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INNOVATIVE MODELING AND ANALYTICAL APPROACH FOR ENHANCING COMMUNICATION EFFICIENCY IS BASED ON AERIAL AD HOC NETWORKS

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Abstract: Aerial Ad Hoc Networks (AANET) connect devices and aerial platforms without a network, drawing interest. These platforms have different goals but need communication infrastructure. Mobility and poor power supply management are particular to these networks and devices. The study shows a user-friendly, adaptable technique. Changing communication network designs and using UAV-mounted base stations enhances results. This role involves selecting station sites in the case of a communications network collapse due to an incident, natural disaster, or technical failure and determining the financial and logistical requirements for aircraft. Game theory and drone communication helped us examine and solve the situation according to its complexities. The simulation covered all possible outcomes after the communication network tower failed. The study recommends creative disaster communication methods: The study encourages faster and more flexible emergency drone-mounted base station deployment. Natural disasters, technology failures, and other events reconstruct communication networks. Innovative drone deployment optimization using game theory across fields achieves this. The article specifies drone base station locations for optimal connectivity. Drone numbers depend on economic or humanitarian requirements, cost-effectiveness, and emergency reaction. Prioritizing network restoration after disasters enhances crisis management and recovery. Using game theory to build drone communication networks is innovative. Our method increased average throughput by 48.4% and user coverage by 36.7% over random deployment while reducing reaction time compared to fixed-cell options.

Keywords: AANET, UAV, ATG, SIR, SNR.

1. Introduction

Various applications, such as extensive agricultural surveys, aerial photography, civil security, military surveillance, and operations, among others, are integrating Unmanned Aerial Vehicle (UAV) networks [1]. These applications include environmental monitoring, communication relays, disaster assistance, cargo delivery, and border surveillance and reconnaissance. There is an urgent want for dependable, efficient, cost-effective, application-specific, and easily adaptable networks to facilitate prompt deployment, given the rising number of applications and the accompanying high costs and risk considerations. UAV networks perform more effectively in this context than conventional wireless networks. Consequently, other research initiatives have commenced exploring the physical layer, network layer, and contemporary developments, together delineating the needs [2]. Figure 1 illustrates the applications of UAV networks. Mathematical research dominates contemporary domain research, which simultaneously advances experimental and implementation frameworks. Agricultural end products, for example, provide the predominant source of commercially utilized solutions. A comprehensive analysis indicates that the market primarily focuses on security assessment and agriculture, necessitating innovative communication techniques for UAVs and a system for controlling the network's ongoing mobility. Defining real-time network management and overseeing these networks for imminent deployment is an intractable challenge [3]. This section revisits UAV networks, linkages, application domains, and network protocols. We will subsequently examine the distinct issues inherent to each application. This phase will also encompass comprehensive system models and the most advanced projects in the sector. We present recent research on game theory analysis and the exploration of UAV networks. Even though these projects lay the groundwork for first detection operations in the area, there is still a lot that can be done to make them better, especially when it comes to air-to-ground communication and game theory-based air-to-air coordination [4].

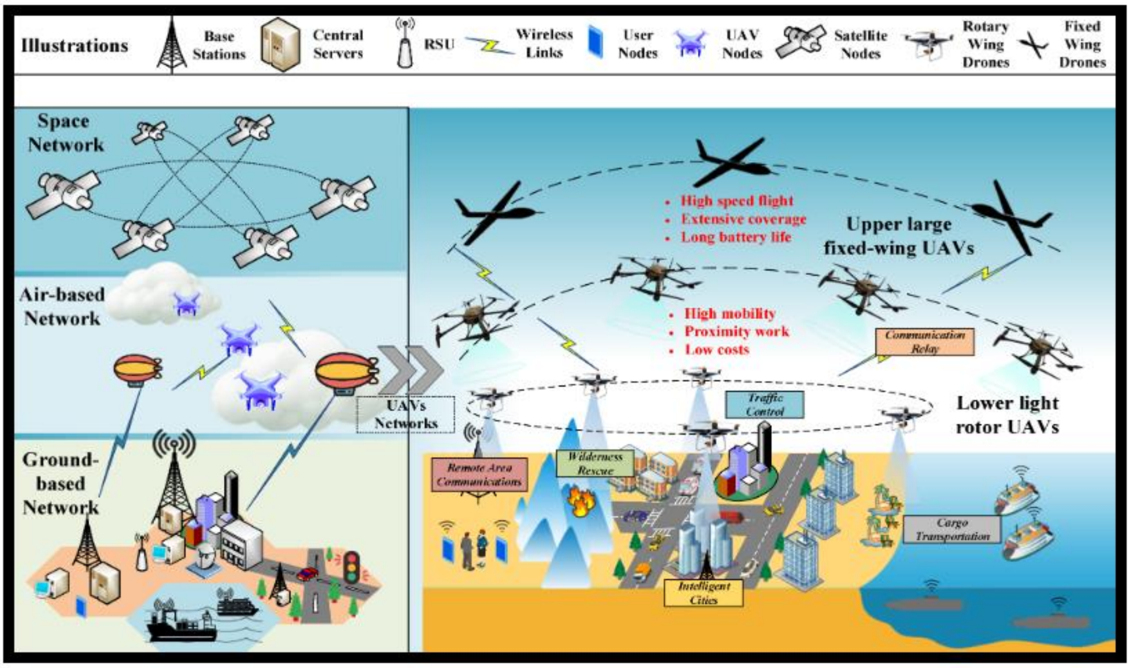

Figure 1:UAV network applications.

1.1. The background and importance of UAV networks

They are attracting considerable interest due to their multifaceted applicability in diverse modern domains. Due to their ease of deployment and mobility, civilian uses of UAV-based wireless relaying services are increasing. Recently, UAVs and drones have integrated payloads such as surveillance sensors and reconnaissance capabilities, utilized in aerial cinematography [5], environmental monitoring, disaster assessment, military operations, precision agriculture, and package delivery. Numerous official organizations and private entities have significantly invested in the creation and implementation of a novel delivery network

utilizing UAVs and drones, wherein the drone network transports small consumer items, apparel, or takeout to consumers or transfers goods between warehouses. The communication channel is uniform across all applications; a proficient, low-latency data pathway is essential to guarantee the quality and dependability of data transmission [6].
UAV networks possess inherent advantages over terrestrial and satellite networks, especially due to their ability to dynamically position themselves at optimal vantage positions. Their flexibility and ability to be deployed anywhere allow them to quickly adjust their field positions to meet end-user needs [7]. UAV-based networks typically provide communication or data transmission. Nonetheless, the deployment of UAVs in data dissemination and other supplementary informative tasks has faced criticism. Battery limitations and data theft are critical obstacles obstructing the widespread use of UAV networks [8]. The power limitations of UAVs, or the time-of-flight constraint, are directly proportional to the potential energy output, which correlates with the battery specifications and frame dimensions of the UAVs. The principal concerns are the selection of the propulsion system, UAV weight, battery management, air traffic congestion, and the sustainability of electrical energy. Consequently, it is essential to evaluate the efficacy of UAV operations from multiple viewpoints [9].

1.2. *An overview of game theory*

Game theory is the mathematical examination of strategic interactions among rational decision-makers [10]. It has persisted for centuries, from traditional card games to the claim that the fundamental objective of game theory is to "demonstrate how to engage in the game." Game theory consists of several fundamental components: players, strategies, payoffs, and outcomes. Players are entities that make decisions, whereas strategies delineate the complete array of decision options accessible to the players [11]. Players express their preferences for game outcomes through rewards, which can undergo quantitative or qualitative evaluation. The participants' decisions dictate the outcomes of a game. Game theory serves to represent competitive scenarios and resource allocation challenges; it also facilitates the comprehension and prediction of strategic interactions within various systems [12]. Game theory can be categorized into various classifications, including static versus dynamic games, perfect information versus imperfect information games, and cooperative versus non-cooperative games, among others. In a UAV network, the interaction can be succinctly characterized as a game. The players are the UAVs that can work together or against each other; the possible paths are the actions that could be taken; and the cost function is the differential or integral equation that controls how the UAV quad moves along a certain path. The players are aware of each other's objectives, although they refrain from disclosing their aspirations. Consequently, trajectory design must incorporate a game-theoretic perspective [13]. Case studies show that UAVs can be thought of as agents operating under game theory in simple situations or as imperfect models of game theory when it comes to rigid body dynamics [14]. We look into how CoSiMAg boards and RED-COWL agents make decisions when they are spread out, focusing on how they can last longer and sense more when they are working together in the same environment. The situation is straightforward and lacks dynamic limitations. Reachability limitations only remove impediments [15].

1.2.1 *Game Theory Fundamentals*

The study of game theory fundamentals is a branch of applied mathematics and economics. A game comprises a payoff for various combinations of the players' actions. Terminology is essential for describing games. A strategy profile signifies the selection of a strategy by each participant [16]. In the absence of other indications, we presume that each player is required to choose one plan from their respective accessible strategy set. - When a player possesses many strategic options, it is presumed that at least one of the possible tactics is less advantageous than the others. - A player's utility function delineates the result associated with a specific strategy profile. - Collaboration is inferior to modernization. Economic agents may be entirely distinct, yet they share a fundamental characteristic: each agent must evaluate the outcomes of their possible actions and select the one that aligns most rationally with their valuation or objectives [17]. Strategic difficulties inherently involve that each decision is made within the context of others' decisions. Consequently, each participant acts to maximize their payoffs, resulting in varied outcomes from strategic interactions at any given moment. In a dynamic system of participants, each individual seeks to choose a strategy that maximizes their payout. The fundamental concept in a game framework is that no one acts autonomously from others. The aforementioned principles elucidate the decision-making processes underlying each maneuver in a game [18]. Various types of games exist. - The variable categorizes games based on their structural characteristics: etymologically, it is an acronym derived by Latzo, and according to his findings, such a framework signifies a dynamic and more realistic perspective. - The variable delineates the characteristics of the reward-penalty structure: If the rewards and punishments cumulatively equal zero, the framework in question aligns with a conflict of interest. Alternatively, the setting might facilitate both collaboration and rivalry [19].

