Placement of 6G UAV-Mounted Mobile Base Station through K-means Clustering of User Load

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***Abstract*—Temporary high traffic request in cellular networks is a challenging problem to resolve. Recently, unmanned aerial vehicles have been applied to cover these types of traffics. However, UAV-Mounted Mobile Base Stations placement becomes a challenge in case of achieving high performance. Also, the user-required traffic has not been considered in UAV placement. Here, we propose incorporating the user-required traffic as a new feature to assign users to the UAVs. This task is accomplished by K-means clustering to find the optimum clusters. The simulation results show that the proposed algorithm succeeds in placing the UAVs close to the high traffic users to achieve higher performance.**

***Index Terms*—Unmanned aerial vehicles; Base station; K-means; 6G; Clustering; Sensor Placement**

I. Introduction

Drones have found a variety of applications in our daily life including surveillance, inspection, rescue, wildfire detection, delivery systems, and many more [1]–[13], [29]. Over recent years, we have observed the increase of drone usage, as a class of unmanned aerial vehicles (UAVs), in assisting 5G cellular networks to extend the coverage and service quality [14]. As one the important merits, UAV-assisted networks can be deployed in areas where extending infrastructure networks might not be possible or very expensive to develop [15].

The next decade will be defined by 5G and 6G networks, as well as automated devices. As a result, UAVs equipped with base stations can be considered as a safe, dependable, and cost-effective wireless solutions [16]. Furthermore, there are areas where a temporary traffic burst often occurs. These areas host overcrowded events such as football games, public demonstrations, and political protests where a sudden extreme demand will needed for communication capacity on cellular networks around the duration of the events [17]. These locations do not have consistent high traffic requests and therefore it is not economical to deploy costly permanent infrastructures. Thus, some agile on-demand mobile systems are required to cover these temporary service requests. UAV systems have applied to a plethora of these types of applications over recent years [1]–[3]. There are undoubtedly small, rural locations where mobile stations are either unavailable or extremely expensive to establish. Drone Base Stations (DBSs) are base stations that may be installed onto drones to provide improved networking services to remote locations. Rural locations are the only places where there exist no or few base stations. As a result, using the internet to communicate with others presents a variety of challenges. DBSs may thus be a feasible choice for delivering such network traffic. Furthermore, the drone's location may be shifted in response to network traffic demands. And provide a better network to everybody who needs it. Many businesses are working on the same research and have developed chips that can be incorporated onto drones and utilized as DBSs systems, as well as our study [18].

DBSs will obviously provide excellent performance since they will be closer to the user than the carrier network to which they are attached. We want the drone to hover over a specified area so it can provide the greatest service to the customer. In addition, we're focusing on establishing the best location from which consumers may get the best performance based on their network traffic needs. Multiple users requesting heavy traffic in the same area where the drone is hovering are just a few of the issues that must be solved in order to achieve a result that can be used to deploy the drone in the best possible location. There will also be difficulties in detecting traffic demands and relocating the drone to offer connectivity. To our knowledge, the study on Drone Base Station has not been fully examined.

The concept of applying swarming UAV-mounted mobile base stations as on-demand cellular network infrastructure has been studied to cover temporary high traffic requests. For example, Lyu et al. [19], minimized the number of UAV-mounted mobile base stations (MBSs) needed to provide wireless coverage for a group of distributed ground terminals, ensuring that each terminal is within the communication range of at least one MBS.

In this work, a polynomial-time algorithm was proposed for a successive MBS placement [19]. In 2016, Galkin et al. [20] applied a K-means clustering algorithm to partition the ground terminals to be served by p drones.

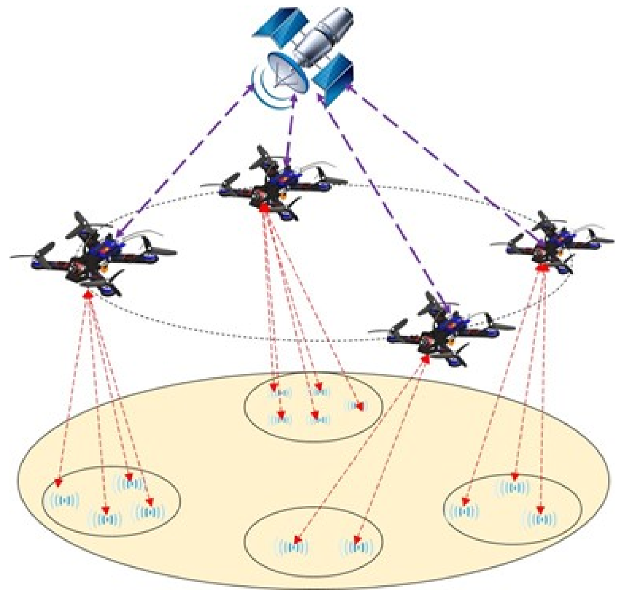

Fig. 1. Cellular networks served by UAV-Mounted Mobile Base Station.

