any situation.
Khabbaz et al., IEEE Transactions on Vehicular Technology, (2019) [103]	Scopus	Research Gap: speed and density of the network nodes are not appropriate. Objective: It can be used to increase the speed and density of network nodes.
Tang et al., IEEE Access, (2019) [101]	Scopus	In a 6G intelligent network, proactive security solutions can be implemented.
Mahjri et al., Journal of Network and Computer Applications, (2018) [96]	Scopus	The key restrictions of this stochastic model in the case of real-world UAV nodes are adequacy and accuracy. Objective: Malicious nodes can be found using different techniques.

Journal/Book Details	Indexing of journal	Research Gap and Objectives
Arafat et al., IEEE Access, (2018) [63]	Scopus	It will be used to increase the resilience of location estimate systems in the future by looking for the best path. Objective: It will be utilized to improve the routing method for network traffic balancing.
Lim et al., IEEE Transactions on Smart Grid, (2018) [58]	Scopus	Research Gap: Computational performance has not been improved. Objective: It can be incorporated into a single model and can offer a cost-effective solution technique to improve computational performance.
Dai et al., Ad-hoc Networks, (2018) [59]	Scopus	It will look into online adjustment mechanisms to ensure that sensing quality is maintained in unpredictable scenarios. Objective: To deliver satisfactory visual observations to end-users, effective communication channels will be required.
Zheng et al., Ad-hoc And Sensor Networks, (2018) [43]	Scopus	More flying UAV mobility models can be considered. Research Gap: Flexibility of routing protocols are not there. Objective: It will also be utilized to improve the flexibility of routing protocols by optimizing their calculation performance. In the future, the size of the FANET could be increased (in terms of nodes).
Wu et al., IEEE Transactions On Wireless	Scopus	It will be utilized to optimize the UAV trajectory in tandem with user scheduling and

Journal/Book Details	**Indexing of journal**	**Research Gap and Objectives**
Communications, (2018) [55]		power control optimization. It can be suitable for both aerial and ground-based stations.
Sánchez-García et al., Computer Communications, (2018) [46]	Scopus	Research Gap: Not beneficial for long term network. Objective: It will be beneficial as a starting point for UAAV network architecture in the future.
Lu et al., IEEE Transactions On Wireless Communications, (2018) [47]	Scopus	Research Gap: Impact of quick pattern creation is not appropriate. Objective: The impact of quick pattern creation on dynamic UAV-RF will be studied in the future.
Zhao et al., Knowledge-Based Systems, (2018) [48]	Scopus	This will be employed in complicated environments like caves and woods, among other things. As a result, 3D UAV path planning study will become the norm in the future.
Zhao et al., IEEE Journal on Selected Areas in Communications, (2018) [49]	Scopus	The findings of the centralized algorithm may be the best for determining how many UAVs should be deployed to conduct autonomous searching and coverage for the distributed algorithm. The distributed algorithm’s results can be applied to dynamic instances in which on-ground objects are moving.
Thammawichai et al., IEEE Transactions on Aerospace and	Scopus	Research Gap: Energy optimization is missing for both centralized and distributed network. Objective: It can also be used to optimize the energy usage of different units. It will be

Journal/Book Details	**Indexing of journal**	**Research Gap and Objectives**
Electronic Systems, (2018) [50]		utilized in the future to implement both centralized and distributed energy consumption.
Bujari et al., IEEE Transaction on Mobile Computing, (2018) [51]	SCI index	It must be weighed against other factors such as network density and size. Research Gap: Alteration of position is not added. Objective: It will be used in conjunction with a targeted position adjustment technique in which nodes alter their positions on their own.
Wang et al., IEEE Vehicular Technology Magazine, (2017) [53]	Scopus	Research Gap: Not applicable for large multi-UAV networks. Objective: In the future, it could be used for huge multi-UAV networks.
Mahjri et al., IEEE Transactions on Mobile Computing, (2017) [99]	SCI index	This approach is only utilized at the state level for packet loss and uncertainty information in the ideal environment, not for other parameters.
Zeng et al., IEEE Transactions On Wireless Communications, (2017) [56]	Scopus	Research Gap: Energy efficiency is not found accurately. Objective: Based on non-linear state-space approximation and sequential optimization approaches, it will be used to maximize energy efficiency.
Lyu et al., IEEE Communications Letters, (2017) [60]	Scopus	In the future, it will be employed to establish good wireless communication.

Journal/Book Details	Indexing of journal	Research Gap and Objectives
Hung et al., IEEE Transactions on Cybernetics, (2016) [98]	Scopus	By applying function approximation approaches, this formulation can be used for better exploration strategies to speed up the learning process.
Fadlullah et al., IEEE Network, (2016) [57]	Scopus	In the future, it will be utilized for relay communication between two UAVs.
Temel et al., Computer Networks, (2015) [102]	Scopus	Only FANET MAC protocols are restricted; other protocols are not.
Belkhouche et al., IEEE Transactions on Vehicular Technology, (2013) [97]	Scopus	Research Gap: This strategy does not guarantee that the collision risk will not be underestimated, resulting in security standards being violated. Objective: Security will be added.
Wan et al., IEEE Transactions on Vehicular Technology, (2013) [42]	Scopus	The model's validation utilizing UAV flight data will be discussed. In the future, complete coverage and the amount of time required will be critical. Objective: Future research will focus on the performance of routing protocols and designs with more advanced connectivity features (such as path and link duration).
Lin et al., Journal of Computational	Scopus	Research Gap: Not feasible for high-traffic applications.

Journal/Book Details	**Indexing of journal**	**Research Gap and Objectives**
Information Systems, (2012) [41]		Objective: It will be feasible in the network for high-traffic applications. If that is the case, then load balancing must be considered.
Li et al., Ad-hoc Networks, (2012) [44]	Scopus	Research Gap: Emergency landing spots detection is not found. Objective: It can be used to find suitable landing spots for large and multiple UAVs.
Rohde et al., Wireless Networks, (2005) [54]	Scopus	Research Gap: Network performance decrease in connectivity. Objective: More strategies can be utilized to efficiently check the network's performance.

2.3 Objectives of Research Work

1. To propose an algorithm to evaluate the optimal route for sending data from various sources of multiple UAVs.
2. To implement the proposed optimization technique for load balancing.
3. To design a secure approach for the detection of malicious UAVs in FANETs.

2.4 Identification Statement

The flow chart in Figure 2.1 depicts the identification statement summarizes it as follows:

As a result, this thesis proposes a specific routing protocol for FANETs called GPMOR, which utilizes the mobility level, received signal strength indicator, and, specifically, the flight independence of each UAV as dynamic measurements to guarantee network quality of administration and experience. GPMOR protocols provide network effectiveness and accuracy, as well as a scalable, optimized network with flying nodes, node security, and node mobility.

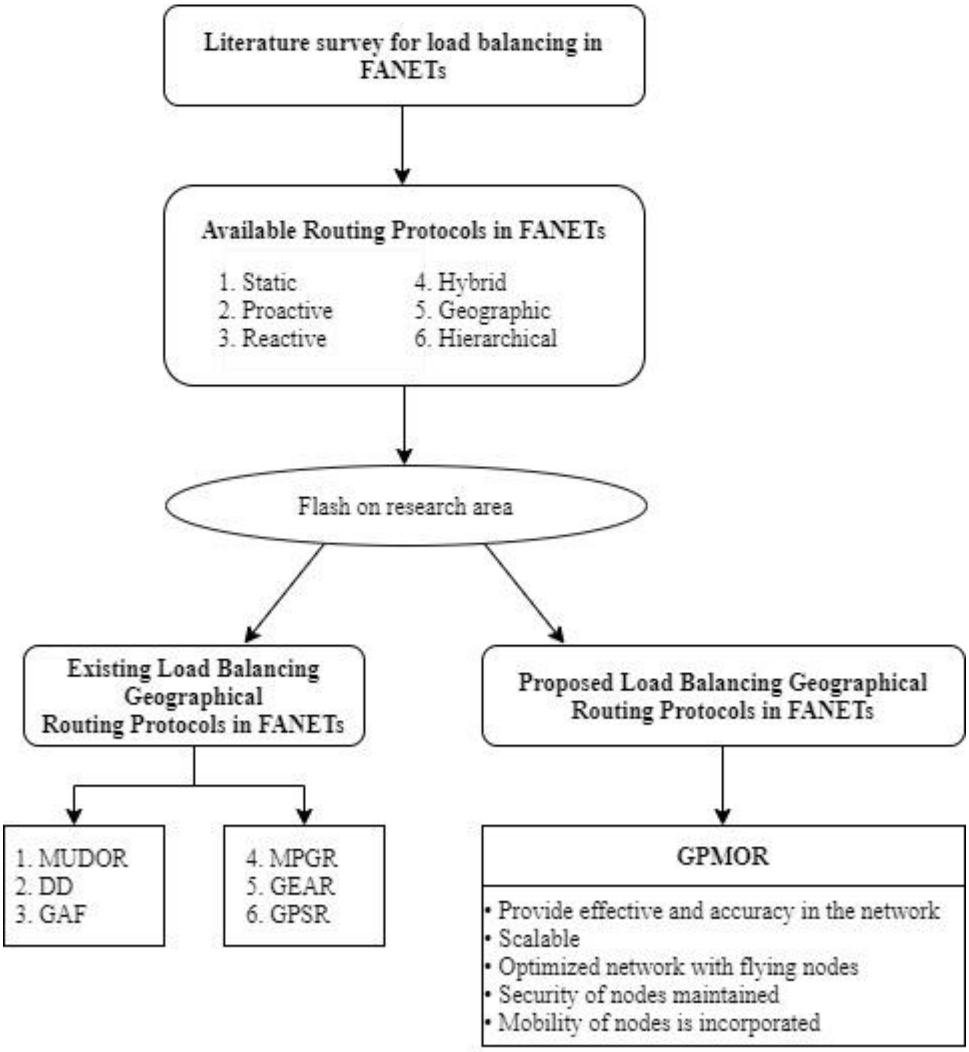


Figure 2.1: Selection of GPMOR Routing Protocol

This thesis also proposes the use of a firefly algorithm for the implementation of the GPMOR, with a set of inputs made out of information gathered in real-time from the network itself. Flight autonomy, mobility level, and signal strength are among the data points gathered. It is feasible to construct communication pathways that will remain operational for a longer amount of time-based on this information.

2.5 Conclusion

It produces outcomes that are dependable, optimal, and best-suited using the most up-to-date technology; yet, there are areas for development in the computational methods used, which are far too high and difficult. They have a significantly longer time limitation to achieve optimal results. It refers to the randomized multi-valued solutions that improvised converge the outcomes with iteration following the global solution. Some algorithms work slowly due to the massive randomization of selected values and the enormous population size. We are well aware that technology and network architecture evolve rapidly over time; as a result, due to the increased number of UAV movements, we are limited to the processing power of UAVs. Such approaches and procedures take a long time to get a valid result, and many times that time is wasted on an incorrect output that can't be used to change the network's structure. These energy-based solutions are not suitable for networking strategies that require high computational and expensive parameters.

CHAPTER 3

Load Balancing and Routing Protocols in FANETs

3.1 Introduction

The load balancing problem in ad-hoc networks remains a significant topic with a high priority, especially with the growing demand for this network. Because of the intricacy of the network's structure and the variety of dynamic connection nodes in an ad-hoc network, designing effective load balancing solutions for this network is known to be difficult. In FANETs, load balancing is a critical issue. Many conventional routing protocols that have been designed cannot provide load balancing. The goal of load balancing is to ensure that the transmission channel is shared fairly. As a result, features and several approaches to the design and development of load balancing routing protocols are discussed.

3.2 Features of FANETs

In general, load balancing is vital in computer networks for distributing traffic load across several lines from the source to its destination. where the most important reason for lowering network efficiency is that the load exceeds the network's capacity [107].

enhancing load balancing has been a hot topic in communication network research, particularly in mobile wireless networks, because wireless communication is one of the fastest developing technologies, as evidenced by recent advances in mobile computers and wireless devices [108]. Traffic and power usage are two ways in which nodes are stressed. A load-balancing algorithm [109] is used to balance this load. Ad-hoc networking can be defined as a temporary wireless network made up of several different devices or uniforms that are linked to each other without the use of an access point or wireless route because the network will be based on direct contact between the card wireless network, which is installed on each device for data transfer from one computer to another, in the network and must adhere to industry standards [110].

The following are some of the features of FANETs:

a) **Mobility Model:** FANET provides specified mobility models as well as unique mobility models for independent multi-UAV systems. The nodes in this model wave in the sky [111]. Models of mobility that can be used to replicate the behavior of mobile nodes in an ad-hoc network. Randomized mobility models [112][113], topology-control based mobility models [114], time/space-dependent mobility models [115], path-planned mobility models [116], and group mobility models [117] are only a few examples of mobility models.

b) **Node Mobility:** With increasing density, the topology of FANET nodes changes. The distance between UAV nodes in FANETs is greater. The speed of a UAV ranges from 30 to 460 kilometers per hour. The mobility degree of a FANET node is higher than that of a MANET or VANET node [118].

c) **Localization:** In FANETs, geospatial localization is provided by Global Positioning System (GPS), Assisted Global positioning system (AGPS), Differential Global Positioning System (DGPS), and Inertial Measurement Unit (IMU). The position information provided by GPS is updated every one second, which may not be enough [119]. The GPS signal can be used to standardize the IMU. As a result, it can provide the UAV’s position at a faster rate.

d) **Topology Change:** The topology of the FANET nodes changes rapidly and unpredictably. Routing Tables must be dynamically reorganized in response to topology changes [120]. It has an impact on the routing protocols' performance.

e) **Computational Power:** Nodes in the FANET environment have only a limited amount of channel bandwidth and compute power. The computing capability of MANET is low, that of VANET is average, while that of FANET is enormous.

f) **Radio Propagation Model:** MANET and VANET are both quite close to the ground, and Line of Sight (LoS) is not available in either network. The radio propagation model in FANET is barely above ground level, yet LoS is available in most circumstances.

g) **Power Consumption and Network Lifetime:** Only mini-UAVs are required in FANET for power consumption and network lifetime. It is not required for tiny UAVs in this case. On the other hand, it is not required in VANET [121]. However, energy-efficient protocols are required in MANET.

h) **Node Density:** In ad-hoc networks, it is a critical factor. The average number of nodes per unit area is known as node density. It has a thin profile in FANET but a medium profile in VANET [122].

3.3 Routing Protocols in FANETs

One of the most difficult difficulties for FANETs is the design of the network layer [123]. This puts more pressure on researchers to develop or adapt new routing protocols while balancing competing design constraints like highly dynamic topology [124], balanced energy consumption [125], link breakage recovery [126], scalability [127], security [128], and efficient use of both UAV resources and allocated bandwidth [129]. Meeting all of the aforementioned criteria at the same time is nearly impossible, hence FANET routing techniques are classified according to the network's circumstances. We will go over each category in detail, as well as the most relevant routing protocols, in the sections that follow.

A. **Topology-Based Routing Protocols**

(i) Static,

(ii) Proactive,

(iii) Reactive, and

(iv) Hybrid

B. Hierarchical-Based Routing Protocols

C. Geographic/Position-Based Routing Protocols

3.3.1 Topology-Based Routing Protocols

Several routing protocols in this category were originally designed for MANETs, but they have since been upgraded to meet the unique features of FANETs [130]. These protocols rely on connection information and employ the IP addresses of mobile nodes to exchange packets between communication nodes. Figure 3.1 depicts the many classifications of routing protocols. Examples of static routing protocols include: load carry and delivery routing, data-centric routing, and multi-level hierarchical routing. The proactive routing protocols examples are: directional optimized link state routing, topology broadcast based on reverse-path forwarding, destination sequenced distance vector. Examples of reactive routing protocols are: ad-hoc on-demand distance vector, dynamic source routing, time slotted on-demand routing. Examples of hybrid routing protocols are: zone routing protocol, temporarily ordered routing algorithm.

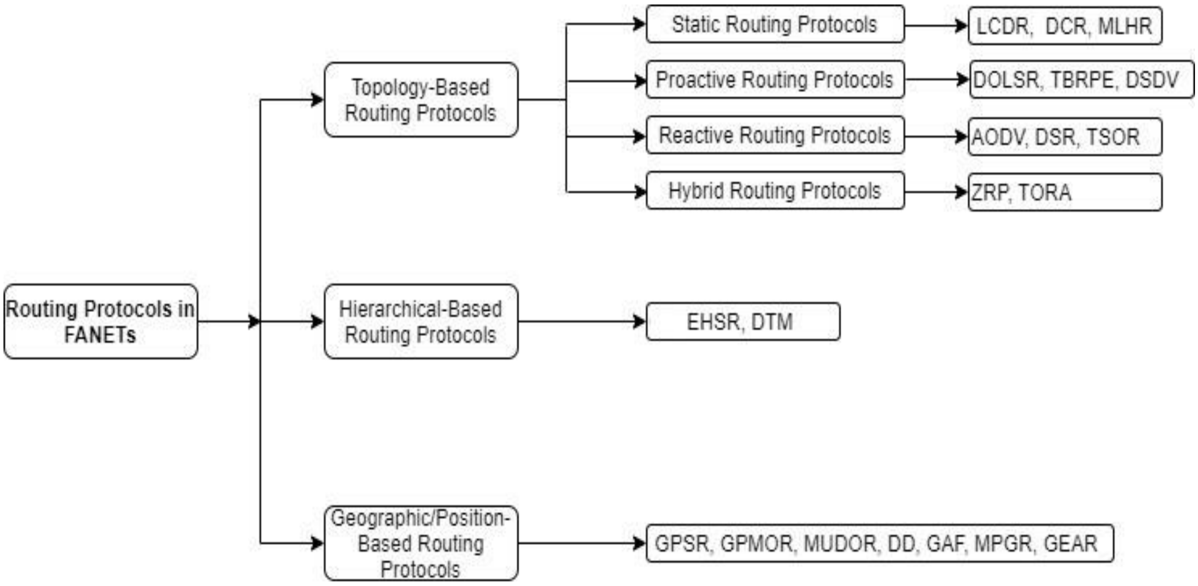


Figure 3.1: Classification of routing protocols in FANETs

This category is further categorized into four categories: These are explained below:

3.3.1.1 **Static Routing Protocols (SRP):** Small networks, such as File Transfer Protocol (FTP), mail servers, and Virtual Private Networks (VPNs), benefit from static routing. It is less expensive and easier to manage because the administrator allocates the path from the source to the destination manually [131]. This is the polar opposite of dynamic traffic [132]. It is a numeric address that is assigned to each host in a network. These aren't as safe. After it is allocated to the computer, it does not alter automatically. As shown in Table 3.1, examples of static routing protocols are further described:

Table 3.1: Types of static routing protocols

Load Carry and Delivery Routing (LCDR)	Data-Centric Routing (DCR)	Multi-Level Hierarchical Routing (MLHR)
i. In FANET, it is the first routing protocol. A UAV loads the data from the ground node and delivered the to the destination node [133]. ii. The primary aim of this routing protocol is to maximize the throughput as shown in Figure 3.2. iii. The research gap of this protocol is that it takes	i. There is a 1:M hierarchy for data transmission. ii. In this, data transmission is completed with the help of data demand algorithms [134]. iii. Data attributes are compulsory for the collection of data as shown in Figure 3.3.	i. In different areas, the number of groups in hierarchical form requires to operate UAV networks. ii. Each group has one head of that particular group, and each head is linked with top and bottom layers as shown in Figure 3.4. iii. It is better routing than others because the

a longer delay for delivery and it also demands high bandwidth.	iv. It can be selected for the small number of UAVs.	UAV controlled the mission area [135].

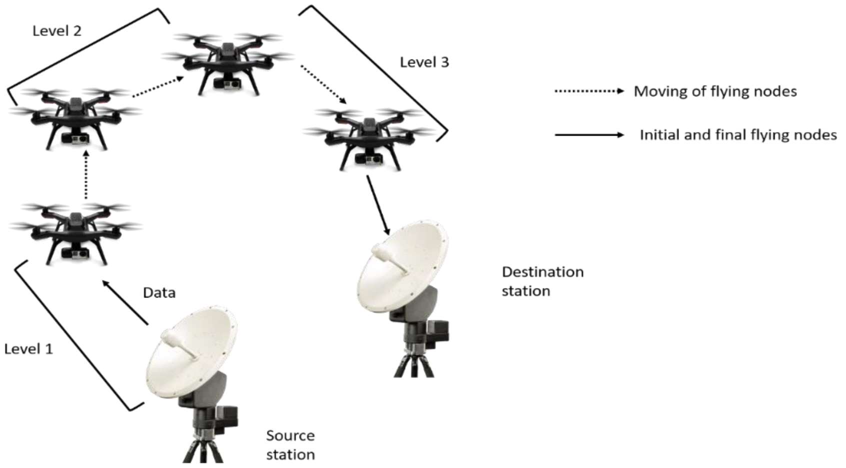


Figure 3.2: Process of Load Carry and Delivery Routing

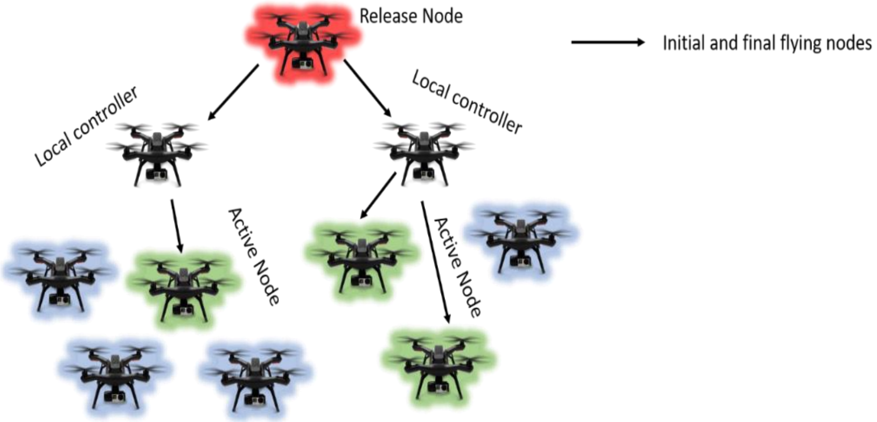


Figure 3.3: Process of Data-Centric Routing

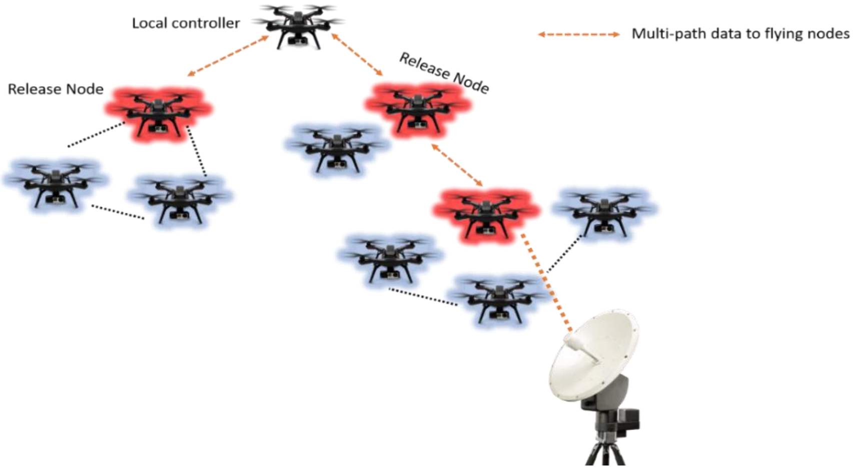


Figure 3.4: Process of Multi-Level Hierarchical Routing

3.3.1.2 **Proactive Routing Protocols (PRP):** Tables are used in these procedures. The goal of this protocol is to store the most recent record of all network routing, making it very easy to choose a route. The network has a medium level of complexity, and the node's route is dynamic. PRP has fault tolerance, which is useful for dynamic missions. As seen in Table 3.2, there are three types:

Table 3.2: Types of proactive routing protocols

Directional Optimized Link State Routing (DOLSR)	Topology Broadcast based on Reverse-Path Forwarding (TBRPF)	Destination Sequenced Distance Vector (DSDV)
i. DOLSR is used to choose the multi-point relay and can decrease the number of relays with directional aerials as shown in Figure 3.5 [136].	i. The main objective of this protocol is to select the dynamic source routing and try to search for an optimal path with delivery time selection as shown in Figure 3.6 [137][138].	i. By using a sequence number, each node keeps a routing table, which assured that the protocol to be looping free as shown in Figure 3.7 [139]. ii. This is also an easy algorithm to select the higher sequence number.

