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Systematic Literature Review on Swarms Of UAVs

Amjad Ali[1]

PhD Scholar, Electronic Engineering, Karachi Institute of Economics and Technology, Karachi Sindh, Pakistan

aliyousafzai17@gmail.com

Muhammad Nafees[2]

PhD Scholar, Computer Science & IT, Karachi Institute of Economics and Technology, Karachi Sindh, Pakistan

Corresponding Author Email: safdarabad@gmail.com

Muhammad Awais Amin[3]

Data Science Consultant, Datamatics Technologies, Gulburg Greens, Islamabad. awais2815@gmail.com

Inam Ur Rehman[4]

PhD Scholar, Electronic Engineering, Karachi Institute of Economics and Technology, Karachi Sindh, Pakistan.

malikinam060@gmail.com

Muhammad Tayyab[5]

PhD Scholar, Computer Science, Karachi Institute of Economics and Technology, Karachi Sindh Pakistan.

mt.tayyab@kiet.edu.pk

Waqar Ahmad[6]

Senior Design Officer, Aerospace Design & Innovation Center (ADIC), National Aerospace Science & Technology Park(NASTP), Kamra, Pakistan. wiqiahmad96@gmail.com

Abstract

The study on Unmanned Aerial Vehicle (UAV) swarms, including scholarly studies, conference proceedings, and industry reports, is thoroughly examined in this survey of the literature. Swarm coordination algorithms, communication protocols, and applications in fields like firefighting and disaster management are important areas of interest. The review emphasizes new trends, identifies

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implementation-related issues, and makes suggestions for further study. The usefulness, constraints, and public perception of UAV swarms which come in a variety of configurations and operating capabilities are investigated. Academic populations' experimental surveys highlight the significance and promise of these systems. Additionally, the paper suggests a swarm design that uses cellular mobile networks to improve dependability and autonomy. More autonomous systems with reliable UAV-to-UAV coordination and communication are needed to advance UAV swarms. Notwithstanding notable advancements, there are still unanswered questions in certain areas that need further research to fully realize the promise of UAV swarm technology.
Keywords: Unmanned Aerial Vehicles (UAVs), Swarms of UAVs, Multi-UAV System, Applications of UAVs

Introduction

Unmanned Aerial Vehicles (UAVs) are aircraft that are mostly controlled and maintained by embedded autonomous computer programmers or remotely. They are not piloted by humans. Another name for unmanned aerial vehicles is drones, or UAVs. New applications and economic prospects across a range of sectors might be made possible by the paradigm shift brought about by aerial robots. Small unmanned aircraft systems, or UAS, have gained popularity as a means of transportation for a number of businesses uses. A strong argument is made for UAS's potential to launch payloads into the sky for utility, sensing, and other uses without requiring a human operator Unmanned Aerial Vehicles (UAVs) are another name for drones, which are autonomous or remotely controlled aircraft with a range of applications [4]. They are easy to use, flexible, and reasonably priced. Both military and civilian contexts are covered by the application scenarios [5]. Because of its many uses, such as power line inspection, agriculture, war monitoring, environmental monitoring, and more, unmanned aerial vehicle (UAV) systems have drawn a variety of interest recently [6]. Advances in autonomous control and communication technology have made it feasible to operate a large number of UAVs to create a swarm, which can offer additional benefits including collaboration and division of work [7], [8]. Unmanned aerial vehicle swarms have demonstrated significant promise for the Internet of Things. The benefits of UAV swarms also increase the possibility of negative use, such terrorist strikes. Radar detection and localization of unmanned aerial vehicle (UAV)

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swarms has consequently emerged as a crucial aspect of national security. However, swarms of UAVs have a special characteristic of high density, which makes radar resolution challenging, unlike a single UAV [9]. Groups of drones that maintain some internal structure and are controlled remotely or autonomously are known as drone swarms. These swarms are helpful in many different fields and jobs, such as defense, construction, search and rescue, and surveillance (coverage) [11, 12]. Typically, swarms depend on some kind of position input to preserve their predetermined structure [10].

Instead of using a separate unmanned aerial vehicle (UAV), an organized group now often conducts an airborne surveillance mission (e.g., a search operation). Such a group (swarm or flock) engaged in autonomous flying (GS) is managed by the base station. Nonetheless, a few goals require the mission to be entirely self-contained. For instance, the limited bandwidth of data processed by a swarm of UAVs and the difficulties of transmitting large volumes of data might make scanning broad areas problematic. Additionally, the high energy capacities of the power sources now in use are not present in existing aircraft [13].

Route establishment is a challenge in unmanned aerial vehicle (UAV) swarm networks. Given the very dynamic nature of UAV networks and their ability to produce several swarms, we assume that some backup UAVs are available to provide pathways between the swarms. Our objective is to build a bridge-like high-throughput inter-swarm communication network [14].

As the use of unmanned aerial vehicles and drone swarms has grown in recent years, a great deal of research is being done on the subject. The most common uses include vehicles, surveillance, mapping, inspection, and vehicles on the ground and on the surface (UGV & USV) [5, 6]. The autonomous decision-making capabilities of unmanned vehicles vary depending on the activities involved or the degree to which the vehicle can make decisions without explicit guidance from a remote operator [7], [8]. A variety of sensors are frequently installed aboard unmanned aerial vehicles to aid in situational awareness and autonomous decision-making while in flight [9]. In general, control may be manual, contingent on the situation. The assistant editor evaluated and gave the manuscript the go-ahead to be published. Examples include self-contained systems that use feedback sensor data from a mounted

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camera and other sensors, live footage from a camera mounted on a vehicle (controlled remotely), or anything in between [20].

Methodology

One of the most challenging motion planning problems in 3D space is path planning for target interception, particularly when a swarm of UAVs is involved. Setting targets for swarm members and figuring out the best route from source to target while avoiding collisions with other swarm members and barriers is known as path planning. An evaluation (cost) function is then used to optimize the result while accounting for kinematic and dynamic restrictions. A thorough plan for target interception. There are three easy steps in the process. The following figure shows the arrangement and structure of the paper:

