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Improving Cellular Coverage using Optimal Number of Drone Base Station

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Abstract- In wireless network, the deployment of drone based Unmanned Aerial Vehicles (UAVs) as a base station has started to draw attention. Drone base stations (DBSs) improve the reliable coverage of network and area by providing optimized data rates against user requests. Improving the positioning of networks is a favorable strategy. However, installation of such kind of base stations can face certain constraints that need to be deemed in a microcell while optimizing the number of base stations for drones. As the drones can move freely, and operate in dangerous environments, areas that have natural or unnatural disaster. Drones movement can be controlled and repositioned easily and quickly based on demand. With the help of drones, another advantage to the ground user is to improve coverage with clear line-of-sight (LoS) connection. Finding location of DBS in such a way that it guarantees service and to achieve traffic necessities to all the users in a micro-cell is a very difficult problem. The proposed solution tries to find out the best position of DBS in a micro cell environment by using K-means clustering. While establishing the voronoi polygon as micro-cell, it provides increase in capacity and optimal coverage in the entire service area because of area reduction.

I. INTRODUCTION

A drone, also known as unmanned aerial vehicle (UAVs) which designed to hovered by remote control or through robotically using embedded software and other hardware antennae, such as GPS tracking. Wireless communication have already changed the way people communicate, the messages can be send, access the internet and call through wireless connectivity. In wireless ad hoc networks, such as Flying Ad hoc Networks (FANET), UAVs can also be used as a communication node [1]. A mobile base station is also known as a "Cell Site" as it sends and receives radio signals and forms the cell area. Cellular network consists of area divided into multiple connected cells and each cell has its own base station. There are multiple shortcomings in the fixed base station. One of its most exciting uses now being researched by many scholars is the use of drones to place in small cells in locations where there have been urgent demands. Cellular network evaluate rapidly since then. The expectation of wireless user is to achieve limitless service capability everywhere and for all the time, at a reasonable cost [2]. The future wireless networks will be described by a high degree of suppleness compared to the past due to user's expectancy of full coverage at any time and at any place.

A drone is an unidentified flying object that can be remotely controlled or operate automatically by using GPS type sensors and embedded software [3]. Drones have traditionally been used primarily for spying by the military, but with latest advances in lightweight drones powered by batteries, various civilian applications are emerging. Following generation cellular nets are more reliable and convenient in providing demands, exclusively in a natural tragedy, extreme widths of user area, the receivers have higher need of the communication network [4-5]. Recent research on UAVs specializes in the UAV placement optimization which mainly desires to cover the way to a varied scale positioning of UAVs in the wireless networks, especially for mission crucial use cases [7]. In [8] author proposed that small cell technologies aid in solving the wide range of network difficulties which the cellular industry is facing. Small cell systems provide several advantages, including a large increase in system capacity, low power consumption, and equipment downsizing that lowers costs and allows for flexible deployment [9]. The construction of these modern microcellular networks, especially in heavily populated metropolitan regions, demands highly complicated planning techniques. Drones have become a popular choice for a variety of neighborhood applications because drones can roam around freely

[10]. Drones can be outfitted with base station (BS) gear and used as a flying BS, making them a more appealing option than the more predictable roof or pole-mounted base stations.

When it is required, coverage of the network and area capacity can be increased [11]. Drone base stations (DBSs) by moving supply in direction of demand is a quite successful approach. With limited increase in capacity and coverage it helps the ground network of base station (BS), whenever it is essential. Coverage of the cellular network in the disaster effected/ crowded areas can be attain by Drone Base Station but it is dependent on the Drone Base Stations' locations. Optimal placement of these Base Stations in a microcell is a challenging task particularly due to user's mobility, in order to get optimal coverage area. Also, the service should be quite satisfactory to deliver optimal coverage for maximum number of users. The DBS identify the coverage area according to the user's density. It's very hard to achieve the best possible placement with optimal number of drone base stations.

II. Literature Review

Recently the drone mounting with the base station is very popular among the researchers and a considerable amount of research is done on this theme and there is always some room for improvement as this is a very dynamic and emerging technology.