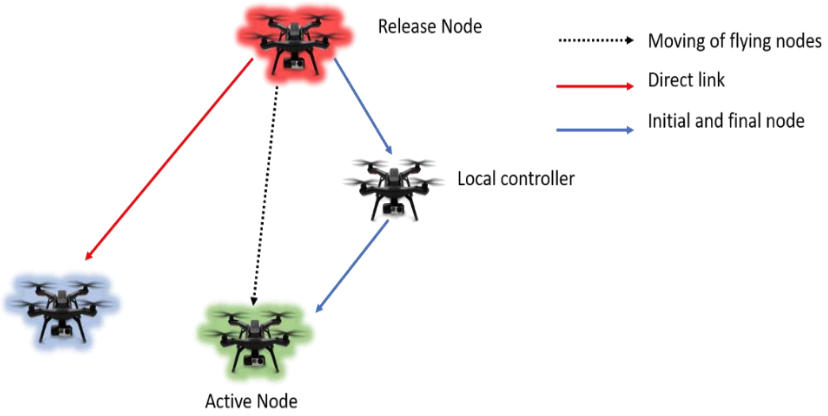


Figure 3.5: Process of Directional Optimized Link State Routing

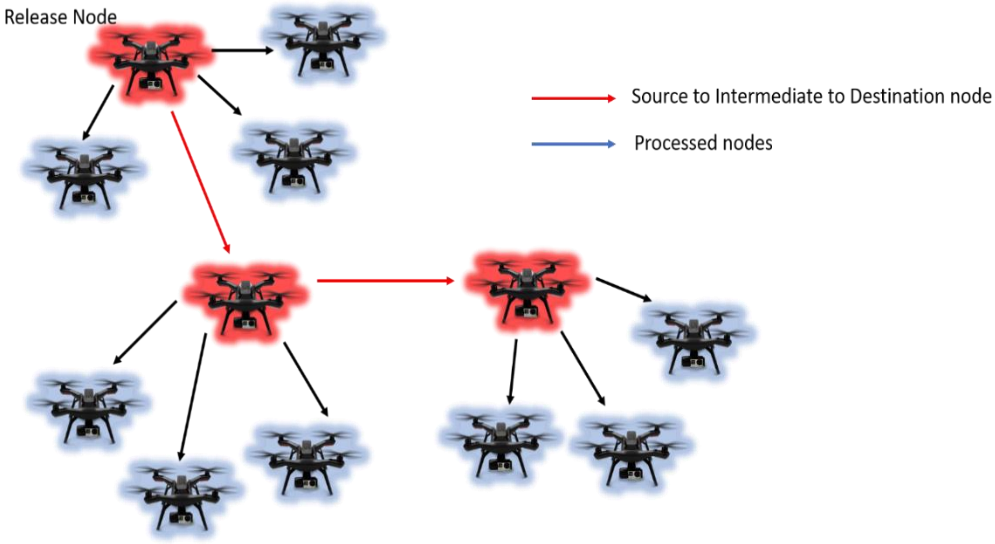


Figure 3.6: Process of Topology Broadcast Based on Reverse-Path Forwarding

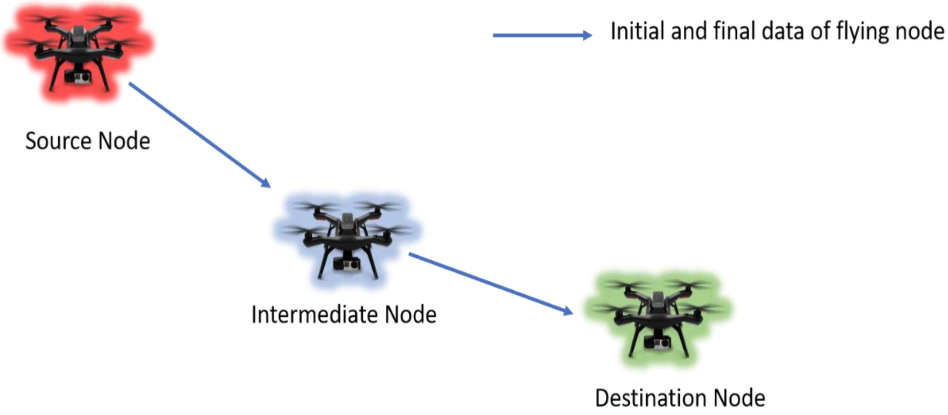


Figure 3.7: Process of Destination Sequenced Distance Vector

3.3.1.3 Reactive Routing Protocols (RRP):

Reactive Routing Protocols (RRP): The overhead problem is solved by using this protocol. There is no requirement to compute a route between two nodes in this protocol, which is also known as the Demand Routing Protocol (DRP). Because there are constant communications, searching for a route between nodes is a time-consuming process. The RRP's network complexity is average, and the node's path is dynamic. RRP has fault tolerance, which is useful for dynamic missions. This protocol is further broken into three groups, as shown in Table 3.3:

Table 3.3: Types of reactive routing protocols

Ad-hoc On-demand Distance Vector (AODV)	Dynamic Source Routing (DSR)	Time Slotted On-demand Routing (TSOR)
i. This protocol is especially for routing table maintenance and the source node keeps the next information of the network as shown in Figure 3.8. ii. There is only a single record for each target. iii. There are different three phases such as discovering the route, transmitting the packets, and maintaining the route [140].	i. This protocol is the same as of AODV. ii. Firstly, the source node sends the message to neighbor nodes and then route restoration is activated as shown in Figure 3.9 [141]. iii. This is specially intended for the wireless mesh network. There are multiple records for each target.	i. It is considered as a time-slotted type of Ad-hoc On-demand Distance Vector. ii. This protocol uses committed time slots during sending the data packet from one node to another node as shown in Figure 3.10 [142]. iii. It ensured the delivery of every packet.

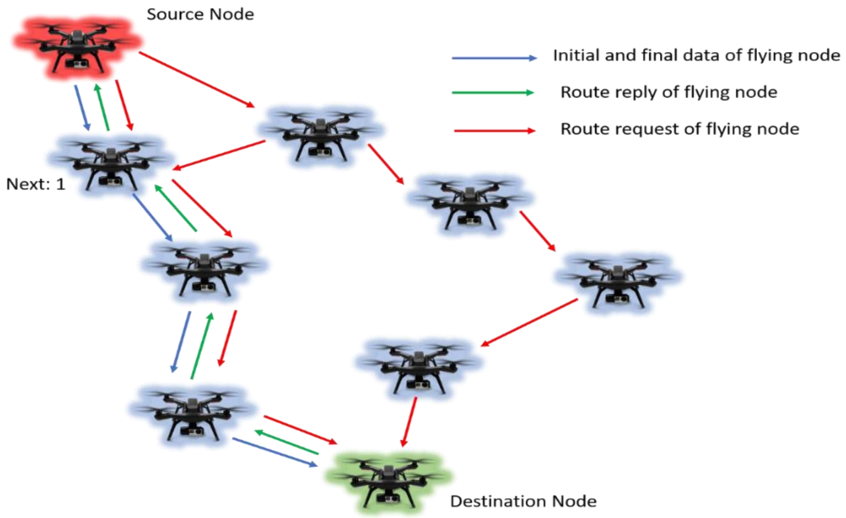


Figure 3.8: Process of Ad-hoc On-demand Distance Vector

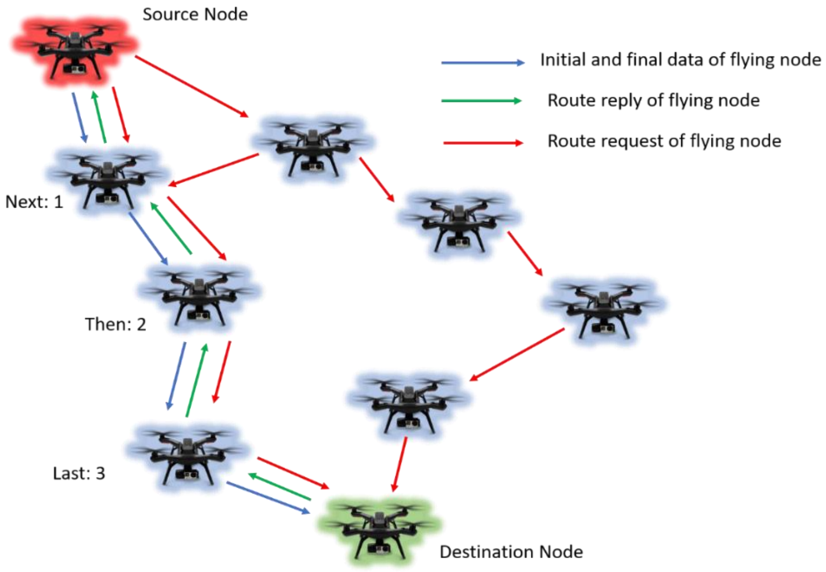


Figure 3.9: Process of Dynamic Source Routing

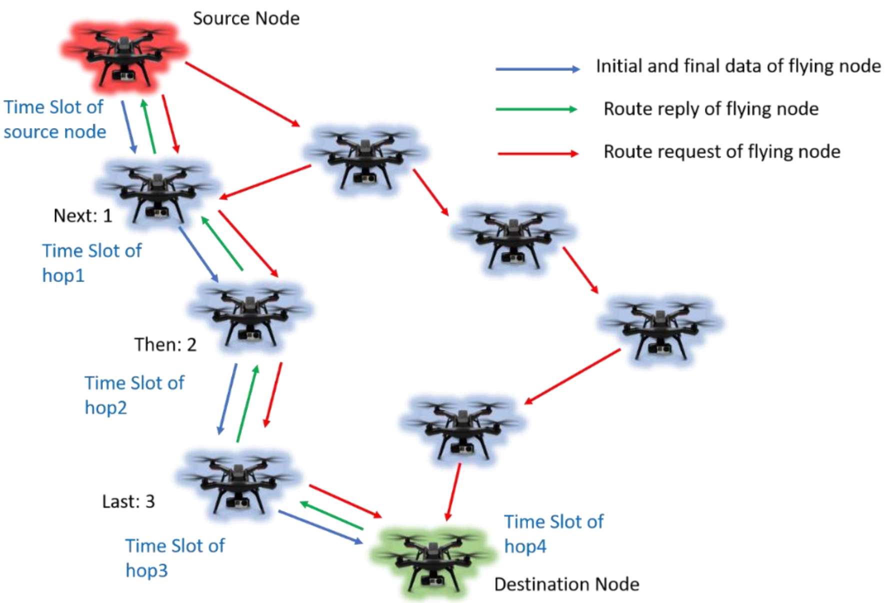


Figure 3.10: Process of Time Slotted On-demand Routing

3.3.1.4 **Hybrid Routing Protocols (HRP):** Routing protocols that are reactive take longer to determine the route. This is RRP’s most significant flaw; to circumvent it, adopt the hybrid routing protocol. It’s the result of combining PRP with RRP. The complexity is calculated as an average in the network, and the node’s route is dynamic. HRP has a medium memory size and is used for dynamic missions. This is for large networks, and the protocol is further separated into two groups, as shown in Table 3.4:

Table 3.4: Types of hybrid routing protocols

Zone Routing Protocol (ZRP)	Temporarily Ordered Routing Algorithm (TORA)
i. In this, each node has a discrete zone and the minimum distance of each node is already defined [143]. ii. There is one condition such as if both of the nodes (source as well as destination nodes) are in the same zone, then immediately the source node can start the data communication as shown in Figure 3.11.	i. This protocol is based on adjacent routers and this protocol depends on both of the previous protocols reactive routing protocol as well as the proactive routing protocol. ii. It preserves a Directed Acyclic Graph (DAG) and this protocol performs three basic functions [144] such as route creation, route maintenance, and route erasure as shown in Figure 3.12.

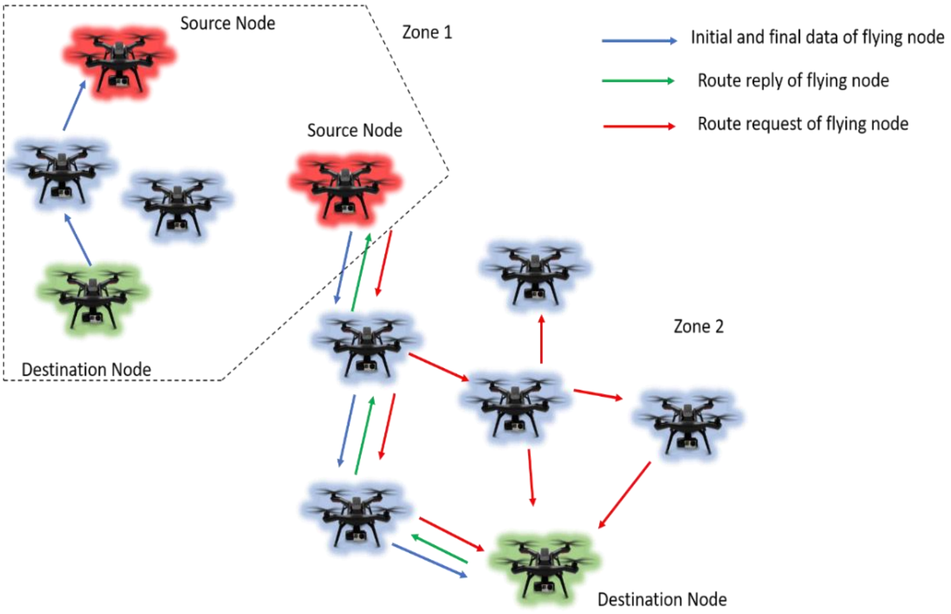


Figure 3.11: Process of Zone Routing Protocol

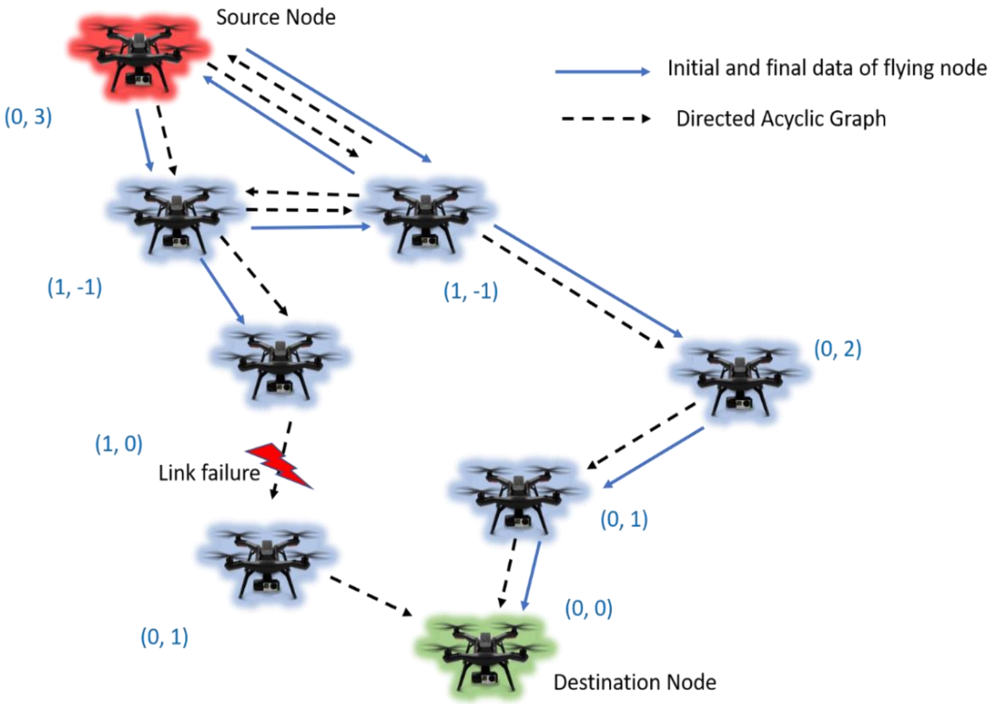


Figure 3.12: Process of Temporarily Ordered Routing Algorithm

3.3.2 Hierarchical-Based Routing Protocols

A reactive approach was employed at the lowest levels, and a proactive strategy was used at the highest levels. Hierarchy is used to keep the lowest and highest levels in order. There are two factors: mobility prediction clustering [145] and the UAV networking clustering method [146]. It is complicated, but the memory requirements are minimal. In this protocol, the bandwidth utilization is high, and the mission failure rate is low.

In general, the hierarchical method is built on the establishment of clusters, each of which is supervised by a cluster. This has the dual benefit of reducing the number of packets sent to ground stations while also reducing UAV energy consumption. Hierarchical protocols have the disadvantage of being difficult to build clusters and, in most circumstances, do not tolerate frequent link disconnections. Different examples of hierarchical-based routing protocols are: extended hierarchical state routing protocol, disruption tolerant mechanism. In Table 3.5, different hierarchical-based routing techniques are discussed.

Table 3.5: Types of hierarchical-based routing protocols

Extended Hierarchical State Routing Protocol (EHSR)	**Disruption Tolerant Mechanism (DTM)**
i. This protocol is based on cluster architecture. ii. It consists of different levels: • UAV network, • Ground network, and • Backbone network. When a level 1 UAV (source node) desires to connect with a level 2 UAV (destination node) in a separate cluster, the data packet travels through the upper layers [147] of the architecture until it reaches the UAV (destination node), as shown in Figure 3.13.	i. This protocol adopts a cluster architecture that is based on the AODV routing protocol [148]. ii. If the target UAV is a member of the cluster, the packet is automatically transmitted to it. Otherwise, as seen in Figure 3.14, the packet is supplied hop by hop.

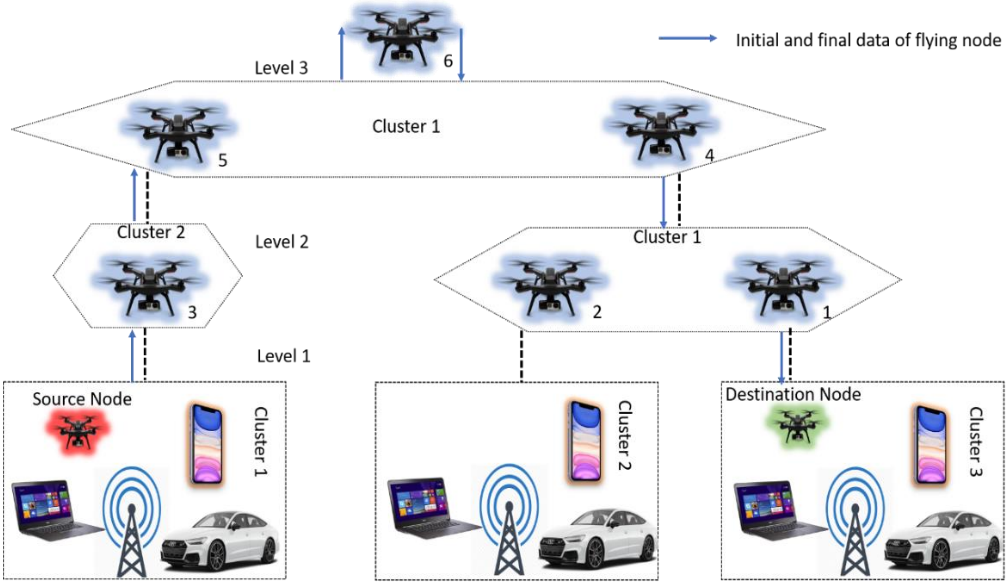


Figure 3.13: Process of Extended Hierarchical State Routing Protocol

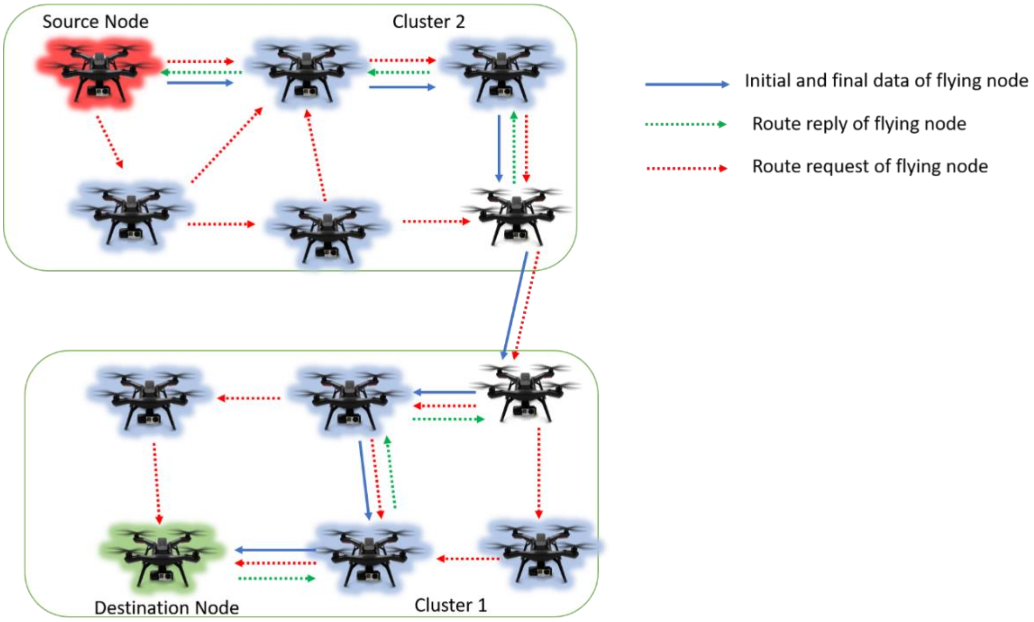


Figure 3.14: Process of Disruption Tolerant Mechanism

3.3.3 Geographic/Position-Based Routing Protocols

In this category, each UAV uses the inbuilt GPS to determine its position. In most circumstances, the sender uses a location service to determine the receiver's location and interacts without going through the discovery procedure. Because numerous strategies are employed to avoid or recover from disconnections, position-based routing protocols are the best appropriate for FANETs. Examples of Geographic/Position-Based Routing Protocol are: greedy perimeter stateless routing, geographic position mobility-oriented routing, multipath doppler routing, mobility prediction based geographic routing, directed diffusion, geographic adaptive fidelity, geographic and energy - aware routing.

Position Routing Protocol is another name for this protocol. Physical position information is required, as is calculating the location using various facilities. It's complicated, and the amount of memory required is enormous. This protocol uses extremely little bandwidth and has a very low mission failure rate. This protocol is further divided into seven categories, as listed below, with a comparison of routing protocols in Table 3.6 and Table 3.7, respectively:

Directed Diffusion (DD): It is a kind of data-centric routing protocol (DCRP). The contact between the nodes is confined to a small network neighborhood, which saves energy and extends the network lifetime [149].

Geographic Adaptive Fidelity (GAF): This method was created for mobile ad hoc networks, but it might also be used for ad hoc sensor networks. It is a position-hierarchical routing protocol, with clusters based on position or geographic location. The clusters are separated into zones, which form a communication grid [150]. In terms of packet routing, nodes with the same point in the grid are considered equivalent. The cluster head notifies the base station of all network activity.

Geographic and Energy - Aware Routing (GEAR): It is based on location and requires full information from the network's connected nodes. The position of specific sensor nodes in a network was determined using Geographical Information System (GIS) in this protocol [151].

Table 3.6: Types of geographic-based routing protocols

Greedy Perimeter Stateless Routing (GPSR)	**Geographic Position Mobility Oriented Routing (GPMOR)**
i. This protocol is the type of GRP and the major concern of this routing protocol is reliability [152]. ii. It can be used for efficiently positioned FANET. iii. It is depending on the location information of the nodes as shown in Figure 3.15.	i. This protocol guesses the movement of the UAV. ii. For the checking of movement of any node, the Gaussian technique has been used [153]. iii. It is used to check the information of the next node as shown in Figure 3.16.

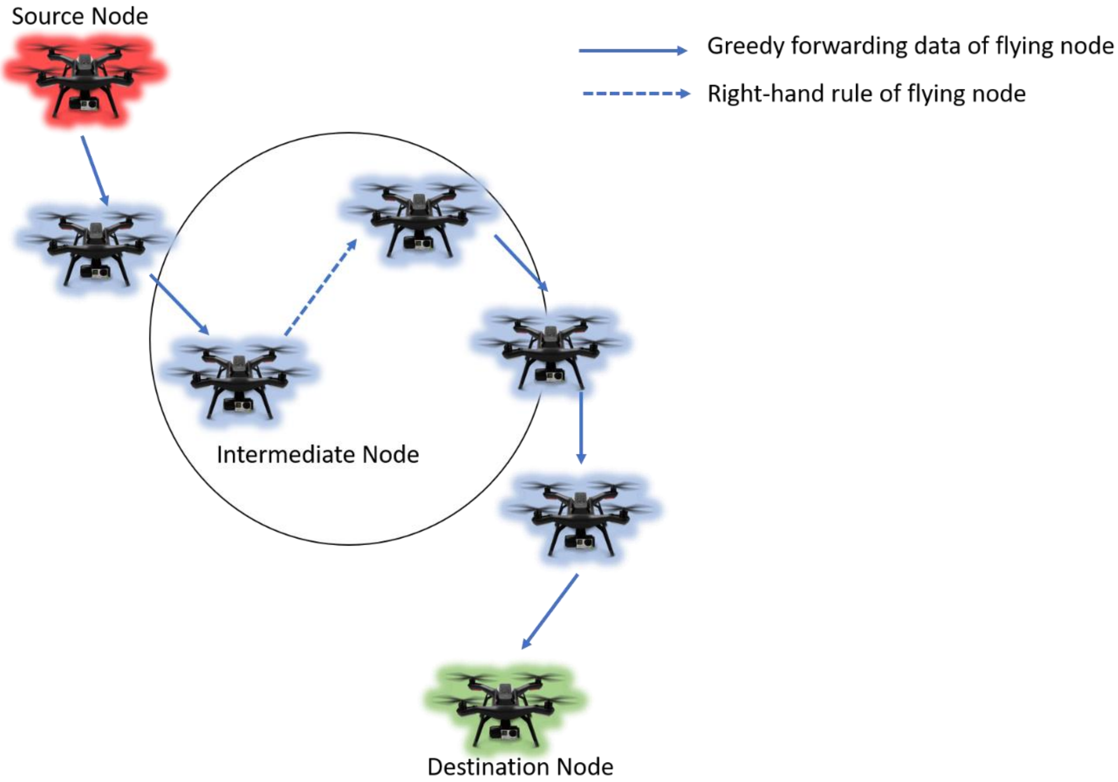


Figure 3.15: Process of Greedy Perimeter Stateless Routing

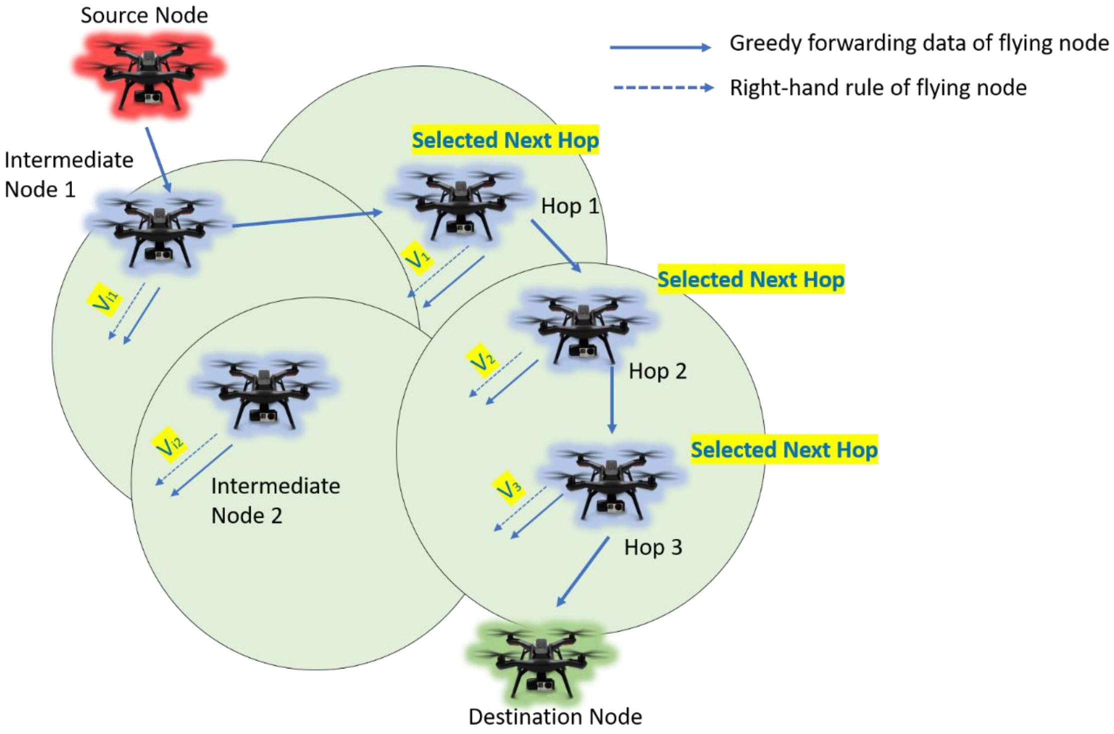


Figure 3.16: Process of Geographic Position Mobility Oriented Routing

Table 3.7: Types of geographic-based routing protocols (Cont'd)

MUltipath DOppler Routing (MUDOR)	Mobility Prediction based Geographic Routing (MPGR)
i. This protocol is the position-based reactive routing protocol that uses the Doppler shift of control packets to determine routing paths. ii. It initiates Route REPly (RREP) and Route REQuest (RREQ) [154][155]. iii. It allows you to choose the best stable UAV sequence by sending a unicast route reply packet to the UAV (source node), as seen in Figure 3.17.	i. This protocol is based on the greedy forwarding technique [156]. ii. As demonstrated in Figure 3.18, it is utilized to reduce node overhead and also uses the Neighbor Discovery packet.