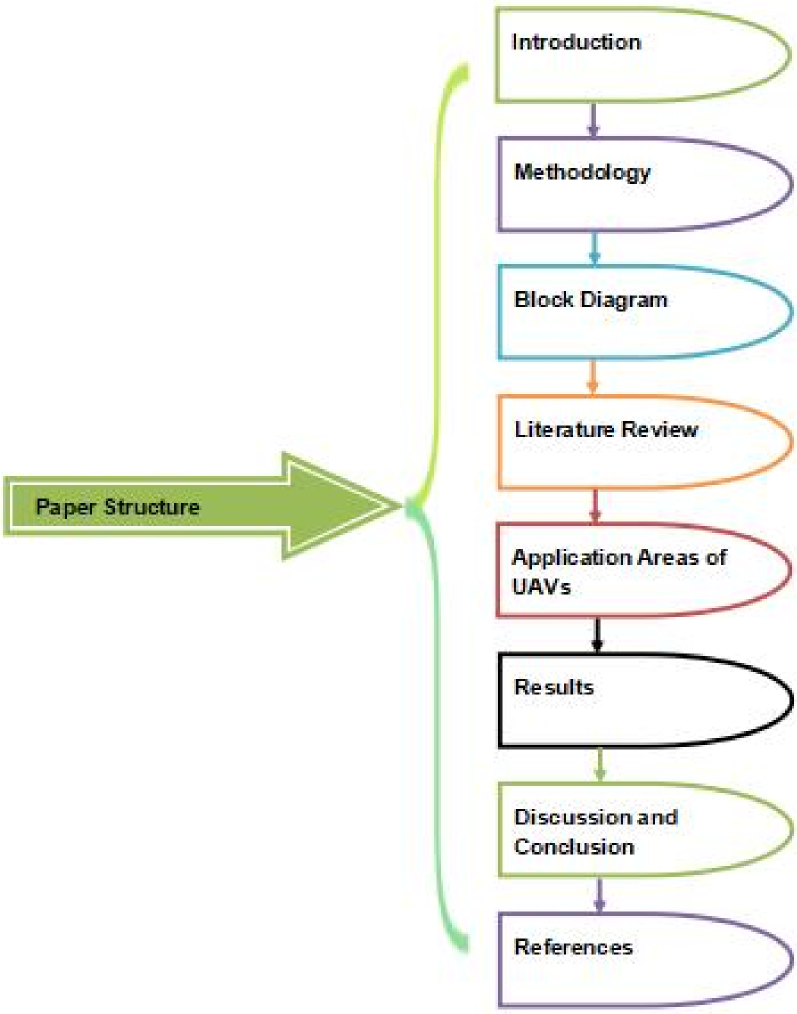

Fig 1: Paper structure diagram

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Block Diagram

According to our study, a variety of UAV technologies are employed as swarms in many industries. A few of these are covered in depth below. Additionally, fig 2 shows a graphic view as well.

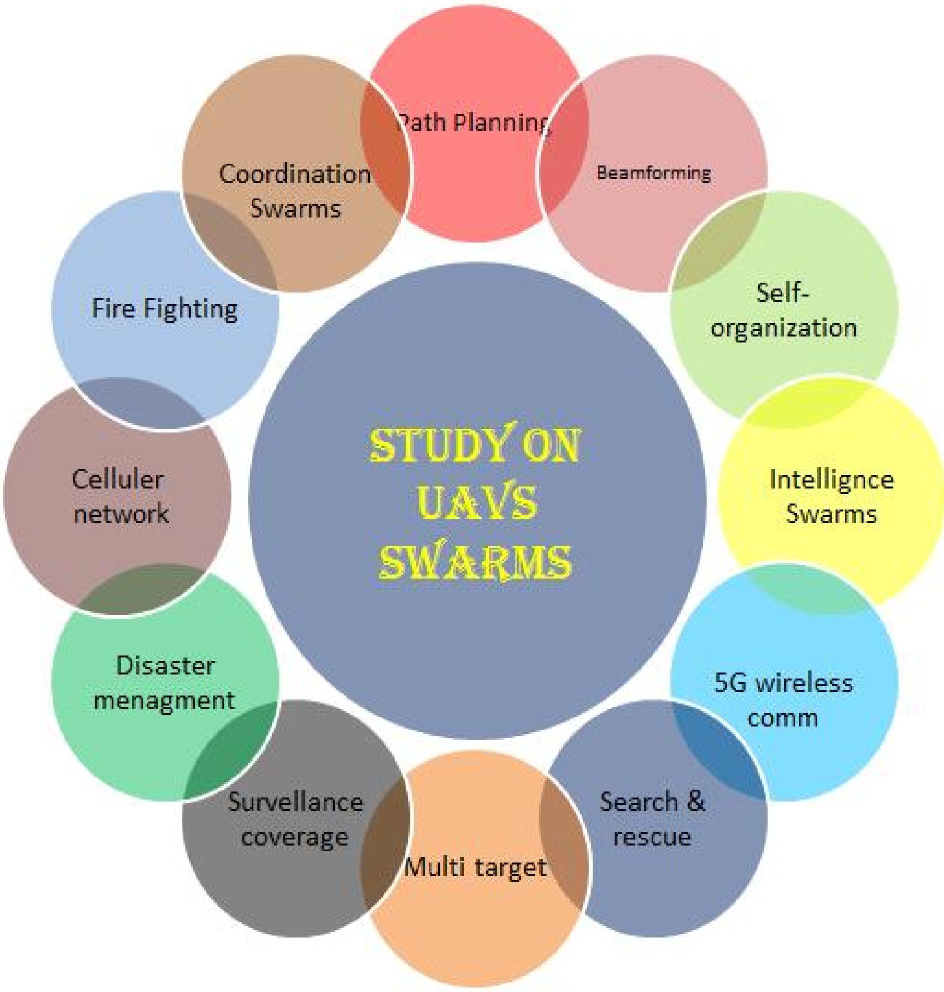

Fig 2: Block Diagram of usage of UAVs

Literature Review

With research into novel ideas like bio-inspired algorithms and machine learning approaches to enhance swarm intelligence, the evaluation of related work highlights the dynamic nature of swarm technology. The literature highlights the need for more study in areas including ethical issues, regulatory frameworks, and the integration of swarm systems into current airspace control structures, as there are still knowledge gaps despite major advancements. Future research efforts in the subject of swarm UAVs are

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guided by this synthesis of relevant work, which provides the foundation for a comprehensive grasp of the current situation. The details of LR are as follows:
The goal of this study on UAV path planning is to determine the shortest route for UAVs while consuming the least amount of resources and energy [1]. Through a review of 44 carefully selected and highly recommended articles, this study provides specifics on UAV path planning algorithms.

It is used for route optimization. Path optimization, path completeness, optimality, efficiency, and attaining resilience are the main obstacles of UAV path planning. Planning its route to avoid obstacles like communication towers and tall buildings is one of the most well-known issues. Appropriate route planning is essential for UAV activities including communication, calculations, and remote sensing. The main concept of path planning is figuring out the optimal path or route for a UAV to take from its starting location in order to accomplish its objective. To enable the UAV to go around kinetic and physical obstacles in its route, path planning comprises a variety of computations and maneuvers. In route planning, navigation, trajectory, and motion planning are essential terms and stages. They are all essential for the best possible path planning and are tied to one another. Path planning algorithms are also covered in great length in this study. A categorization framework is also explained, and path planning algorithms are employed to determine a UAV's route from its starting location to its destination [17]. To manage the mission process across many groups, all group leaders follow a coordinated approach. In order to accomplish inner-group coordination, the remaining followers obey their direct leaders [25].

We propose the Optimised Ad-hoc On-demand Distance Vector (OAODV) [6] to improve the beam forming capacity technique on swarm UAS networking while being limited by beam formation constraints. This study presents a low-cost beam-forming architecture that makes use of antenna arrays installed on unmanned aerial vehicles (UAVs). It is advised that beam switching be used to increase antenna gain towards the ground station using two to three-element arrays beneath the UAV's wings [4].

A problem that optimizes the achievable rate between the SN and the DN while taking into consideration the UAV's position, analogue beam shaping, and other factors was described in this paper.The beam forming vectors are designed to minimize interference and optimize the beam forming

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gains of the target signals [7].The anther recommended that a straightforward method for beam formation from a drone swarm be created. Each drone carries a vertical resonant half-wavelength wire that is illuminated by light sent vertically by a ground-based transmitter [24]. In this research, the ZF preceding approach determines the active beam forming, and we will explore future ideas by optimizing the pre coding matrix using machine learning techniques. Continuous transmit beam forming and phase shift were optimized concurrently [29].