1.2.2 Types of games

Game theory comprises multiple game types classified by diverse criteria. In game theory, players' decisions are influenced by multiple factors, including the characteristics of their actions. Experts' viewpoints on the definition and categorization of a game differ. This section will offer a comprehensive analysis of these kinds of games [20].

1.2.3 Cooperative and Non-cooperative Games

The primary distinction to establish for a game is whether it is cooperative or non-cooperative. The ability of participants to establish binding, enforceable agreements is a fundamental distinction between cooperative and non-cooperative games. In a cooperative game, participants can establish explicit, binding agreements [21]. Cooperation can occur either implicitly or explicitly. A cooperative game is sometimes known as a powerful coalition game, and it can be represented in factored matrix form. Independent players engage in non-cooperative games without any additional assumptions on their coordination behavior. In non-cooperative games, one or more other players or elements determine the payoffs for the strategies that players employ [22, 23].

1.3 real-world constraints

There are real-world implementation constraints such as cost. The economic viability of deploying a fleet of UAVs is evaluated, and our model has a cost-optimization element that reconciles network performance with financial limitations. Latency: We look at potential delays in communication caused by UAVs passing messages through each other and offer ways to reduce these delays, such as choosing direct flight paths and using fast communication methods. UAV Battery Life: We recognize that UAV endurance is a vital consideration. The model now incorporates flight time restrictions into the deployment approach, guaranteeing that coverage plans remain viable within energy limitations. This addition seeks to connect theoretical modeling with actual implementation in emergency situations. **This paper organizes Section 2, Modeling of UAV Communication Channels, wherein we will examine two air-to-ground (ATG) communication channels between the drone and the ground user. Section 3: Structure of the Proposed Communications Network In this chapter, we establish air stations to improve network efficacy. To enhance cluster advantages, users with low SNR (signal-to-noise ratio) and SIR (signal-to-interference ratio) are grouped according to the metrics employed by all cluster communication systems to establish alliances; Section 4 will offer a comprehensive analysis of the default outcomes, while Section 5 will deliver the conclusion.**

2. MODELING OF UAV COMMUNICATION CHANNELS

Modeling of UAV communication channels We will be interested in this study with the Air-To-Ground (ATG) communication channel, which is the channel between the drone and the ground user, which is quite clearly dominated by two possibilities:

Either there is a LoS (line of sight), and therefore the Friis equation for the loss of the free path measured in function (1) decibels will apply to it:

$$\text{FSPLn} = 20 \log (\text{dn}) + \log (\text{MHz}) - 27.55 \qquad (1)$$

Where:

$$d_n = \frac{\Delta h}{\sin \theta_n} \qquad (2)$$

$$FSPL_n = 20\log\left(\frac{\Delta h}{\sin \theta_n}\right) + 20\log(f_{MHz}) - 27.55 \qquad (3)$$

$$P(h) = \frac{h}{\gamma_0{}^2} \exp\left(\frac{-h^2}{2\gamma_0{}^2}\right) \qquad (4)$$

$$\alpha_0 = \frac{W^2 N_b}{(1000D)^2} \qquad (5)$$

$$\beta_0 = \frac{N_b}{D^2} \qquad (6)$$

$$W = 1000\sqrt{\frac{\alpha_0}{\beta_0}} \qquad (7)$$

$\boldsymbol{d_n}$:The distance betwdrone's drone's transmitter and the receiver is measmeters (equation (2)). Is). $\boldsymbol{f_{MHz}}$: Is the central frequency of the MHz? measured in MHz. $\boldsymbol{\Delta h} = \boldsymbol{h_{LAB}} - \boldsymbol{h_{RX}}$ Where $\boldsymbol{h_{LAB}}$ is the height of the drone, while $\boldsymbol{h_{RX}}$ is The height of the user's device receiver is indicated. $\boldsymbol{\theta_n}$ it is the drone's elevation angle from the receiver measured in degrees in the figure. 2. This refers to the angle of elevation the drone perceives from a forward perspective. Or the presence of obstacles and therefore the absence of an NLOS line of sight, which needs modeling related to the environment and the frequencies used.

2.1. ATG channel modeling

One of the most important conditions in the urban environment is the layout and characteristics of buildings the International Telecommunication Union (ITU-R) proposed in its recommendation document [24] a unified model of urban areas, based on three simple coefficients, $\boldsymbol{\alpha_0}$,$\boldsymbol{\beta_0}$ and $\boldsymbol{\gamma_0}$, which reasonably describe the general engineering statistics of a particular area where the radio frequency signal will propagate. These coefficients are shown below: coefficient $\boldsymbol{\alpha_0}$, represents the ratio of the built-up land area to the total land area (dimensionless) equations (5). Coefficient $\boldsymbol{\beta_0}$: represents thebuildings/ber equations (6s pCoefficient: a measuregs / km) equations(6). Coefficient: $\boldsymbol{\gamma_0}$ measure that describes the distribution of building heights accordinwherethe Rayleigh probability density function (4), Where (h) is the height of the building in meters. For this model to cover a wide range

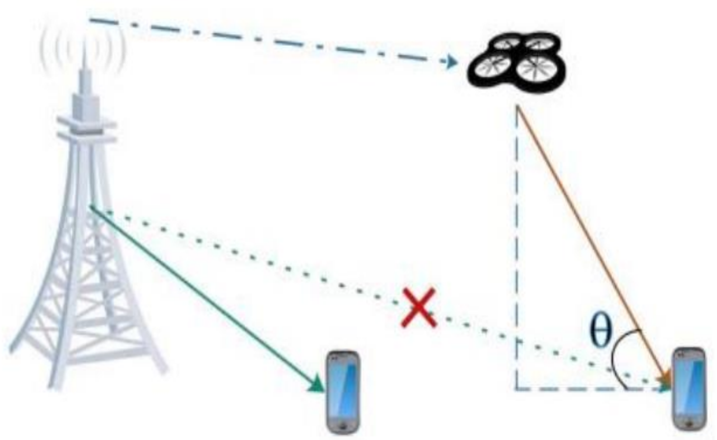

Figure 2: The angle of elevation as the drone sees it from the future.

To cover a broad range of possible applications for this model, we chose four simulation environments:
1. A suburban environment that also covers rural areas.
2. The urban environment is the most common, representing medium-density cities.
3. A dense urban environment that represents some types of cities where buildings are near each other.
4. The urban environment with high-rise buildings, where cities are represented in the style of skyscrapers.

Table 1 summarizes the coefficients selected from the ITU-R Radiocommunication Sector for these environments.

Environments/Factors	α_0	β_0	γ_0
Suburban environment	0.1	750	8
Urban environment	0.3	500	15
Dense urban environment	20	300	0.5
Urban environment with high-rise buildings	50	300	0.5

Identifying an engineering model that meets these criteria while concurrently reflecting an appropriate configuration for a certain city remains challenging due to the unique urban planning approaches characteristic of various cities and suburbs. Consequently, the Manhattan-like standard model was employed to construct the virtual environment illustrated in Figure 3. where in equation (7), **W** represents the width of buildings, while **S** represents the distance between buildings, and from it, the coefficients **SW** can be linked with the coefficients of the **ITU-R** standard by the relationships (5, 6). equations (8) Where **D** represents the width of the map measured in kilometers by assuming a square area, while $\boldsymbol{N_b}$ the number of buildings within the map is represented. The relation of **W** can be deduced as follows: (7, 8, 9), Where: **S** includes all open areas, such as roads, sidewalks, parks, and open garages.

$$D = \frac{S + W}{1000}\sqrt{N_b} \tag{8}$$

$$S = \frac{1000}{\sqrt{\beta_0}} - W \tag{9}$$

$$f_\theta(\eta, \xi) = f_\theta(\eta|\xi).p_\theta(\xi) \tag{10}$$

$$\int_\theta f_\theta(\eta, \xi).d\theta = f(\eta, \xi) \tag{11}$$

$$f_\theta(\eta|\xi) = \aleph\left(\eta_\xi, \sigma_\xi^2(\theta)\right) \tag{12}$$

$$\sigma_\xi(\theta) = a_\xi \exp\left(-b_\xi.\theta\right) \tag{13}$$

A path loss model for low-level UAVs in various environments, as described by ITU-R, was published by the researchers [24]. The method they employed was to simulate the receiving energy of numerous devices and random models that were determined by the parameters of the selected environment. Figure 4 shows the three types of diffuse rays that were found after testing a number of hypotheses (for example, all building layers are made of concrete and all edges are sharp), but they didn't take into account the effects of plants, lampposts, and moving objects.