So, in this research, we'll be focusing on two key components. There will be a cluster of network traffic, and regardless of whatever the user demands the most data, we will offer the drone for that cluster. The second function is for the drone to locate the cluster's ideal centroid and deliver the greatest performance to the user based on their desired traffic. We're utilizing the well-known K-means method to figure out where the drone should be placed for maximum performance. The K-means algorithm separates each request into a different cluster based on its weight and discovers the cluster's centroid, which may be connected by all users within a certain radius.

Through numerical analysis, they demonstrated that clustering algorithms could be employed to position the aerial access points and select users to offload from the macrocells [20]. These systems can be programmed to move to any place to serve the users in a very short time. Fig. 1 shows a sample cellular network served by the UAVs-mounted mobile base station, which is connected to the core networks through satellite connections. In this paper, it is assumed that there is no base station tower infrastructure to cover the area and UAV systems are the only transmitters to serve the users in that area.

Despite all advantages of the UAV-Mounted Mobile Base Station, some challenges need to be addressed. UAV-Mounted Mobile Base Stations placement is one of the main challenges that researchers are investigating to find the optimum values. Although different methods have already been proposed to find the proper places for the UAVs, to the best of our knowledge, they only consider the number of users as the traffic load, which is not a realistic scenario. In more realistic scenarios, different users usually run different applications, such as web browsing, voice call, or video calls. Therefore, users consume and require a variety of radio link bandwidth and quality. In this paper, a weighted K-means clustering approach is used to find the cluster centroid.

This structure will be followed for the remainder of the article. The strategy for how we're going to create the base station and the complete UAV is going to plan of work section. Then, in the following section, we looked at how the K-means algorithm works and how it might help us achieve the best results. Last but not least, we discussed potential tasks that we may do.

II. UAV Systems and Swarm

UAVs can be designed very differently, which highly depends on the variety of the mission requirements. They can also be classified based upon their characteristics such as size, weight, flight endurance, and capabilities. Hovering flight mode is one of the major capabilities of the UAVs that is essential in many civil applications. Rotary wings, multi-rotors, tilt-rotors, and tilt-wings are some types of drones that can hover while they perform their missions. In the UAV-Mounted Mobile Base Station application, a UAV system with hovering capability should be used to serve radio network users. Navigation is also another major part of UAV systems. Manual remote control is the very first and simple control system to navigate drones to their final mission location. However, recent advances in autonomous systems help drones to navigate automatically based on their neighbors and environments. This type of autonomous system can deploy GPS information to find their final positions.

In this research, we are particularly interested in how the drone determines its ideal location in order to deliver greater performance. Following the acquisition of the appropriate drone, it will fly over the area where traffic requests have been submitted. The drone will bind its zone and begin collecting network traffic requested by users as soon as it arrives at that area, as well as initiate the radius around the requests. After gathering the data, it will separate the requests into various clusters depending on their weight; a cluster is a collection of related data, and in our instance, the clusters will be divided by the traffic request weightage. The requests from customers that requested more traffic than the threshold will stay in one cluster, while the remaining traffic requests will be in the other. For that, we've established two possible approaches: it will weigh all user requests equally and utilize the K-means method to locate the centroid. Because it does not weigh the consumer's request and provides the same network to all customers, this strategy is less accurate. However, the second method is more intriguing because if the user's request weightage is greater than the threshold weightage, the algorithm will identify new clusters and the drone will shift its location, which may be beneficial for the user who is requesting more traffic requests. After we've discovered the centroid, we can start sending network traffic straight to the client, which will result in better performance because they were previously connecting to a distant carrier network and are now connecting to the closest available link. It will provide them with the necessary network traffic, allowing them to rapidly move on to the next activity.