A self-organized reciprocal choice method for multi-UAV swarm sensing coverage is introduced. There is no need for repeated trials to determine the ideal settings because modeling and optimization are carried out immediately in velocity space [2]. Based on a basic rigid-body model, a path planner in this study arranges swarm members into formations that provide the swarm with a safe, collision-free route to its target in a variety of barriers [8]. Examples of self-organization include elliptic and linear forms, split/rejoin, obstacle-avoiding tunneling techniques, and helical milling routes. The spatial grid model is converted into floating-point operations based on longitude, latitude, and altitude coordinates into spatial distance queries under the grid's spatial features in space distance measurement, and the surrounding individuals are frequently used in UAV self-organizing swarm control [5].

Swarm intelligence is used in conjunction with the Cooperative Intelligent Transportation System (C-ITS) concept and knowledge of connected and autonomous vehicles (CAVs). Most manufacturers want to use a large portion of the current understanding of sensors, actuators, telemetric, and artificial intelligence when delivering level-5 fully autonomous ground vehicles on urban roadways [5].

Five well-known swarm intelligence techniques are covered in this article [15], along with two practical methods for continuous and dynamic optimization problems. New techniques for intelligent UAV swarm collaboration are made possible by the advancement of artificial intelligence [19]. In addition to the idea of linked and autonomous vehicles, swarm intelligence makes use of the extensive body of current knowledge about sensors, actuators, TELEMATICS, and artificial intelligence in the framework of a cooperative intelligent transportation system. Swarm intelligence is used in

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the concept of a Cooperative Intelligent Transportation System to comprehend autonomous and connected cars [27]. The authors discuss self-moving platform strategies in 5G and beyond artificial intelligence in this study [37]. In addition, we have already discussed the applications of UAV swarm networks in urban environments [38].

A Comprehenssive Study on UAVs Swarms

References	Path planning	Beam forming	Self-organized	Swarms intelligence	5G wireless Comm	Search & rescue	Multi targets	Surveillance coverage	Disaster management	Decision making	Autonomous swarms	Cellular Network	Fire fighting	Coordination swarms
Zakriaqadir ,fahim 2021	✓			✓	✓			✓	✓		✓	✓		✓
Juan jesusroldan 2021							✓	✓			✓		✓	✓
Sandeep,A, kumar 2021	✓		✓	✓										
Nikolaos A. Kyriakakis 2020	✓			✓		✓	✓				✓			
Egarguin, Neil J. A2020		✓												✓
Kaya kuru 2021				✓						✓	✓		✓	✓
Jianwang 2020		✓			✓							✓		
Leonardo c.dossanto s 2021		✓						✓	✓					

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R.gupta, A.kumari 2021			✓	✓	✓			✓	✓	✓				✓
Yugangliu 2019						✓					✓	✓		✓
dos Santos, Leonardo C 2021	✓	✓									✓	✓		✓
Qian Mao 2018				✓	✓		✓							
EvsenYanmaz, 2018					✓	✓	✓	✓			✓	✓		✓
HanifUllah, nithya G 2019	✓				✓			✓	✓	✓		✓	✓	
Tao Tang,Taohong 2019					✓		✓					✓		✓
Bangkui Fan 2020	✓		✓	✓	✓									
AzadeFotouhi 2019	✓			✓	✓			✓				✓	✓	
Yubingwang 2019	✓			✓			✓							
Anamtahir 2019		✓		✓	✓	✓			✓		✓		✓	
Haochen 2021	✓			✓			✓			✓		✓	✓	✓
Kaya kuru 2021			✓	✓	✓	✓	✓	✓		✓	✓	✓		

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Julian weidnger 2018				✓									✓	✓
Chen, Runfeng, NingXu 2018			✓	✓						✓	✓			
Ursula challita, 2018			✓	✓		✓						✓		✓
Yi Huang,2021	✓	✓						✓				✓		✓
GeorgiosTzoumas2022													✓	
Muhammad Asghar Khan 2022												✓		
Shumaila Javaid,2023														✓

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Rigoberto Martínez-Clark 2023					✓									
Kayalvizhi Manikandan 2022	✓													
My study	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 1: A Comprehensive Study On UAVs Swarms

Application Areas of UAVs

Applications for drone swarms are many and include surveillance and rescue missions [41]. An Internet of Things scenario was examined in which a set of ground nodes are covered by a swarm of UAVs functioning as ABSs, with any nodes that do not take part in the communication process being regarded as eavesdroppers. By suggesting a BCA secure framework that consists of the ground nodes' association, the UAVs' 3D placement, and the power distribution for the associated nodes, the scenario's goal of maximizing the number of nodes with positive secrecy is addressed. Techniques based on optimization and game theory were used in various ways. After extensive simulations, the suggested framework outperformed greedy association and placement, as well as the top response dynamics benchmarks, in terms of secrecy performance while retaining low complexity [43]. A cloud-based approach is proposed that utilizes state-of-the-art methods and algorithms to develop fault-tolerant systems and construct a decentralized swarm of UAVs [42]. The use of UAVs and swarms is explained as follows:

Path Planning in UAVs

Unmanned aerial vehicles, or UAVs, are frequently utilized as platforms to operate in a variety of environments due to their exceptional mobility and capacity for vertical takeoff and landing. Path planning is a crucial part of deciding on a task. In order to prevent collisions with obstacles and optimize the cost function while accounting for kinematic restrictions, the system's overall objective is to design a global path to the target in real time. The issues with this route the mission of the UAV must also solve planning problems. Considers Basic 2D path planning techniques cannot handle complex 3D scenarios with numerous constraints and uncertainties. Thus,

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these days, 3D path planning algorithms are crucial for UAV navigation, particularly in complex environments like cities, tunnels, and forests. Compared to 2D path planning, the complexity of the dynamic and kinematic restrictions leads the problems to grow exponentially, even if there are many options for route planning in 3D scenarios. To explain these constraints and retain such information, a set of mathematical tools is required in order to create a path that avoids collisions in the crowded environment.

There are no common solutions since, according to optimization theory, finding a 3D complete route is an NP-hard issue. Over the past few decades, a number of solutions have been created to address comparable issues [1].

UAVs are frequently used for high-risk activities and risk assessment without posing a threat to human life. Human interaction is vital with UAVs, particularly when ongoing monitoring is required. However, a human's ability to keep an eye on a massive swarm of UAVs is restricted. Restricted. UAVs should be able to help in these situations. Planning a safe path for a UAV from takeoff to landing is a challenging task that is influenced by a variety of parameters such as path length, obstacle avoidance, power consumption, and so on. This requires effective path planning methods or algorithms to make self-decisions about task assignment and a safe route navigation. With the help of effective path planning algorithms and integrated job allocation, UAVs may follow the best routes for target interception and collision avoidance. In this work, we investigate the challenges of a swarm of UAVs integrating target interception and route planning. A swarm of UAVs is frequently made up of extremely redundant, basic UAVs with basic sensors on board for communication with the environment and other UAVs. For these reasons, a swarm of UAVs is very resilient, flexible, and scalable. Even though there are several review articles on UAV swarm path planning that address the route planning problem, none of them address the challenge of shifting target interception. Target dynamics and surrounding impediments are taken into account while deciding on a path to intercept a moving target. Current Swarm Intelligence (SI)-based algorithms are examined in this work along with their modifications to handle problems like integrated path planning and target interception for a swarm of unmanned aerial vehicles in a three-dimensional (3D) environment. This work on UAV path planning focuses on determining the shortest path for UAVs while consuming the least amount of energy and

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resources [2]. This study provides a detailed description of UAV route planning algorithms based on a review of the literature that comprised 44 carefully chosen and highly recommended studies. Path planning techniques that fit into these categories include RRT, Artificial Potential, Voronoi, D-Star, A-Star, Dijkstra, MILP, Neural Network, Ant Colony Optimization, and Particle Swarm Optimization.