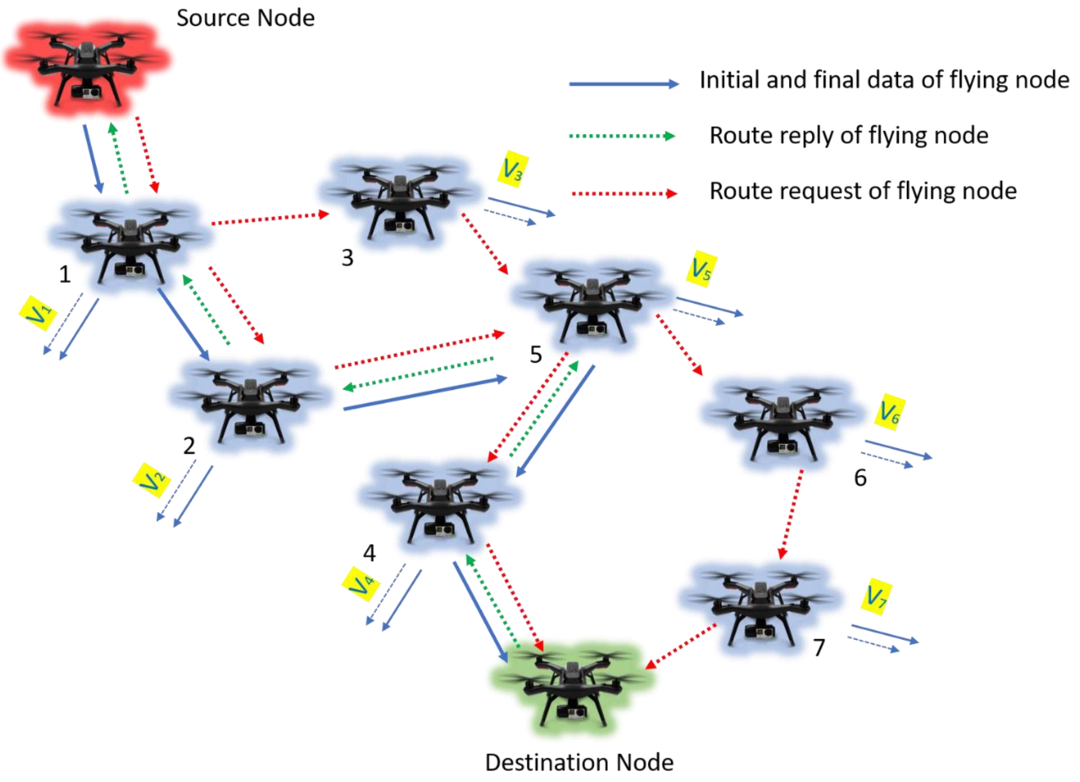


Figure 3.17: Process of Multipath Doppler Routing

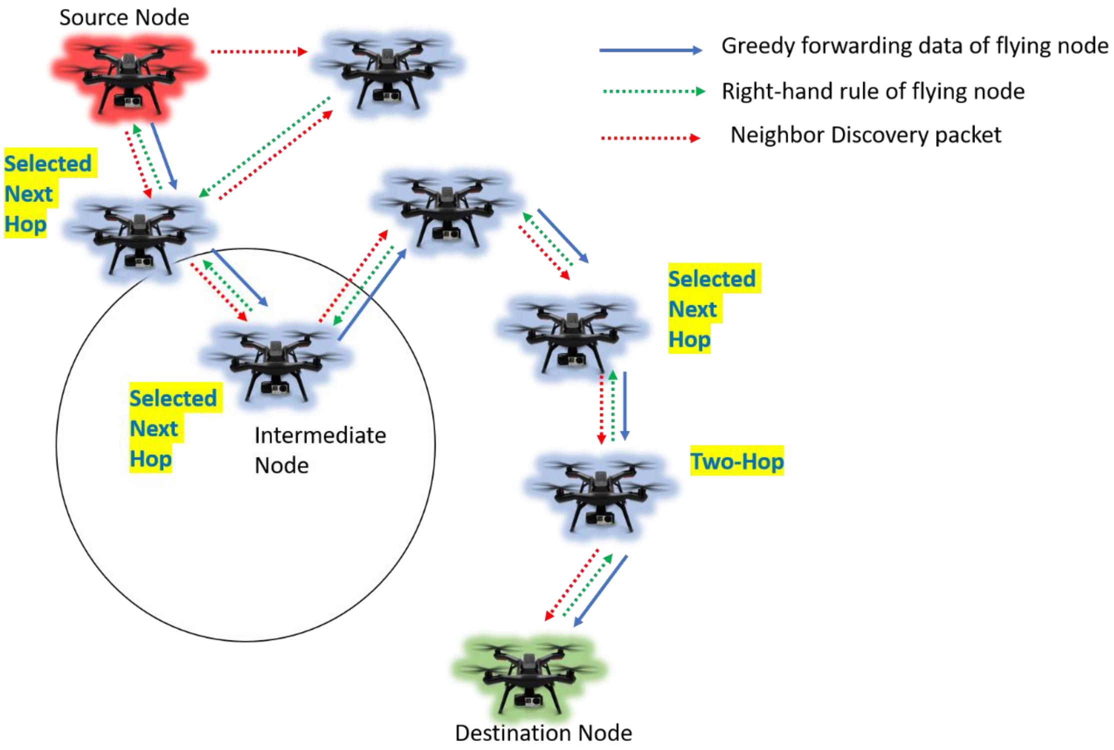


Figure 3.18: Process of Mobility Prediction based Geographic Routing

3.4 Applications of FANETs

FANETs can be used as stand-alone systems or as part of existing cellular networks. The topic has piqued the interest of industry and academic specialists alike. As a result, suitable wireless technologies and lightweight security techniques are required to dramatically improve battery life, reduce computational costs, and encourage greater connectivity.

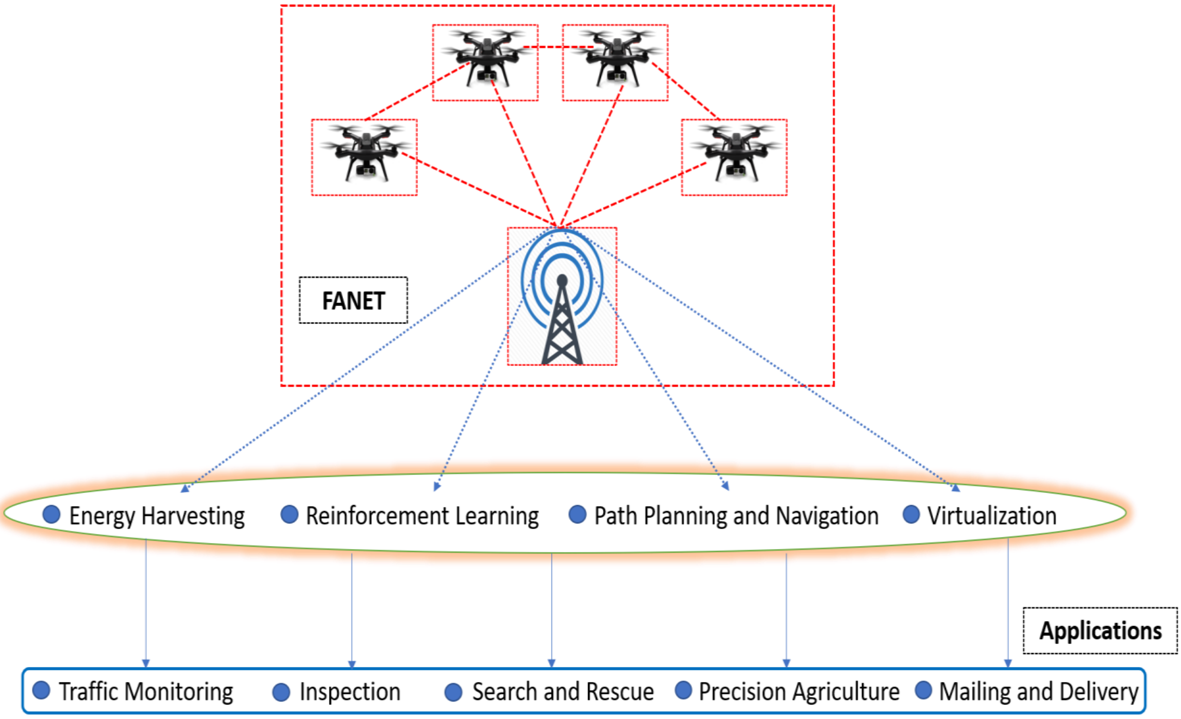


Figure 3.19: Applications of FANETs

The deployment of small UAVs for various civilian and commercial purposes is expected to provide favorable results when it comes to providing precise and dependable data transfer. There are several real-world applications of ad-hoc networks such as medical field, military field, emergency condition, and environmental field. In medical field, an ad-hoc network can use to monitor and observe patient. In military field, it will give admittance to the military to keep an organization among every one of the fighters, vehicles and central command. In emergency condition, it can be used to send or convey emergency messages. In environmental conditions, it can be used to check forest fire, temperature, tsunami, light intensity, pollution level, and so forth. As demonstrated in Figure 3.19, FANETs can be used for a range of applications, including traffic monitoring, inspection, search and rescue, precision agriculture, mail and delivery, and more. The description of some of the applications mentioned below:

3.4.1 Traffic Monitoring

FANETs could also be used to replace the current hard and complex infrastructures required for highway traffic surveillance. UAVs are more expensive than traditional roadside traffic control devices including loop detectors, microwave sensors, and video surveillance cameras [157]. Furthermore, the data obtained by detector technology is statistical and does not allow for the precise tracking of individual vehicle routes within a traffic stream. It places limitations on the utilization of calibration research data, human driving behaviors, and simulation models [158].

As a result of these flaws, the transportation network's capacity to track and acquire data is completely depleted [159]. FANETs that can track and record accidents or conduct traffic management statistics are an economically and socially feasible choice due to their 3D mobility, high speed, and vast coverage. UAVs are employed in traffic monitoring to transmit photographs and video streaming in real-time to the control center; as a result, licensed technology is a superior option. Furthermore, approved technologies may function without line-of-sight and take advantage of existing communication infrastructures, which is especially useful in metropolitan settings.

3.4.2 Inspection

UAVs have been used for surveillance purposes for a long time. The introduction of FANETs, on the other hand, is expected to change the concept of surveillance. The use of UAVs in patrolling a certain geographic location helps to reduce human intervention. A border surveillance UAV team, for example, can detect not just unanticipated humanitarian crises such as firearms and narcotics, but also unlawful border crossings [160]. Unlicensed technologies such as Wi-Fi and Bluetooth 5 can be used in inspection situations with limited coverage regions and fewer node connections, but licensed technologies can be employed in situations with vast coverage areas and mass deployment of UAVs, comparable to search and rescue operations.

3.4.3 Search and Rescue

Among the most prominent aerial robot driving applications are search and rescue missions. This is partly owing to UAVs' distinct advantages over human vehicles, such as mobility, flexibility, and scalability [161]. Furthermore, UAVs can fly separately, access difficult landscapes, and collect data in ways that human vehicles cannot. With the introduction of FANETs, UAV engagement in active search and rescue operations has expanded even more [162]. With these limits in mind, unlicensed technologies like Wi-Fi and Bluetooth 5 may be used for limited coverage areas and fewer nodes, whereas cellular technology, can be used for large coverage areas and mass UAV deployment.

3.4.4 Precision Agriculture

Crop health is monitored as part of agriculture production management. Although human aerial vehicles have been employed in this sector for decades, the new concept of autonomous UAVs is seen as more helpful because they execute field operations with higher precision on both smaller and larger areas [163]. Small UAVs can be used to capture high-resolution crop photos. Short-range wireless technologies, notably Wi-Fi, may be the best option for meeting crop health monitoring needs in terms of coverage, delay, and throughput.

3.4.5 Mailing and Delivery

Package delivery is one of the most appealing UAV uses, with major courier businesses supporting it for speedy, cost-effective, and efficient transportation of parcels weighing less than the maximum bearing weight of a UAV [164]. Low throughputs are required for trajectory planning in mailing and delivery operations, although coverage areas might be large. Because the communication range of unlicensed technologies is limited, any acceptable licensed technology can be used for mailing and delivery activities.

3.5 Design Factors of FANETs

FANET is another kind of MANET wherein the nodes are UAVs. Single-UAV systems cannot build up a FANET, as indicated by this definition, which is just valid for multi-UAV frameworks. Not all multi-UAV frameworks, on the other hand, form a

FANET. An ad-hoc network between UAVs should be utilized to work with UAV communication. As a result, if UAV-to-infrastructure communication is completely reliant on UAV-to-infrastructure linkages, it cannot be classed as a FANET.

Traditional sensor network design difficulties include energy consumption and node density [165], neither of which apply to multi-UAV frameworks. The UAV ad-hoc network [166] is another idea that is closely related to FANETs. There are no notable discrepancies between existing UAV ad-hoc network research and the aforementioned FANET specification. The most important FANET design factors, such as flexibility, scalability, delay, UAV platform limits, and bandwidth demand, are described in this subsection.

3.5.1 Adaptability

During the activity of a multi-UAV framework, different FANET parameters can change. FANET nodes are extremely portable and frequently change locations. The routes of the UAVs may fluctuate due to operational reasons, and the distance between UAVs cannot be persistent. It is capable of scanning the parameters and selecting the best physical layer option. The network layer protocols are further affected by the very dynamic nature of the FANET environment. In an ad-hoc network, route maintenance is tightly linked to topological changes. As a result, the system’s performance is dependent on the routing protocol’s ability to react to link changes. The transport layer should also be adjusted by FANET’s current state.

3.5.2 Scalability

In comparison to a single-UAV framework, the collective work of UAVs can further develop system enhancement. It is for this reason that a group of UAVs is used. In numerous applications, the number of UAVs used to improve performance is directly proportional to the number of UAVs used. A larger UAV, for example, can perform a search and rescue process quicker [167]. FANET routing protocols should be designed in such a way that multiple UAVs may coexist with little performance degradation.

3.5.3 Delay

Delay is a critical design consideration for different categories of networks, and FANET is also not different. The amount of delay required by FANET is entirely depending on the application. Several packets must be transferred anywhere in a specific delay constraint, particularly for significant FANET military applications surveillance. Another prerequisite for collision avoidance of many UAVs is low delay [168][169].

3.5.4 UAV constraints

FANET methods must be installed on the UAV platform, imposing various constraints. Even, the hardware has a significant impact on the UAVs' performance. Lighter hardware translates to a lighter payload and increased endurance.

The process of implementing additional sensors on the UAV is another advantage of the lightweight hardware. If the overall payload is assumed to be uniform and the transmission server is minimal, more complex sensors and other devices can be installed. Another concern with UAV platforms for FANET systems is a shortage of area. The limited area is crucial for devices that can be integrated into the UAV platform, particularly mini-UAVs. [170].

3.5.5 Bandwidth necessity

The goal of the majority of FANET applications is to gather environmental data from the situation and transfer it to a ground station [171]. For example, in an investigation, surveillance, or salvage mission, the target region must be relayed from the UAV to the direction central controller with a tight delay limit, necessitating a huge amount of bandwidth. Furthermore, because of technical improvements in sensor technologies, it is now likely to capture information with extremely high resolution, resulting in a substantially greater bandwidth requirement.

Additional bandwidth is required for the collaboration and coordination of many UAVs. On the other hand, there are numerous restrictions on how available bandwidth can be used, including:

- the communication channel’s capacity,
- the speed of UAVs,
- the fault structure of wireless connections, and
- All factors to examine include the absence of security with the broadcast transmission.

A FANET protocol must fulfill the bandwidth required to send highly higher expected pictures or video under a variety of limitations.

3.6 Conclusion

Load balancing is a critical problem in FANETs, and routing is one of the most important components for ensuring proper functioning and cooperative network operations. The characteristics of FANETs were discussed in this chapter. The most widely used strategies by the routing protocols of FANET are explained in the second stage. Following that, the classification of routing protocols of FANET is presented, with the protocols divided into three primary groups and subcategories. The applications and design factors of FANETs are also described in this chapter. Each category is detailed independently, with descriptive figures of its routing methods, which are then contrasted based on different applications.

CHAPTER 4

An Improved Firefly Algorithm with its Properties for Flying Nodes

4.1 Introduction

The enhancement and reduction of an objective function by selecting appropriate entries for the parameters from a list of possible values are referred to as an optimization issue. When a person wishes to travel from one location to another and has several options, for example, a decision must be complete on which route to follow. The selection could be made to reduce travel time, fuel consumption, and other factors. A firefly algorithm is based on how fireflies communicate with one other by flashing their lights to attract mates or identify predators.

In this chapter, we propose an upgraded algorithm of the firefly algorithm in FANETs using its two different properties. Along with the proposed algorithm, the 3D view model is also shown. The simulation of the firefly algorithm and the parameters results are thoroughly analyzed.

4.2 A Standard Firefly Algorithm

The Firefly method is one of many metaheuristic algorithms with various uses. It is simple and easy steps, as well as its effectiveness, draw scholars from various disciplines. Several studies have been conducted to improve the basic firefly algorithm’s performance and adapt it to the task at hand. Fireflies connect by flashing their wings. There are about 2500 distinct kinds of fireflies, each with its flash structure. They normally emit a brief flash with a regular structure. Light is produced by a biological phenomenon called bioluminescence. The flashing transmission should be used to both lure and alert predators away from a mate. A suitable individual will respond by either replicating the same structure or responding with a particular structure depending on the light pattern. It is worth mentioning that light intensity diminishes with distance; consequently, flashing light from a firefly brings fireflies within the flash’s visual variety.

Effective load balancing is critical for network performance optimization. The Ant Bee Colony (ABC) algorithm was introduced in MANET for load balancing. This technique was used to select the best node to avoid traffic congestion on mobile nodes [172]. This was also done to increase Quality of Service (QoS) performance. In his work [173], he proposes the following load-balancing steps:

(i) [Start.] If the bandwidth and energy requirements are met, the bee route is discovered.
(ii) Examine the situation to see if scout bees are present.
(iii) If there is one, see if the termination condition is met.
(iv) If the scout bee does not exist, develop a new solution for the bee and go through the steps again (i).
(v) When the termination condition is met, the best path is chosen and communication is started.
(vi) Stop.

The technique assigns a light intensity to an arbitrarily produced possible solution called firefly based on their performance in the objective function. The firefly's brightness, which is proportional to its light intensity, will be calculated using this intensity. For minimization issues, the highest light intensity will be awarded to the solution with the minimum functional value. Each firefly will follow fireflies with higher light intensity when the brightness of the solutions has been allocated. The brightest firefly will conduct a local search by traveling about randomly in its neighborhood.

4.3 An Improved Firefly Algorithm

This technique was used to choose load-balancing-based routing paths for data transmission from source to destination. It will, nevertheless, be reliable in highly mobile networks. In VANETs, there is also a requirement to balance the load [174]. Few authors have proposed solutions for VANETs based on Genetic Algorithms (GA), power-saving models for Road Side Units (RSU) placement, and Binary Integer Programming (BIP) [175]. It is self-evident that the battery lifespan and network stability in nodes can be improved. The effects of several proposed strategies on network load, energy consumption, and average packet delay.

The Geographical Position Mobility Oriented Routing (GPMOR) protocol is used to locate the best available subsequent hop in the network [176]. This protocol is used for highly dynamic structures. The major issue is determining which network has the best accessible next hop. The Gauss Markov (GM) mobility model [177] is used to answer this question. The node position in the FANET is predicted using this model. It also reduces the number of routing failures by doing so [178]. The next step is to employ the mobility relationship after forecasting the node position. The mobility relationship procedure is used to select the network’s next best hop, which should be more precise for the network. This mobility paradigm is utilized to create a more resilient environment in the event of route failures.

Yang Xin-She introduces the firefly algorithm. This approach is used to tackle optimization issues that take advantage of fireflies’ alternating behavior in nature. In

FANETs, optimization is the concept of determining the optimum route. The action of creating decisions and providing the optimum option from a set of available options utilizing a 3D view is referred to as optimization and XBAR control graph of Improved Firefly Algorithm as shown in Figure 4.1 and Figure 4.2 respectively. The following are the three most important parameters to consider while using optimization techniques:

(a) Write an optimization function,
(b) choose a value based on a probable answer, and
(c) analyze the optimization rule and approach.

Rules of firefly algorithm:

(i) Fireflies are unisex, which implies that one firefly will be drawn to another firefly regardless of gender.
(ii) The brightness is comparable to the attractiveness, and both decreases as the distance between them increases. As a result, if there are dual flashing fireflies, the less bright one will transfer to the brighter one. If there isn't another firefly that is brighter than it, it will move at random.
(iii) The intensity of a firefly is determined by the geography of the optimization problem.

An Improved Firefly Algorithm with its properties can be stated as:

(Improved Firefly Algorithm) With the help of two properties, this approach is used to determine the shortest path in a network. The first is the firefly's brightness, which is proportionate to its mate selection and prey attractiveness. The other is that the difference between the couples (two) of fireflies is inversely proportional to the difference between them.

Pseudo-code for the selection of path using an improved firefly algorithm

```
Begin
1.  Initialization Obj_func ( ), Max_Gen_func ( ), $f(pkt)$, $pkt = (pkt_1, pkt_2, \ldots, pkt_n)^t$
2.  Generation of the initial population, $pkt_i\ (i = 1, 2, 3, \ldots, k)$
```

```
Define light intensity ($L_i$) and light absorption coefficient ($Co_{eff}$)
Do
  for i = 1: k, all 'k' fireflies
    for j = 1: i, all 'k' fireflies
      if ($Li < L_j$),
        Move firefly i towards j
      Else
        Do not move firefly i towards j
      end if
      while (pkt < Max_Gen_func ($M_G$))
      Compute attractiveness value of the fireflies using
      $\beta = \beta_0 x e^{-yr^2} - 1! = 0$, where, $\beta_0! = 0$
    end for j loop
  end for i loop
  Update the latest $L_i$ of the fireflies.
  Then, rank all the fireflies and display the best-desired path.
end do while
End
```

4.4 Results and Discussions

The firefly algorithm is used to discover the quickest route that is both feasible and practical. With the help of the firefly algorithm, the procedure is a set of methods for well-organized routing in a FANET. There are two approaches in FANET: one is to find the neighbor node, and the other is to determine the destination position. Following the application of an objective function to obtain a sorted list, the firefly algorithm broadcasts each packet. The next step is to select the highest value from the network, followed by a check of the internal node. If the internal node is the receiver node, return to the starting node and adjust the objective function for the next step in the process, and you'll get the desired outcome. The firefly algorithm is a particle swarm algorithm that is still in development. The flashing action of the firefly and the stepwise procedure, which describe the collection of instructions to be performed in a detailed order to get the best-desired output.