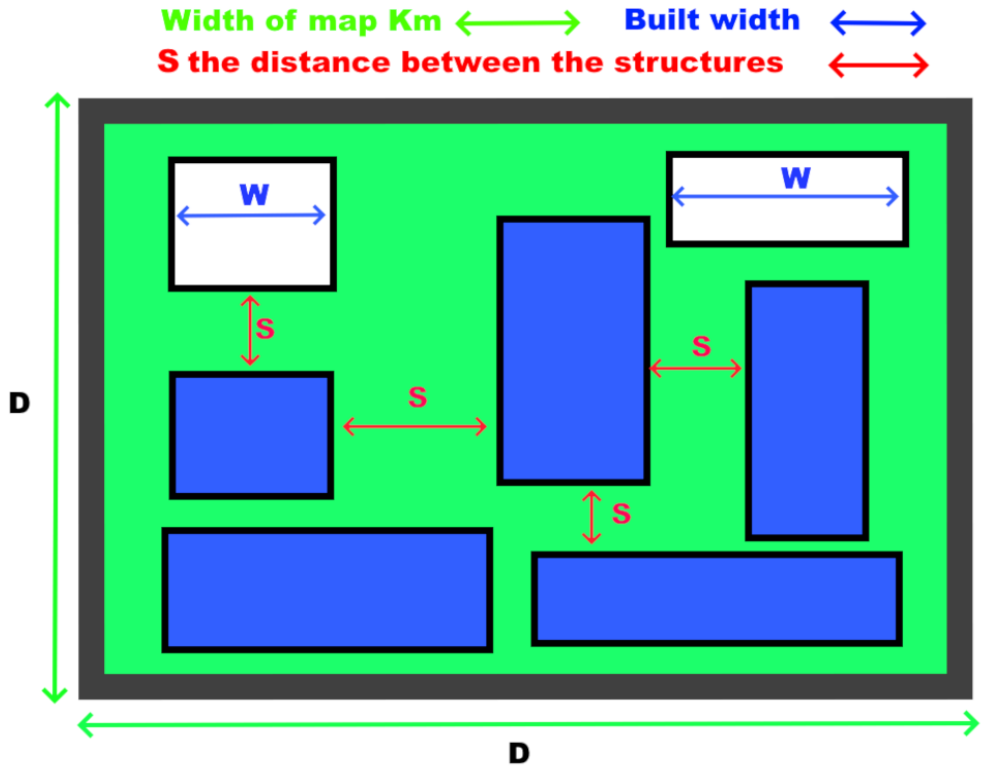

Figure 3: Buildings are placed in the area.

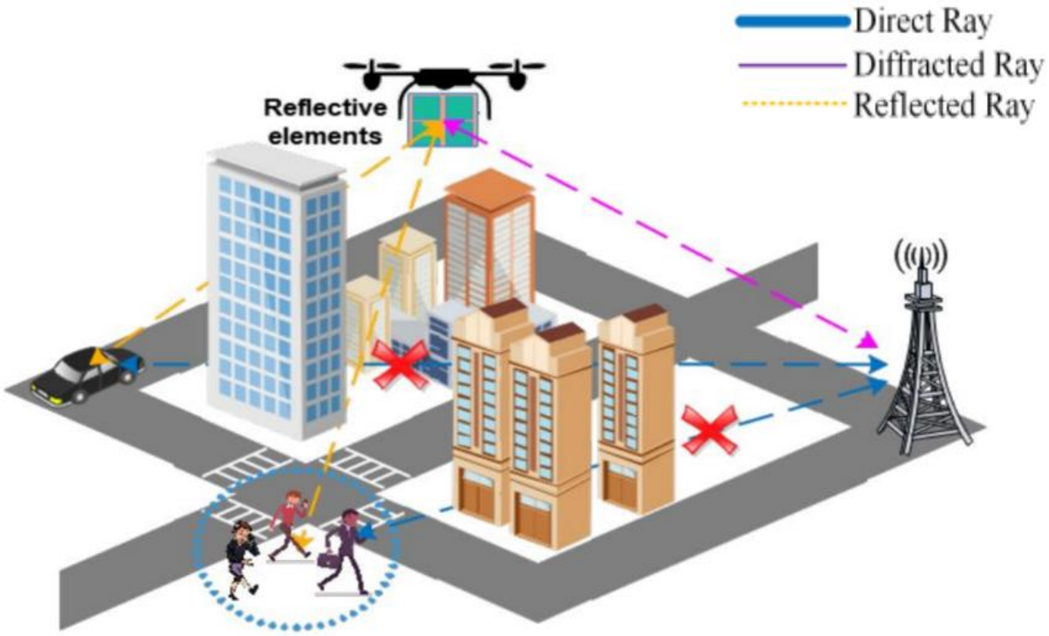

Figure 4: 4;Three types of diffuse rays were identified.

3. The structure of the proposed communications network

The proposed solution in this work is illustrated in Figure 5. This area will no longer be serviced if one of the ground stations ceases to function due to a disaster or technical issue. This also affects users in secure areas or areas where there was no network failure. Their devices will attempt to communicate through stations that are still operational, resulting in increased partial load-bearing. Consequently, numerous users will be disconnected, even in safe areas. This issue will be resolved by the deployment of numerous base stations on drones to serve disaster areas, thereby enhancing the overall network performance. However, it is well-established that an infinite number of drones, or in other words, air base stations, cannot be deployed. Consequently, this study presents an assessment of the situation and a study to enhance network performance by increasing the number of air stations. The solution is to gather groups of users whose SNR (signal-to-noise ratio) and SIR (interference signal levels) are insufficient (based on the values that all communication systems in clusters use to form alliances) in order to ensure that everyone benefits from each cluster optimally. We deploy these stations in accordance with the order of clusters in terms of benefit until the desired network performance is attained, provided that the station mounted on a drone is deployed above the center of the cluster.

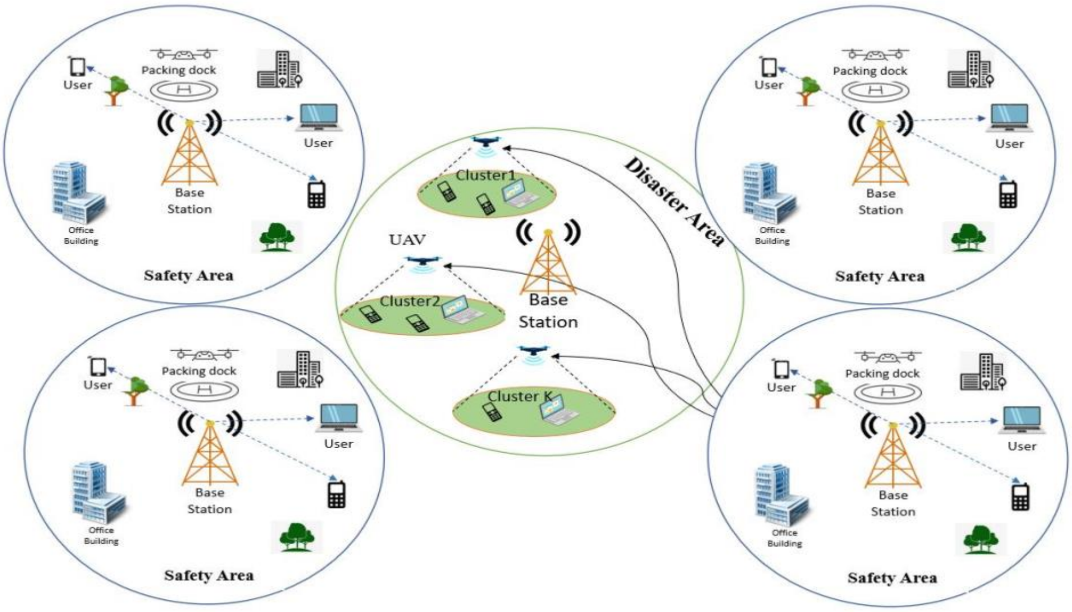

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Figure 5:The status of the network according to the proposed solution.

System model the presence of ground base stations and aerial base stations mounted on a drone, working together with the same communication network leads us to the need to modify the structure of the approved communication networks to achieve work integration between both types of stations in terms of establishing communication and resource distribution, we will use to implement this solution the network model, where the tasks of the MANO coordinator will be added to the task of forming alliances of the greatest benefit to form clusters of candidates for service according to stations mounted on drones, due to the assumption that the MANO coordinator has information about user locations and performance indicators for each user. Also assume that there are several drones charged and ready to fly as soon as an order from the United Aerospace Navigation Command (UANC) arrives, which can be positioned on dedicated stands on communication towers or any other suitable places. This study employs game theory to implement UAV-mounted base stations for communication recovery following disasters, an area where conventional optimization methods are inadequate due to the dynamic and unpredictable nature of emergency situations, by forming alliances of the greatest benefit to form clusters of candidates for service according to stations mounted on drones. This strategy examines strategic interactions inside UAV networks to dynamically modify the network architecture in real time, in contrast to static placement or heuristic-based approaches. This facilitates prompt, economical decisions about UAV quantity and positioning, informed by financial constraints and humanitarian need. Our architecture incorporates many catastrophic scenarios, a feature absent in previous models; hence, it enhances flexibility and scalability.

Channel model: We have two types of communication channels. The first is the ground communication channel between users and ground base stations, which is the channel that was modeled by most of the studies, and the second channel is the air-ground ATG channel between the base station mounted on the drone and users on the ground, because we will be interested in studying the downlink only. Below, we will show the two channels and their modeling methods adopted in the study.

Terrestrial channel models the normal obstacles of urban environments, such as dimming, that affect the wireless channel that terrestrial base stations use to serve users. The model that we will use for the channel between the ground base stations and users implies the presence of a shadow, which, we assume, is normally distributed with a standard deviation of σ=6, and it will consider the path loss coefficient of β=3.6.

The model of the air-to-ground channel for drone-borne stations serves users through a wireless channel that has two possible natures: it can be an LoS channel or an NLoS channel, as this probability relates to the terrain of the area and the angle between the line connecting the user and the drone and the horizon line, where the probability that the channel is LoS increases as the angle approaches the value 900. The following steps will be taken to choose between the two cases using the model from the first chapter:

1. Choose the environment style specified in Table (1).

2. Calculate the coefficients a and b for the curve S as described in, substituting the values of α, β, and σ chosen.

3. Choosing a set at random that shows whether there is a line of sight (LoS) or not (NLoS). The following 14 equations show how to figure out the probability of there being an LoS line of sight [25]:

$$P_{LoS}(\theta) = \frac{1}{1+a exp(-b[\theta-a])} \tag{14}$$

The variable θ represents the angle of elevation in degrees from the ground station to the drone.