In [2] author proposed that for finding the location of the DBSs of user densities of different types, heuristic algorithm can be used for the purpose of discovering minimum number of BS and the 3D placement of BS to fulfill all users' needs. Purposed idea was to provide good coverage for some targeted population with special quality of service. In [6] author highlighted possessions of the DBS deployment position problem, because an optimally located DBS can serve the highest possible users.

According to [3], the main purpose of this research is find the advantages of the variable reposting of drones while providing different services to different users actions. In this research the spectral efficiency of drone small cell is improved. For determining the dynamic placement of drone BS by itself, three algorithms are proposed in this research. Algorithms for equally partition of bandwidth are proposed. The users which have less data, the drone find such users and give all bandwidth to them.

LTE technology over Wi-Fi which has low throughput due to uncontrolled and unlicensed band nature [12]. LTE femtocell base station placed on drones by using a deployment algorithm having four different steps which determine not only needed amount of drones, but also its accurate locations for emergency scenarios.

In [13] author proposed smart UAV base station by using genetic algorithm to improve work quality and system optimization. [10] gives the proposal of backhaul limited optimal drone base stations placement algorithm for various algorithm design parameters i.e., number of user served or total rate of users served in cluster, along with its effectiveness. The limitation of drone-BS is its availability of reliable wireless links. To overcome this problem, 3D backhaul-aware drone-BSs were introduced which maximize the total users served and sum rates. In [14] author proposed a UAV aided network which is dynamic and tunable due to which service radius can be adjusted on macro base stations.

According to [11] author proposed a macro-BS (MBS) as well as DBSs that depends on wireless conjunction to macro-BS for backhaul. Suggested an approach to increase the sum logarithmic rate of frequent and uRLLC clients by finding optimal 3D placements of DBSs, as well as client-BS relationships and wireless backhaul bandwidth allocations. Allocation of resources at Backhaul, client identification depends on its kinds, and DBS 3D positioning need to be considered collectively. There is a new issue model that focus on equality, as well as a mathematical resulting approach. Using dissection approach to determine the client-BS relationship as well as frequency allotment. After that, to improve Drone Base Station positioning a Genetic algorithm heuristic particle swarm optimization (PSO) approach is used. This approach not only identifies the client correlations by considering user type but also assign bandwidth to transport backhaul networks as well.

The research focus of [15], was to design 5G-UAV Base station algorithms which is being used for dynamic positioning. The idea is to identify the spatio temporal type of relationship among points of data demand which illustrate the clusters and centers throughout carefully chosen time stamp. For this research to simulate the behavior of given procedures relying on real-time routes in Beijing town center. Research can be enhanced if in natural disaster plus Extreme dense area that placement algorithm be able to implement by slightly updating. You can form a sample reliant on the authentic 3GPP soft-pedaling for the purpose of data testing. The proposed algorithms can be combined together for larger network based on Internet of Things. To optimize location of the Internet of Things (IoT) network gateway, also less power (battery life) is required when the IoT gateway is nearer and ascendible. One of the research work proposed a new model for mobility of unmanned ariel based stations, wherever unmanned aeronautical vehicle can travel easily in the system, supervising the cell threshold. These cells unveiling backhaul responsible connectivity, link capacity of UAVs also require great ability to connect via relations with a static conceivable wireless backhaul base station. Due to these extra resources utilization, effects the rate of UAVs gone high. In [16] researcher examine the most cutting-edge developments in drone communication as well as assisted drone mobile networks. The researchers next look into the progress of a multi-tier drone communication in respect to downstream performance, statistically displaying the ideal activity as well as position of UAVs in various levels. The research targets the minimum utilization of energy for the ideal placement of drone with respect to elevation, also trade with load control of wireless communication which utilizes fewer resources and enhances the coverage area for users. In [17] study it was found that clustering the small cells make it easier to operate drones and solve complexity of larger problems related to cellular network. By employing that tactic, the drone can also be used to deploy the small cell and base station.

Based on literature review discussed above, it can be concluded that finding location of DBS in such a way that it guarantees service and to achieve traffic necessities to all the users in a micro-cell is a very challenging problem. Some researchers solve this problem by changing altitude of DBS. Others considered user demand to get the optimal placement of DBS. However, these techniques do not guarantee the QoS as per user requirement.

