A Study on Flight Route Optimization of UAV Air Base Station

Yujie Li, Sang-Chul Kim
Department of Computer Science
Kookmin University, Seoul, Korea
Email: {994885943,sckim7}@kookmin.ac.kr

***Abstract*—UAVs have been used in a variety of industries recently due to its affordability, ease of deployment, flexibility, mobility, and maneuvrability. Base stations for UAVs Unmanned aerial vehicle (UAV)-borne base stations offer a practical way to accomplish wireless connectivity in terrestrial communication networks lacking sufficient infrastructure. On demand, dependable wireless connection to the desired location can be offered. Notwithstanding these benefits, there are still obstacles in the way of incorporating UAVs into wireless communications. The selection of a reasonable deployment location for UAV-BSs has become an issue that deserves to be investigated. The UAV-BS selection and deployment method, or BSSU algorithm, is what we suggest in this study. The algorithm guarantees the lowest possible number of air base stations to achieve network communication coverage in a given area, hence minimizing the switching overhead of the UAV network, given a limited number of network base stations.**

keywords:unmanned aerial vehicle, UAV, Drone base station, unmanned aerial vehicle base station, Drone

I. INTRODUCTION

UAV has the advantages of high mobility, on-demand deployment, and low cost, which can be used as a UAV base station to provide communication services, enhance network coverage and data transmission performance. UAV base stations (UAV-BS) have many practical application scenarios, such as providing stable and reliable wireless communication services in disaster environments where ground base stations are damaged, and acting as auxiliary communication base stations when traditional ground networks are congested. UAVs can be used as mobile drone base stations to provide wireless connectivity to areas without infrastructure coverage such as battlefields or disaster sites [1], [2]. Unlike ground base stations (BS), even those mounted on ground vehicles, UAV-mounted UAV-BS can be deployed at any location and move along any trajectory limited only by their aerial characteristics to provide communication services in a given range covering ground terminals or other UAVs that do not have satellite communication capabilities.

UAV-BS are backhaul connected via satellite links, and each UAV base station is projected onto the ground with an equivalent coverage radius r. Therefore, we focus on the problem of UAV base station placement in order to provide wireless coverage for a specific location in a given area. Our algorithm is to deploy the reasonable location of the UAV base station in order to reach the target position on the basis of a certain available ground base station in the battlefield or disaster scene, so as to realize the uninterrupted network communication of the ordinary UAV under the network coverage combination of the base station and the UAV base station.

II. BACKGROUND

In this section, we present related historical studies on UAV-BS.

In recent years, the use of UAV as air base stations to provide wireless communication services has attracted more and more attention. In the research of UAV base station, there are many works devoted to finding the deployment location of the base station UAV [3]–[5]. Compared with the traditional ground base station, the UAV base station has a higher flying height ratio, which can adapt to the communication scenarios in emergency situations, such as rescue, search, and hot spot area coverage. Most of the current research is to achieve better communication quality by optimizing the position deployment of unmanned aerial vehicles, the flight trajectory of unmanned aerial vehicles or resource allocation.

Literature [6] has studied minimizing the number of UAV-BS and the location of deploying UAVs to cover a given number of ground users. Literature [7] studies data collection in UAV-assisted wireless sensor networks. Literature [8] studied the trajectory optimization and power allocation of multi-hop UAV relay communication system. Literature [3] seeks the best deployment position of UAVs with the goal of maximizing the user experience quality. Literature [4] enhances the target signal strength and reduces channel interference by designing the 3D deployment position of the base station without human machine. In Literature [5], the best 3D deployment position of the base station UAV was calculated with the goal of maximizing the minimum system throughput achievable by all ground users in the presence of co-channel interference. Such studies use UAVs as static air base stations, ignoring the high maneuvability and controllability characteristics of UAVs.

The algorithm proposed in our study is that in the case of a certain number of available ground base stations remaining in the battlefield or disaster site, we deploy a small number of UAV base stations to provide uninterrupted network communication in specific areas, so as to guarantee the work tasks of Uavs in certain areas.

III. MEASUREMENT METHODOLOGY

In this section, we propose a novel base station selection algorithm with UAV base station deployment, which we call

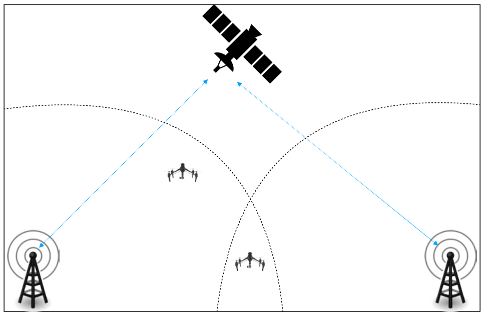

Fig. 1: Base station network connection

the BSSU algorithm. The BSSU algorithm is A metaheuristic based on the mutation A* algorithm, and we describe our BSSU algorithm in detail below.