- Model Based Conventional
- Learning-Based Conventional

It is used for route optimization. Path optimization, path completeness, optimality, efficiency, and attaining resilience are the main obstacles of UAV path planning. Planning its route to avoid obstacles like communication towers and tall buildings is one of the most well-known issues. Appropriate route planning is essential for UAV activities including communication, calculations, and remote sensing. The main concept of path planning is figuring out the optimal path or route for a UAV to take from its starting location in order to accomplish its objective. To enable the UAV to go around kinetic and physical obstacles in its route, path planning comprises a variety of computations and maneuvers. In route planning, navigation, trajectory, and motion planning are essential terms and stages. They are all essential for the best possible path planning and are tied to one another.

Path planning algorithms are also covered in great length in this study. A categorization framework is also covered, and path planning techniques are utilized to determine a UAV's route from its starting point to its destination [7]. The author of this study explains how to regulate the UAV's course between two mobile nodes that they investigated. He brought it up in relation to path loss as well. The path loss exponent of ground-to-aerial communications drops is also calculated using the 3GPP model [13]. All group leaders are coordinated in this paper's path planning to manage the mission process across several groups in a cooperative manner. In order to accomplish inner-group coordination, the remaining followers obey their direct leaders [14]. A new set of mission-oriented metrics may be proposed in this innovative optimum routing and multi-robot route planning design problem [18]. This book aims to give a general introduction of trajectory planning and discusses the significance of path planning. The potential use of UAV swarms to operate independently and cooperatively in a variety of scenarios has been

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demonstrated throughout this study through the development of route planning and autonomous navigation algorithms [20].Finding a practical route from the beginning point to the finishing position while abiding by a number of optimization criteria and mission limitations is the aim of the path planning issue for a UAV, according to the author [32].

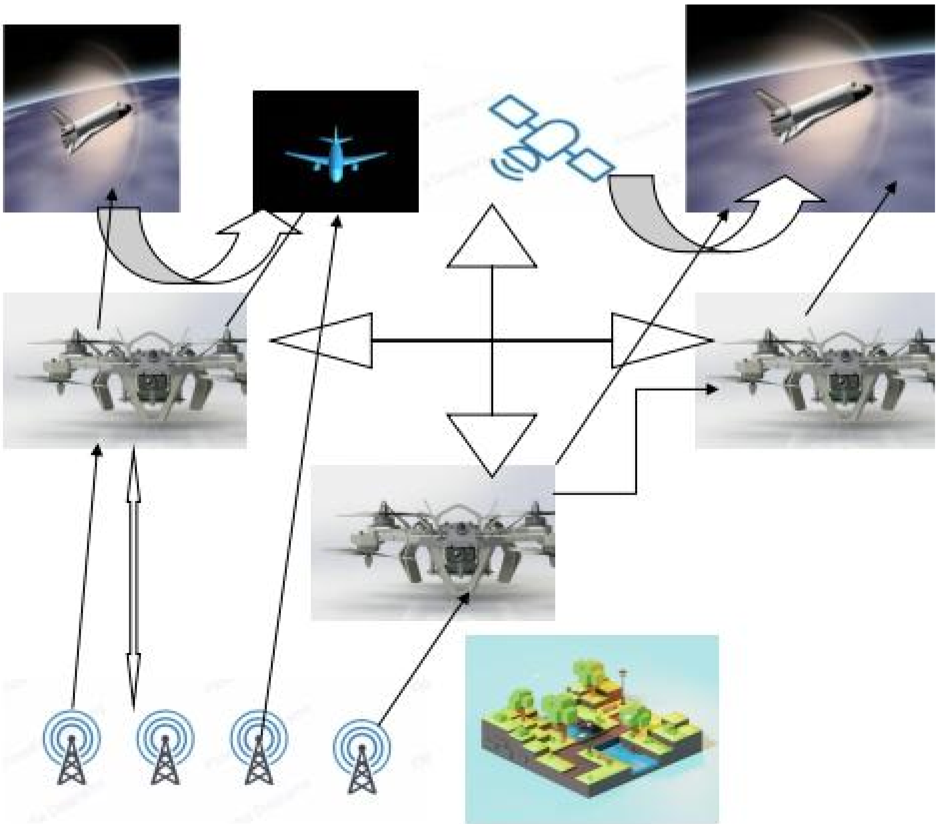

Fig 3: Path Planning UAVs to UAVs to Base Station

Beam Forming Explanation

There are several military, commercial, and civilian uses for unmanned aerial vehicles, or UAVs. One of the most important technologies for UAVs has traditionally been wireless communication. However, as UAVs are employed in increasingly complex application situations, communication bandwidth is starting to become a limitation. The sub-6 GHz band is too congested to handle very high data-traffic requirements. Since huge antenna arrays may be packed into a tiny space on the UAV to achieve three-dimensional (3D) beam creation, using millimeter-wave (mm Wave) frequency bands is one potential path for UAV communications. However, when used as aerial access points or relays, UAVs have the potential to greatly improve the coverage and quality of service of terrestrial millimeter Wave cellular networks.

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In this paper, we give a comprehensive review of wave beamforming-enabled UAV networking and communications. The first section discusses the technological possibilities and limitations of mm Wave-UAV communications. Next, we go over some of the most important millimeter wave antenna configurations and channel modeling. Next, the technologies and solutions for mm Wave-cellular networks with UAVs and mm Wave-UAV ad hoc networks are discussed. Finally, we discuss unresolved issues and promising avenues for future study in mm Wave beam creation for UAV communications and networking [13].

Unmanned Aerial Vehicle (UAV) technology, encompassing platform, communication, flight control, and surveillance techniques, has advanced rapidly in recent years. UAVs are widely used in both military and civilian purposes, such as surveillance, transportation, infrastructure inspection, agricultural irrigation, disaster relief, and more, because to its high mobility, quick deployment, and affordable price [15]. These UAV-enabled uses could significantly reduce labor expenses while also enhancing public safety. While performing various jobs, UAVs typically need to provide mission-related data, like sensor data and high-resolution photographs, to ground terminals. As such, UAVs occasionally need higher-data-rate connections.

However, because of the extreme interference and severe spectrum shortages in the crowded sub-6 GHz bands, the microwave band, which has been widely employed in terrestrial communication networks, would not be able to manage UAV communications properly [17]. However, millimeter wave communication has a vast spectrum resource and can achieve high-rate transmission, as demonstrated by satellite communications and indoor short-range communications. Antenna arrays are widely utilized in mm Wave communications to offer array gain and overcome high propagation loss [18], [19]. The short wavelength of the mm Wave signal enables the installation of a large antenna array in a small area, which is advantageous for UAVs with limited space and energy [24]. Therefore, UAV communications may be made possible via mm Wave communication with customizable beam shaping [32].