4. The selection of a sample of the Gaussian random variable represents the path loss. Where the value and standard deviation are calculated.
5. Depending on the resulting propagation group φ, the path loss measured in dB is calculated according to the equation (15) [24]:

$$PL_{dB}(j) = FSPL_{dB}(j) + \eta \tag{15}$$

Where equations (16) the user's free path loss is given by the relation:

$$FSPL_{dB}(j) = 20\log(d_j) + 20\log(f_{c,UAV}) - 27.55 \tag{16}$$

Calculate the throughput. After modeling the channel, we can calculate the throughput for each user by calculating the ratio of SNR noise and SIR interference capacity for their connecting signals equations (17). We will consider the downlink only after calculating all receiving capacities at each user for all frequencies or partial carriers assigned to the user.

Suppose the communication network is an LTE network operating on the GHz frequency. Which is considered a candidate for providing the 5th service in cities, and let it be the width of the partial frequency carrier, then we can write the phrase the noise capability ratio for the carrier assigned to user M in the form [26]:

$$SNR_{m,n} = \frac{P_{r\{m,n\}}}{2.N_0.B_{subc}} \quad (17)$$

The interference capability ratio equations (18) [27] can also be written as

$$SIR_{m,n} = \frac{P_{r\{m,n\}}}{\sum_{i=1}^{N_{BS}} P_{r\{i,n\}}} \quad (18)$$

NBS represents the total number of base stations. How fast data can be sent depends on the Signal-to-Interference-plus-Noise Ratio (SINR). The rate is controlled by the smallest ratio between SNR and SIR, so we know the coefficient **X** for each partial carrier **n** datum for user **m** in this form of equations (19):

$$X_{m,n} = min(SNR_{m,n}, SIR_{m,n}) \quad (19)$$

Thus, the productivity obtained by the user is defined as in [28]:

$$T_m = \frac{B}{N}\sum_{n=1}^{N} C_{m,n} log_2(1 + X_{m,n}) \quad (20)$$

Where the coefficient takes $C_{m,n}$, value is 1 if the partial carrier is asotherwise it otherwise takes the value 0.
The total throughput of the network can then be calculated by adding the transfer rates of all users:

$$T = \sum_{m=1}^{N_{UE}} T_m \quad (21)$$

4. SIMULATIONS AND RESULTS

We will simulate the concept in this study using MATLAB software. As seen in the box diagram in Figure 6, we will photograph the system whenever there is a major change to the network structure. We will then do the calculations assuming that the communication network works according to the LTE standard on the frequency. Which is considered a strong candidate for providing fifth-generation 5G services in cities? We will also consider that the package used is 5 MHz, which, according to the standard, contains 300 partial carriers. Since the aim of the research is to put forward an idea to serve a specific area in case one of the partial stations fails completely, there is no need to introduce the concept of small cells; the partial stands will be distributed to the users so that the transfer rate is secured; data is 100 Kbps per user regardless of the fairness of the distribution; therefore, every user who does not get enough partial loads will be considered outside the coverage.

Define a square region with a side length that is serviced by nine base stations, or an average of four kilometers per station. The NUE user is then randomly distributed within the aforementioned geographical area, after which we calculate the capabilities of the incoming signals for each user from each cell using the log normal shadowing terrestrial channel model, then the user registration process is carried out on the base stations according to the strongest incoming signal for the user and according to the availability of a sufficient number of partial carriers to secure the required data transfer rate for the user, which is calculated after calculating the SNR and SIR values for each user, where the SNR and SIR rates will be calculated separately instead of calculating the SNIR value, in order to determine the problem of each user.

After the network structure is stabilized, we assume that the location of a base station is randomly exposed to failure, and therefore the values of the connecting capabilities will be changed for each user, which in turn will change the network structure and the distribution of users to the base stations and the number of partial racks allocated to each user, and here the MANO will take over the process of grouping users into clusters with the greatest profit in terms of the number of users who will be returned to the network and the total data transfer rate, and then the clusters will be arranged by profit, so that each cluster is served by a UAV-mounted base station positioned above the cluster center, starting from the cluster with the largest profit, in order by the number of available drones and according to For the economic or humanitarian feasibility of the defect.

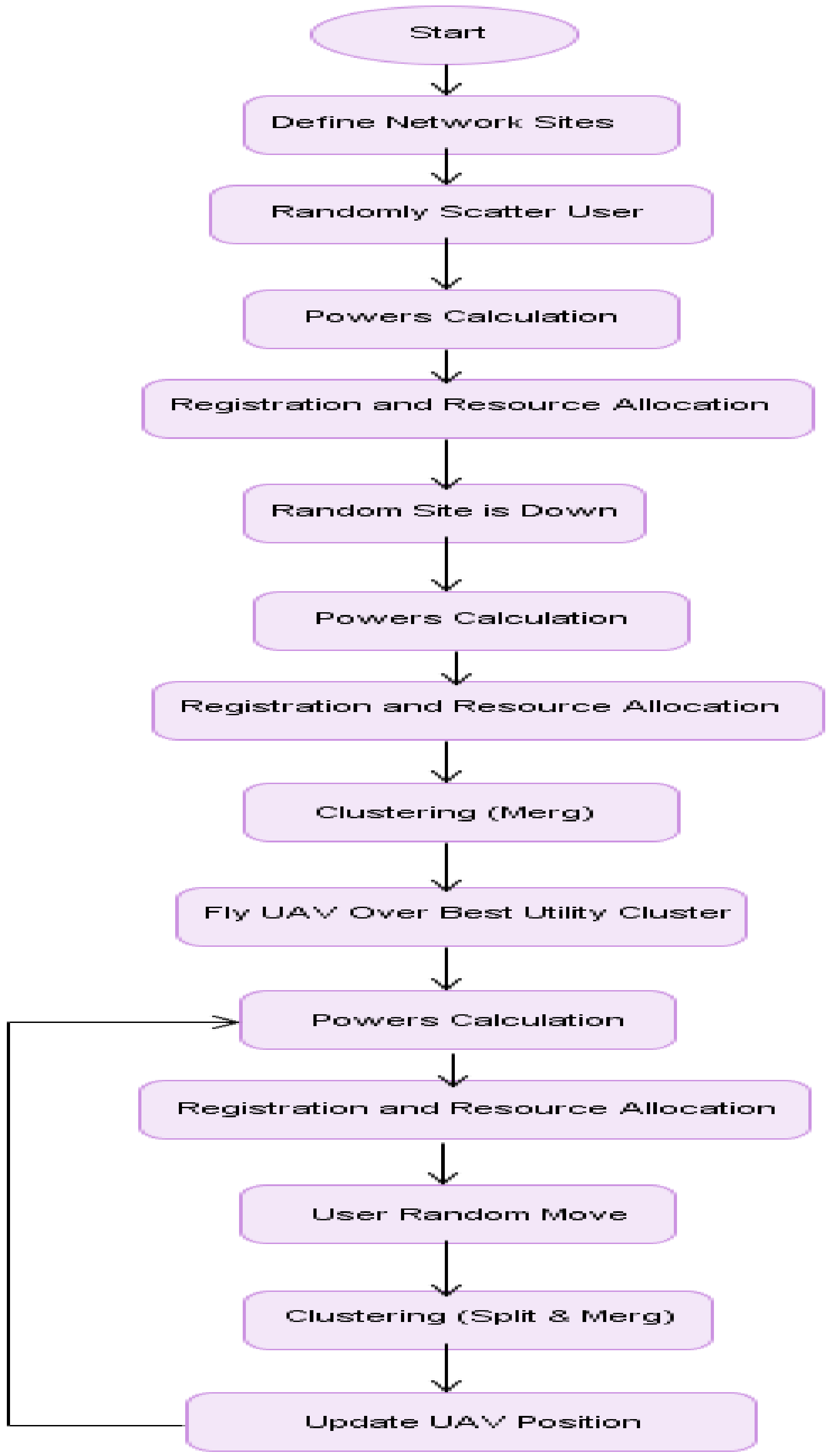

Figure 6: the stages of the proposed simulation implementation

We assume that each user has moved at a random speed and direction within the time interval between the two shots, where the capabilities are recalculated at each time frame, and then the clusters are reconstituted by a sequence of split merges to obtain the clusters with the greatest profit, and then the UAV-portable base stations are repositioned/launched/terminated. Table 2 presents the proposed simulation coefficients.

Table 2. proposed Simulation coefficients.

Factor	**Symbol**	**Value**
area dimensions	L	4000m
N ground base stations	N_site	9
N of users	N_{UE}	Variant
The ability to TX to ground stations	Pt_TBS	43 dBm
The ability to TX to stations carried on drones	UAV_pt	9 dBm
Gain transmission antennas ground stations	Gtx_TBS	12 dB
RX antennas gain for user equipment	Grx_UE	12 dB
acceptable minimum noise capacitance ratio	SNR_min	10 dB
Acceptable minimum interference capability ratio value	SIR_min	3 dB
The minimum productivity required for each user	Throughput_min	100 Kbps
The number of drones	N_uav	Variant
View the LTE package	Bandwidth	5 MHz
Number of partial carriers	SC_total	300
Central carrier frequency	F_C	3.6 GHz
The height of drones	UAV_z	200m
Noise intensity	NO	4×10^{-20}W/Hz
Sensitivity of the future	RX_S	-110dB

The ground channel model is displayed in Figure 7, where the effects of dimming and distance are plainly seen. In the event of 500 Non-Uniform Environment (NUE) users, the subsequent screenshots illustrate the network condition for each specified circumstance. The initial form consistently displays an acceptable signal-to-noise ratio (SNR) in green and an undesirable ratio in yellow. The second form consistently displays users with acceptable SIR in green and those with unacceptable SIR in yellow. The red tint signifies users who are under-resourced and hence lack coverage. Standard condition Figure 8 illustrates the network status in Normal mode, wherein the station connecting each user allocates station numbers to them. It is evident that users experiencing inadequate SNR or SIR are located near the peripheries of the cells. Figure 9 presents an alternative depiction of user connectivity to stations. It indicates that users who lack coverage due to insufficient signal strength (SNR) for their receivers or an inadequate number of incomplete stands are accessible.