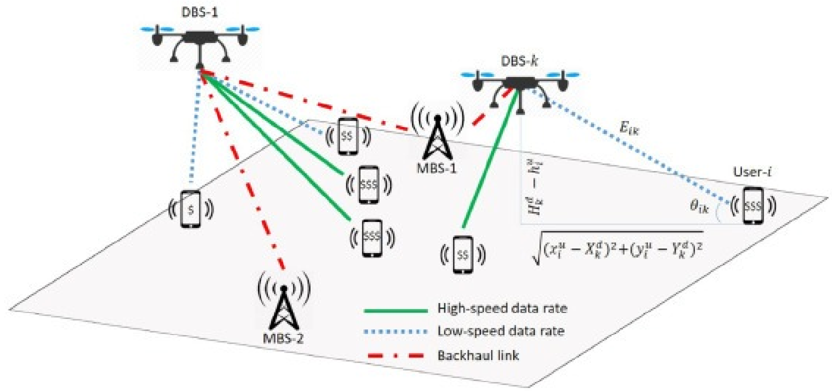

Fig. 2. Finding best centroid position to provide better performance [35].

The drones will determine the centroid position to deliver the optimum performance to the users based on their network traffic requirements, as illustrated in Fig. 2 [35]. And the drones will link directly to the consumer, as well as to the nearby network on the other end. The red dotted line in the image depicts the link to the network towers, which will select the network with the highest efficiency. Consumers seeking a greater rate of packages are represented by the green line, while users requiring lesser speed are represented by the blue dotted line. By employing this strategy, you may solve the difficulty that rural regions or remote locations confront, as well as everyone who has a network connection problem.

III. Pre-Processing and Clustering Approach

User to UAV assignment can be thought of as a clustering task that could be performed based on various parameters. There exist various clustering algorithms. These algorithms differ significantly in their understanding of what constitutes a cluster. The most popular type of clustering algorithm is grouping the objects based on their distances. Distance definition can differ in various applications. Connectivity-based, centroid-based, distribution-based, density-based, and grid-based clustering are different types of clustering that are applied to a variety of applications. K- means is one of the most popular centroid-based clustering algorithms that is applied in this study for users to UAV assignment application. K-means clustering approach is one of the well-known clustering methods [21]–[23].

The K-nearest neighbor algorithm is used to select the best location for the drone to hover. Using this method, each user will be served by the cluster with the nearest UAV-Mounted Mobile Base Stations. K-means is the iterative clustering approach to find the best centroid, which is the position of the UAV in this problem.

The method works by randomly deploying the model inside its radius, after which the drone will decide the best place for giving a better network to the users. To offer the optimum performance, the model will find the cluster's centroid. The centroid may be discovered by calculating the distance between multiple data points (different network traffics) and identifying the optimal location to supply all data points with an equal distance. In our situation, the drone will locate the centroid and perform better.

K-means algorithm initiates by random positioning of the UAVs and iteratively updates the location of the centroid and cluster borders. Considering the user traffic weights, an idea of considering user traffic load as another feature for clustering purposes is proposed. For example, a user who is consuming one-megabyte download traffic can be considered as a user with a load feature of one. A typical user to UAV assignments, x and y location of the users are considered as the main features. In this scenario, user traffic load as the third feature to the user x and y location is added.

Two ways for discovering optimal clusters in the K-nearest neighbor are the Elbow approach and the Silhouette method. The Elbow method will find the data point where adding new data points does not influence on the cluster's data points. To avoid data points overlapping, the Silhouette method includes spacing the clusters as widely apart as feasible. It describes the following values [33] and has a range of -1 to 1.

- -1 means clusters are wrongly distinguished.
- 0 means the distance between the clusters is not sufficient.
- 1 means clusters are correctly separated.

In this model, there are two methods for determining the optimum position. We can simply compute the distance between the data points and the centroid position because there is no network traffic weighting in the first point. However, because network traffic is included in the second technique, we must prioritize network traffic based on its weightage, and we can assign a greater priority to traffic with a higher weightage [34]. As a consequence, the drone will be able to find the centroid at the proper location. As a result, this technique could be able to satisfy the needs of both sorts of customers. The model we're employing can figure out how to connect to the network in the most efficient way possible. If connecting to the nearest carrier network will deliver a better result than connecting to the internet, the drone will connect to that network instead of the internet.

The following algorithm shows the K-means clustering steps.

K-means clustering uses features to assign users to the UAVs. In this proposed method, user traffic as another feature of the system is added to find user clusters and compare the results with the two- dimensional geographic location features.