In a wireless communication network with base station Uavs deployed, there are multiple base stations providing wireless communication services for Uavs, and the location of Uavs may continuously change, as shown in Fig. 1. Since the position of the UAV changes at any time, it may lead to frequent link switching between the base station deployed in the fixed position and the UAV. Therefore, it is necessary to plan the selection of the location of the wireless base station by the UAV to maintain efficient communication between the UAV and the base station UAV and reduce frequent network switching link overhead.

First we define some notation needed to describe the algorithm, we take the number of base stations to be K, with the set $K = \{1, 2, \ldots, n\}$. All base stations can establish communication connections with external networks through communication satellites, and the network coverage radius of base stations is R.

We define a rectangular region of $m \times n$, UAV starting position $S$and target position, the corresponding coordinates respectively $S = (x_S, y_S)$and $D = (x_e, y_e)$. According to the base station deployment environment in the target area, it is divided into two cases :1) the ground base station can completely cover the communication network along the road from the departure location $S$to the target location D; 2) the ground base station cannot completely cover the communication network along the road from the departure location $S$to the target location D. So how to provide an efficient and stable network for the UAV from the departure location $S$to the target location $D$and how to select a reasonable selection of base station connections for the UAV becomes particularly important. The path between the departure location $S$and the target location $D$is covered by different base stations K. When the UAV passes through the area covered by a base station, we declare that it can connect to the network and can execute the command to visit the target location D. In order to achieve the purpose of visiting the target location D, the distance between the UAV and the base station Kalong the path is required to be within the coverage radius threshold of the base station.

When the ground base stations in the target area completely cover the communication network along the road, in order to maintain efficient communication along the road and reduce the link overhead caused by frequent network handoffs, We use the A* algorithm to select the next base station that can be reached by the current connected base station for the UAV, and ensure the minimum number of base station switching in the whole task process, and select the base station position sequence that can ensure that the UAV can reach the network switching cost is minimal. We use the A* algorithm to ensure that the network communication is continuously connected during the movement of the UAV, and the minimum number of switching base stations can be moved from the starting position S to the target position D sawith the shortest path. When the ground base station in the target area cannot completely cover the communication network along the road, the communication transmission of the UAV will be interrupted when performing the task. In order to prevent this from happening, we use the UAV base station to provide network relay support for the UAV performing the task. We define the network coverage radius of the air base station as r. We arrange air base stations at the information terminals between base stations along the route for Uavs to realize network communication support along the route. Our algorithm guarantees the minimum handover overhead of UAV network with the minimum number of air base stations on the basis of the existing network base stations. Pseudocode show as algorithm. 1.

Algorithm 1 BSSU algorithm

Input: BSL, S, D, R, r
Output: ListBS, ListUAV-BS

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BSL: Base station position list
S: Src
D: Dest
R: Coverage radius of UAV as base stations
r: Coverage radius of terrestrial base stations
Start ← S
End ← D
N ← 0
Last ← []
while True do
    ListBS, ListUAV-BS ← A*(BSL, Start, End, N, R, r)
    if E ∈ ListOfBS then
        break
    else
        if Last = ListBS then
            N←N + 1
        else
            N ← 0
            Last ← ListBS
return ListOfBS, ListOfUAV-BS
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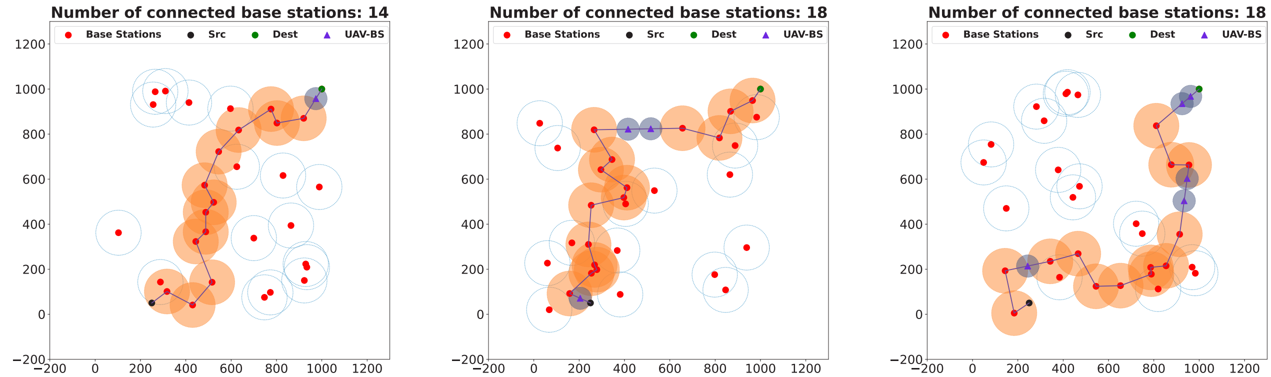