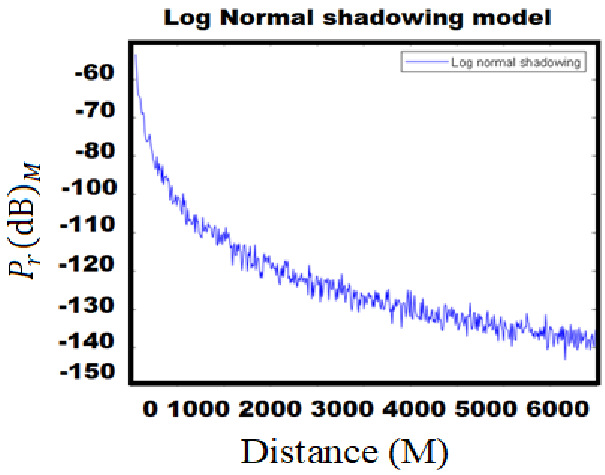

Figure 7:Ground channel model.

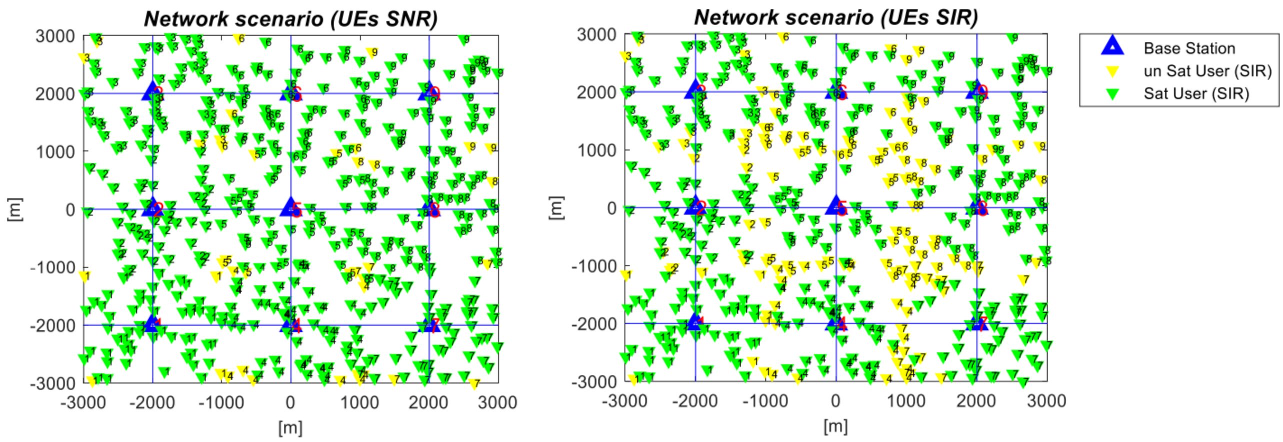

Figure 8 :The network mode is the normal state.

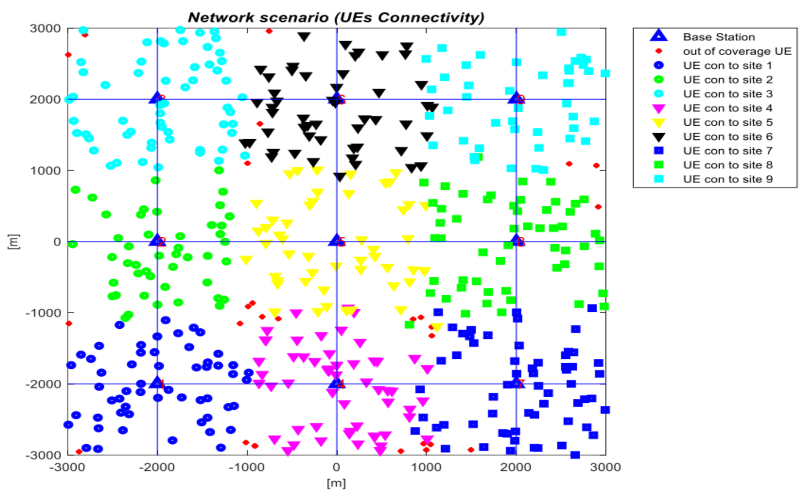

Figure 9 :Clarify the Association of users with stations and users outside the coverage area

In the case of failure of one of the ground stations, figures 10 and 11 represent the network situation after the failure of one of the ground stations in terms of users' connections with the stations; users with SNR or SIR are unsatisfactory, and users are considered to be out of coverage, as we observe the effect of station failure on users with neighboring cells.

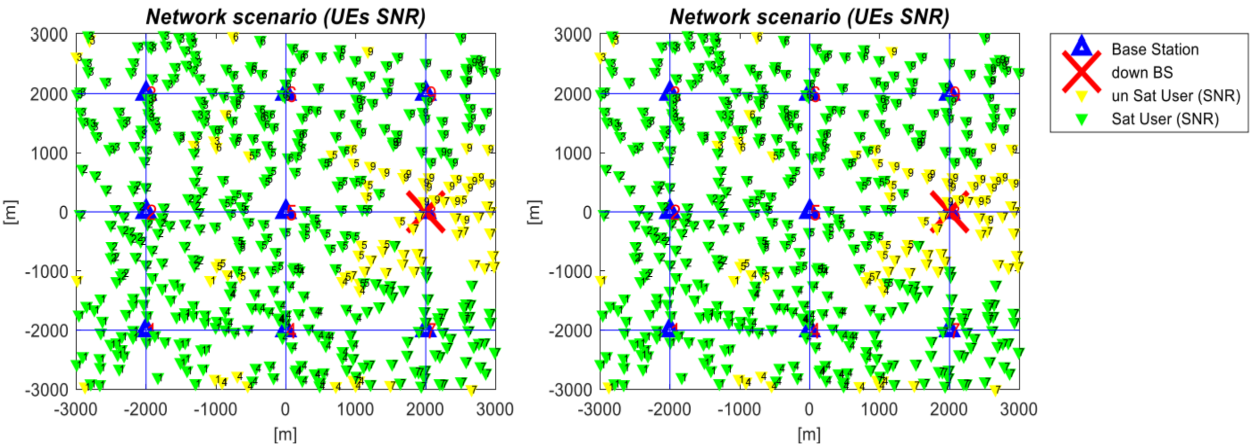

Figure 10 : Network mode after the failure of one of the stations.

Forming clusters: Figure 12 shows the clusters of users resulting from the game of forming alliances to get the best benefit, as they will be arranged later in descending order so that the stations mounted on drones will be deployed above the centers of these clusters starting from the cluster of greatest benefit and according to the number of aircraft to be deployed.

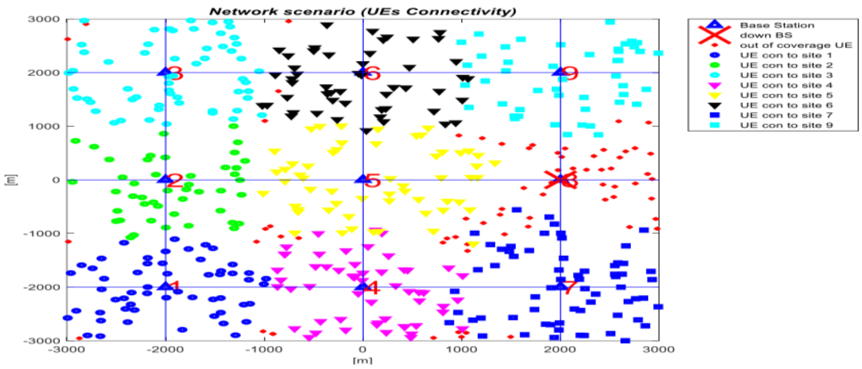

Figure 11: Clarify the association of users with stations and users outside the coverage area after the failure of one of the stations.

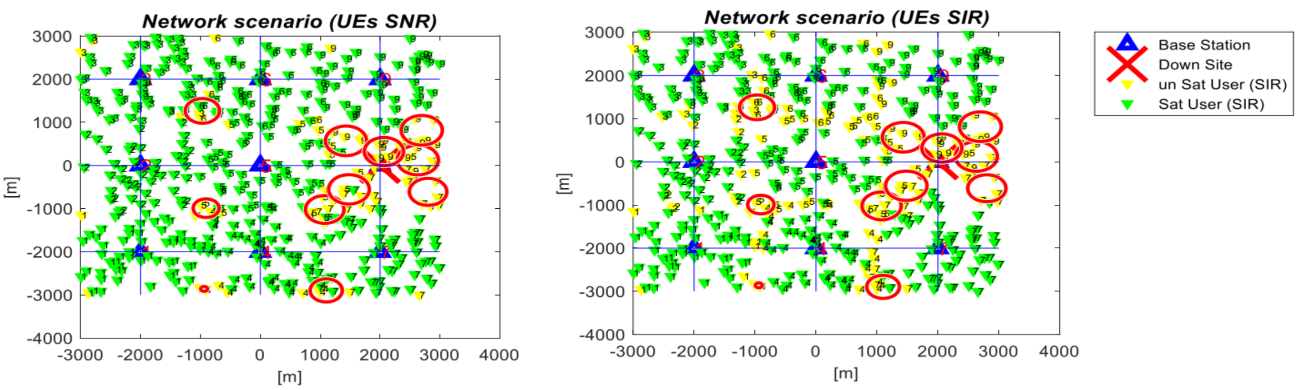

Figure 12:Clusters resulting from the application of the game form alliances.