The proposed work is distinguished from other reviews discussed above in the sense that it aims to improve cellular coverage using optimal number of drone base station using K-means clustering, as this algorithm is very useful in such scenarios.

III. METHODOLOGY

The research attempts to achieve optimal exposure that launching optimal number of base stations in any area. The overall methodology is divided into following methods i.e., computing remoteness, Placement of drones accordingly, Consumer scattering records, selected area (cluster) formation, launching drones base station wisely at ideal position and total boundary area arrangement in coplanar and spatial plane.

The optimization model for wireless channel between the mobile user on the ground and DBS is formed. in [18] author proposed a model of probabilistic LoS where the probability of LoS depends on the transmission link's boost angle (Θ) between a drone and its user. According to [18] the function of LoS probability can be written as

$$P^{LoS}(u,n) = \frac{1}{1+\alpha\exp(-\beta[\theta-\alpha])'} \qquad (1)$$

In this scenario, α and β have constant values regardless of the environment (either it is rural or urban), and θ is the elevation angle equals arctan($\frac{h}{r}$), where h *is the* DBS's altitude and r is its straight distance from the receiver side, respectively.

$$PL(dB) = 20\log\left(\frac{4\pi f_c d}{c}\right) + P(LoS)_{\eta LoS} + P(CLoS)_{\eta CLoS} \qquad (2)$$

Where carrier frequency is f_c and c is the light speed, d is the distance between the receiver and a drone-BS and is equal to $\sqrt{h^2+r^2}$. This shows the average additional loss to the free space propagation as proposed in [19]. Here is the algorithm to find the optimal placement of DBS's:

Algorithm 1: Algorithm for optimal placement of drone base station.
Input: X = (x1,x2,…..,xn)//NO of Users in Plane X > 1, C ≥ 1
Output: C= (c1,c2,…..,ck)// Set of cluster, (DBS Location)

Initialization:
1. for all $c_1 \in C$ do
2. $c_1 \leftarrow (x_i \in X)$
3. end for
4. for all $x_i \in X$ do
5. *findminDist* ← *minDist(*$x_i \in C_i$)
6. find euclidean distance
7. (1/n) * $\sum(\min_j d^2(x_i, C_j))$
8. Update DBS location C_i
9. end for

In [20] authors proposed diagram in a symmetrical way that consider the nearest rule that is associated at each point in the R_n space closest to the point. The graph that focus is on each segment situated inside that is polygon. And each polygon has a representation also known as voronoi area.

Consider a point in R_n space, $C = \{c_1, c_2, c_3, \ldots\ldots\ldots c_n\}$ are the set points where DBS is located. $W_{(i,j)}$ is the edge of two site points *i, j* and V_i the Voronoi region formed by C_i. The proximity relation $x \in V_i$ happens in accordance with the proximity rule IF x is closer to C_i than some other site point THEN $x \in V_i$. The Voronoi region is determined using this proximity rule. Algorithm for coverage area is as follows:

Algorithm 2: Algorithm for Voronoi Partition for Coverage.
Input: DBS Location C(x,y)=d(x,y)
Output: [$d_1,\ldots\ldots,d_k$], W_{ij}

Initialization:

1. $d \leftarrow 0$, $[d_2, \ldots\ldots, d_k] \leftarrow d_{ij}$
   d_{ij} is difference separating two DBSs
2. Compute parameters of vertices a, b
3. Compute V$\leftarrow [v_1, \ldots\ldots, v_k]$
4. if V_i-$V_j > d_1$++, d-- then
   Goto Step 3
5. else
   $W_{ij} \leftarrow d_i/d_j$
6. end if

Using the drone position as the seed for voronoi diagram. Voronoi procedure is used to claim the coverage area. Where the *V* shows the boundary of the Micro cell of providing coverage to the cluster.

IV. RESULTS

The platform for the purpose of simulation being used MATLAB 9.7 R2019b software. The total area is 10 km^2 and by different ways in the entire area is distributed in 500 users. In Scenario I, the user uniformly distributeds in the left and right regions, respectively. While keeping the microcell ranges from 200 m to 2 km. The parameters that are taken in the simulation are given in the table 1.