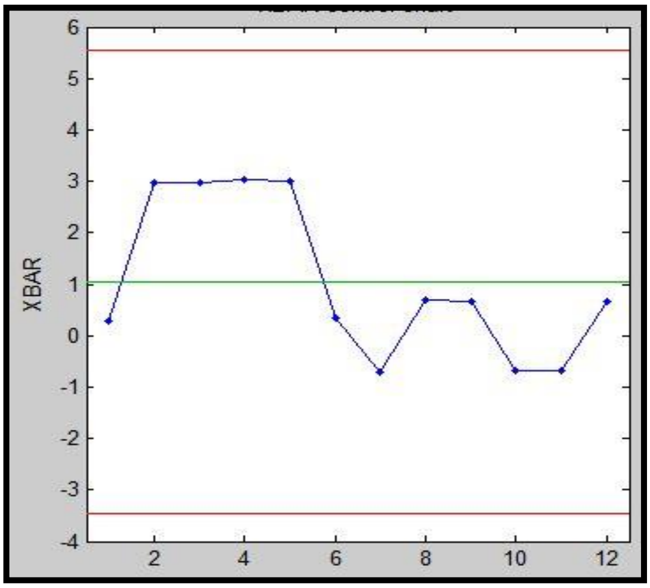


Figure 4.1: Improved firefly algorithm

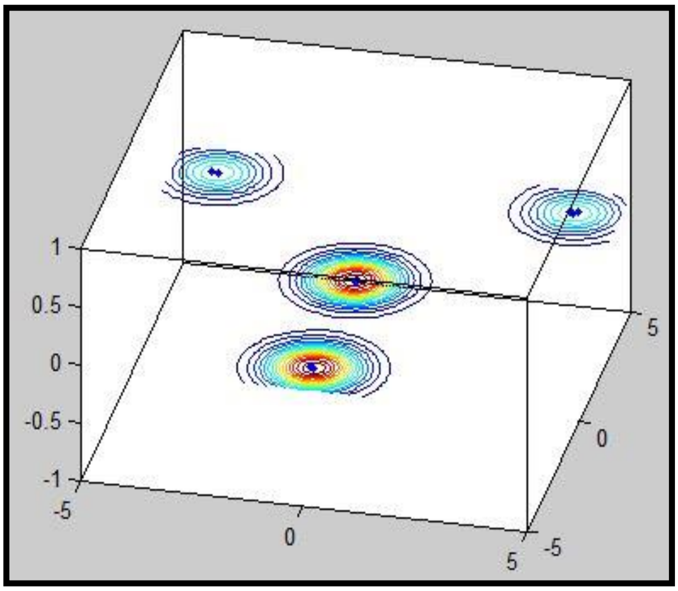


Figure 4.2: 3D view of an improved firefly algorithm

A comparison of recent metaheuristic algorithms such as the Genetic Algorithm (GA), Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Cuckoo Search (CS), Firefly Algorithm (FA), and Improved Firefly Algorithm (IFA) is also discussed. The comparative analysis of metaheuristic algorithms with simulation time in seconds shown in table 4.1. GA mimics biological systems' evolutionary behaviour. To produce two new individuals, two genomes are chosen from the mating pool of N genes. A specific fraction of the values in the list of genes are changed by genetic mutations. The second method a GA examines a cost area is through mutation. It allows for the introduction of features that were not present in the original population, as well as preventing the GA from resolving too quickly before covering the complete cost surface. A single genetic disorder converts a 1 to a 0 and the other way around. The mutation points are chosen at random. The expenses involved with the offspring and mutant genes are computed once the mutations occur, and the bottom genes are selected. The number of iterations that evolve is determined by whether an adequate solution is found or if a certain number of iterations has been achieved. If it weren't for the genes and accompanying costs, everything would be the same for a while. The algorithm should be terminated at this moment.

In ACO, ants lay a signal path as they travel to discover the quickest path to food. The signal path leads to food for other ants. Ants who take the shorter road create a stronger signal path faster than those who take the longer path. Because a stronger signal attracts ants more effectively, more and more ants will use the shorter path until all ants have discovered it. The ACO is a logical fit for the problem of travelling salespeople. It starts with a swarm of ants following a trail through various towns. Each ant leaves a trail of signal in its wake. The process starts by assigning each ant to a city at random. And next city is chosen using a balanced probability formula that takes into account the intensity of the signal on the road as well as the distance between the two cities. Short pathways with a lot of signals have the best chance of being selected. signal is applied on unproductive pathways in the beginning. As a result, part of this signal must vanish over time, or the algorithm will conclude on a path that is ineffective.

In the same way that continuous GA starts with a randomised matrix, PSO does as well. PSO lacks evolution operators where e ach particle has a velocity as it goes around the cost surfaces. The particles' velocities and positions are updated based on the best large and small solution. The PSO algorithm adjusts each particle's velocity vector before adding it to the particle's position output values. Both the globally leading solution connected with the least price ever found by a particle and the best local solution connected with the lowest possible cost in the population impact velocity changes. If the top local solution is less expensive than the globally leading solution, the top local solution will take the place of the leading global solution.

The abnormal behavior of some cuckoos in placing their lay eggs of other birds inspired CS. If a bird realises that the eggs are not its own, then it will throw them away or depart the nest. Some cuckoo organisms have adapted to specialise in the colour and pattern mimicking of host species' eggs. A cuckoo egg signifies a new resolution, and each egg in a nest indicates an alternative. The solution is to establish a less-than-ideal solution in the nests with potentially highly superior options. Each nest has one egg in its most basic form. The procedure can be expanded to more sophisticated scenarios, such as when each nest contains many eggs, each signifying a range of solutions.

Table 4.1: Comparative analysis of metaheuristic algorithms with simulation time in seconds

Number of cities (N)	**GA**	**ACO**	**PSO**	**CS**	**FA**	**IFA**
	(Time)					
10	0.67	3.9	0.41	2.08	0.59	0.52
20	0.54	16.5	0.78	2.83	0.53	0.47
30	0.53	38.8	1.42	3.98	0.47	0.43
40	0.51	45.7	1.59	4.08	0.40	0.39
50	0.49	52.4	1.74	4.64	0.37	0.34

With the aforementioned data, it can be shown that the simulation time for IFA and FA is reduced for smaller numbers of N (cities), but increases as N increases. The simulation time in the ACO, on the other hand, expands as N increases, as illustrated in figure 4.3. At the same time, while the CS algorithm takes longer to simulate for small values of N, the duration remains nearly constant as the number of cities grows (N). Because the CS method has lower controlling values than the IFA, FA, and GA algorithms, it may be a better choice for problems that require a lot of iterations and where the controlling parameters are kept to a minimum. IFA is a superior solution for applications that require a lesser number of iterations and fine control over the search.

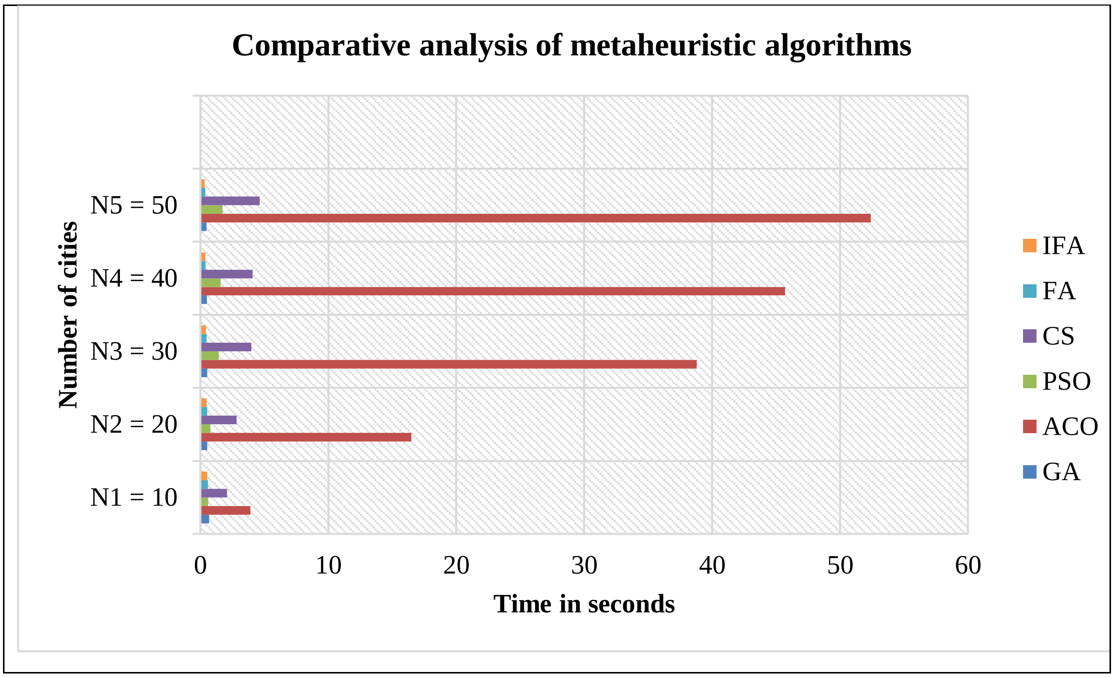


Figure 4.3: Comparative analysis of metaheuristic algorithms

Table 4.2: Comparison of accuracy analysis of metaheuristic algorithms

Algorithms	**Parameters Values**	**Accuracy**
GA	c = 1110100000, $V_{10} = 928$, X = 8.87, f(x) = 2.57	86.17%
ACO	$\tau_{ij}^{\alpha} = 12$, $\eta_{ij}^{\beta} = 16$, S = 4	95.3%
PSO	$c_1 = c_2 = 1.494$, w ϵ [0.4,0.9], $V_{max} = 1$, $V_{min} = -1$, N = 30, T = 1000	94.5%
CS	$P_A = 0.25$, N = 30, T = 1000	92.8%
FA	x = 1.0, $\beta_0 = 1.0$, r = 1.0, N = 30, T = 1000	96%
IFA	x = 1.0, $\beta_0 = 1.0$, r = 0.2, e = 1.0, N = 30, T = 1000, where, $\beta_0! = 0$	98%

With this knowledge, we utilised the IFA to determine the best path, proving that the IFA can provide a fair mix of exploitation and observation. We've also demonstrated that IFA necessitates considerably fewer function evaluations. Based on this framework, a critical evaluation of a number of metaheuristic algorithms is presented, including variants of GA, ACO, PSO, CS, FA, and IFA. The comparison is based on several benchmark problems of varying complexity and accuracy, As demonstrated in Table 4.2, when compared to GA, ACO, PSO, CS, and FA, the IFA improves the accuracy of the solutions and greatly improves the resilience of the solutions for the test functions, associated with high test problems.

Complexity of improved firefly algorithm: Improved firefly algorithm has two loops: one inner loop when going through the population 'n', and one outer loop for iteration 'j'. So, the complexity at the extreme case = O (n^2j) i.e, O (n^2). Because the method complexity is linear in terms of 'j', the computing cost is very low when n is small (usually, 'n' = 50) and j is high (say, 'j' = 3000). After all, objective assessments are the most computationally intensive element of any optimization tasks. If 'n' is high enough, one inner loop may be used to rate the attractiveness or brightness of all fireflies using sorting algorithms. In this case, the algorithm complexity of improved firefly algorithm will be O (nj log(n)).

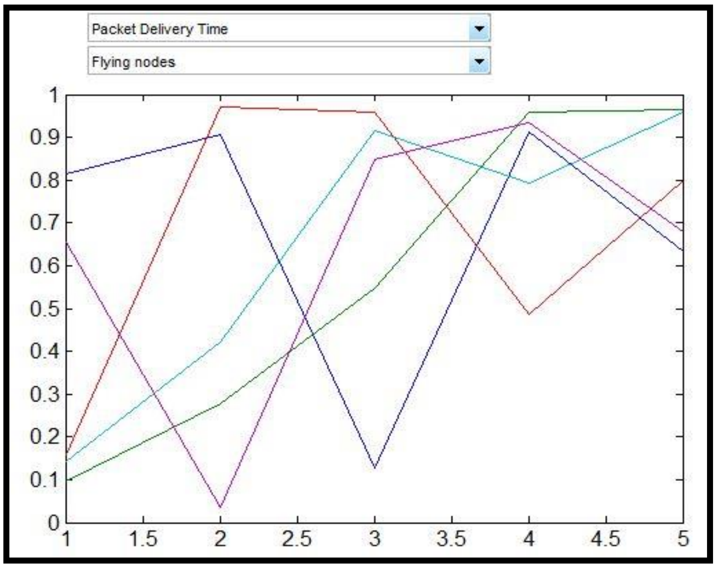


Figure 4.4: Packet Delivery Ratio of flying nodes

The overall results based on a well-organized routing protocol can be measured using a variety of parameters, which are listed below. The Packet Delivery Ratio (PDR) of flying nodes is shown in Figure 4.4. This graphic depicts the relationship between the overall number of data packets transferred from the origin to the destination and the total number of data packets produced at the destination. GPMOR’s packet delivery ratio has remained consistently high. The results show that, in a highly dynamic environment, GPMOR can outperform other protocols in terms of packet delivery ratio. In a high mobility setting, GPMOR can provide significantly more effective and precise routing for the highly dynamic aerial network.

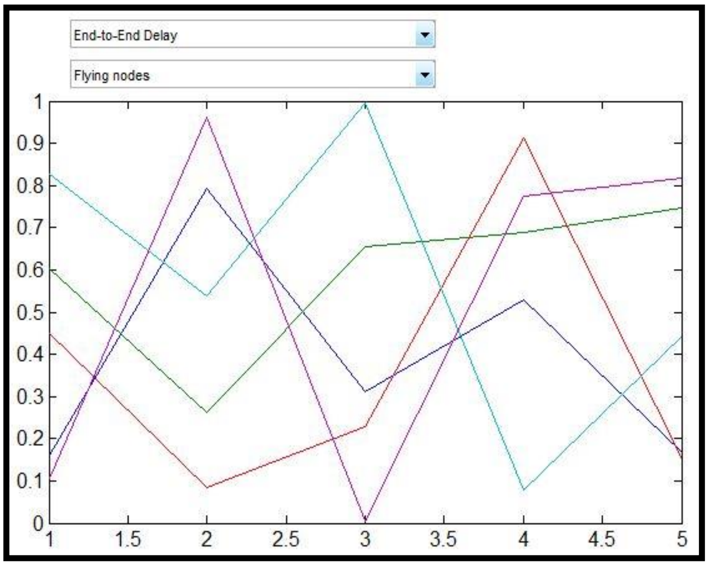


Figure 4.5: End-to-End Delay of flying nodes

The End-to-End Delay (EED) of flying nodes is depicted in Figure 4.5. This graphic depicts the distance between the transmission times of each node at the sender and the receiving times of each node at the destination.

The number of hops made by flying nodes is depicted in Figure 4.6. A hop happens when a packet is transmitted from one particular portion to the next, as illustrated in this figure. As data packets travel between source and destination nodes, they pass through routers.

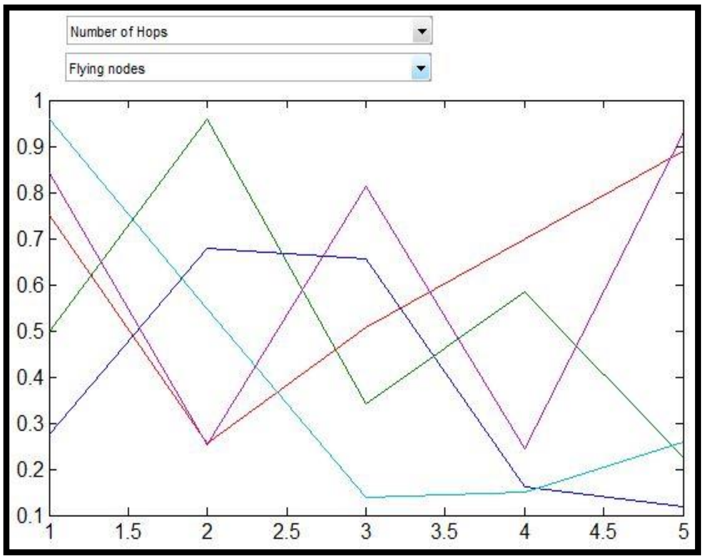


Figure 4.6: Number of hops of flying nodes

4.5 Conclusions

A detailed review of an upgraded firefly algorithm is presented in this chapter. We have developed a new (improved) firefly algorithm. We then implemented it on different parameters. The fundamental firefly method is incredibly efficient, but as the goals approach, we can observe that the solutions are still changing. By gradually reducing the randomness, the solution quality can be improved. We utilised the IFA to determine the best path, proving that the IFA can provide a fair mix of exploitation and observation. We demonstrated that IFA necessitates considerably fewer function evaluations with 98% accuracy. The complexity of the IFA is O (n^2).

Variable the attractiveness parameter so that it lowers gradually as the goals approach is another way to improve the algorithm’s convergence. This suggests that the improved firefly algorithm may be more effective in resolving other issues, which will be examined further in future research.

CHAPTER 5

GPMOR Routing Protocol to Manage Load Balancing Scheme

5.1 Introduction

Unmanned Aerial Vehicles (UAVs) are commonly utilized in modern warfare for surveillance, reconnaissance, sensing, and attack. Because of the extremely dynamic environment, however, communication between UAVs always practices packet loss. As a result, data routing for UAVs faces several challenges that are not present in a low mobility context. The main objective is to implement the proposed optimization technique for load balancing. In this chapter, we present a geographically based routing system that is both efficient and effective. To avoid the impact of highly dynamic movement, our solution uses a Gauss-Markov mobility model to anticipate the movement of UAVs. Then, in addition to distance, it chooses the next hop based on the mobility relationship to make a more precise judgment. This chapter compares and contrasts various position-based routing protocols. The load balancing of different flying nodes has been studied in conjunction with the suggested technique.

The proposed approach divides the computational strain among flying nodes when calculating the position of unknown nodes. Furthermore, using the firefly method, the technique has been optimized in a FANET. The optimized backbone is used to locate the unknown nodes. The simulation results show that our technique significantly improves network durability and balanced traffic because the computational effort is distributed efficiently among the flying nodes. The simulation of the load balancing concept is thoroughly examined, as are the outcomes.

5.2 GPMOR Routing Protocol

GPMOR is an acronym for Geographic Position Mobility Oriented Routing. It is a routing protocol that is based on position. Except in the instance where UAVs are widely dispersed, this protocol's approach is based on single path greedy and prediction abilities, which represent a reliable result in this situation. This routing technique is unique in that it predicts node movement using mobility models. This was created for high-speed UAVs that travel at speeds of above 300 km/h and follow predetermined paths. The goal of GPMOR is to find the subsequent best hop in circumstances where the network is severely fragmented. To do so, it uses a Gauss-Markov mobility model to expect the UAV's future situation and a Metric-To-Connect (MTC) to detect the node-to-node connection and, as a result, more precisely select the next hop. The neighbor finding stage and the phase of data transmission are the two phases of GPMOR as shown in Figure 5.1. During the neighbor detection phase, a beacon method similar to Greedy Perimeter Stateless Routing (GPSR) is employed to broadcast node velocity and position obtained by Global Positioning System (GPS). The 'hello' beacons are used to maintain the neighbor table, which is utilized to determine the distance between the destination and MTC of individual neighbors to make routing selections. Every node sends its location to its immediate neighbors frequently, seeking to predict their new positions in real-scenario. The starting node can select the best relay node for the end node (receiver) using this method. The source node determines the location of the destination and its neighbors during the data forwarding phase, taking into account their next movement. Before it selects the closest neighbor to the end node, and if there are other candidates, it selects the node with the maximum MTC.

GPMOR's benefits stem from its capacity to collect data on UAV velocity and position, as well as make predictions about their motions using a Gaussian Markov mobility model. Furthermore, when compared to the GPSR's outside mode, which is created on an arbitrary pick, its potential to consider the mobility link between neighbors and destination is an approach that may offer a better solution [179]. As a result of the routing being selected relying on its future location and mobility connection with the target, the network's average delay and packet delivery ratio may enhance. When network density is exceedingly short, GPMOR fails to function as predicted, ensuing in significant network performance degradation, particularly when it comes to EED.

In this chapter, we discussed about GPMOR, a unique geographic-based routing protocol that can select the best available next-hop to effectively reduce the impact of intermittent connectivity caused by highly dynamic mobility, as shown in Figure 5.1. To reduce routing failure, we first utilize a Gauss-Markov mobility model to forecast node position. Second, we exploit the mobility relationship to more precisely choose the next-hop for routing.

- Every GPS-enabled flying node knows its coordinates. Each node periodically exchanges the information about one-hop neighbors with a timestamp and updates the neighbor list table with beacon messages at a predetermined interval.
- The flying nodes are said to move in random directions and do not change their directions frequently or abruptly.
- In the actual world, the flying nodes will continue to move for a long time, except for emergencies. Because the flying nodes may fly at the same altitude, it is assumed that their movement is in 2D to simplify the problem.

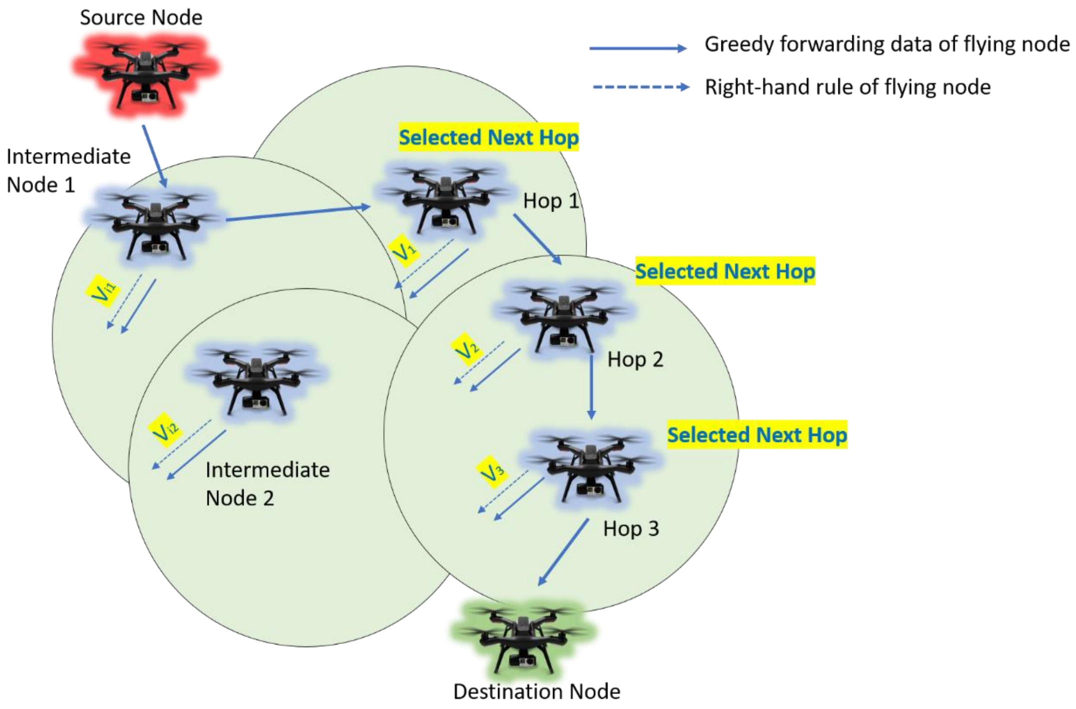


Figure 5.1 Process of GPMOR routing protocol

5.2.1 Information Update

Although UAVs are equipped with GPS, it is difficult for one vehicle to determine the position of all others. The most popular and effective method is for the node to only receive and use incomplete information to complete global routing. As a result, each node will broadcast its position, velocity, and other routing information regularly. The broadcasting period, on the other hand, is critical. Because of the long delay, the position will be erroneous. The short interval, on the other hand, will result in more overhead. We fixed the interval of beacons with several seconds in this chapter to create a compromise between accuracy and overhead. Position, velocity, and time stamp are the major contents of the beacon. In addition, all of the data will be saved in the neighbor table.

5.2.2 Movement Prediction

The current beacon interval, local position, and velocity may differ from the neighbor table data. As shown in Figure 5.1, the relay node R’ may be moved out of the range of communication of the starting node. Even though the relay node R can transfer data based on the information contained within the packet, the real position of destination D will vary during forwarding, especially in the case of highly dynamic mobility. The routing option would thus be incorrect, resulting in packet loss or excessive delay. As a result, properly predicting the movement of aircraft nodes is critical. Unlike typical random movable nodes, UAVs move according to aerodynamics criteria. The UAV movement can be predicted using the Gauss-Markov mobility model [180] if current velocity and direction are known. Because existing UAV velocity and direction concerns formers, the new ones can be modulated as follows:

There are various sorts of procedures in each of these areas. GPMOR is compared to the most commonly used protocols in today's society. Table 5.1 lists the major procedures, together with their benefits and drawbacks, as well as why GPMOR is the best of them.

5.2.2.1 MUDOR vs GPMOR

The fundamental issue with the Multipath Doppler Routing (MUDOR) protocol is that the routing path is insecure owing to flexibility and density, therefore the discovery process must be repeated normally, and it has limits to fragmentation. In GPMOR, the goal is to recognize the optimal solutions in instances where the network is experiencing discontinuity [84].

5.2.2.2 MPGR vs GPMOR

Mobility Prediction-based Geographic Routing (MPGR) is based on the connecting principle, but it ignores connect lapse time and does not include structured direction [85]. However, GPMOR was developed for high-speed UAVs that follow predetermined paths.

Table 5.1 Pros and Cons of geographic-based different routing protocols

Protocol	Pros	Cons
Multipath Doppler Routing (MUDOR)	Creating routes that will last a long time	Disconnections
Mobility Prediction based Geographic Routing (MPGR)	Packet loss and delivery delays are reduced.	Information on the state of the links is ignored.
Greedy Perimeter Stateless Routing (GPSR)	GPMOR's alternate option	a smaller perimeter
Directed Diffusion (DD)	Increases the network's lifespan Caching in terms of delay	Paths are retransmitted. Unaware of energy
Geographic Adaptive Fidelity (GAF)	High scalability	It has an impact on energy efficiency and power management. Extremely overburdened
Geographic and Energy-Aware Routing (GEAR)	Increases network longevity and outperforms GPSR in terms of packet delivery.	Scalability is limited. It has an impact on energy efficiency and mobility.
Geographic Position Mobility Oriented Routing (GPMOR)	Improve packet delivery while decreasing EED.	In this case, the performance is based on the mobility model.

5.2.2.3 GPSR vs GPMOR

The capacity of GPMOR to gather data on the speed and location of UAVs and estimate their motions using a Gaussian-Markov mobility model is a significant advantage.

Furthermore, its ability to evaluate the mobility connection between neighbors and the target is a system that might be useful as a superior alternative to the GPSR perimeter technique, which is the result of an arbitrary judgment [86]. As a result, the forwarder will be chosen based on its future position and mobility relationship with the destination, potentially improving the network's average delay and packet delivery ratio.

5.2.2.4 DD vs GPMOR

Directed Diffusion (DD) is a routing technology that achieves reduced packet exchange while also improving energy efficiency. GPMOR, on the other hand, improves packet delivery in the network and reduces packet EED [87].

5.2.2.5 GAF vs GPMOR

Geographic Adaptive Fidelity (GAF) is a location-based protocol that extends the network's lifespan. First, the network must be divided into square grids, followed by the selection of higher residual energy and forwards rest in sleep mode. If the sleep time has expired, sensory data must be sent.

Otherwise, the preceding phase is resumed. The major goal of this protocol is to maximize network longevity, however, because it employs the Gaussian-Markov mobility model [88][89][90], positions in GPMOR are updated frequently.