Fig. 2: UAV-base station deployment and selection algorithm based on greedy algorithm(Baseline)

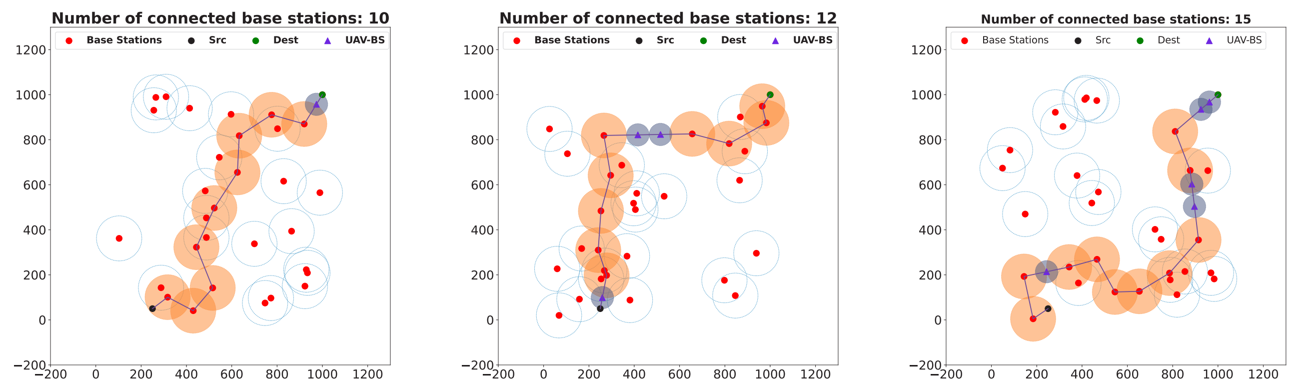

Fig. 3: BSSU algorithm

IV. EVALUATION

In this section, we evaluate the performance of the proposed algorithm compared with the baseline algorithm using the greedy algorithm. We first build a model with an area of $1000m \times 1000m$, in which we randomly generate 30 ground base stations with a coverage radius of 100m for the ground base station and 50m for the air base station. In Fig. 2 and 3, black nodes represent departure locations, green nodes represent arrival locations, red nodes represent ground base stations that can communicate in this environment, and triangles represent locations of UAV-BS deployed by the algorithm.

We produce three types of ground base station distributions at random in a $1000m \times 1000m$ environment. We set the Src coordinate of the UAV's starting point to Src(250,50), and the Dest coordinate to Dest(1000,1000). Fig. 2 depicts the position of the UAV base station deployment and the ground base station selection results based on the greedy algorithm for the three types of ground base station distribution.

In the case of the same ground base station as in Fig. 2, the locations of the ground base stations that can be connected and the deployment locations of the UAV base stations are shown in the process of using the BSSU algorithm from the starting position to the target position of the UAV. In the comparison of BSSU, it is easy to find that our proposed algorithm reduces the switching times of UAV connecting to the base station and greatly reduces network switching overhead in the three environments, reducing 28.6

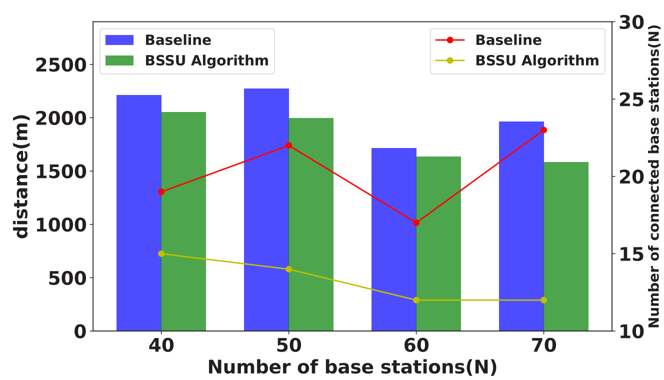

Fig. 4: comparison

To further compare the performance of our proposed algorithm, we keep the area size setting constant and set the number of base stations available in the area to 40,50,60,70, respectively. Then we compare the actual distance that the ordinary UAV needs to fly and the number of deployed UAV base stations by using the sequence of base stations selected by the two algorithms, respectively. Fig. 4 shows the comparison results, and the picture clearly shows the performance of our algorithm. Our proposed algorithm has significant advantages in both the actual flight distance of ordinary UAV and the number of deployed UAV base stations.

V. Conclusion

In this paper, we propose the UAV base station selection and deployment algorithm BSSU algorithm. On the basis of limited network base stations, the algorithm ensures that the network communication coverage in a certain area is realized with the least number of air base stations, and the minimum switching overhead of the UAV network is guaranteed. Simulation results show that our BSSU algorithm has good performance.

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