Table 1: Parameters for Simulation

Symbol	Definition	Value
X	Number of users per microcell	1800
H	Maximum DBS Height	2 km
K	Number of Cluster	1/microcell
LoS	Line of Sight	4.15
F	Occupied Frequency	2 GHz
α, β	Environmental Parameters	9.16, O.16

In this scenario, the user distribution is by using random function and K-means Clustering algorithm for the location of the 2D projection of DBSs. Figure 1 shows distribution of 6000 random users in an area of 5000 m^2. It also shows that the users are scattered in a particular area with a random way point model, each user location is gathered and the Euclidean distance is measured to find the nearest neighbor and the clusters are made from it.

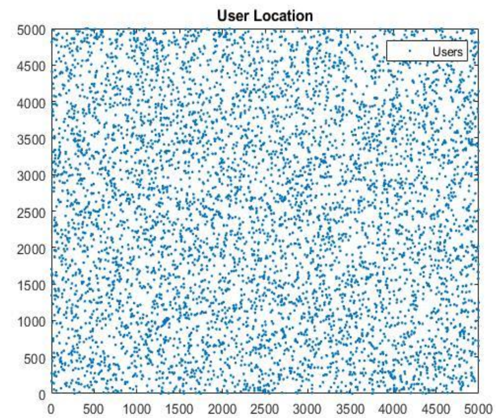

Figure 1: User Location or User Distribution

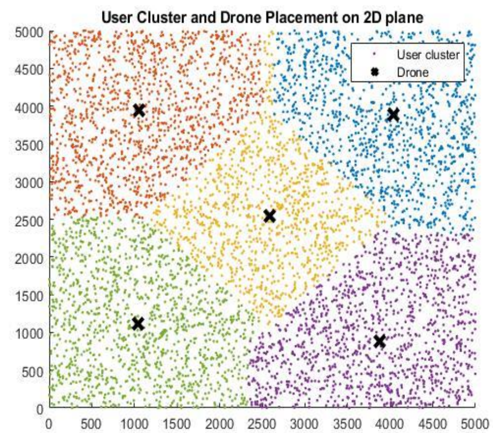

Figure 2: Clusters data with DBS Projection

Drone base station are established on the area and each cluster have a designated drone on it. The Figure 2 shows the drone establishment where the DBS are denoted by Cross(X) sign.

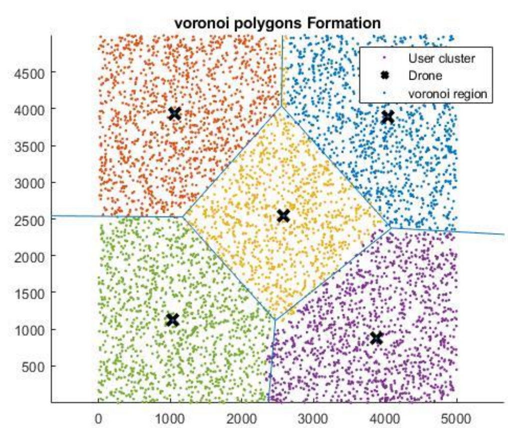

Figure 3: Voronoi Polygon formation

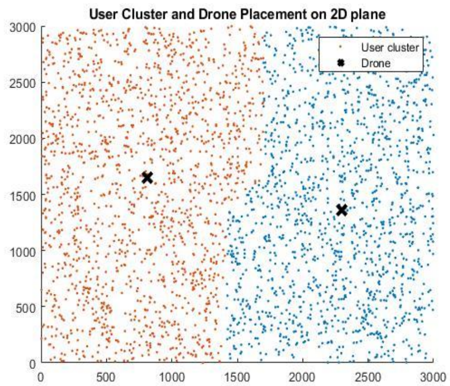

Figure 4: Distribution of 3000 users

Figure 4, 5 and 6 shows the user distribution of 3000, 5000 and 8000 in an area of 3000 m^2. In case of sudden increase of users in an area to double more DBS can be deployed. Figure 7 shows the distribution of 3000 users in different area and the cluster formation of the users and the deployed DBS. The voronoi polygon of the DBS are additionally appeared to give a better insight about the placement of DBS. Limiting the altitude of DBSs to 2 km maximum, the projection of DBS is shown in figure 7.