IV. Experiments and simulation results

In this experiment, we generated random users distributed around the area with two levels of required traffics. In the first scenario, the K-means that only works based on the 2-d Euclidean positional distance is applied, which is essentially based on two coordinate features. In the second scenario, the required traffic is employed as the third feature. Fig. 2(a) shows the two-feature user assignments and Fig. 2(b) illustrates the traffic applied for three-feature user assignments. As demonstrated in Fig. 2, there are three users with high traffic required which are in the border of the two-feature clustering approach (Fig.2(a)) while these three users are located in a high-quality region of the three-features clustering approach (Fig. 2(b)). As demonstrated in Fig. 2 (a), all users are considered as the same load users. Then, they are presented as the same size orange dots. However, in Fig. 2(b), high-speed users are presented as dots larger than the low-speed required users.

V. Conclusions

A UAV-Mounted Mobile Base Station is a new way to cover locations with high traffic demand on a temporary basis. However, in order to provide the best service, UAV placement becomes a difficult task. To cover the audience's unexpected high requests, a UAV placement depending on crowd location is recommended. Because 4G and 5G networks may deliver high-speed communications, this strategy still has to be researched and adjusted to fit the design of more sophisticated networks like 4G and 5G. In this work, the suggested technique clusters user traffic as an extra user feature. As a result, UAVs may be deployed closer to high-speed consumers' needs, allowing them to serve more people.

VI. Future Work

UAV adaptable placement is still another issue that has to be handled, especially given the users' dynamic activity. As a result, the clustering processing time will be evaluated in the future to decrease real-time user behavior. Furthermore, UAV systems' maneuverability allows them to modify the coverage radius of cells in response to traffic fluctuations. Another future job will be to analyze the power change or altitude of the UAV system in order to determine the lowest necessary power to respond to traffic fluctuations.

If network traffic in a particular place is heavier than expected, we can offer two drones for future operations. To fulfill the user's traffic demands, the first drone will descend and decrease its area, while the second drone will cover the remaining space. The drone will utilize real-time live data to determine its new location. For example, if a user consumes 10 gigabytes of traffic, the drone will change its location to accommodate the situation, but after the user's request is fulfilled, the drone will reposition itself to accommodate the traffic time.

Algorithm 1 K-means Clustering Algorithm

1: **Pre-processing:** Each user is split into several users with minimum possible traffic.
2: **Initialization:** Set K-means UAVs to random positions.
3: **Assignment step:** Each user is assigned to the nearest UAV. Euclidean distance is used to find the distance between users and cluster centroids. $s_i^t = \{x_p : |x - m_t^i|^2 \leq |x - m_t^j|^2,\ \forall j,\ 1 \leq j \leq k\}$, where in this equation x is the set of users, m is the set of means of clusters, k is the number of clusters, and t is the iteration number.
4: **Update centroid:** Recalculating the centroid for the assigned users. $m_i^{t+1} = \frac{1}{|s_t^i|} \sum_{x_j \in s_t^i} x_j$
5: Repeat the steps will converge to the step that assignments no longer change.

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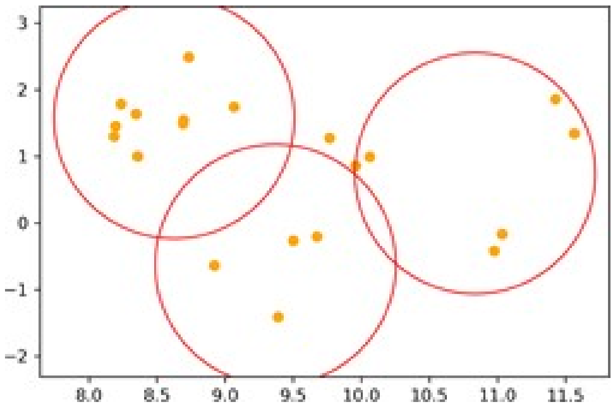

Fig. 3. Two-feature K-means clustering.

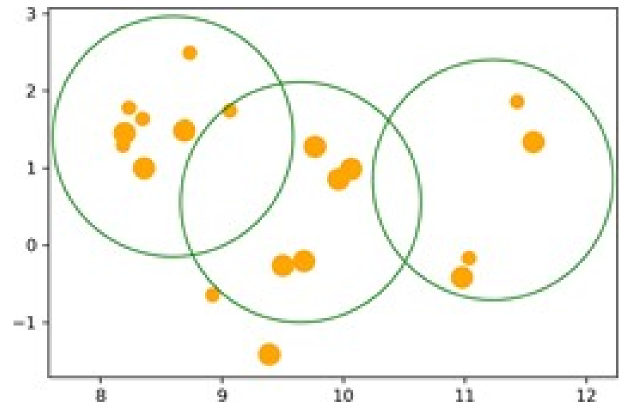

Fig. 4. Three-feature K-means clustering.

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