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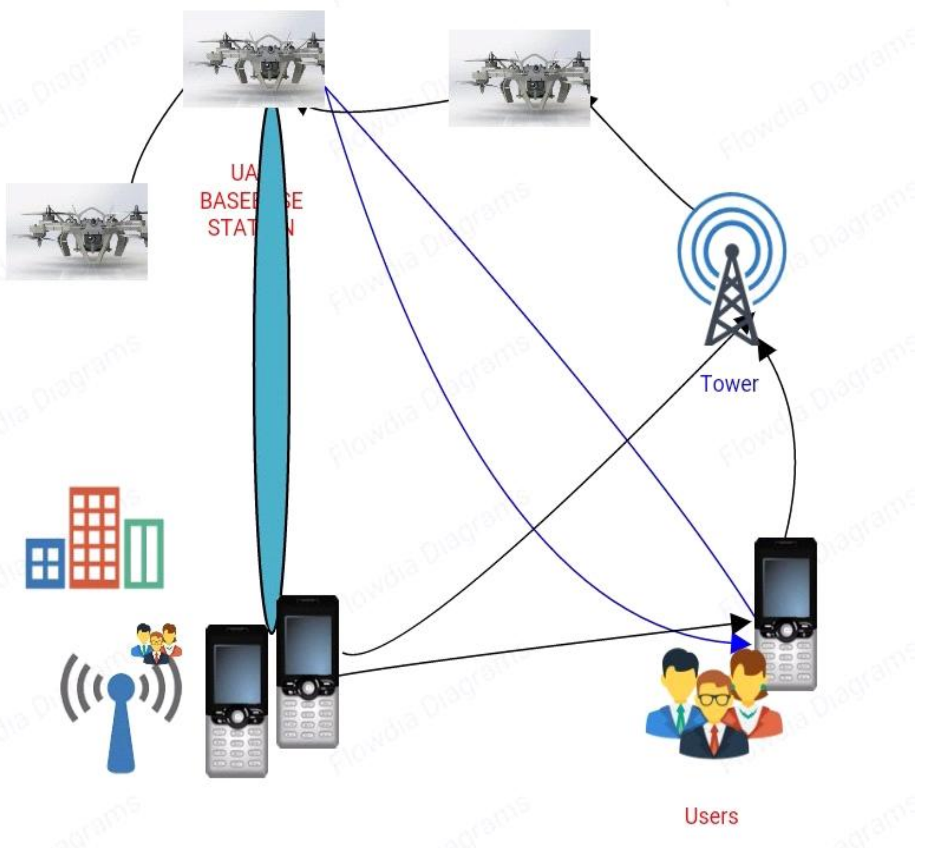

Fig 4: Beamforming in UAVs

Self – Organized Network

For autonomous multi-UAV systems, self-organization offers a number of benefits. The use of a Self-Organization (SO) paradigm to the development of UAV swarm behavior is examined in this research. A dynamic simulation of UAV swarms is developed using this SO framework. A genetic algorithm (GA) is then used to evolve the swarm behavior in order to efficiently detect and eliminate stationary targets that are retaliating. This system is tested with both homogeneous and heterogeneous UAVs, yielding interesting outcomes [24]. This paper describes a self-organized reciprocal choice strategy for sensing coverage with multi-UAV swarms, which eliminates the need for repeated experiments to determine the ideal parameters by modeling and optimizing directly in velocity space [30]. In this study, a path planner using a straightforward rigid-body model arranges swarm members into formations that provide a safe, collision-free route for the swarm to reach its target in

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environments with many obstacles. Examples of self-organization include elliptic and linear formations, split/rejoin, tunneling maneuvers for avoiding obstacles, and helical trajectory for milling [31]. In this work, a single-layered UAV serves as the leader of multi-layered swarms, which are composed of multiple unmanned aerial vehicles that operate in a coordinated and self-governing manner. Self-governing multi-swarm UAVs protect their wireless communication channel from several security threats [32]. In this study, the spatial grid model is transformed into floating-point operations into spatial distance queries under the grid's spatial features in space distance measurement [33] based on longitude, latitude, and altitude coordinates. Often, UAV self-organizing swarm control relies on the surrounding individuals. When UAVs create direct communication LOS linkages with sensor nodes, they can provide potential conveyance opportunities for data collection in self-organized topologies, as the author describes [40].

Surveillance Monitoring and Intelligence Autonomous Swarms

Swarms or fleets of Unmanned Airborne Vehicles (UAVs) are groups of aerial robots, or drones that cooperate to accomplish a common objective. A specific number of rotors allows a swarm of drones to hover vertically, take off, and land (VTOL). Using internal processors, the drones can fly themselves, or they can be controlled manually using a remote control [25]. Drones are widely used in the military, but in recent years, interest in their civilian applications has grown. In fact, low-cost drones and their swarms offer a solid foundation for creative research initiatives and upcoming commercial applications that will benefit people in their personal and professional lives.
Figure 1 illustrates fully and partially (semi) autonomous swarms, for example.

From a different perspective, the classification can be seen as either multi-layered swarms, where the devoted leader drones of each layer report to their higher-layer leader drones, or single-layered swarms, where each drone acts as its own leader. At the summit of this hierarchy is a server station that is situated on the ground. Each UAV in a swarm may carry out particular data collecting and processing activities in real time if it has enough processing power. Either a faster server/base station or the cloud are used for its primary processing [27].

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Security, Survey, Monitoring, and Surveillance

Unmanned Aerial Vehicles (UAVs) have historically been employed in military surveillance operations. In a number of fields, including geophysics and agriculture, drones have been employed for airborne surveys, surveillance, and monitoring [25], [26]. For instance, updates on any activity detected outside of regular business hours may be necessary for the surveillance of a building or environment. Manual monitoring would need a big number of individuals in a large institution or setting. By automatically and quickly alerting the base station when movement is detected, a swarm of drones, on the other hand, can cover/monitor the terrain much more efficiently with less manual labor [27]. The study of artificial intelligence (AI) focuses on human intelligence judgments that are represented through formal and computational methods, as well as cognitive processes and reasoning. The DSR is therefore based on adductive scenarios to represent the connected solutions to the identified problem in the farming sector, and the actions of the players are likely to directly affect the problem area's future ramifications and alternative strategic choices. We will use a semi-natural policy language and adductive reasoning techniques to handle the scenario's decisions, conflicts, and directions [28].