5.2.2.6 GEAR vs GPMOR

The GEAR (Geographic and Energy Aware Routing) protocol can help save energy. The UAV's geographic position is expected in the GPMOR protocol, and the data is sent to the destination nodes without determining the actual route [91].

5.2.3 Simulation and Results

The findings will be analyzed in this section, with different parameters of the various routing protocols MUDOR, GPMOR, GPSR, GAF, MPGR, GEAR, and DD being compared.

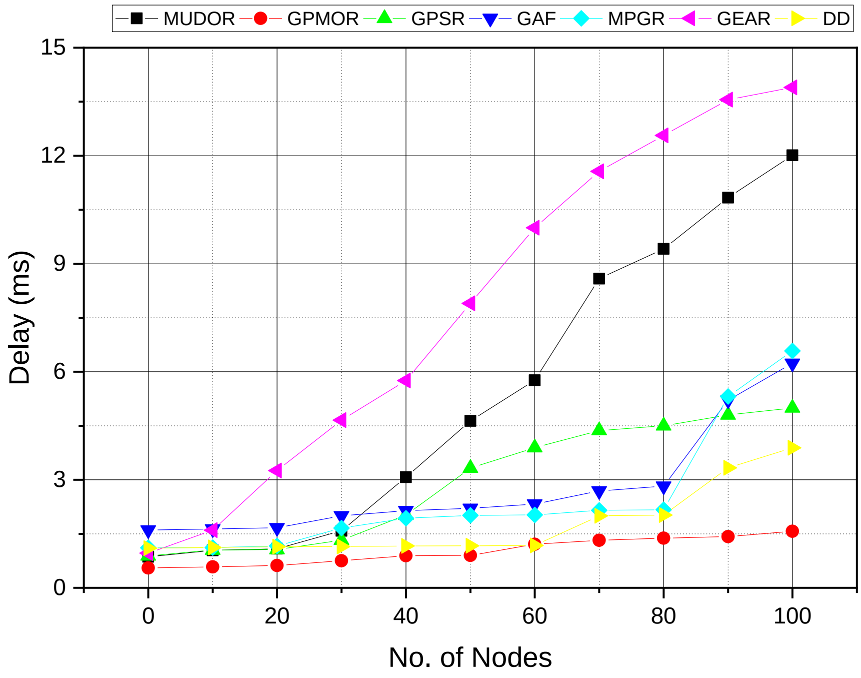


Figure 5.2: Average End-to-End Delay (measured in ms) versus the number of nodes

In comparison to the other routing protocols, GPMOR has shown improved outcomes (see Figure 5.2). When comparing MUDOR, GPSR, GAF, MPGR, GEAR, and DD, MUDOR, GPSR, GAF, MPGR, GEAR, and DD performed well for a smaller number of nodes, whereas DD, MPGR, and GAF performed better for a larger (more) number of nodes. GPMOR has an average end-to-end delay of 0.7 to 1.5 milliseconds for 100 nodes, which is faster than conventional routing protocols. The GEAR routing protocol showed that the average end-to-end delay for 100 nodes ranged from 1 to 13.8 milliseconds, showing that there was a significant delay throughout the network.

Figure 5.3 shows how MUDOR, GPMOR, GPSR, GAF, MPGR, GEAR, and DD perform in terms of throughput (measured in kbps) and cumulative node density.

In comparison to other routing protocols, GPMOR has demonstrated superior performance. In comparison to other routing protocols, GPMOR showed an average throughput of up to 20kbps for 100 nodes, which is more effective data with maximum throughput. The average throughput for 100 nodes using the GEAR routing protocol was 0.8kbps-15.3kbps, showing that it was the least successful in the network.

However, for smaller nodes, GPSR, MUDOR, and DD outperformed GAF, GEAR, and MPGR, while other routing protocols outperformed GAF, GEAR, and MPGR.

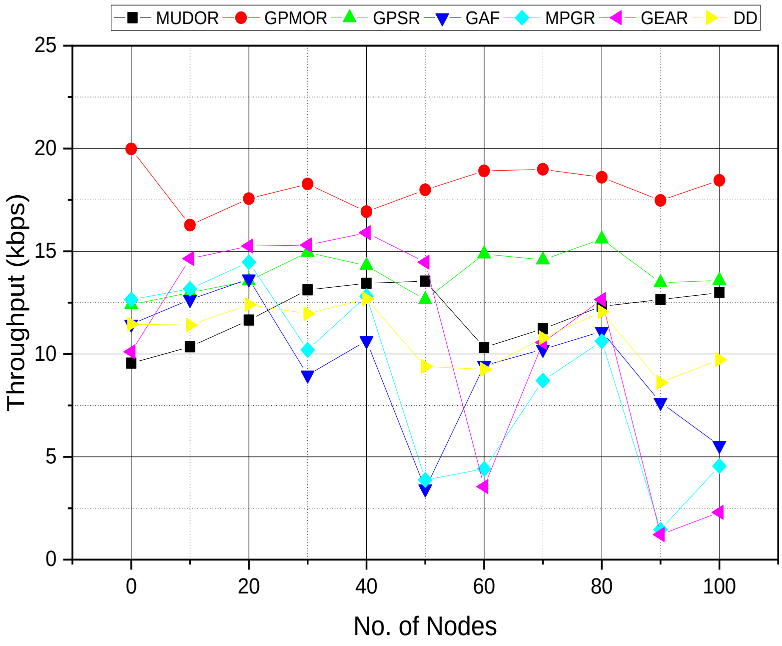


Figure 5.3: Average Throughput (measured in kbps) versus the number of nodes

The PDR of the GPMOR routing protocol is again superior to that of other routing protocols, as seen in Figure 5.4. In comparison to other routing protocols, GPMOR showed an average packet delivery ratio of 87 percent to 96 percent for 100 nodes, which is more effective data (with the highest packet delivery ratio in percent). The GEAR routing protocol showed that the average packet delivery ratio for 100 nodes was less than 8%, signifying the network's worst performance.

GEAR, GPSR, and MUDOR performed well for lower nodes, but the rest of the protocols performed better for higher nodes.

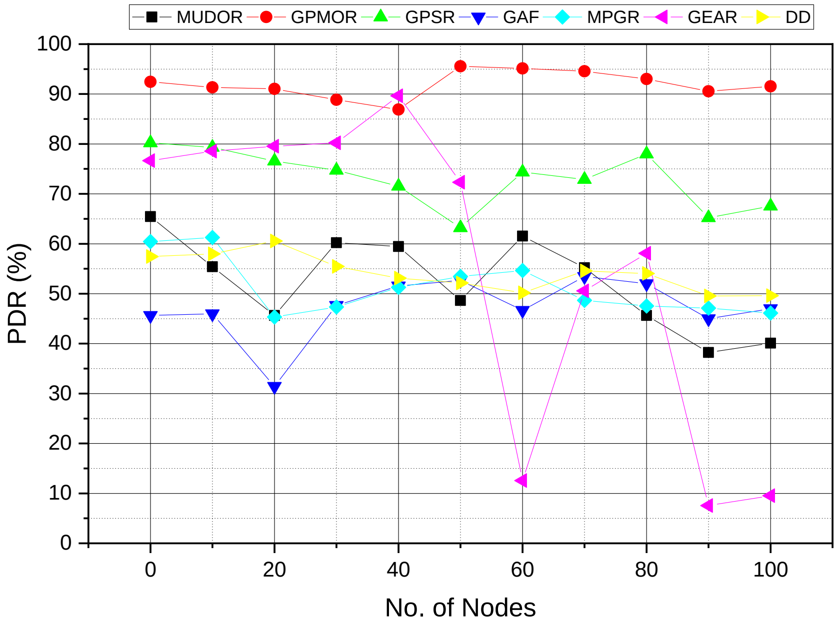


Figure 5.4: Average Packet Delivery Ratio (measured in %) versus the number of nodes

As seen in Figure 5.5, GPMOR currently has the lowest number of packet losses when compared to other routing protocols. In comparison to other routing protocols, GPMOR showed an average packet loss of 300 to 800 packets for 100 nodes, which is more effective data. The GEAR routing protocol revealed that the average packet loss for 100 nodes was approximately 3600 packets, indicating that there was higher packet loss throughout the network. When compared to other routing protocols, MUDOR, GPSR, and MPGR exhibit lower packet losses for lower nodes and lower packet losses for higher nodes. The tabular representation of measurement parameters of different routing protocols is shown in Table 5.2.

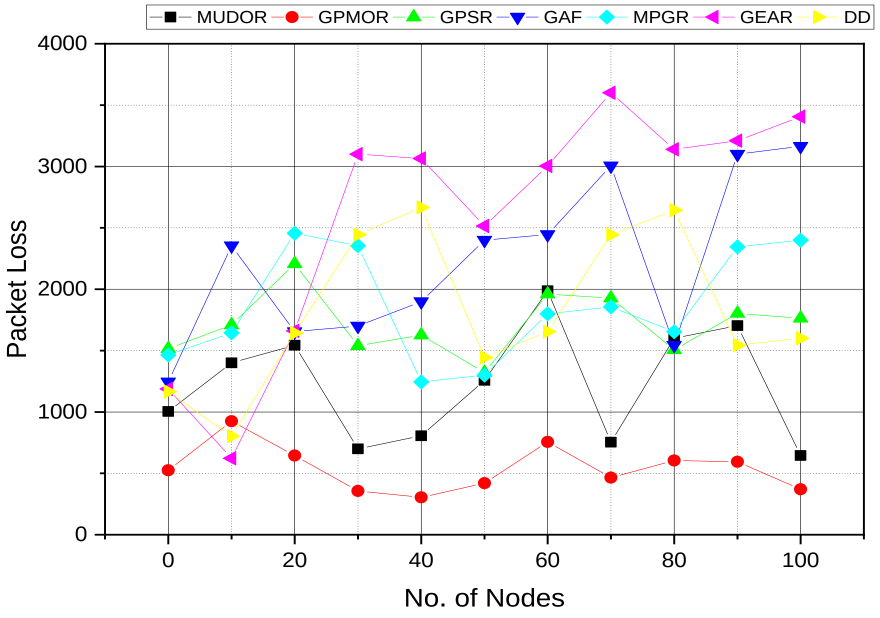


Figure 5.5: Average Packet Loss versus the number of nodes

Table 5.2: Tabular representation of measurement parameters of different routing protocols

Routing Protocol	**Number of Nodes (For Maximum 100 nodes)**			
	Average End-to-End Delay (in ms)	**Average Throughput (in kbps)**	**Average Packet Delay Ratio (in %)**	**Average Packet Loss (in numbers)**
MUDOR	12	14.8	65	1600
GPMOR	1.5	20.0	96	800
GPSR	5	15.2	80	2300
GAF	6.2	13.5	53	3100
MPGR	6.3	14.6	61	2500
GEAR	13.7	15.3	90	3600
DD	4.1	13.0	60	2600

In FANETs, GPMOR beats all other routing protocols in terms of end-to-end delay (ms), throughput (kbps), packet delivery ratio (percent), and packet loss, outperforming MUDOR, GPSR, GAF, MPGR, GEAR, and DD.

5.3 Traffic Congestion and Load Balancing

Load balancing is the act of dispersing system traffic flow over various servers, and localization is the process of estimating the location of unknown nodes placed in FANETs. As computing moves more and more to the network, load balancing plays an increasingly critical security function. In such networks, the accuracy of the node's position estimation is determined by two key processes. The first is node location estimation, which involves calculating the position of unidentified nodes, and the second is node position confirmation, which involves comparing the computed location to the real site. To expand the correctness of the localization process, several expressions have been developed.

Congestion is always an undesirable circumstance in wired and wireless networks since it can degrade the communication environment. At the media access control address level or above levels, congestion can cause packet loss and retransmission. The task of planning and executing a traffic congestion control algorithm along with a firefly algorithm is difficult since numerous elements must be considered. The congestion control system is not equipped to deal with the unique characteristics of shared wireless multi-UAVs in the network. Packet loss and retransmissions can occur for a variety of reasons, including route pause due to mobility, concealed terminal problems in the wireless networks. Unpredictable packet delivery ratio and loss of packet rates are caused by affected fluctuations in topology and a weak wireless network, posing a challenge for congestion control in FANETs. Furthermore, due to the random link-state induced by UAVs' fast mobility, it is hard to control overall transmission delay within a specific threshold. Consequently, it is required to plan an accurate traffic congestion control of flying nodes algorithm which can adjust to the different status of the link, guarantee the interruption prerequisites, and different parameters.

To the best of our knowledge, only a few earlier studies have looked into the load-balancing problem in FANETs. In summary, we make two contributions:

(i) For FANETs, we propose the specific functions F_1 and F_2 with the optimization process by taking different parameters such as End-to-End Delay (EED), Packet Delivery Ratio (PDR), fuel emission, and throughput. The technique is used to resolve the constraints of the optimization problem with the firefly algorithm which is used to estimate the exact match of the dynamic network topology. The primary problem is therefore converted into a distributed solvable problem, allowing senders to compute the attractiveness of flying nodes to execute congestion control.

(ii) To reach the best solution, we present a distributed traffic congestion control algorithm that incorporates the delay constraints. We propose Rs, Rd, and Rp variables for all flying nodes to verify the incoming flow of the flying nodes and outgoing flow of the flying nodes probability to exploit network utilization and decrease transmission delay in a circulated manner. Finally, we examine the optimization method's performance and demonstrate its convergence using a simulator.

5.3.1 Proposed Network Model

There are different categories of load balancing as follows:

- Load balancing using Software Defined Networking (SDN),
- User Datagram Protocol (UDP),
- Transmission Control Protocol (TCP),
- Server Load Balancing (SLB),
- Virtual load balancing, multi-site load balancing, and elastic load balancing a.k.a. Global Server Load Balancing (GSLB), and
- Geographic load balancing.

Table 5.3: Mathematical Notations

Symbol/Notation	Description
$\sum_F$	The notation depicts a limited set that contains all of the UAVs that are free to fly in the specified area.
L_i	Indicates a link linking a pair of UAVs
L	Denotes the set $\{\forall l \in L\}$
U_j and U_i	If the distance between U_j and U_i is below the communication radius, $j \in Ne_i$, where Ne_i is a set of U_i's neighbors.
S	A session initiated by a source UAV
E	A collection of all consecutive sessions
L(s)	Collection of links followed by session Us
$S(l) = \{Us \in \sum S \mid L_i \in L(s)\}$	A collection of all sources that use link L_i
$\sum D_i < \theta$	The entire delay along the path L(s) < threshold (θ).
Cn	Capacity of node-link
$D_n = P/(Cn - \sum S * r)$ (1)	It is expressed as a single-hop delay where P is the length of the packet and r is the rate of the source node.

Geographic load balancing reallocates user traffic among datacentres in multiple locations for maximum efficiency and security. Internal load balancing takes place inside a centralized environment, whereas geographic load balancing takes place across numerous sites. The mathematical notations are described in Table 5.3:

Assume that each flying node can achieve function fn(r) by creating a packet flow rate of r, where fn(r) = ω log (r) and ω is a constant. This effort purposes at exploiting the overall function of all the flying nodes in the network under the node-link capacity of the network and total delay along with the multiple flying nodes. Hence, the problem can be formulated as a function F_1, which is defined as below:

$$F_1 = max \sum_{s}^{E} fn(r)$$

(2)

Here, the optimization problem F_1 is the main problem of optimization of flying nodes in the network. Here, the equation (2) with subject to,

$$\sum_{s}^{S} r \leq \mathrm{Cn} \tag{3}$$

$$\sum_{\mathrm{Li}}^{\mathrm{Ls}} Dn \leq \theta \tag{4}$$

5.3.2 Solution of the Problem

It should be noticed that the function defined in equation (4) is more complex. As a result, the following equations used to breakdown the relationship of equation (4):

$$\sum_{s}^{S} r \leq \mathrm{Cn} - \mathrm{p} \tag{5}$$

Where, p = K/$\overline{\mathrm{D}_\mathrm{i}}$, where K is the constant value and $\overline{\mathrm{D}_\mathrm{i}}$ is the network's single-hop delay limit. The value of p should be greater than zero, i.e., p > 0.

From equations (3) and (5), we can formulate as

$$F_2 = max \sum_{s}^{E} fn(r) \tag{6}$$

Here, the equation (6) with subject to;

$$\sum_{s}^{S} r \leq \mathrm{Cn} - \mathrm{p} \tag{7}$$

$$\sum_{Li}^{Ls} . \overline{D}i \leq \theta \tag{8}$$

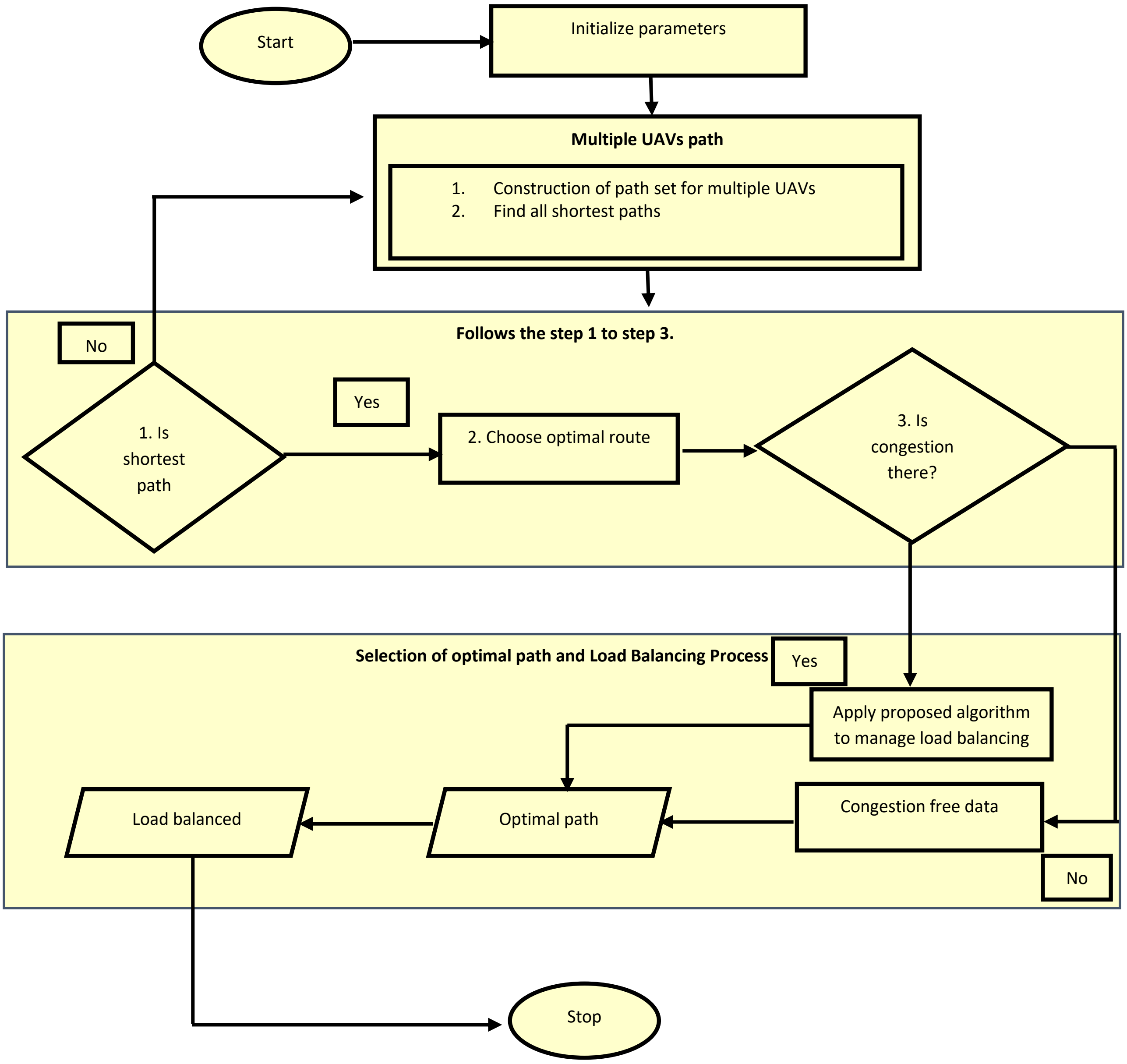


Figure 5.6: Flowchart diagram for load balancing process

It is rather challenging to tackle the traffic congestion problem of flying nodes in the network with various settings in a centralized manner. To ease the optimization process, equation (6) can be denoted as χ. As a result, the new form of F_2 can be expressed as:

$$S = max\left(\sum_{\mathrm{s}}^{\mathrm{S}}.\mathrm{r} + \sum_{\mathrm{Li}}^{\mathrm{Ls}}.\chi - \left(\mathrm{Cn} - \left(\mathrm{p} + \sum_{\mathrm{s}}^{\mathrm{S}}.\mathrm{r}\right)\right)\right) \tag{9}$$

After reordering equation (9), a next form can be obtained as

$$S = max\left(\sum_{\mathrm{s}}^{\mathrm{S}}.\left(\mathrm{r} - \mathrm{r}\sum_{\mathrm{Li}}^{\mathrm{Ls}}.\chi\right) - \sum_{\mathrm{Li}}^{\mathrm{Ls}}.(\chi * \mathrm{p})\right) \tag{10}$$

Furthermore, we have two different equations from the equation (10), we have as follows:

$$S1 = max\sum_{\mathrm{s}}^{\mathrm{S}}.\left(\mathrm{r} - \mathrm{r}\sum_{\mathrm{Li}}^{\mathrm{Ls}}.\chi\right)$$

and,

$$S2 = min\sum_{\mathrm{Li}}^{\mathrm{Ls}}.(\chi * \mathrm{p}) \tag{11}$$

The Firefly Algorithm is defined as follows:

Algorithm 1: (Firefly Algorithm) With the help of two properties, this approach is used to determine the direct path (shortest) in a network. The first is the firefly's brightness, which is proportionate to its mate selection and prey attractiveness. The other is that the difference between the couples (two) of fireflies is inversely proportional to the difference between them.

Step 1: Begin by initializing the objective function.
Step 2: Create a small population of fireflies (nodes).
Step 3: Calculate the light intensity and the state absorption coefficient.
Step 4: Repeat Steps 5–8 until the maximum generation value is reached (maximum iteration).
Step 5: Repeat for I = 1 to N, where N represents all of the ‘N’ fireflies.
Step 6: Repeat for J = 1 to I:
Step 7: If J’s light intensity is larger than I’s light intensity, then set: change mate selection and prey attractiveness with their distance.
Step 8: Reposition the firefly based on I’s attraction to J and test different solutions.
Compute attractiveness value of the fireflies using $\beta = \beta_0 x e^{-yr^2} - 1! = 0$, where, $\beta_0 ! = 0$ (12)

[The end of the If structure]
[At the end of the Inner for structure.]
[At the end of the Outer for structure.]
Step 9: If the result cannot be discovered, proceed to step 4.
Step 10: Show the best-desired outcome.

In a conclusion, we have two different solutions of flying nodes, S1 and S2; which are to be considered as the final method to solve the traffic congestion problem of flying nodes in the network. In the decentralized environment, the topology changes of flying nodes can be the issue of flying nodes in the network, so the solution of the particular problem is to calculate the speed (Rs), distance (Rd), and path (Rp) constraints of the flying nodes. We can calculate the actual values of Rs, Rd, and Rp as defined as follows:

$$Rs = \max\ (r - s * \sum_{\mathrm{Li}}^{\mathrm{Ls}} . \chi) \tag{13}$$

$$Rd = \max\ (r - Cn * \sum_{\mathrm{Li}}^{\mathrm{Ls}} . \chi * \mathrm{p})$$

(14)

And,

$$Rp = \exp \{ -(Cn - \sum_{s}^{S} . \mathrm{Rs}) * \mathrm{Rd} \}$$

(15)

Similarly, the traffic congestion control algorithm can be implemented as:

Algorithm 2: (Traffic Congestion Control Algorithm) This approach is based on the following scenario: when a large number of flying nodes are present in the network, yet their performance diminishes, the network is said to be congested. The following algorithm is used to resolve or balance the traffic of flying nodes:

Step 1: First of all, we need to initialize different parameters such as Rs, Rd, and Rp.

Step 2: If the flying node arrives at link L_i;

Step 3: Then we have to calculate the value of $\sum_{\overline{Di}}$, which is based on equation (8);

$$\sum_{\overline{Di}} = -n\chi \,/\, (Cn - \sum_{s}^{S} . \mathrm{Rs}) + \chi 1) \tag{16}$$

Here, n is the error of flying nodes due to environmental issues, and $\chi 1$ is the delay errors of flying nodes at node-link Cn.

Step 4: Further, calculate the value of $\chi 1$.

Step 5: $\chi = \chi + \chi 1$, where $\chi = 0$.

Step 6: As per the firefly algorithm, update the attractiveness as described in equation (12).

Step 7: Calculate Rs based on equation (13).

Step 8: Update the value of attractiveness until β remains unchanged.

Step 9: Stop.

The value of χ can help to alleviate traffic congestion; If more packets are dropped because the threshold θ is set too high, a higher value χ is necessary. Algorithms 1 and 2 are used in the implementation.

5.3.3 Results and discussions

In this chapter, we use the NS2 simulator to pretend the network scenario. In the beginning phase, flying nodes are dispersed arbitrarily and altitude of UAVs is 40m and the directional gain is 10 dBi with a frequency range of 2.4 GHz. The value of the transmission power is 0.005 W for each session is set to speed of UAVs varies up to 60 m/s. In addition, we use the queue type as priority queue to simulate wireless physical medium channel and estimate the link quality, respectively. Table 5.4 contains full descriptions of simulation parameters. Thus, whether the UAVs are self-driving or monitored by a base station, important information for the movement of one or more UAVs must be forwarded to other UAVs in the network or the base station, and the transmission of UAV drive rules if they are controlled by a base station. Stationary or mobile base stations are also available. The flying nodes are designed to capture actual data and send it through sensor nodes to base stations. Sensor nodes, on the other hand, are designed to accept queries from base stations and disseminate them to the flying network in their network coverage. The goal of this study is to regulate the congestion level of the entire network by satisfying various characteristics of flying nodes.