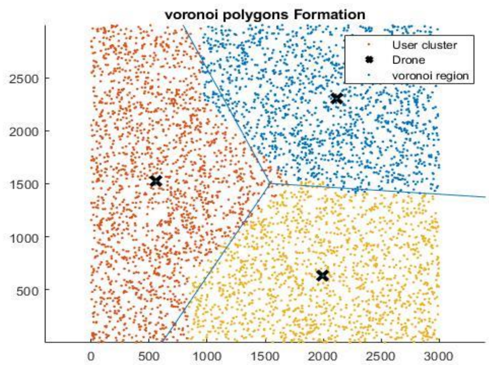

Figure 5: Distribution of 5000 users

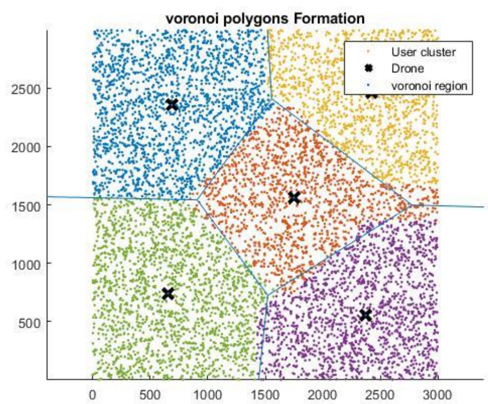

Figure 6: Distribution of 3000 users

The different techniques were compared in figure 8. On X-axis a Kmean PSO, PSO and proposed scheme, whereas on Y-Axis the number of users and altitude in meters. The significances have proven the effectiveness and usefulness of each spatial mappings by using voronoi diagrams. If PSO is being compared with proposed scheme, it is clear that for same number of users PSO need more drones/base stations as compare to proposed scheme. The reason is that our proposed algorithm optimise the altitude and reduces the requirement of additional drones.

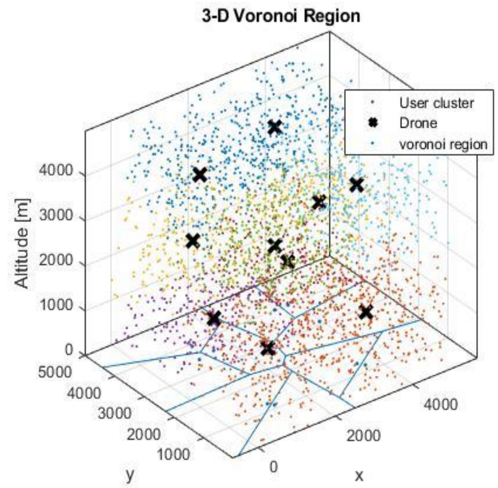

Figure 7: Voronoi Polygon formation

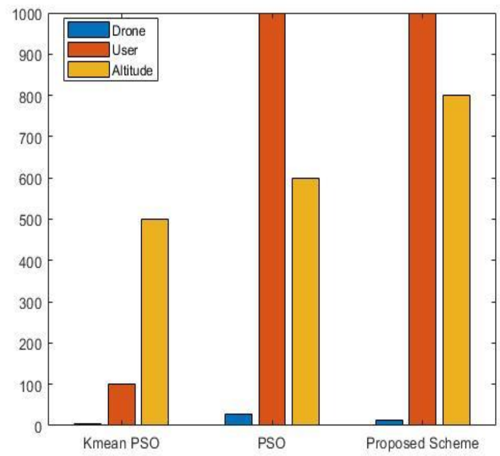

Figure 8: Comparison of another scheme with proposed scheme

V. CONCLUSION

The research focuses on an attempt to deliver the ideal results to achieve the defined objective. The simulation is capable to achieve the location of the user scattered in the area and attempts to cover them all, by dividing them in to clear cluster on the basis of its distance and location.

The user with minimum distance is to be in a cluster which is further served by the drone base stations which will hover on to them. If the user tends to uninvolved then the cluster will renew and DBS changed its location, and set up the coverage area which is the minimum (micro cell) to provide optimal coverage to the user.

The results making an allowance for different user crowds based regions, established the satisfactory performance of the suggested method. These improvements can be carried by low complex algorithms.

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