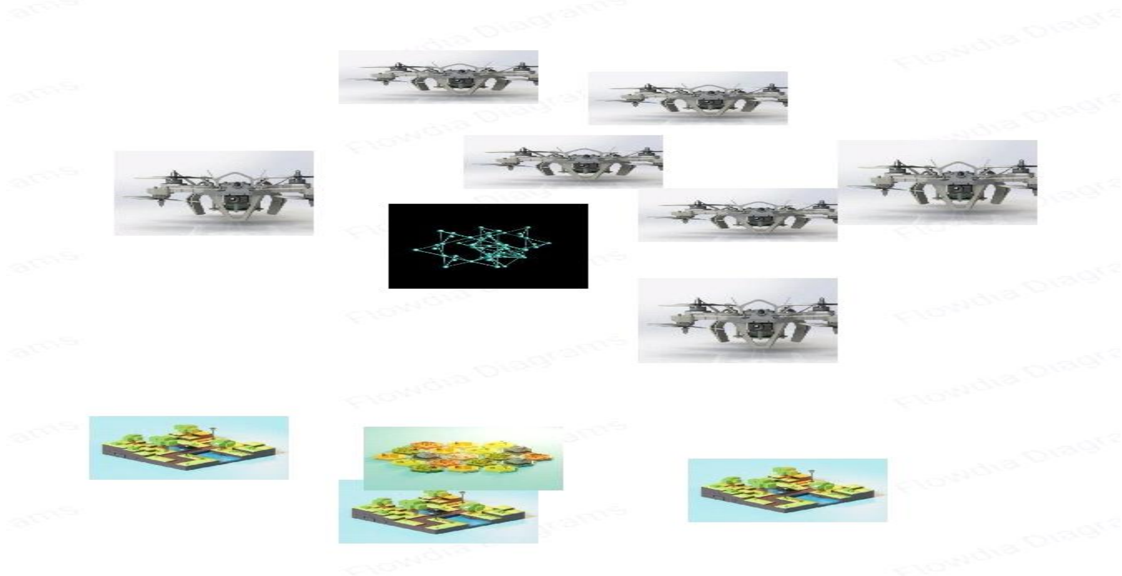

Fig 5: UAVs Monitoring, Surveillance and Security Usage

Disaster Management

In the event of a natural disaster, UAVs can quickly reach areas that would otherwise be hazardous and difficult to reach. Thus, they are able to provide catastrophic forecasts and facilitate the implementation of effective preventive

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measures. A swarm of drones equipped with fire extinguishers or other such tools, for example, might quickly assess and control a sizable region during a wildfire without posing a threat to human life. While the majority of articles on disasters focus exclusively on the post-event period, employing both classical and learning-based algorithms with applications to locate victims and optimize routes, UAVs are rapidly being used in rescue and disaster relief operations [1].

Two important applications discussed in the study are environmental monitoring and disaster management. Under such conditions, it is possible to scan large regions without exposing people to hazardous environments [3]. Hurricanes are seldom discussed in relation to large-scale disasters like earthquakes, although they have a substantial influence on human society and can result in the loss of life. It is critical that search and rescue workers act swiftly and efficiently in times of crisis. Lack of communication infrastructure, however, is a significant problem during this period as much of the current network may be broken during a disaster, which lowers the efficacy of the rescue team and their ability to find isolated individuals [20]. According to this paper about natural disasters, UAVs can quickly reach disaster-stricken areas that would otherwise be hazardous and difficult to reach [24]. They can provide disaster estimates and aid in the implementation of appropriate countermeasures. In order to provide logistical supply and communication coverage during emergencies, this paper focuses on network and communication technologies that can assist UAV disaster management systems [25]. The networking technologies needed for UAV deployment in actual disaster management and response situations are also covered by the authors [32].

Firefighting, Search & Rescue and Coordination Swarms

The current condition of firefighting outlines current fire prevention, surveillance, and extinguishment measures, collects important data to illustrate important issues, and offers professional opinions through two polls. Even though Spain provides the most of the material in this section, other European and Mediterranean nations may find it useful. 83,963 hectares were burned in 10,883 fires in Spain in 2019; 7290 of these fires affected less than one hectare, while 3593 affected more than one hectare [19]. An average of 12,182 fires and 99,082 hectares burnt year occurred between 2009 and 2018,

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which was similar to prior years. In other words, 0.356 percent of Spain's forest acreage is affected by fires each year.

The worst outcomes are in July and August, when there are more surface burns than throughout the year [19]. Most of these fires happen in the spring and summer, particularly in March, July, August, and September. According to this study, which examines a Search and Rescue mission with a uniform fleet of Unmanned Aerial Vehicles, the objective of this scenario is to minimize the total arrival times at all places in the area of interest, hence completing the search with the least amount of delay [25]. Explain the possibilities of a quad copter-based multi-drone system for aerial surveillance and search and rescue. This study uses many robots for search and rescue, based on design difficulties and possible solutions [29]. Fire surveillance is the term used to describe the actions taken to identify fires as soon as possible. Detection and reaction timeframes have a major impact on the amount of damage caused by forest fires. The average burnt surface in Spain in 2019 was 7.10 hectares when reaction time was less than an hour and 30.66 hectares when response time was more than an hour [31], [34]. In recent years, research currents have evolved to improve the autonomous and coordinated action of drone swarms in varied environments, with the goal of providing society with an effective tool that can support, carry out, and facilitate law enforcement performance when acting in emergency situations [38].

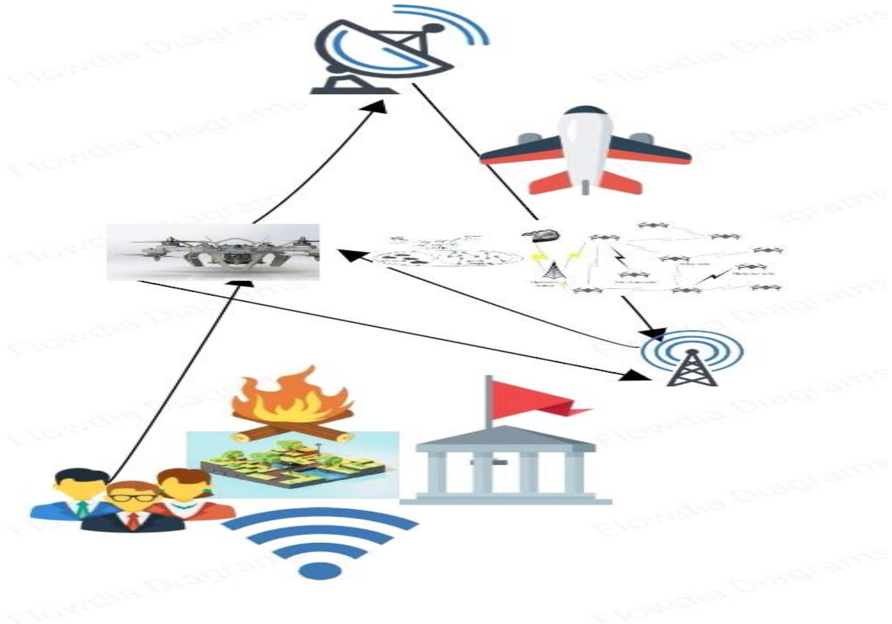

Fig 6: UAVs Use as Fire Fighting

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Cellular Network and 5G Communication

Including unmanned aerial vehicles (UAVs) in fifth-generation (5G) and beyond cellular networks is a promising approach to guarantee safe UAV operation and enable a range of applications with mission-specific payload data delivery, given the advancement of cellular technologies and the dense deployment of cellular infrastructure. Enhanced mobile broadband (EMBB), ultra-reliable low-latency communications (URLLC), and large machine-type communications (MMTC) are the three typical use cases that 5G networks must accommodate. UAVs can be used as inexpensive aerial vehicles to provide more communication choices for ground users by utilizing their high cruising altitude and controlled mobility in three-dimensional (3D) space. However, the need for extensive 3D signal coverage and the high levels of air-ground network interference make it difficult to simultaneously provide such communication services for both UAV and ground users. In addition to high-performance wireless communications, 5G and future 3D heterogeneous wireless networks with coexisting aerial and ground users require effective and efficient sensing and network intelligence. In this paper, we give a comprehensive overview of the most recent research efforts on integrating UAVs into cellular networks, using advanced techniques (e.g., intelligent reflecting surface, short packet transmission, energy harvesting, joint communication and radar sensing, and edge intelligence) to meet the various service requirements of next-generation wireless systems [10]. In theory, a variety of licensed and unlicensed millimeter wave frequency bands, such as the 28 GHz licensed band and the 60 GHz unlicensed ISM band, might be used by UAV-assisted wireless networks. The mm Wave wavelength is much shorter, which enables the development of physically smaller mm Wave circuits and antennas, enabling the construction of beam forming antenna arrays with multiple antennas packed on a chip in a tiny component size [16], [17]. We examined the potential integration of 6G with UAV networks.