Table 5.4: Dimensions of UAVs in the network

Parameter Type	Value
Number of UAVs	100
Queue Type	Priority queue
Altitude of UAVs	70 m
Traffic Type	CBR
Directional Gain	10 dBi
Frequency	2.4 GHz
Wireless Medium	Wireless physical medium
Data Rates	54 Mbps

Parameter Type	Value
Packet Interval (s)	Exponential (1)
Routing Protocol	GPMOR
Packet Size (byte)	1024
Fuel (kg)	80
Simulation Time	200 s
Pause Time	Variable
Antenna Type	Omni-Directional
Transmission Power	0.005 W
Speed of UAVs	Can vary upto 60 m/s

The network is initialized with the help of multiple flying nodes at 70 m altitude of UAVs. The transmission power is constrained by the connectivity between terrestrial base stations and UAVs. To prevent these, UAVs can communicate with one another using purely Ad-hoc architecture. In Figure 5.7 and Figure 5.8, initialization of flying nodes and particular source as well as destination nodes are defined with RoadSide Units (RSU).

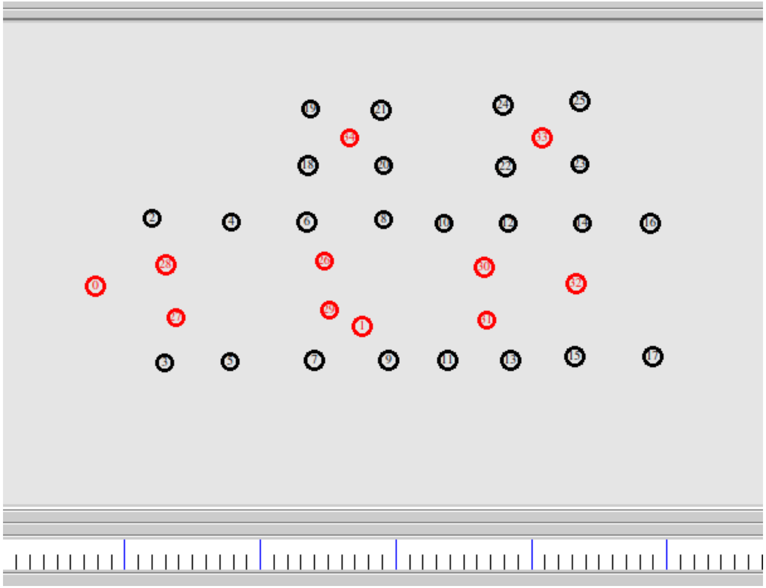


Figure 5.7: Initialization of flying nodes

Figure 5.8: Source node and destination node

Furthermore, such wireless communication may be used to enable multi-node communications and other applications if a data packet needs to be delivered to another node that is outside of the range. In the network, the node with naming 26 and node 30 is described as the root nodes mentioned in Figure 5.9.

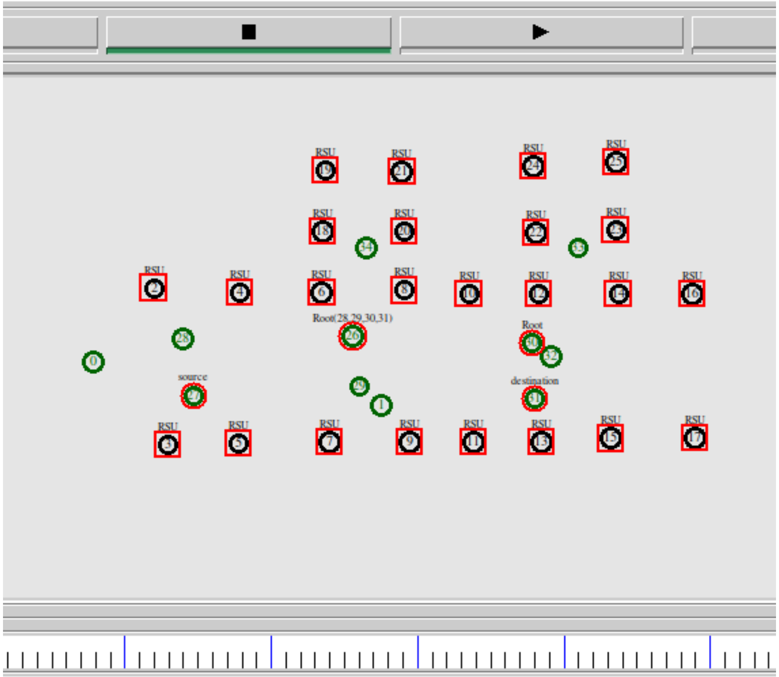


Figure 5.9: Root nodes in the network

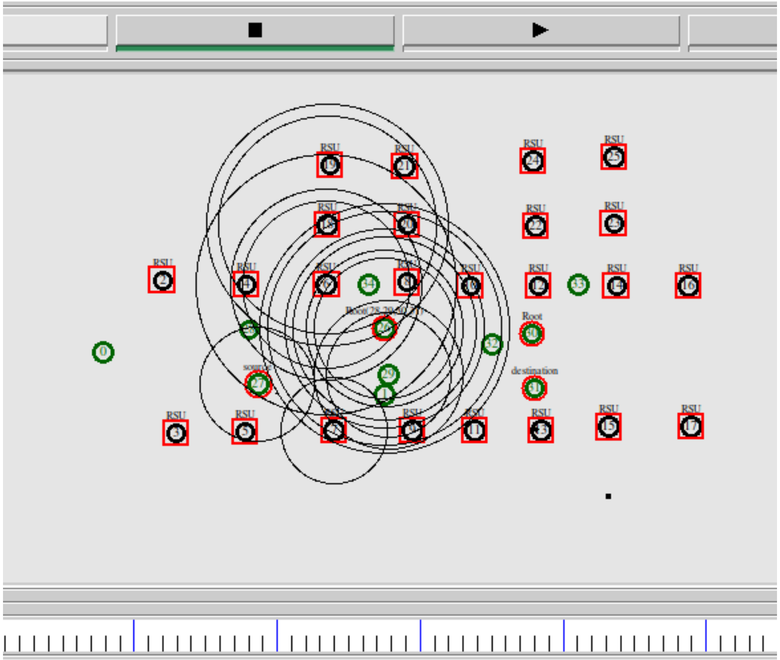
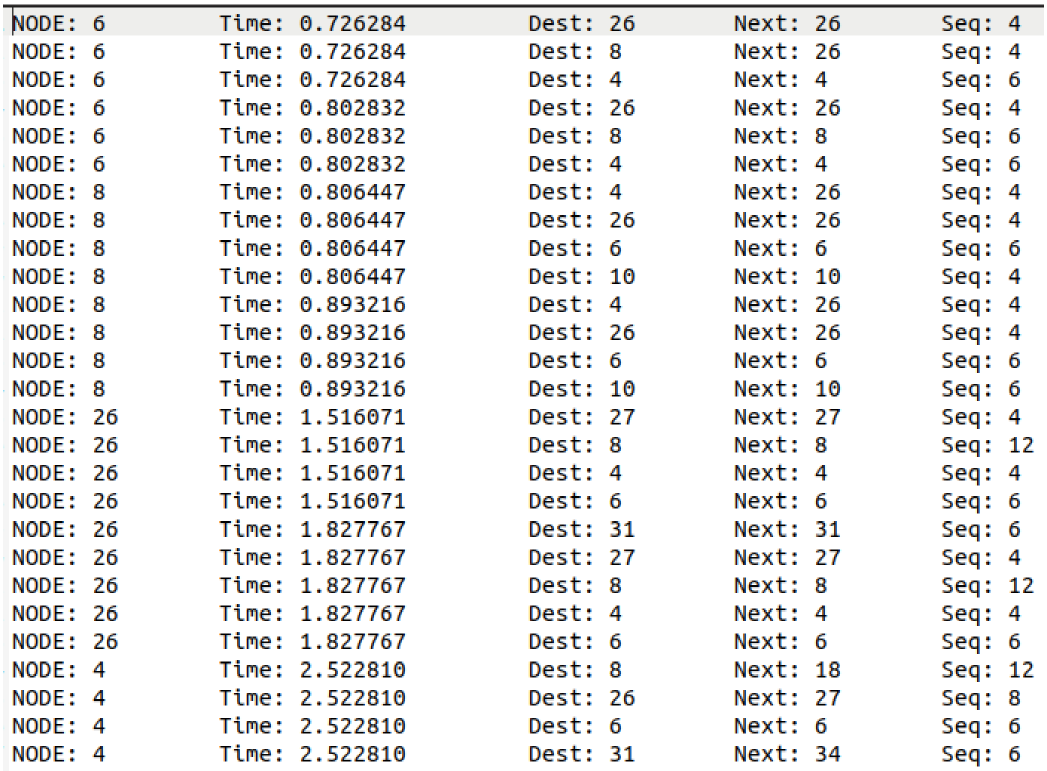


Figure 5.10: Root node send a Route Reply Packet

In such a case, each node selects a random destination, then travels with a random velocity and pauses at the destination. When the stop time expires, the node chooses a random destination with a random velocity and a similar pause duration based on set probability. Further, the root node sends a Route Reply Packet (RRP) to the next neighbor node as shown in Figure 5.10. A few entries of statistical data from the source node to destination with appropriate time are shown in Figure 5.11 below:



```
NODE: 6         Time: 0.726284        Dest: 26        Next: 26        Seq: 4
NODE: 6         Time: 0.726284        Dest: 8         Next: 26        Seq: 4
NODE: 6         Time: 0.726284        Dest: 4         Next: 4         Seq: 6
NODE: 6         Time: 0.802832        Dest: 26        Next: 26        Seq: 4
NODE: 6         Time: 0.802832        Dest: 8         Next: 8         Seq: 6
NODE: 6         Time: 0.802832        Dest: 4         Next: 4         Seq: 6
NODE: 8         Time: 0.806447        Dest: 4         Next: 26        Seq: 4
NODE: 8         Time: 0.806447        Dest: 26        Next: 26        Seq: 4
NODE: 8         Time: 0.806447        Dest: 6         Next: 6         Seq: 6
NODE: 8         Time: 0.806447        Dest: 10        Next: 10        Seq: 4
NODE: 8         Time: 0.893216        Dest: 4         Next: 26        Seq: 4
NODE: 8         Time: 0.893216        Dest: 26        Next: 26        Seq: 4
NODE: 8         Time: 0.893216        Dest: 6         Next: 6         Seq: 6
NODE: 8         Time: 0.893216        Dest: 10        Next: 10        Seq: 6
NODE: 26        Time: 1.516071        Dest: 27        Next: 27        Seq: 4
NODE: 26        Time: 1.516071        Dest: 8         Next: 8         Seq: 12
NODE: 26        Time: 1.516071        Dest: 4         Next: 4         Seq: 4
NODE: 26        Time: 1.516071        Dest: 6         Next: 6         Seq: 6
NODE: 26        Time: 1.827767        Dest: 31        Next: 31        Seq: 6
NODE: 26        Time: 1.827767        Dest: 27        Next: 27        Seq: 4
NODE: 26        Time: 1.827767        Dest: 8         Next: 8         Seq: 12
NODE: 26        Time: 1.827767        Dest: 4         Next: 4         Seq: 4
NODE: 26        Time: 1.827767        Dest: 6         Next: 6         Seq: 6
NODE: 4         Time: 2.522810        Dest: 8         Next: 18        Seq: 12
NODE: 4         Time: 2.522810        Dest: 26        Next: 27        Seq: 8
NODE: 4         Time: 2.522810        Dest: 6         Next: 6         Seq: 6
NODE: 4         Time: 2.522810        Dest: 31        Next: 34        Seq: 6
```

Figure 5.11: Statistical data from the source node to destination with appropriate time

In the simulation, a large number of flying nodes with defined direction or speed changes are used. We investigated various degrees of flying node density, velocity, and network activity from source to destination during the simulation.

Further, in Figure 5.12, the source node starts sending data to the further node accordingly to identify the traffic in the entire network. Then, the source node multicast route request packets (Figure 5.13) and root node again send route reply packet to the next neighbor node (Figure 5.14). The neighbor nodes data with exact distance value is shown in Table 5.5 below. Finally, the source node starts sending data to the next proceeding nodes to achieve the target for traffic balance in-network as shown in Figure 5.15.

Furthermore, the implementation of load balancing for flying ad-hoc network is as follows:

/NodeList/2/$ns2::MobilityModel/Code2 x = 277.606, y = 1541.19, z = 111.792

```
/NodeList/2/$ns2::MobilityModel/Code2 x = 266.704, y = 1605, z = 187.006

/NodeList/2/$ns2::MobilityModel/Code2 x = 259.181, y = 1662.9, z = 268.189

/NodeList/2/$ns2::MobilityModel/Code2 x = 248.673, y = 1613.81, z = 354.671

/NodeList/2/$ns2::MobilityModel/Code2 x = 249.565, y = 1552.08, z = 433.337

/NodeList/2/$ns2::MobilityModel/Code2 x = 253.046, y = 1478.29, z = 500.737

/NodeList/2/$ns2::MobilityModel/Code2 x = 255.055, y = 1421.75, z = 583.201

/NodeList/2/$ns2::MobilityModel/Code2 x = 260.456, y = 1377.16, z = 672.542

/NodeList/2/$ns2::MobilityModel/Code2 x = 259.246, y = 1313.84, z = 789.937

/NodeList/2/$ns2::MobilityModel/Code2 x = 252.771, y = 1247.83, z = 824.772

All Tx Packets: 20
All Rx Packets: 20
All Delay: 0.00895207
All Lost Packets: 0
All Drop Packets: 0
Packets: Delivery Ratio: 100%
Packets: Loss Ratio: 0%
Num clients = 10, Average throughput = 0.825793kbps
```

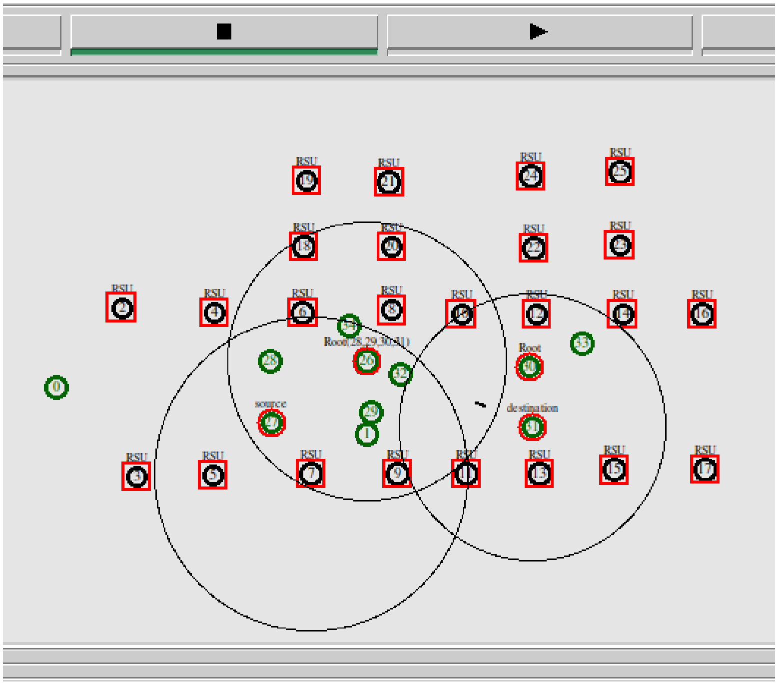


Figure 5.12: Source node starts sending data

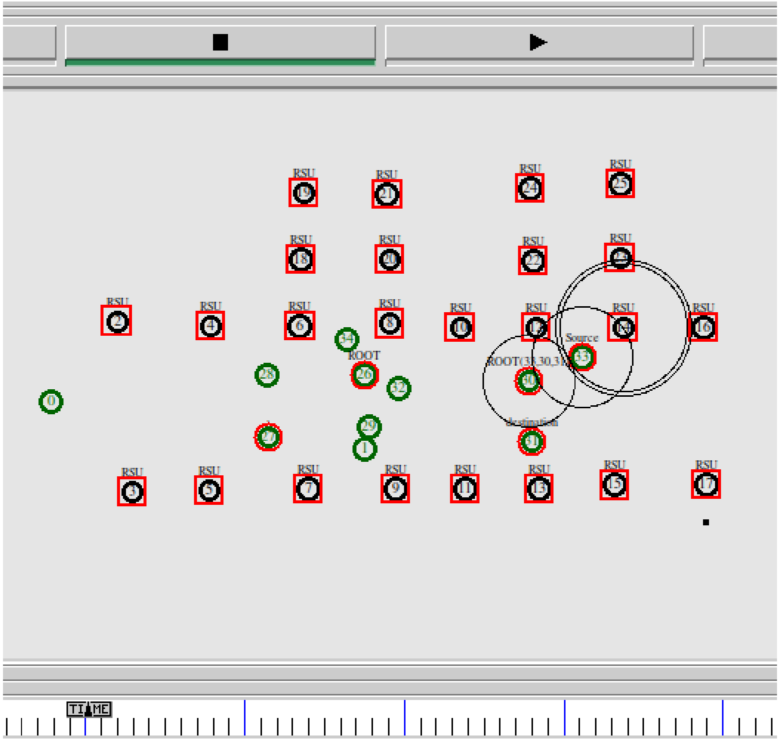


Figure 5.13: Source node multicast route request packets

Table 5.5: Neighbor data with a distance value

Source	Neighbor	SX-Pos	SY-Pos	Distance (d)
0	2	-247	358	161
1	6	239	284	216
1	7	239	284	106
1	8	239	284	198
1	9	239	284	78
1	11	239	284	168
1	26	239	284	115
1	27	239	284	159
1	28	239	284	209
1	29	239	284	36
1	30	239	284	229
1	31	239	284	204
2	0	-145	483	161

2	4	-145	483	145
2	28	-145	483	225
3	0	-122	218	187
3	5	-122	218	120
3	27	-122	218	220
4	2	0	475	145
4	6	0	475	139
4	18	0	475	173

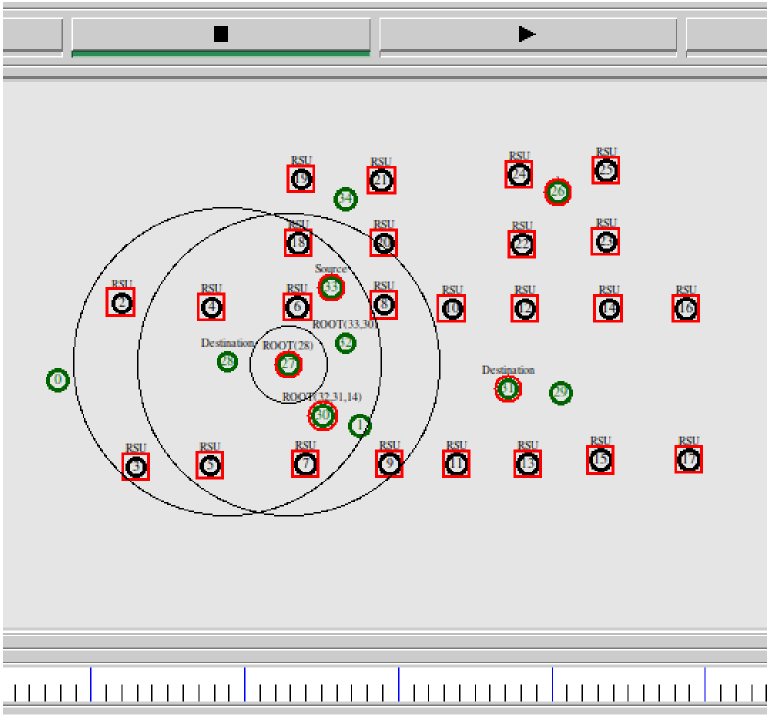


Figure 5.14: Root node send a Route Reply Packet

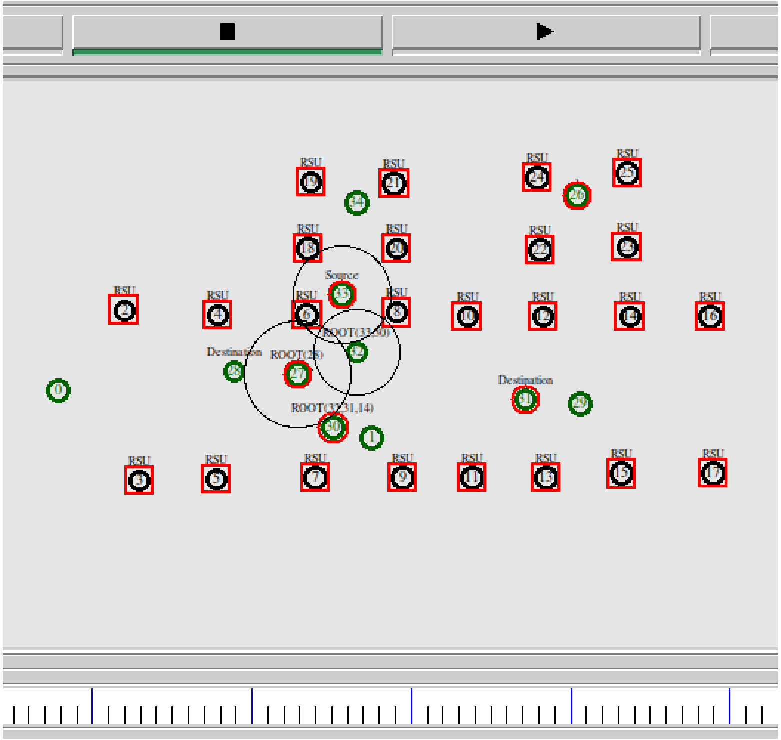


Figure 5.15: Appropriate load balancing between source to destination

Different performance metrics (parameters) are to be taken further in this research work such as delay analysis, fuel emission analysis, packet delivery ratio analysis, and throughput analysis of flying nodes. There is a comparison between two routing protocols such as GPMOR and GPSR.

Delay: The average time it takes for data packets to move across the network from the starting flying node to the target flying node is referred to as delay. The delay of a communications network is a significant design and performance aspect. The processing and transmission delays of a network link are all included in end-to-end delays.

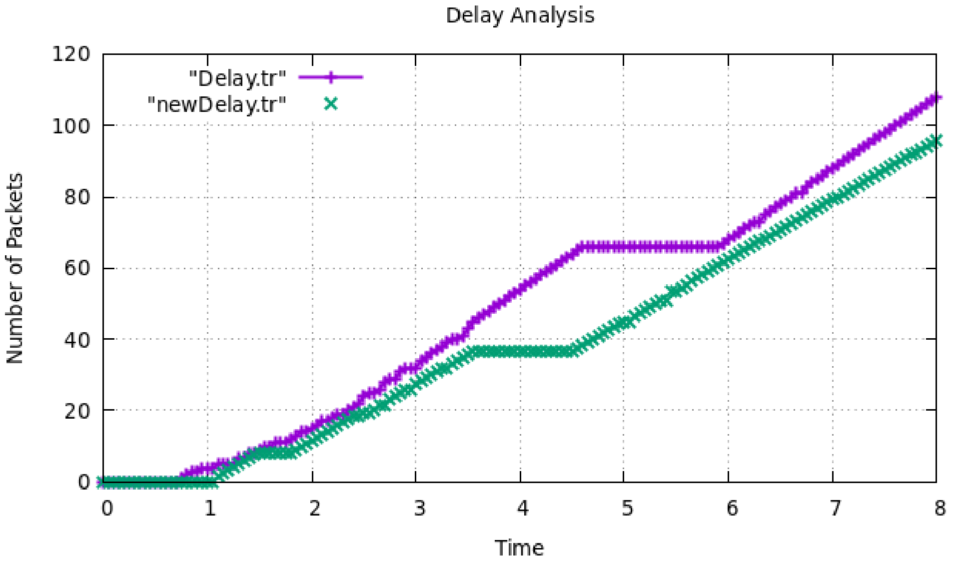


Figure 5.16: Delay analysis of flying nodes

Figure 5.16 depicts the working of a network in terms of EED when the number of UAVs, speed, and area magnitudes are varied. The X-axis depicts the time in m/s, while the Y-axis denotes delay in seconds. The EED decreased with the number of UAV nodes. It is because packets are more likely to be routed rather than captured in the suspension buffer. Once the delay for each of these measures was compared, GPSR (purple bar) had the longest delay, even when the region was smaller. It was because when a route request was made, the target responded to every RREQ that it got, which made calculating the least crowded route take longer. When compared to the GPSR protocol, GPMOR had the shortest delay.

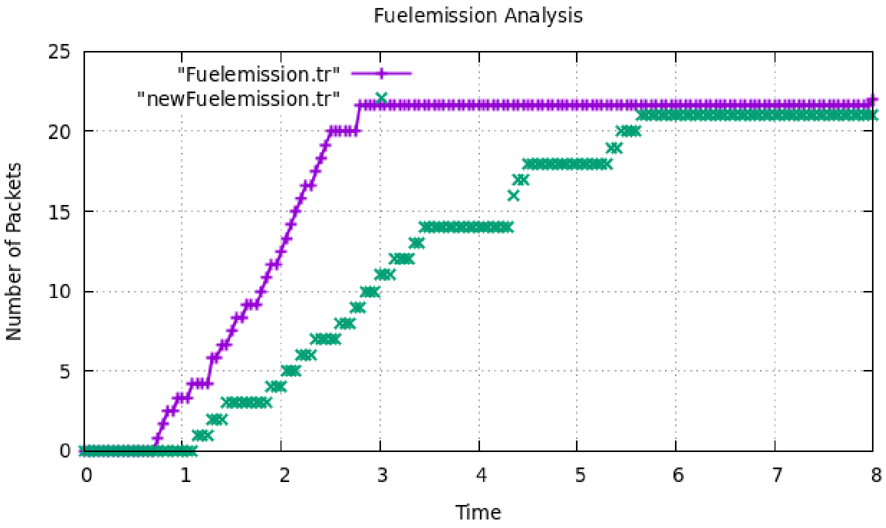


Figure 5.17: Fuel emission analysis of flying nodes

Fuel Emission: In fuel emission, to accomplish connection dependability and the quantity of stored fuel in terms of energy and input buffer, the system chooses a route based on the present processing status of a node. Figure 5.17 **shows that GPSR released more fuel than the GPMOR technique.** Several requirements must be satisfied, such as the minimum fuel necessary to process packets in kilobytes. A node's current processing state in terms of fuel and input buffer. Node priority based on threshold value route selection based on node priority in terms of fuel, a node meets the threshold criteria to participate in routing. To avoid a node becoming a bottleneck, the optimal information capacity of a metric node concerning traffic and remaining fuel is employed.