The following will show the changes in the network status when deploying one UAV station and then when deploying three UAV stations. The state of the network after the deployment of one station mounted on a drone As shown in Figures 13 and 14, the network's state changed after one station was put on a drone and flown over the most important cluster center. Users whose SNR or SIR are poor are considered "out of coverage," and their connections and statuses change accordingly. Due to communication channel issues, not all drone users in the station's coverage area are connected.

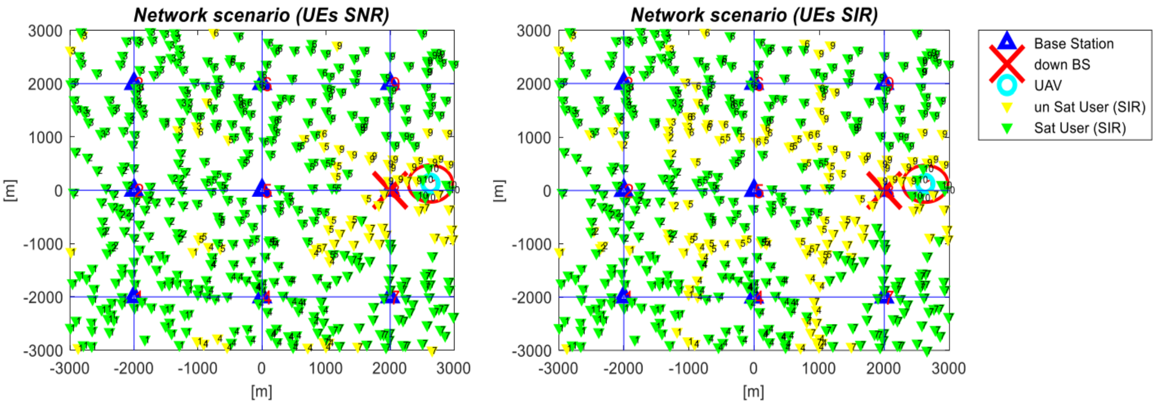

Figure 13: The network was put in place after the failure of the deployment of a single station mounted on a drone.

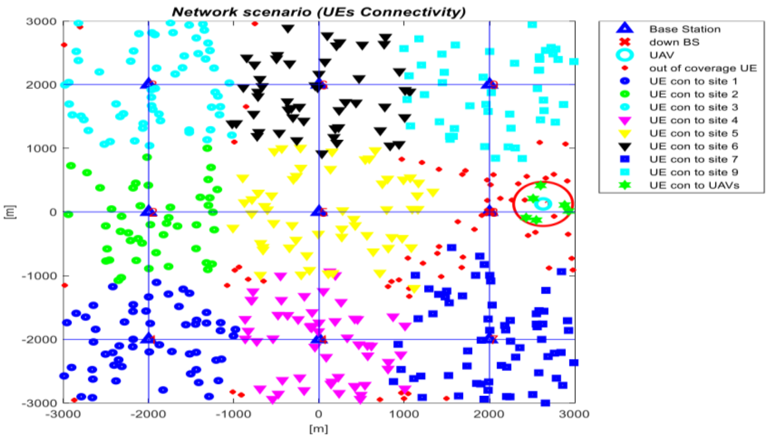

Figure 14: Clarify the connection of users with stations and users outside the coverage area after the deployment of one portable station on an unmanned aircraft.

The network's condition has improved following the installation of three drone-mounted stations. Figures 15 and 16 show how the network looked after three stations were put on drones and flown over the middle of each of the three clusters. The stations helped users connect with each other, especially those with poor SNR or SIR or who were thought to be outside the coverage area. Where we note the significant improvement in the network condition, which will be evident by the values of the key indicators listed in the following paragraph, we also note that some users within the coverage of the station mounted on a drone did not get sufficient receiving signal capability, especially on the edges of the cell due to the shader (as the probability that the signal will be exposed to the NLOS channel increases near the edges of the coverage circle, and therefore it can be noted that some of them remained outside the scope). While some users within the mobile station's coverage circle are on a drone call with neighboring ground stations, others remain outside the coverage area.

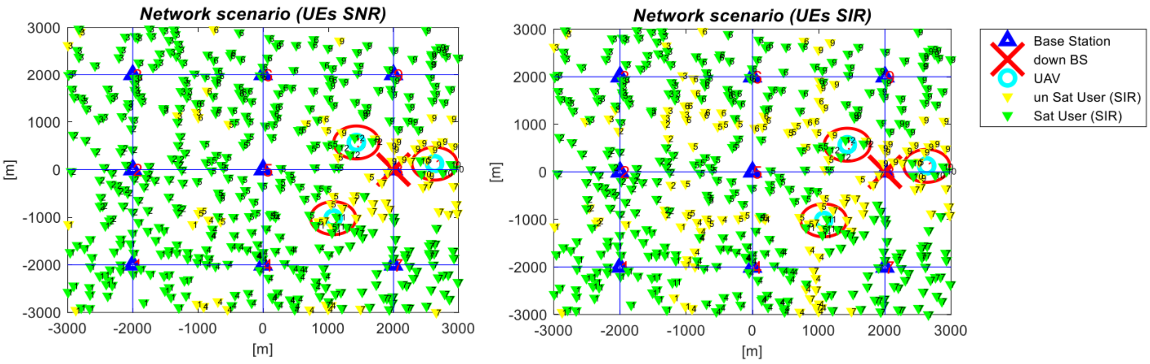

Figure 15:The network was put in place after the deployment of three UAV-mounted stations.

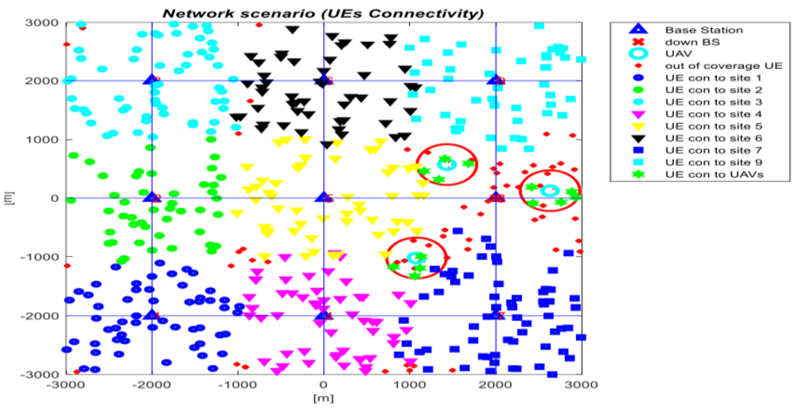

Figure 16:Clarify the connection of users with stations and out-of-coverage users after the deployment of three UAV-mounted stations.

Performance indicators: In Table 3, we show the values of the KPIs used in this study for the previously listed network cases for 500 users. The values were centered on 1000 random repetitions, and an out-of-service station was put in the middle to make sure that all the repetitions were fair.

Table 3. Values of the approved KPIs depending on the network status.

Performance Index	**The value before the failure of one of the terminals**	**The value after the failure of one of the stations**	**Value after deployment of a flying station at the best cluster**	**Average total productivity**
Average total productivity	**62.38 Mbps**	**58.41 Mbps**	**59.18 Mbps**	**60.33 Mbps**
Average number of users out of coverage	**19.98**	**57.80**	**52.31**	**44.21**
The average number of users with a satisfactory non-SNR	**34.13**	**75.47**	**69.37**	**60.18**
The average number of users with unsatisfactory SIR	**125.36**	**131.30**	**124.97**	**115.25**

For the sake of clarity of comparison, we will define the profit or loss coefficients attributed to the values in the normal network situation, and we will also compare the situation with the deployment of stations mounted on drones in a random place within the emergency zone or that can be fixed.

The profit numbers are shown in Table 4. There is a big difference in profits between putting stations in a random or fixed location versus putting them in the middle of clusters that are most interesting to us. As the number of users for one UAV changes, so does the profit. It will do everything that comes up by doing the calculations shown and showing the results after 1000 random repetitions of the network situation and all the scenarios used in this study, including random distribution of users, calculations of future capabilities, cluster construction, and deployment of a station on a drone over the center of the best cluster, with the exception of installing the station that isn't in the middle of the geographical area so that the geographical situation is the same for all repetitions.

Table 4. Profit values resulting from the deployment of a single station mounted on a drone.

The index	**Percentage of loss after the failure of one of the stations**	**The percentage of compensation for loss after the deployment of a flying station to a random place**	**The percentage of compensation for loss after the deployment of an aircraft station over the station is out of Service**	**Loss compensation ratio after deployment of a flying station at the best cluster**	**The percentage of loss compensation after the deployment of 3 flying stations in three random places**	**Loss compensatio n ratio after the deployment of three aircraft stations at the top three clusters**
Average total productivity	6.4%	10%	13.1%	19.4%	23.7%	48.4%
Average number of users out of coverage	189.3%	7.6%	10%	14.5%	17.9%	35.9%
The average number of users with a satisfactory non-SNR	121.1%	7.8%	9.1%	14.8%	18.9%	37%
The average number of users with a satisfactory non-SIR	4.7%	54.7%	71.5%	106.6%	130%	270.2%

Total productivity of the network changes to some extent depending on the number of users. The policy of partial load-bearing quotas ensures a minimum of 100 kbps for each user. This is done to illustrate how the number of users in the normal network state affects productivity. One of the stations is in a state of failure, while another station is in the process of being deployed onto a drone. As Figure 17 shows the curves of changing the average value of productivity by the number of users in the cases mentioned, we will center the total productivity of the network on the number of users. If one of the stations fails, deploying a station on a drone improves the average value of productivity and thus the total productivity of the network. By about 200 kbps per user, and secondly, we note that the average value of productivity decreases significantly after a certain number of users as the network resources are no longer enough to serve all users.