Technical Advantages and Challenges of 5G MM Wave Communication

Technical Benefits: mm Wave communications will be crucial to 5G and B5G wireless networks due to its ability to manage orders of magnitude increases in network capacity. The main technological benefits of 5G mm Wave communications will be discussed in the following sections from four distinct

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perspectives: narrow beam, shorter wavelength, higher bandwidth availability, and enhanced security/interference immunity.

• Greater Bandwidth Availability: The mm Wave range, sometimes referred to as the Extremely High Frequency (EHF) range, is the region of the electromagnetic spectrum between 30 GHz and 300 GHz that sits between microwaves and infrared waves. The availability of unused bandwidth at mm Wave frequencies, as opposed to the constrained microwave spectrum resources below 6 GHz currently utilized by traditional wireless systems and contemporary 4G LTE, is one of the main benefits of 5G mm Wave communications. The mm Wave frequency ranges of 71.76 GHz and 81.86 GHz (often referred to as the E-band) provide greater usable bandwidth than any other authorized spectrum for current wireless systems.

• Shorter Wavelength: Higher frequency electromagnetic waves in the electromagnetic spectrum may convey more information in a given amount of time since they have shorter wavelengths. The wavelengths of Mm Wave transmissions are significantly shorter than those of microwave signals below 6 GHz, which were formerly used by WLANs and increasingly congested traditional cellular networks. Their sizes vary from 10 mm to 1 mm3 [18].

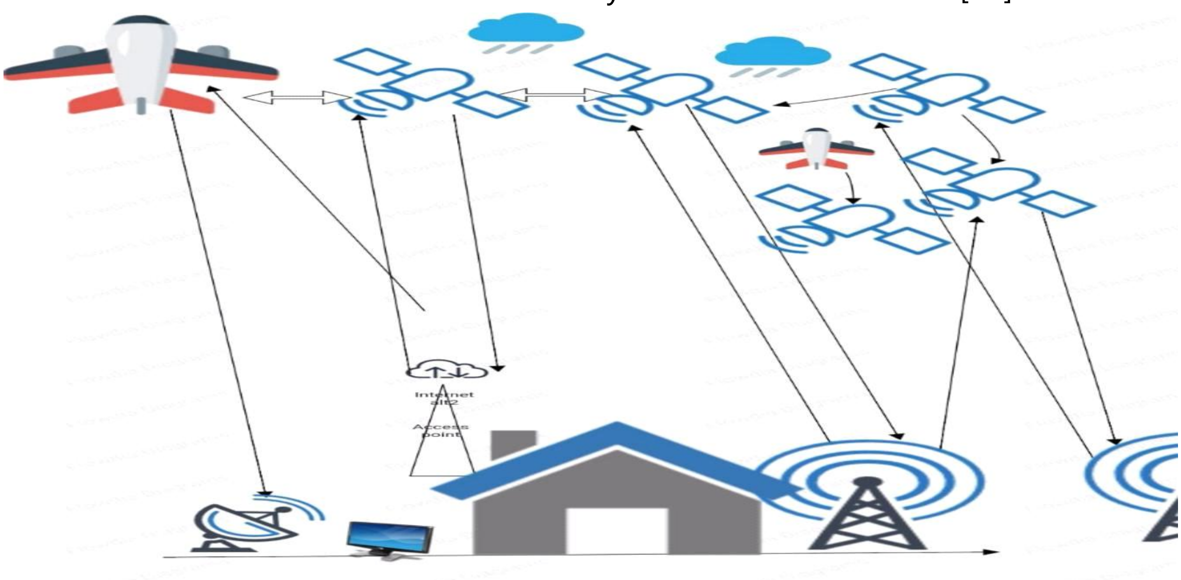

Fig 7: UAVs as Cellular Networking

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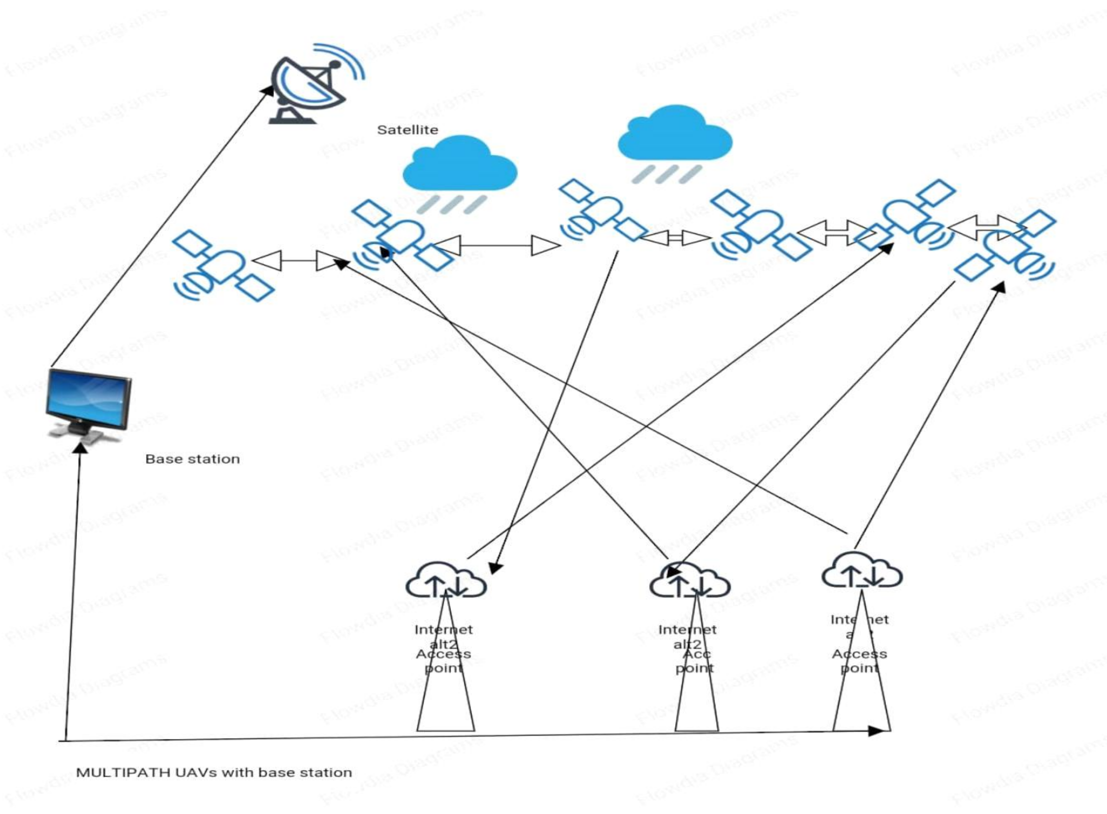

Fig 8: UAVs as Cellular Network Through Satellite

Results

In this paper we, discussed a number of methods are used in UAVs to make easy to use as swarms and categories into two subsections as follows:

Result (Domain Wise Papers Study

The examination of the data acquired from our systematic literature review on swarms of Unmanned Aerial Vehicles (UAVs) demonstrates a distinct emphasis within the research landscape on the disciplines of swarm intelligence and coordination algorithms. The prominence of bar and line graphs in these regions demonstrates the importance focused on optimizing UAV collective behavior and improving coordination mechanisms. This discovery reflects a collaborative research focus on improving the algorithms that regulate swarm intelligence, demonstrating a common goal in improving the efficiency, adaptability, and overall performance of swarm UAV systems. As a result, the findings indicate a crucial need for continued research and development in swarm intelligence approaches and coordination tactics in order to expand the capabilities and uses of UAV swarms.