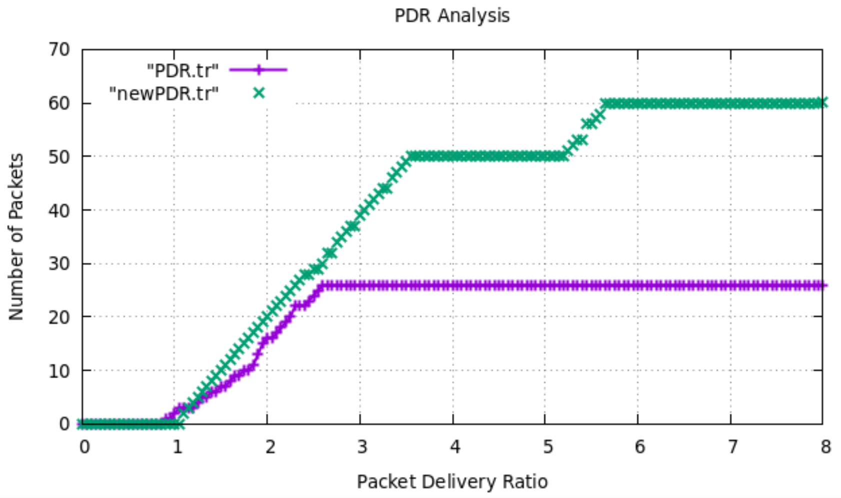


Figure 5.18: PDR analysis of flying nodes

Packet Delivery Ratio (PDR): A network generates certain data packets, which are then delivered through a routing mechanism. A data packet is considered delivered when it is received in full and without loss by the destination node.

Packet Delivery Ratio = (all packets received by the receiver successfully * 100)/all packets produced by the senders

In the simulation results analysis, we discovered that the network connectivity giving a packet delivery ratio of more than 95% is dependent on the network characteristics of the GPMOR protocol as opposed to the GPSR protocol. Figure 5.18 shows the simulation results of a network of varied nodes with the transmission power of a flying node configured.

As the simulation results show, the number of packets should range from 0 to 120, and the duration should range from 0 to 12 m/s, to ensure the requisite connection between flying nodes. It represents two lines in the outcome, such as purple and green. The green line denotes the maximum amount of data packets that must be sent to the destination. In this case, increasing the number of nodes does not enhance data quality according to the GPSR protocol, however it does improve the data quality of flying nodes according to the GPMOR protocol. As a result, the appropriate packet delivery ratio values were obtained using the simulation settings and network configuration utilized. When the number of nodes is increased to 120, simulation results demonstrate that FANET connection with a packet delivery ratio greater than 95 percent is obtained.

Throughput: Throughput is an important measure for measuring network performance. Throughput can be affected by the distance between the sender and the receiver. Throughput is defined as the average data probability of a successful data packet or message passing across a communication connection from the starting node to the target in a given time unit. Because the flying nodes' positions may be changed, the distance between two nodes can be modified, and the capacity of the related link can be tuned to increase network throughput. Here, each flying node provides its position and user location information to the ground station, which utilizes all of the flying nodes' current positions.

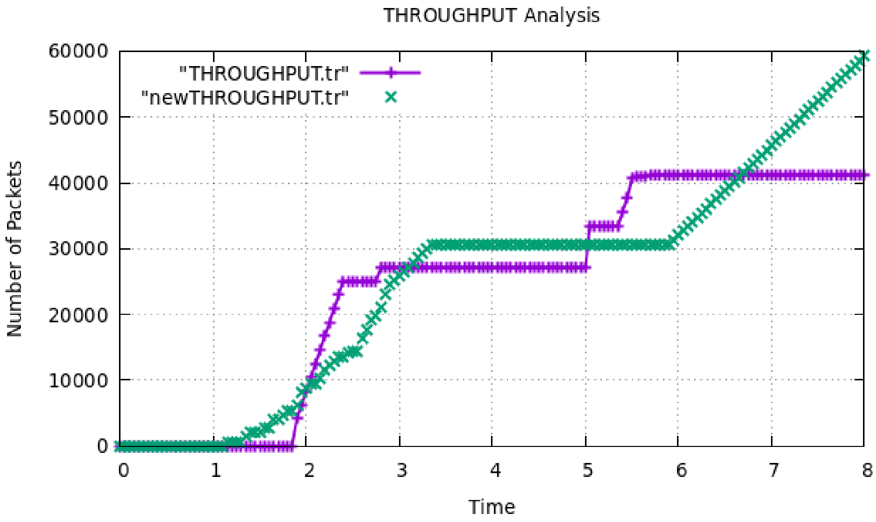


Figure 5.19: Throughput analysis of flying nodes

Figure 5.19 depicts the analysis of a network in connection with throughput when the number of UAVs, area sizes, and speed is varied. The X-axis represents simulation time in m/s, while the Y-axis represents throughput in bits per second (bps). The network's throughput grew as the number of UAVs increased, as did its performance.

So, when UAVs' speeds were reduced to 0 m/s and 12 m/s, respectively, the GPMOR protocol beat the GPSR protocol, with the number of UAVs growing to almost 100, as shown in figure 5.19. This is because GPMOR allocates allocated time slots for packet transfers to prevent network congestion.

5.4 Conclusion

To deal with the problems of a highly dynamic environment, highly-dynamic airborne networks require unique communication protocols. In this chapter, we discussed geographic-based routing system for high-speed UAVs. We simulated the GPMOR protocol and compared it to existing geographic-based routing protocols to ensure that our technique is effective. In terms of PDR, delay, and hops, GPMOR betters GPSR and GLSR, according to simulation data. As the number of applications grows, our future research will look into the possibility of heavy traffic applications in the aerial network. With other factors such as EED, PDR, fuel emission, and throughput, this study proposed a traffic congestion control algorithm for FANETs utilizing the firefly algorithm, which may increase network throughput and restrict the EED to a set particular value (θ). The FANET system is used to express the key problem mathematically. The simulation results showed that the proposed techniques considerably increase network throughput and decrease packet delay rates. Further effort will be made in the future to include these challenges and relevant answers into the optimization method and transmission-related strategy.

CHAPTER 6

A Secure Approach using Two-Ray Model with Shadowing Effects

6.1 Introduction

In this chapter, we offer a secure method for locating the malicious flying node in a network utilizing a two-ray model and shadowing effect. The main objective is to find the malicious node in the network and design a secure approach for FANETs. The two-ray model has been frequently used to evaluate an ad-hoc network’s performance as a propagation model. The shadowing propagation model, a more realistic model, used in this chapter. An access point in a shadowing model may acquire a message with a signal level lower than the required critical limit. The routing protocol and the medium access control protocol of a network are both affected by the low signal level. The simulation’s results are also discussed in this chapter.

6.2 Technique Description

The method we developed accurately characterizes collisions between flying nodes in the same network. Unlike most existing stochastic algorithms, ours is not as complex, complicated, or reliant on a variety of vectors; instead, it is based on two metrics: the load key of an ideal path and the bandwidth usage threshold. This chapter's key contributions can be summarized as follows:

- We give simple yet exact words and mathematical formulations for various crash nodes in FANET based on only two parameters (load key of an ideal path and bandwidth usage threshold). It calculates the likelihood of numerous nodes in the network colliding, and hence the security of multiple UAVs. We primarily derive and discuss mathematical equations for the network's predictable number of collisions.
- The LoK parameter describes how the network's distinct node pathways are connected. The standard mathematical formula obtained is then utilized to identify the rogue node that initiated the network attack. Furthermore, when compared to two effects such as secure and insecure two ray and shadowing effects, we acquire accurate expressions.
- We propose an upgraded firefly algorithm to boost the efficiency of the nodes. The suggested technique combines the benefits of various characteristics, such as reduced packet loss, delay, and network overhead while maintaining high throughput.
- To assess the network's security, a rigorous comparison analysis was performed. In the graphical representation of the simulation, we validate the acquired results.

The major purpose of our suggested technique is to comprehend the evolution of UAV systems, to assist UAVs in operating in a safe mode free of collision risk factors, and, last but not least, to address the issue of collision risks. This project entails developing an algorithm to determine the best route for delivering data from numerous UAVs' diverse sources. The firefly algorithm works in two portions when using the proposed methodology: one is the firefly's flashing behavior, and the other is the step-by-step procedure, which describes the set of rules or instructions to be executed in a certain order to produce the best-intended output. It’s utilized to solve optimization problems that take advantage of nature’s alternating performance of fireflies. The concept of optimization is to identify the optimal way in, and the phrase optimization refers to the act of making decisions and selecting the best answer from a list of all practical and conceivable options. The function to optimize, the value to select utilizing possible solutions, and the rule of optimization are three parameters of optimization approaches.

6.3 Mathematical Description

This section starts with the mathematical notations and data structures of the network under consideration. The load key of an ideal path and the bandwidth utilization threshold is then considered. The lists of mathematical notations and data structures for the flying nodes are shown in Table 6.1. We also provide detailed definitions of the mathematical notations used. Here, we’ll go over the network’s stats, which are listed below:

6.3.1 Load Key (LoK) of an optimal path

This measure was created to identify the connections between distinct node pathways throughout the routing process. This also defines how the various packets in the network are distributed. When we examine the network, we will notice several overloaded flying nodes. The reason for this is that the nodes in the network receive the most data transmissions. In this chapter, we’ll look at how to divert this specific load away from overburdened networks and onto other routes. For this objective, we describe the Load Key (LoK) measure, which looks for efficient pathways at each flying node in the network.

Table 6.1: Mathematical notations and their meaning

Mathematical Notations	Meaning of notations that used in the expression
A_L	The average load of flying nodes
B_t	The total bandwidth of the network
B_f	Fixed bandwidth of flying nodes
LoK	Load key of an optimal path
L_{yz}^{Ti}	Total load of the entire network
M	Total number of distinct destinations of flying nodes
N	Number of flying nodes
TB	Threshold of bandwidth utilization
TB_{max}	A Maximum threshold of bandwidth utilization
T_i	Time period
V_{yz}^{Ti}	Vector node at the same time period of network
T_p	Transmission power of flying nodes
R_p	Receiver power of flying nodes
T_r	Transmit receiver
T_s	Transmit sender
S_d	Sender data in the network
R_d	Receiver data in the network

Case 1: Suppose a variable as 'Ti' which represents time period, and the total load of the entire network is denoted as 'L_{yz}^{Ti}'.

In simple terms, it is the sum of all the loads on all the flying nodes in the network, as shown in (1):

$$L_{yz}^{Ti} = L_{11}^{Ti} + L_{12}^{Ti} + L_{13}^{Ti} + \ldots + L_{1n}^{Ti} + \ldots + L_{n1}^{Ti} + L_{n2}^{Ti} + L_{n3}^{Ti} + \ldots + L_{nm}^{Ti}$$

Where, m is equivalent to n-1. (1)

Case 2: If the flying nodes are not connected in the network, then we can use the input vector as 'V_{yz}^{Ti}' at the same time period, where 'y' and 'z' variables are set for nodes from 1 to n as mentioned below in (2):

$$L_{yz}{}^{Ti} = \sum_{y=1}^{n} \cdot \sum_{z=1,\neq y}^{n} L_{yz}{}^{Ti} V_{yz}{}^{Ti} \tag{2}$$

Where $V_{yz} = \begin{matrix} 0, & \text{Access of network does not through UAV} \\ 1, & \text{Access of network through UAV} \end{matrix}$

Algorithm 1. Selection of path using firefly algorithm

```
func: Obj_func ( ), Max_Gen_func ( )
Start: Obj_func, $f(pkt)$, $pkt = (pkt_1, pkt_2, \ldots, pkt_n)^t$ [Initialization mode.]
  Generation of the initial population of different flying nodes, $pkt_i$ $(i = 1, 2, 3, \ldots, k)$
  Define light intensity ($L_i$) and light absorption coefficient ($Co_{eff}$).
  Do
    For $i$ = 1: $k$, all '$k$' fireflies
      For $j$ = 1: $i$, all '$k$' fireflies
        If ($L_i < L_j$),
          Move firefly $i$ towards $j$;
        Else
          Do not move firefly $i$ towards $j$;
        END IF
        While ($pkt < Max\_Gen\_func\ (M_G)$)
        Compute attractiveness value of the fireflies using
        $\beta = \beta_0 x e^{-yr^2} - 1! = 0$, where, $\beta_0! = 0$
      End For Loop (Inner loop of variable $j$)
    End For Loop (Outer loop of variable $i$)
    Update the latest $L_i$ of the fireflies.
    Then, rank all the fireflies and display the best-desired path.
  End Do while
End
```

Case 3: We need to calculate the average load of the flying nodes in the network. The average load 'A_L'of the nodes is defined as:

$$A_L = \sum_{i=1}^{n} \cdot \frac{{L_{yz}}^{Ti}}{Ti} \tag{3}$$

Now, we need to substitutes from (2) to (3), we get the final equation as:

$$A_L = \sum_{i=1}^{n} \cdot \frac{1}{Ti} \sum_{y=1}^{n} \cdot \sum_{z=1,\neq y}^{n} {L_{yz}}^{Ti} {V_{yz}}^{Ti} \tag{4}$$

6.3.2 Threshold of Bandwidth Utilization (TB)

This statistic was created to calculate the network’s actual bandwidth. A TB can be defined as a network link that connects one point to another. The measure of TB usage can be used to track the network’s efficiency. In a flying ad-hoc network, this measure can also be utilized to increase network utilization. Here, we have defined the total bandwidth ‘B_t’of the network as follows:

$$B_t = \sum_{y=1}^{n} \cdot \sum_{z=1,\neq y}^{n} {V_{yz}}^{Ti} . B_f \tag{5}$$

Where ‘B_f ’ is the fixed bandwidth of the flying nodes.

Lower overheads, less congestion, and increased efficiency will all benefit from the strategy. This metric can be expressed as an optimization model (TB_{max}) as stated below:

$$TB_{max} = \frac{\sum_{i=1}^{n} \cdot \frac{1}{Ti} \sum_{y=1}^{n} \cdot \sum_{z=1,\neq y}^{n} {L_{yz}}^{Ti} {V_{yz}}^{Ti}}{\sum_{y=1}^{n} \cdot \sum_{z=1,\neq y}^{n} {V_{yz}}^{Ti} . B_f} \tag{6}$$

Finally, all of the flying nodes are joined to the network along the best path from initial to target. There are several steps to implementing the proposed methodology, including path selection, path possibility, and node movement in multiple directions.

Aside from that, due to changes in the topology structure, it is simple to change the course of the flying nodes. Here, the two-ray model (Raytwo) is used for secure routing of the nodes from one place to another place using Rayf(x) function.

$$\mathrm{Ray}_{\mathrm{two}} = Rayf(x) = TB_{max} + \sum_{n=0}^{i} \left(T_P \cos\frac{Bt}{Bf} + T_R \sin\frac{Bt}{Bf} \right) \tag{7}$$

Furthermore, we need to calculate the secure shadow value i.e., Shadow(v) as follows:

$$\bigcup_{n=0}^{i} (T_r \cap T_s)\, Rayf(x) = Shadow(v) \tag{8}$$

Where T_r and T_s represent as transmit receiver and transmit sender respectively.

Finally, we need to calculate the accurate flying nodes as per sender data (S_d) and receiver data (R_d) in the network,

$$\underset{0 \le n \le 1}{S_d, R_d} = \sum_{n=0}^{i} shadow(v) \tag{9}$$

We have secure shadow effects of the flying nodes in the network using equations (8) and (9), and the outcome of this study is important for the verification of FANET nodes, which can be directly used in all the wireless prediction fields.

6.4 Process Description

6.4.1 Selection of path

Multiple paths are employed in this system to convey data at the same time in the Path Selection technique. When a single route is used, traffic is focused at a few nodes, causing congestion as seen in Figure 6.1.

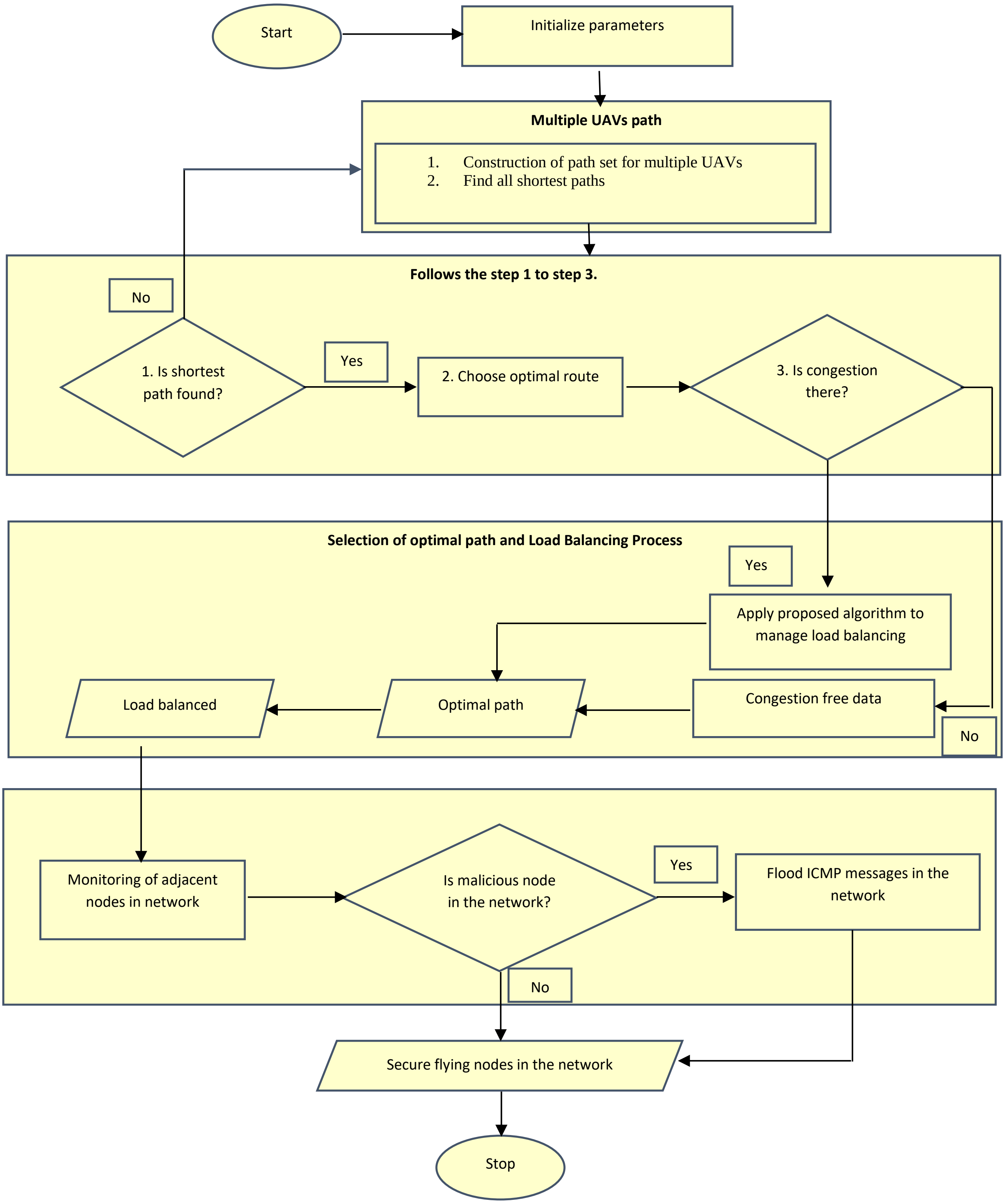


Figure 6.1: Secure flying nodes in the network

As a result, we employ the firefly algorithm to select the best way, preserving the benefits of multipath routing without sacrificing path consistency. Any route starts with a zero count, and the top route is used to route packets. The count of a given path is incremented after each packet transmission across that path. The next route is picked when this count equals.

6.4.2 Possibility of paths

The determined Max Gen func (MG) represents the various paths and paths that are classified according to their counted attractiveness. A path with a higher firefly value is considered superior, and as a result, it is used more frequently than the others. As a result, a path with a higher value will have a higher path selection ratio.

Different paths are explored for packet delivery to a destination, but only a few of them are employed for the optimum path.

6.4.3 Moving of nodes to other direction

When the selected route is no longer identified as a connection exists, the node should be moved in the other direction. Following the evaluation of new solutions and the update of light intensity, we must verify that the node’s path is the path indicated for future usage. This will happen if the path’s status field is attractive. All we have to do now is identify, prioritize, and search for the next path to take. To see this, we must first determine the node’s current path and compare it to alternative paths leading to the same destination. We need to view the flying nodes and add post-processing to the best outcomes thus far.

6.5 Results and Discussions

In this section, we run a series of simulations using the NS2 tool. This project is separated into three sections: the operation of flying nodes, the identification of malicious nodes, and network performance analysis. Packet loss, throughput, EED, and routing overhead factors are all included in the performance study.

6.5.1 Working of flying nodes

The simulation experiment essentially created diverse nodes in the network zone, with source node start times evenly dispersed during the first 60 seconds of simulation time. The simulator NS2 has been used where within simulator area of 400m X 400m, maximum 4000 nodes are arbitrarily and consistently appropriated. Here, FANET has 100 scanned UAVs with transmission power 0.005W. Frequency of the different node is calculated at 2.4 GHz and directional gain is 10 dBi. The packet size is 1024 bytes, where packet interval at exponential (1) in second. In the simulator, priority queue has been considered with CBR traffic type. In the network area, we randomly place some flying nodes. There are two sorts of flying nodes in the defined area: non-malevolent and malicious flying nodes. Table 6.2 lists the characteristics of unmanned aerial vehicles (UAVs):

Table 6.2: Characteristics of UAVs

Parameter Type	Value
Number of UAVs	100
Queue Type	Priority queue
Altitude of UAVs	40 m
Traffic Type	CBR
Directional Gain	10 dBi
Frequency	2.4 GHz
Wireless Medium	Wireless physical medium
Data Rates	54 Mbps
Packet Interval (s)	Exponential (1)
Packet Size (byte)	1024
Simulation Time	200 s
Pause Time	Variable
Antenna Type	Omni-Directional

Parameter Type	Value
Transmission Power	0.005 W
Speed of UAVs	Can vary upto 60 m/s

Normal nodes, which obey the rules from the source point to the destination point, are non-malicious. Malicious nodes, on the other hand, are compromised modes that do not follow the rules from the source to the destination. If malicious nodes are present in a FANET, they may try to diminish network connectivity and so compromise the network's security by posing as cooperative but actually dropping any data they are supposed to provide. Defragmented networks, isolated nodes, and substantially reduced network performance may result from these acts. We aim to see how the existence of malicious nodes affects the performance of flying ad-hoc networks, and what precautions should be used to detect malicious nodes. Regardless, these nodes may adjust or drop the number of packets. Some nodes in the network serve as central controller units, while others serve as UAV nodes. Figure 6.2 depicts the configuration of RoadSide Units (RSUs), which can improve and promote network performance in flying ad-hoc networks, as well as provide new network services like smooth traffic flow, emergency response, and improved safety.