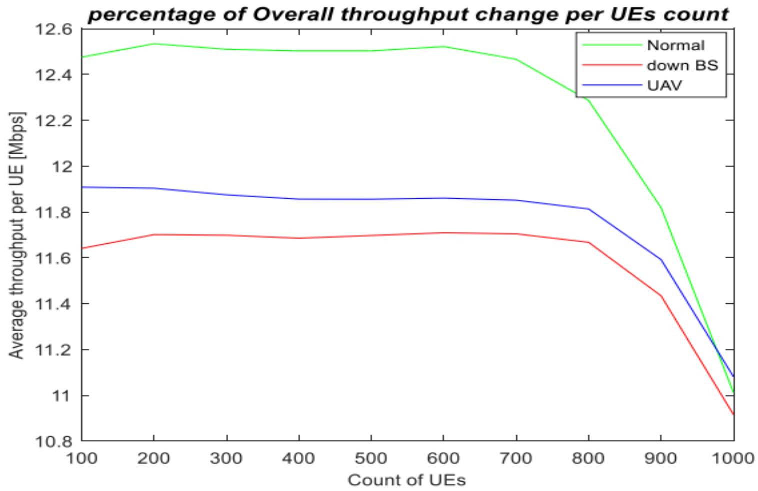

Figure 17:Curve the change in the overall productivity of the network by the number of users.

The percentage of users who aren't covered fluctuates depending on the number of users due to typical network conditions (one station failing) and mounting a mobile station on a drone. This variation is depicted by the curve in Figure 18, which demonstrates how the percentage of users who aren't covered increases over time. According to our research, putting a mobile station on a drone can cut down on the number of exposed users by as much as 1.5%. The network can no longer accommodate any more users at a certain point; thus, the number of unprotected users rises sharply.

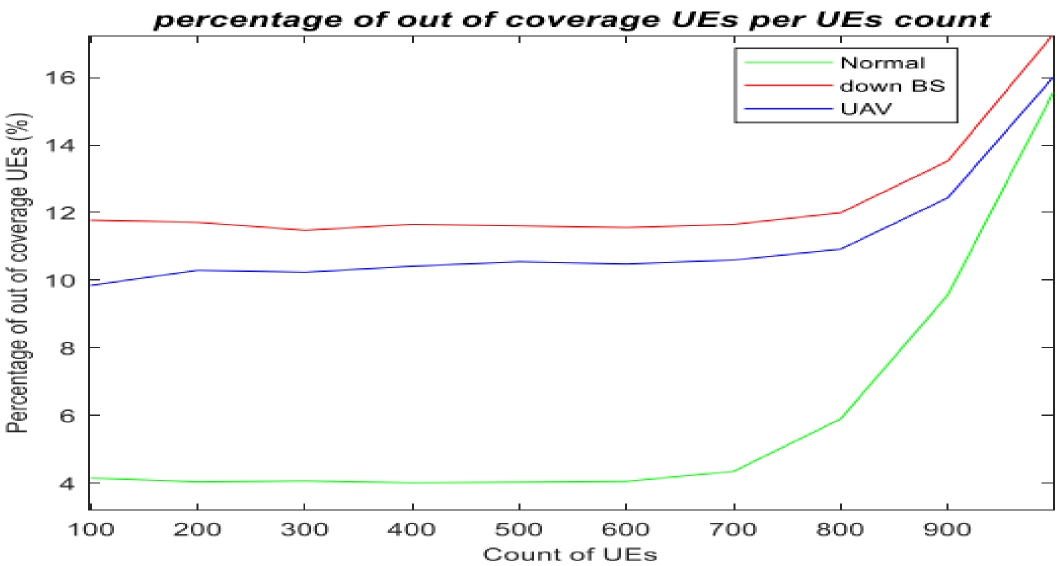

Figure 18:Curve the change of the number of users outside the coverage by the number of users.

The number of users with inadequate SNR as a percentage change curve Curves in Figure 19 illustrate how the proportion of users with an inadequate SNR ratio varies with user count. The deployment of a drone-mounted station, one of the stations malfunctioning, and the typical network conditions are the causes of this variability. After a drone-mounted station is deployed, the number of users with an inadequate SNR ratio decreases by as much as 1.5%, which is a beneficial outcome. But eventually, the network can no longer support any more users, and the proportion of users with an inadequate SNR ratio sharply increases.

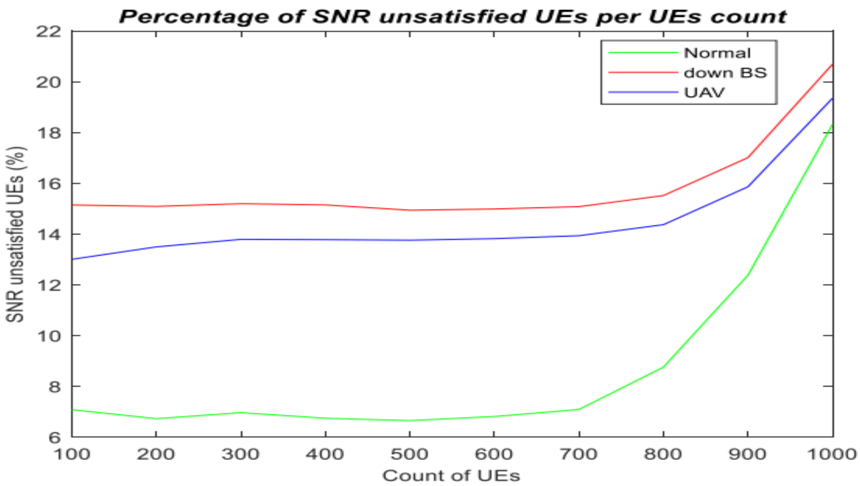

Figure 19:The curve of the change of the number of users with unsatisfactory SNR by the number of users.

The fraction of users with inadequate SIR changes as a curve. Figure 20 's graph illustrates how the proportion of users having an inadequate SIR ratio varies with user count. This happens when we deploy a drone-mounted station following a station failure. The number of users with an inadequate SIR ratio decreases by up to 1.5 times when a drone-mounted station is installed, which is a beneficial outcome. But eventually, the network can no longer support any more users; hence, the number of users with an inadequate SIR ratio increases dramatically. Profit curves for 500 users vary based on the quantity of UAVs used. Figure 21 shows the curve of change in the network's overall productivity, which started to improve as soon as the first drone was deployed and gradually increased as the number of drones increased. This is because drones provide better coverage and reduce overall interference, so an approximate comparison of the amount of improvement can be made by comparing the ratio of the total areas under drone coverage to the ratio of the area served by one ground station, which is estimated to be 4 km, as we mentioned in the chapter's introduction. Figure 22 plots the ratio of the drone coverage area to the coverage area of one ground station using theoretical values. The network's overall productivity has improved. The area proportions in Figure 22 are in line with those in Figure 21.

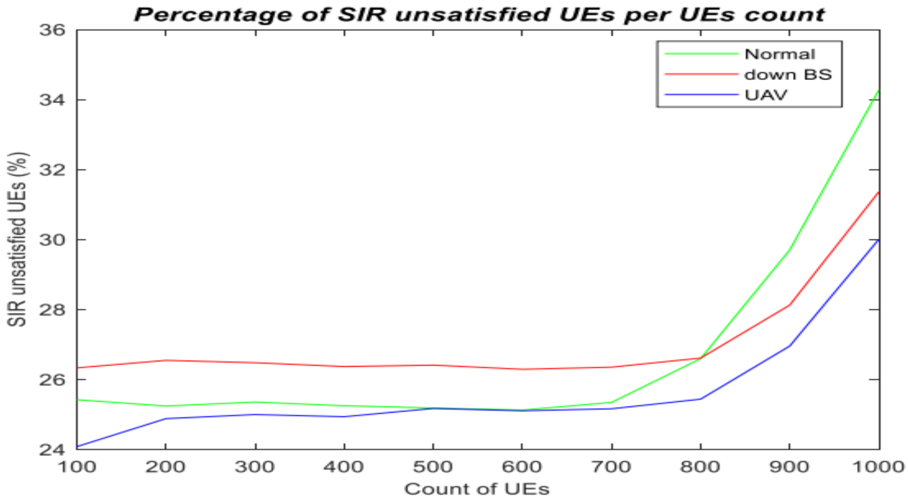

Figure 20:The curve of the change of the number of users with an unsatisfactory SIR by the number of users.

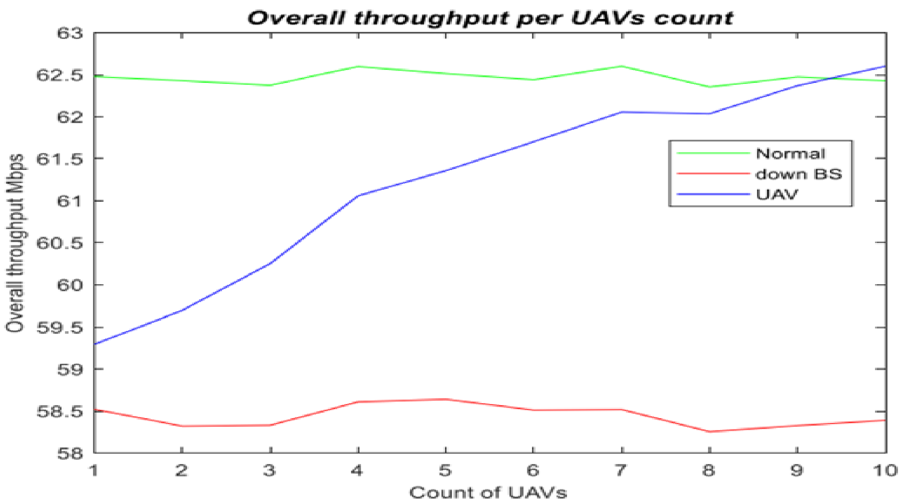

Figure 21: The curve of the change in the total throughput of the network by the number of UAVs.