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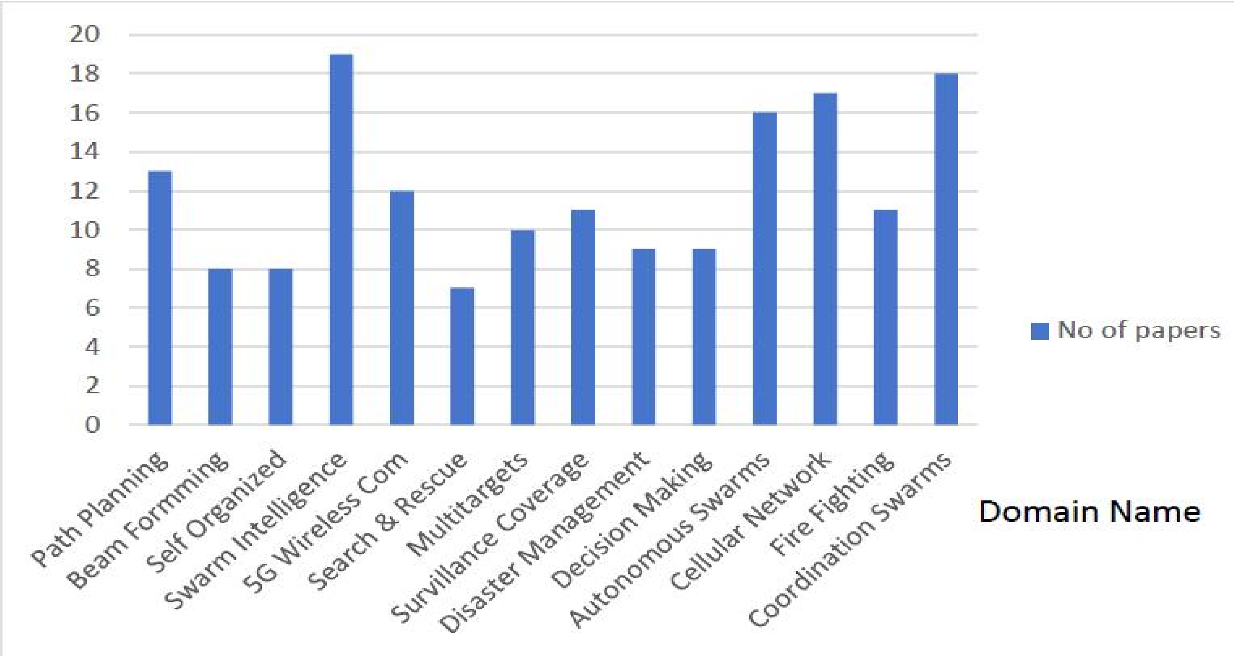

Fig 9: Domain wise papers data

Result (Year Wise Papers Study)

Our comprehensive study, based on a year-by-year review of research articles on UAV swarms, identifies a significant trend in publication activity. The bar chart notably displays peaks in 2021 and 2019, indicating increased research interest over these years. This rise in contributions during these specific years reflects a concerted effort by the research community to investigate and advance understanding of UAV swarm technology. Significant increases in these years may be due to breakthroughs, technological developments, or emergent applications that have piqued the interest of researchers. This result emphasizes the field's dynamic nature, with occasional bursts of scholarly effort reflecting the changing landscape of swarm UAV research. As a result, our research not only gives a thorough picture of the temporal distribution.

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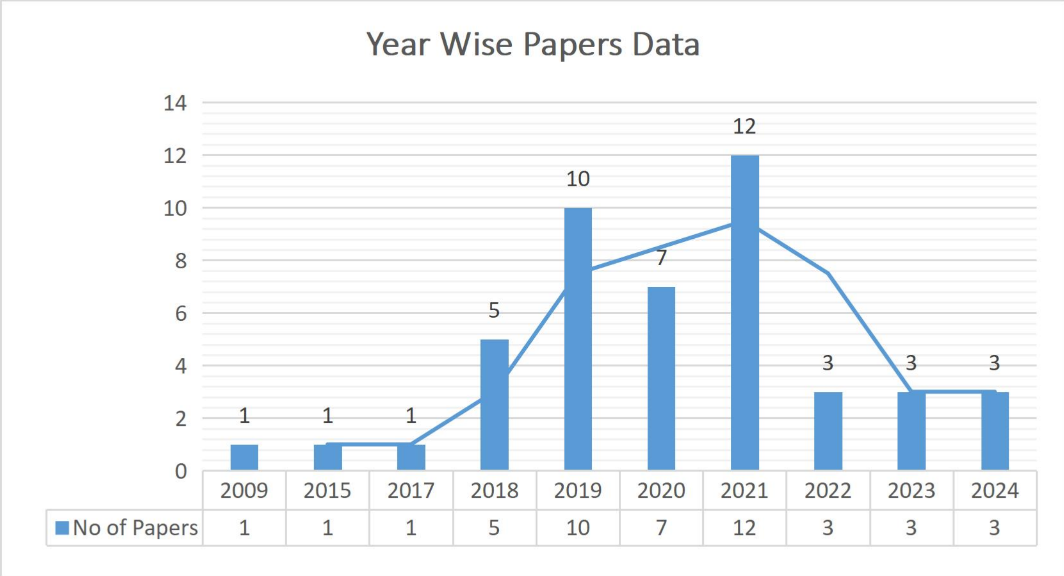

Fig 10: Year Wise Papers Data

Discussion and Conclusion

The paper tackles significant obstacles in the field of swarm Unmanned Aerial Vehicles (UAVs), including problems with decision-making, communication, collision avoidance, and security. In order to overcome communication problems, future research should concentrate on improving coordination algorithms, utilizing the collective intelligence of UAV swarms, and incorporating more advanced sensors for more real-time data transfer. Additionally, the exploration of military defensive applications offers a viable path where swarm UAVs may be essential. Work in these areas will contribute to the advancement of swarm UAV systems' capabilities for a range of applications and the removal of current barriers.

Ultimately, our methodical review of the literature on Unmanned Aerial Vehicle (UAV) swarms provided a comprehensive overview of the current state of research on this dynamic and diverse subject. With notable peaks in scholarly activity in 2021 and 2024, the data analysis showed a discernible focus of research efforts on swarm intelligence and coordination algorithms. These years mark significant advancements in UAV swarm technology as well as times of heightened interest. The results demonstrate the dynamic nature of the field and the ongoing need to improve algorithms and methods in order to optimize UAV collective behavior. Despite advancements, identified

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knowledge gaps in airspace integration, ethical issues, and regulatory frameworks point to areas that need more research.

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