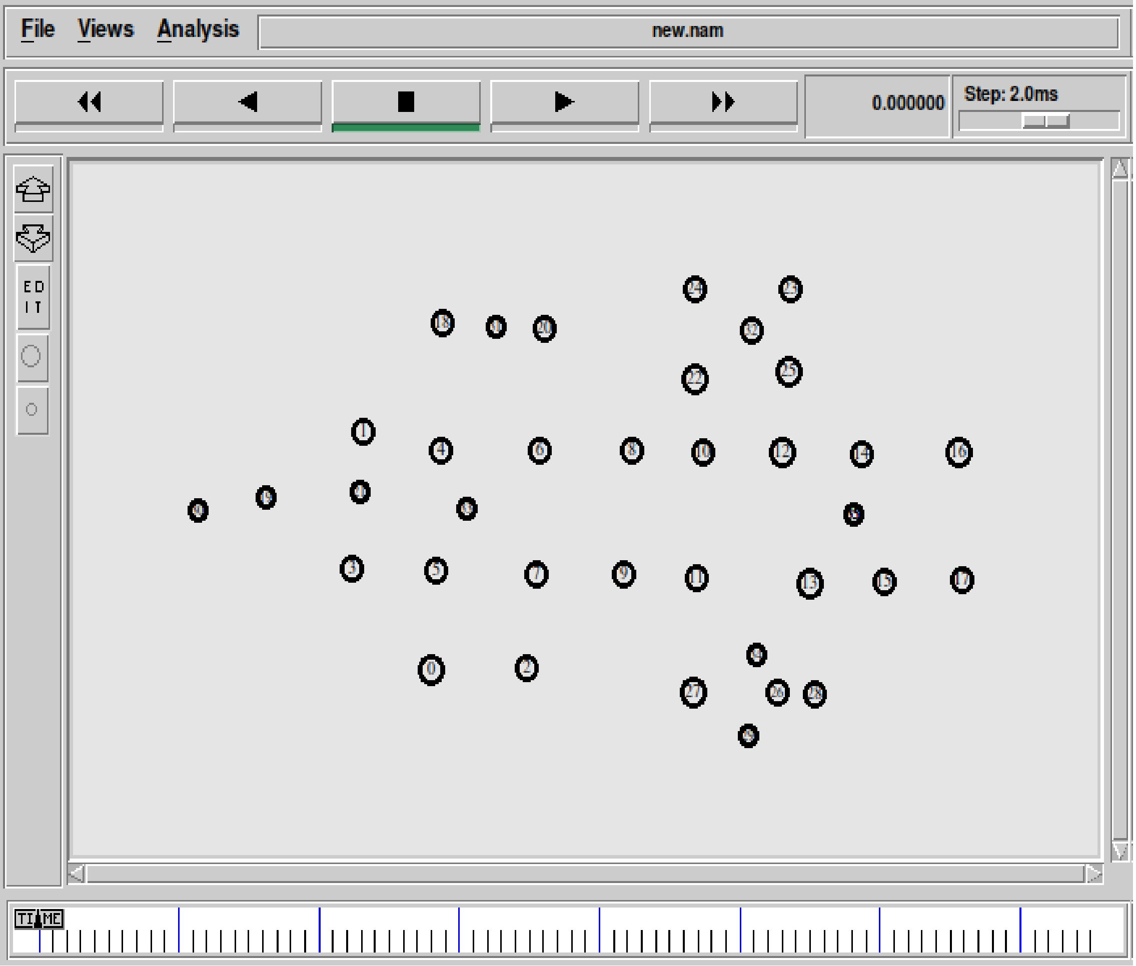
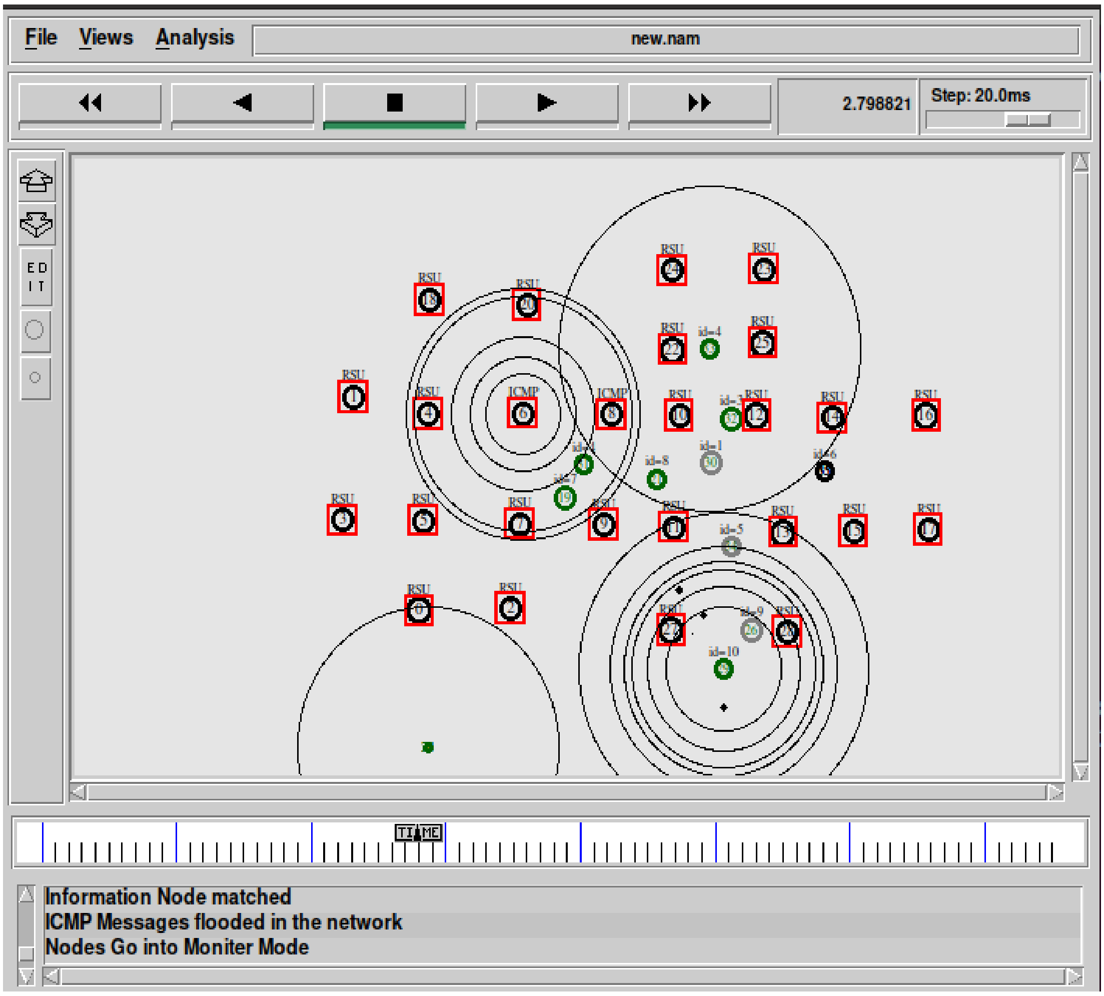


Figure 6.2: The layout of RSU (RoadSide Units) nodes

6.5.2 Detection of malicious nodes

In this compromised node, the suggested method is assessed and then compared to the GPMOR protocol. When the central controller unit discovers malicious nodes in the network, it sends out messages to the rest of the network.

We found a malicious node in the network that started the attack, and connectivity between the two nodes resumed. Again, the node is requesting a new id registration, and it is registering with a new fake ID, indicating that the network is being attacked by a hostile node. As shown in Figure 6.3, flying nodes in the network receive messages and begin watching their neighbors. The monitoring mode technique is used to discover malicious nodes (rogue nodes) in the network.

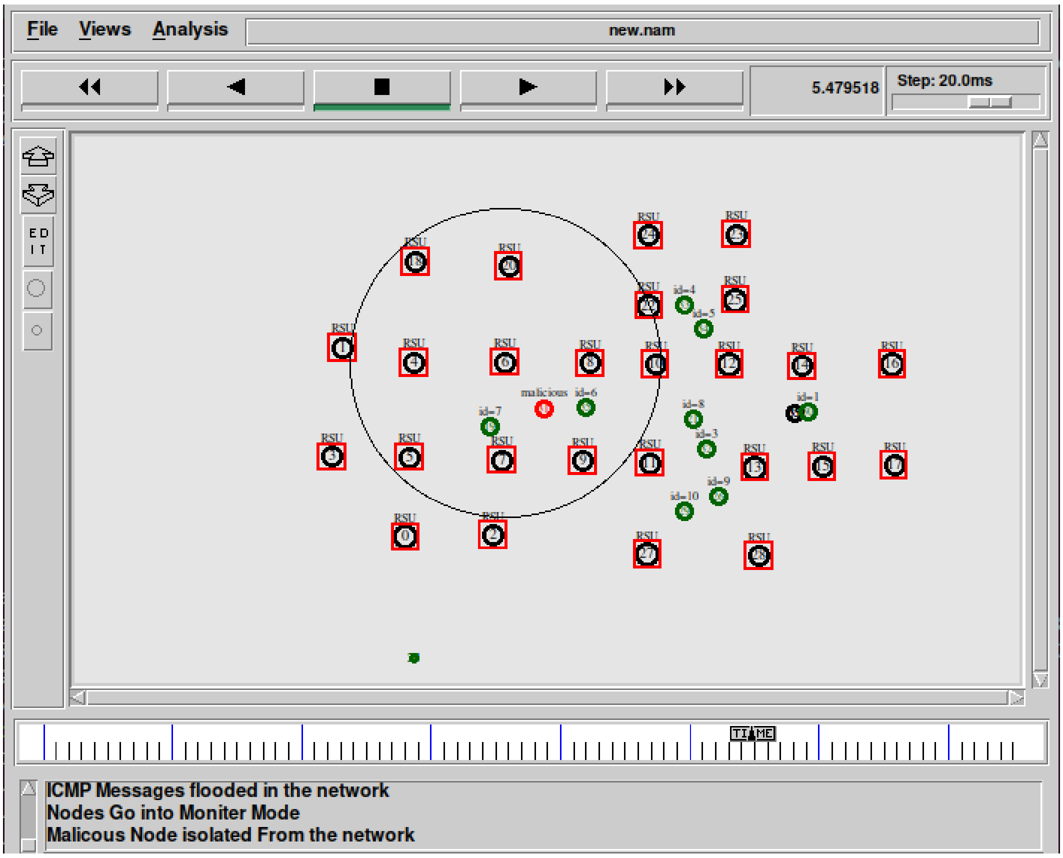


Information Node matched
ICMP Messages flooded in the network
Nodes Go into Moniter Mode

Figure 6.3: Nodes in monitor mode

The roadside units begin flooding the networks with ICMP messages. When nodes receive ICMP packets, they begin watching their neighboring nodes. When the roadside units realized there were some rogue nodes in the network, they flooded the network with ICMP messages. The network’s nodes receive ICMP packets and begin monitoring their neighboring nodes. As demonstrated in Figure 6.4, hostile nodes are spotted in the network as a result of network monitoring.

To summarise, nodes are randomly put in the network. There are total of numerous nodes in the network. The current network's base station is designated as Node 35. There are ten clusters in the network. A Cluster Head is assigned to each cluster. The cluster heads are identified by their Node id number, which ranges from 1 to 10. The cluster heads are chosen based on the nodes' initial energy. These nodes are chosen as cluster heads based on their energy and stability. Each node is positioned at a certain location. Each cluster has its own set of authorities. Separate colours represent the base station, cluster heads, cluster members, and authority. To get to the base station, it takes the shortest route. It will be returned to the exact node when it reaches the base station. It is a secure path if the packet is received. Otherwise, a new path for data processing is chosen.



```
ICMP Messages flooded in the network
Nodes Go into Moniter Mode
Malicous Node isolated From the network
```

Figure 6.4: Malicious node isolated in the network

From the Cluster Head to the Base Station, the request packet is sent. The Cluster Head's route and stability are verified by the Base Station. The path is examined, and if it is secure, the Base Station returns the message to the Base Station. The cluster head switched to a malicious node throughout the procedure, and the process came to an immediate halt. The node is designated as a malicious node, and data is not transmitted through it in accordance with the rules. It examines whether the data is secure at each level. If the malicious node is identified, data transmission is not possible through this node. As a result, security is accomplished during this procedure.

6.5.3 Performance analysis of a network

Finally, using the metrics packet loss, throughput, EED, and routing overhead, we analyze the performance of flying nodes in the network. In Table 6.3, there is a comparison of secure and insecure two ray and shadow effects, which is also displayed in the network.

6.5.4 Packet loss parameter

Packet loss occurs when a network is overloaded, nodes move around, nodes interfere with each other, or the network's structure causes packets to be discarded. Packet loss in the network can be caused by a variety of factors. The packet loss of flying nodes is shown in Figure 6.5, where the x-axis represents the maximum speed of flying nodes in the network and the y-axis represents the packet loss ratio. In the network, there is a comparison of secure and insecure two ray and shadow models.

6.5.5 Throughput parameter

In flying ad-hoc networks, throughput is a key network performance measure. The amount of information transmitted in the network is referred to as throughput, and the position of flying nodes can be moved from one location to another.

To boost throughput, the distance between distinct flying nodes can be altered, and then the limit of relating flying nodes in the network can be optimized. In addition, it depicts the throughput of flying nodes in Figure 6.6, where the x-axis indicates the speed of flying nodes and the y-axis represents the network average throughput.

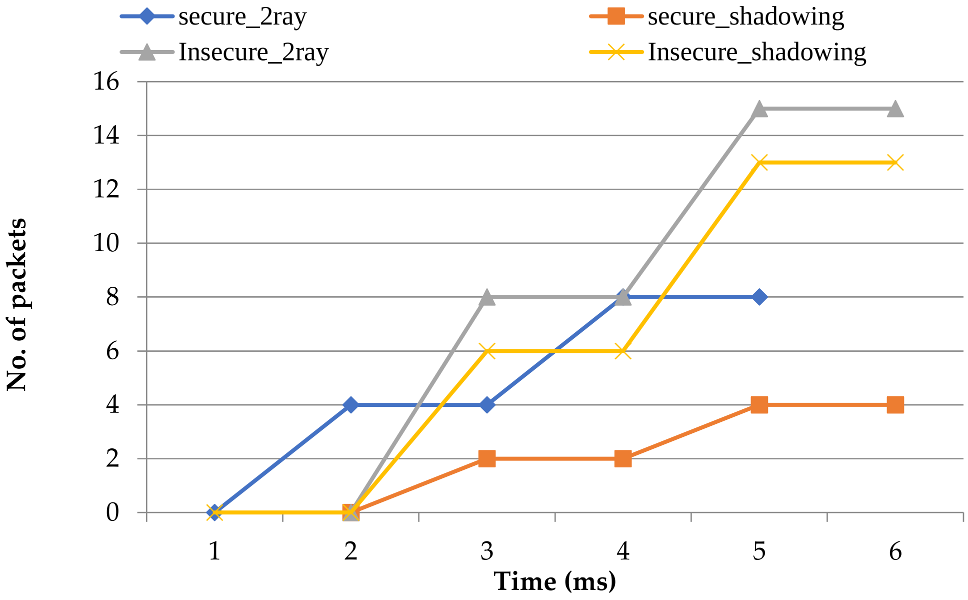


Figure 6.5: Packet loss of flying nodes in the network

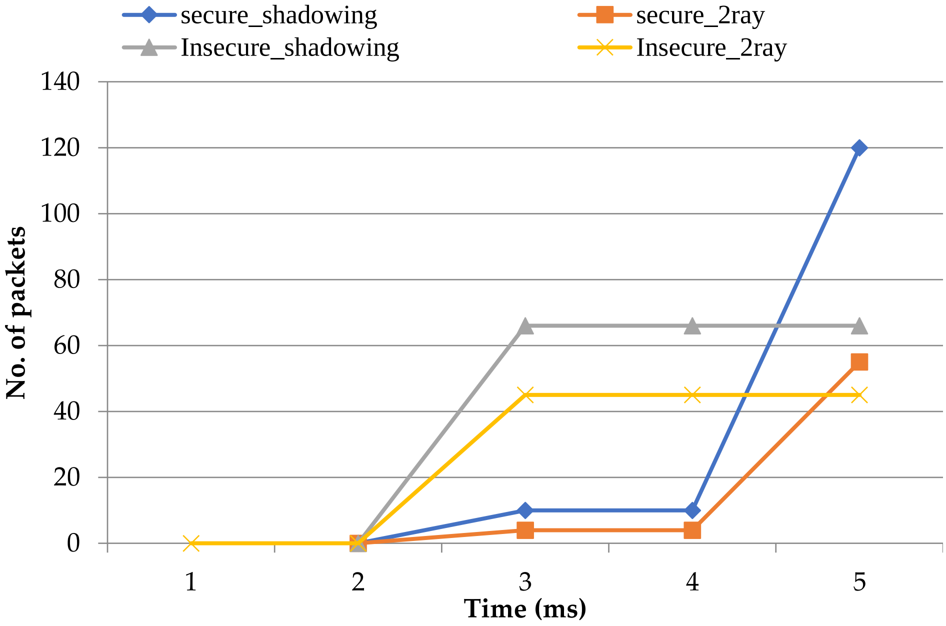


Figure 6.6: Throughput of flying nodes in the network

6.5.6 End-to-end delay parameter

EED of flying nodes is depicted in Figure 6.7. The difference between the transmitting time of each node at the initial time and the receiving time of each node at the target is depicted in this diagram.

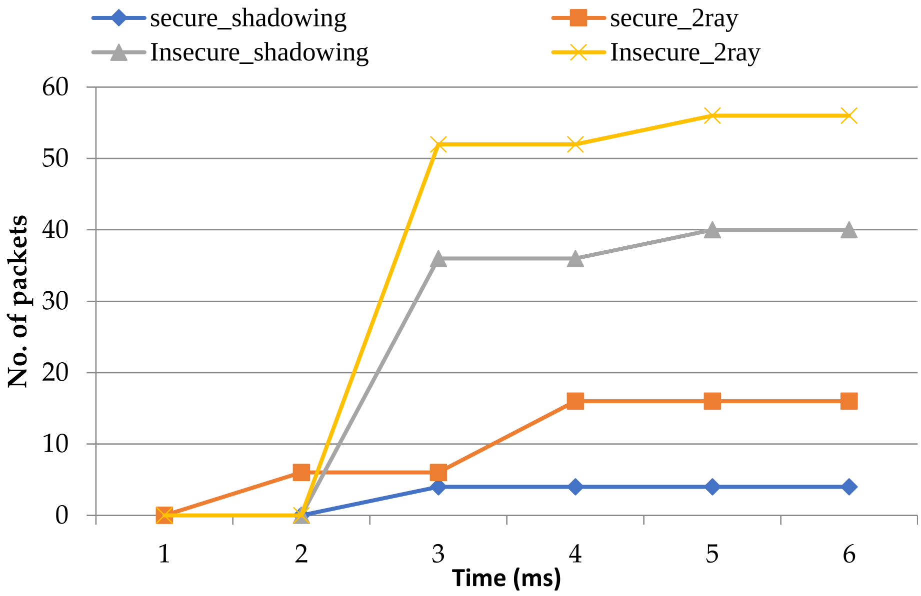


Figure 6.7: End-to-end delay of flying nodes in the network

6.5.7 Routing overhead parameter

The overhead routing of flying nodes is depicted in Figure 6.8. The number of additional packets gathered during the network transmission process is shown in this graph.

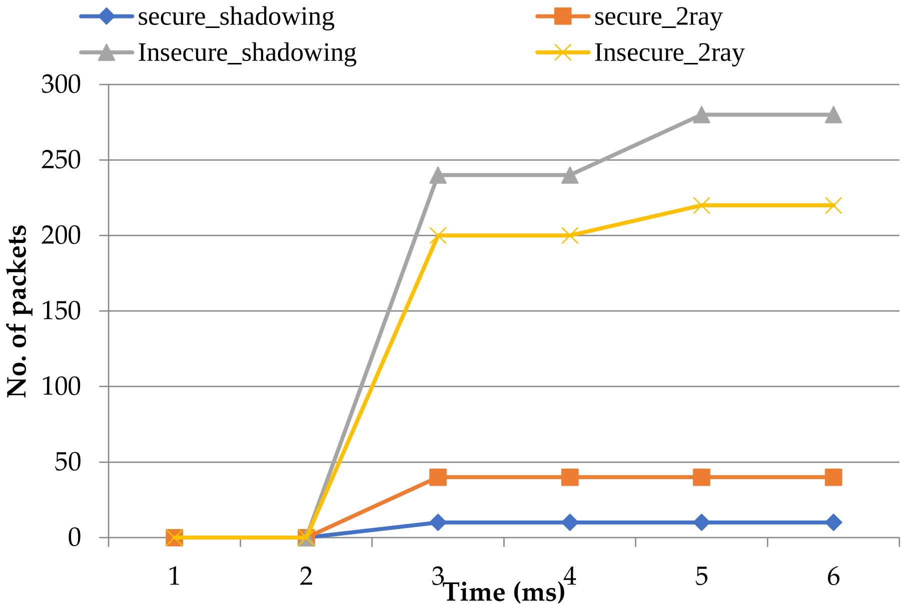


Figure 6.8: Routing Overhead of flying nodes in the network

The proposed model's results are shown in Table 6.3. Each flying node's performance statistics are examined, including packet loss (percent), throughput (kbps), EED (ms), and network routing overhead (byte). For the two-ray effect and shadowing effect, there exist comparison findings of insecure and secure modes. The packet loss value in the unsafe two ray effect is 15%. On the other hand, using the secure two ray effect, the packet loss is just 8%, indicating that the flying nodes in the network have the lowest packet loss. Another effect, the insecure shadowing effect, results in a packet loss of 13% for the flying node, while the secure shadowing effect results in a packet loss of 4% in the network. The throughput of the unsafe two ray effect is 42 kbps. The throughput is just 58 kbps when the secure two ray effect is used, indicating the maximum throughput of the network's flying nodes. Furthermore, the insecure shadowing effect displays a throughput of 63 kbps for the flying node, whereas the secure shadowing effect indicates a throughput of 120 kbps for the flying nodes in the network.

The EED in the insecure two ray effect is 57 milliseconds. The EED when using the secure two ray effect, on the other hand, is only 18 ms. The EED of the flying node in the insecure shadowing effect is 40 ms, whereas the EED of the flying node in the secure shadowing effect is 4 ms in the network, indicating the least EED of the flying nodes in the network. The routing overhead in the insecure two ray effect is 260 bytes. The routing overhead, on the other hand, is only 48 bytes when the secure two ray effect is used. The routing overhead of the flying node in the insecure shadowing effect is 220 bytes, but the safe shadowing effect exhibits 5 bytes routing overhead in the network.

Table 6.3: Comparison between secure and insecure two_ray and shadow effects

Parameters / **Effects (in seconds)**	**Total Received packets**			
	Packet Loss	**Throughput**	**End-to-end delay**	**Routing Overhead**
Insecure two_ray effect	15%	42 kbps	57 ms	260 bytes
Secure two_ray effect	8%	58 kbps	18 ms	48 bytes
Insecure shadowing effect	13%	63 kbps	40 ms	220 bytes
Secure shadowing effect	4%	120 kbps	4 ms	5 bytes

Furthermore, which reflects the network's minimum routing overhead for flying nodes. To summarise, the flying nodes in the network have minimal packet loss, maximum throughput, minimal EED, and minimal routing overhead.

6.6 Conclusion

The most important finding from this research is that we focused our efforts on the firefly method, which has three essential components for improvement. The use of an efficient approach has played an important impact in determining the safe optimization of flying nodes in the network. Using the two-ray model and shadow effects, we investigated the numerous criteria needed to determine the best route for transferring data from various sources to multiple UAVs, and we identified malicious nodes in the network. The simulations undertaken provide useful and crucial insight into the accuracy of the suggested load balancing algorithm. Furthermore, the simulation demonstrated results for various parameters such as packet loss, throughput, EED, routing overhead, secure and insecure two-ray, and shadow effects, indicating that the parameters can extend the predictable objective by adjusting the flying node position in the ad-hoc network. In the future, more research is needed to compare with more security models of flying nodes.

CHAPTER 7

Conclusion and Future Scope

7.1 Introduction

This chapter concludes the thesis and presents some suggestions for how the work provided can be extended. The work done in this thesis is summarised in Section 7.2. It gives a quick overview of the numerous challenges that have been considered and their potential solutions. The overall conclusion of the thesis is presented in Section 7.3, which includes a summary of the outcomes. Section 7.4 identifies some of the thesis's constraints. Finally, Section 7.5 discusses the extent of future work that could be done as a follow-up to the current study.

7.2 Summary of Work Done

The major contributions of the thesis are:

(i) A network outline is established for efficient broadcast between unmanned aerial vehicles and FANETs.

(ii) GPMOR protocol using the firefly algorithm is used to balance a load of different flying nodes for FANETs.

(iii) The comparison of other different geographic-based routing protocols with GPMOR routing protocols is discussed.

(iv) Using the LoK parameter describes how the network's distinct node pathways are connected. when compared to two effects such as secure and insecure two ray and shadowing effects, we acquire accurate expressions.

(v) An upgraded firefly algorithm has been used to boost the efficiency of the nodes, which reduced packet loss, delay, and network overhead while maintaining the high throughput of the entire network.

(vi) A rigorous comparison analysis was performed to assess the network's security of flying nodes.

7.3 Conclusion

In this thesis, an attempt has been made to collaborate the GPMOR routing protocol with the firefly algorithm for flying ad-hoc networks. Load balancing and security between flying nodes in the network are the major issues resolved in this work. The main contribution of this thesis is done in various phases. A summary of each part is as follows:

(i) Because of the vast randomization of selected variables and the large population size, some algorithms take a long time to run. We are well aware that technology and network design improve fast over time; as a result, we are constrained by the processing power of UAVs due to the increased number of UAV movements. Such methods and procedures require a long time to get a valid result, and most of that time is squandered on a useless output that can't be utilized to change the network's structure. These energy-based solutions aren't appropriate for networking techniques that demand a lot of computation and expensive parameters (Chapter 2.)

(ii) Load balancing is a key concern in FANETs in the early stages, and routing is one of the most vital components for assuring proper operation and cooperative network operations. In Chapter 3, the properties of FANETs are described. In the second stage, the FANET routing protocols most generally used techniques are explained. A comprehensive classification of FANET protocols is then presented, with the protocols grouped into three basic groupings and subcategories. Individual type is broken down distinctly, with illustrative data for each routing mechanism, which are then compared based on different applications.

(iii) This chapter provides a thorough examination of improved variants of the firefly algorithm as well as their attributes. The changes are made to improve the performance of the program for both constant and other issues. The approaches' strengths and flaws are also discussed. We utilized the IFA to determine the best path, proving that the IFA can provide a fair mix of exploitation and observation. We demonstrated that IFA necessitates considerably fewer function evaluations with 98% accuracy as compared with other metaheuristic algorithms. The complexity of the IFA is O (n^2). (Chapter 4). As a result, they may perform better.

(iv) To deal with the problems of a highly dynamic environment, highly-dynamic airborne networks require unique communication protocols. We presented a geographic-based routing technique for high-speed UAV environments in this chapter. We simulate the GPMOR protocol and compare it to existing geographic-based routing protocols to ensure that our technique is effective. GPMOR surpasses GPSR and GLSR in terms of PDR, delay, and hops, according to simulation data (Chapter 5). For load balancing, we proposed traffic congestion control and firefly algorithms with parameters such as end-to-end delay, packet delivery ratio, fuel emission, and throughput.

(v) One of the issues that arise in all types of network configurations is security. The use of an efficient approach has been critical in determining the network's safe (secure) optimization of flying nodes. We explored the numerous factors needed to establish the best route for sending data from various sources to multiple UAVs using the two-ray model and shadow effects, and we found malicious nodes in the network. The simulations conducted provide important information about the accuracy of the proposed load balancing technique (Chapter 6).

7.4 Limitations of Work

The following constraints were recognized and listed in this thesis:

(i) The search and tracking-based operations have been the focus of the majority of the work. More sensitive tasks could be used to improve the flying ad-hoc network even more. There are some challenges encountered such as large variation of pose of multiple nodes, illumination, etc.

(ii) Real-time deployment can be used to discover parameters such as QoS satisfaction in FANET that need to be improved further.

(iii) The settings for analyses are set according to basic communication norms, but they can be modified to improve the performance of flying nodes in the network.

(iv) Quantitative metrics are taken in implementation work such as End-to-End delay, throughput, routing overhead, packet delivery ratio etc. More parameters of the flying ad-hoc network need to be identified to improve the outcomes even more. In future, needs to taken qualitative metrics as well such as loop freedom, route stability etc.

7.5 Scope of Future Work

Research is a never-ending process. The work presented in this thesis focuses on load balancing and securing the network’s flying nodes. The following are some ideas on how this work could be expanded:

(i) The suggested routing protocol can accommodate new security measures parameters. The addition of security measures parameters to this routing protocol is expected to improve its reliability.

(ii) Mutual peering and channel authentication for flying ad-hoc networks are still open challenges.

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