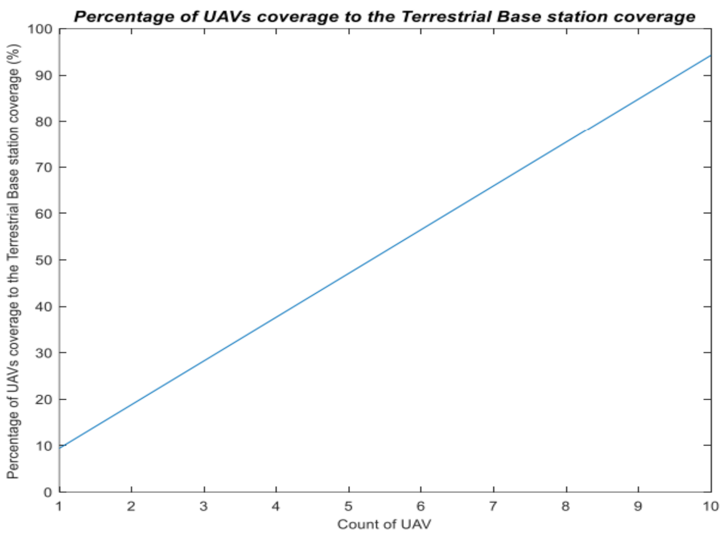

Figure 22: The ratio of the coverage area of UAVs to the coverage area of one ground station.

The variation in the proportion of people not covered by the plan As drones and their closeness increase, Figure 23 demonstrates that the fraction of users out of coverage decreases. To find the UAV coverage area ratio, you may also look at Figure 22. The percentage change curve in Figure 24 displays the number of users experiencing inadequate SNR. Figure 24 shows that the proportion of users experiencing subpar SNR has been declining and is getting closer to the norm. Figure 22 shows the UAV coverage area ratio, which we can compare.

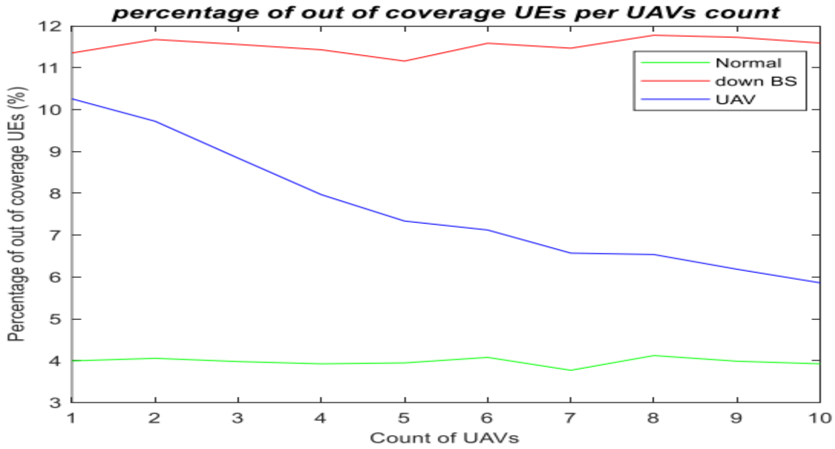

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Figure 23:The curve of the change in the number of users outside the coverage by the number of UAVs.

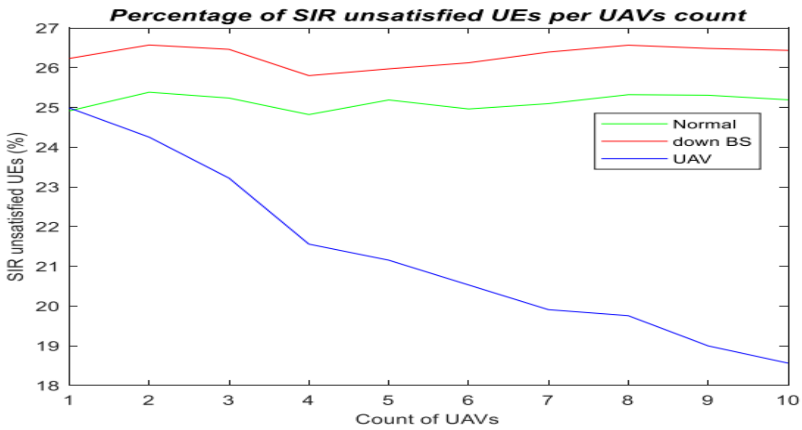

Figure 24:The curve of the change of the number of users with unsatisfactory SNR by the number of UAVs.

The percentage of users having an inadequate SIR changes with time, as shown by the curve. The pre-failed condition exceeds the low proportion of consumers with an unsatisfactory SIR, as seen in Figure 25. Less interference is the cause of one of the stations.

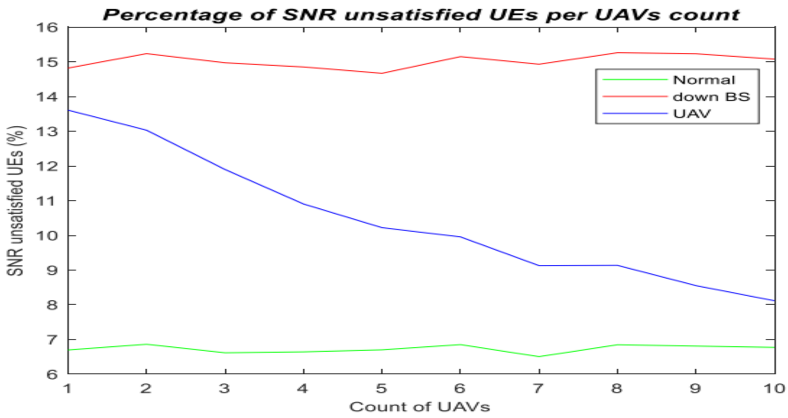

Figure 25:The curve of the change of the number of users with an unsatisfactory SIR by the number of UAVs.

5. CONCLUSION

The proposed simulation seeks to precisely quantify and evaluate all variables of the hypothesis. The focus is on the ATG communication channel, which serves as a link between the drone and the ground operator. They are examining the deployment of drones to create base stations in the case of a terrestrial station failure, whether due to a technical problem or a natural disaster. We will intentionally cultivate partnerships to improve research outcomes. This method improves network throughput with a minimal number of UAVs. A coalition of users forms an alliance by deploying a station on a drone situated above the center of each group. Stations are organized in descending order of utilization based on the quantity of drones accessible for commercial or humanitarian applications. Subsequently, we conducted a simulation of the system and the proposed solution. We additionally juxtaposed the study with the concept of employing drones to transport mobile phone towers and relocate them arbitrarily to illustrate the potential advantages of the suggested strategy, as its significance had not been previously demonstrated. Essential performance metrics, such as average throughput, coverage efficiency, and deployment duration, are utilized to demonstrate the superiority of our proposed methodology. Our solution achieved a 48.4% improvement in average throughput and a 36.7% increase in user coverage compared to the random deployment strategy, while significantly reducing reaction time compared to fixed-cell alternatives.

the random deployment strategy, while significantly reducing response time compared to fixed-cell methods.

The study report outlines a series of novel insights and contributions to the enhancement of communication tactics during disasters as follows: The work introduces a flexible and swiftly implementable method for the deployment of drone-mounted base stations during emergencies. - It dynamically restructures communication networks in reaction to failures caused by natural disasters, technological malfunctions, or other events. - It utilizes game theory as an innovative analytical tool to address the complex challenge of optimal drone deployment—this multidisciplinary approach is groundbreaking in this field. The study introduces a methodology for determining optimal locations for drone base stations to maximize communication coverage and effectiveness. It determines the optimal number of drones, considering economic or humanitarian aspects and balancing cost-effectiveness with emergency response needs. - Practical implementation: - The system emphasizes immediate network restoration post-disasters, providing swift benefits in crisis management and recovery efforts. - The use of game theory in communication networks involves utilizing it to elucidate and tackle the intricacies of deployment, serving as a unique approach for drone-based communication systems.

Future Work

The expected responsibilities of upcoming projects are outlined as follows: Continue to improve the communication efficiency of AANETs through the application of game theory. Perform simulations and theoretical analyses of the proposed methods for credibility assessment. Conduct comparative analyses of current methodologies in relation to alternative open scenarios. Analyze and model AANETs with considerable UAV mobility in real-world applications. Expand the research to include multi-layer AANETs. Develop and evaluate models that incorporate practical limitations in AANETs. Examine the incorporation of alternative methods, such as reinforcement learning and soft computing techniques. Implement developed protocols in practical settings and evaluate their feasibility.

Aerial ad hoc networks (AANETs) composed of unmanned aerial vehicles (UAVs) are expected to serve multiple purposes, improving surveillance, broadcasting, infrastructure, and data collection in various disaster situations. Current routing and scheduling methods in terrestrial networks do not adequately ensure communication performance in AANET conditions. These protocols may experience considerable latency and significant data loss in densely populated networks with high node mobility in three-dimensional space. Game-theoretic methodologies have been thoroughly investigated to address various network performance issues beyond routing. They obtain rational behavior through mathematical modeling, leading to more efficiently designed distributed solutions. Game approaches have evolved to address new and complex challenges in UAV-enabled networks .

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