3-Dimensional Drones' Allocation Control Based on Machine Learning in Multi-Hop Wireless Networks

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Abstract-A drone multi-hop wireless network by using is one of the most effective schemes to construct a temporary communication infrastructure in isolated disaster areas. The conventional drones' height-only control has not been enough to increase average mobile terminal throughputs. In this paper, we propose 3-dimensional drones' allocation control based on machine learning to further increase average mobile terminal throughputs. In the simulation of the proposed scheme, the drones air interface parameters are introduced according to the IEEE802.11a standard link adaptation characteristics. The simulation results show that the proposed scheme can increase the average mobile terminal throughputs by 10.51 [Mbps] compared to the conventional scheme with only height control of drones.

Keywords—drone, multi-hop network, 3-dimensional drones' allocation control, machine learning, link adaptation

I. INTRODUCTION

In the times of disasters, the disaster areas would be isolated from the networks. So we need technologies to connect mobile terminals in the disaster areas to the Internet. In isolated disaster areas, a multi-hop wireless network using multiple drones have been studied to build temporary communication infrastructures [1]. Because drones have high mobility, they can quickly deploy networks over the disaster areas, and they are suitable for building temporary networks in times of disasters. Figure 1 shows an image of a drone multi-hop wireless network in this study. It consists of "ground control station", "mobile terminals" and "drones", similar to Ref.[2]. The ground control station is a gateway to the Internet. In this paper, communications between drones and the mobile terminals correspond to access lines, and the communications between drone and drone and between drones and ground control station correspond to the backhaul lines. We also focus on access lines for simplicity, the same as Ref.[2]. The backhaul line is assumed to be of higher capacity, than the total capacities of the access lines. We assume that drones will use separate wireless channels because there is no radio interference.

When mobile terminals on the ground are uniformly distributed, the same number of mobile terminals would be equally covered by drones of the same heights, and throughput performances would be equally achieved. However, in the actual disaster areas, the distribution of mobile terminals might almost be non-uniform. This would make the throughput performances of some mobile terminals worse. To solve this problem, drones' height-only controls have been proposed in conventional studies, and their increased average mobile terminal throughputs have been reported [2]. However, the conventional schemes that do not move horizontally are not enough to increase average mobile terminal throughputs.

To further increase average mobile terminal throughputs, we propose a 3-dimensional (3D) drones' allocation control scheme that controls the drones' allocations horizontally in addition to the height controls of the drones. The conventional studies have already considered 3D drones' allocation control using machine learning [3][4][5]. In Ref.[3], they used the particle swarm optimization algorithm to find an efficient 3D placement of UAVs to cover indoor users with the least total transmission power. In Ref.[4], they proposed a 3D ABS Placement and Power allocation algorithm (KQPP) that combines K-means and Q-learning to maximize the system sum capacity of the network. In Ref.[5], they proposed the optimization of 3D placement of UAVs to cover the most aerial users under a spectrum sharing policy with ground networks. On the other hand, this paper focuses on the comparison between drone height-only control and 3D drones' allocation control. So, any drone algorithm is fine. Here, we use the K-means++ algorithm as an example. The simulation results show that the proposed scheme can increase the average mobile terminal throughputs by 10.51 [Mbps] compared to the conventional schemes with only height controls of drones with IEEE802.11a physical specifications.

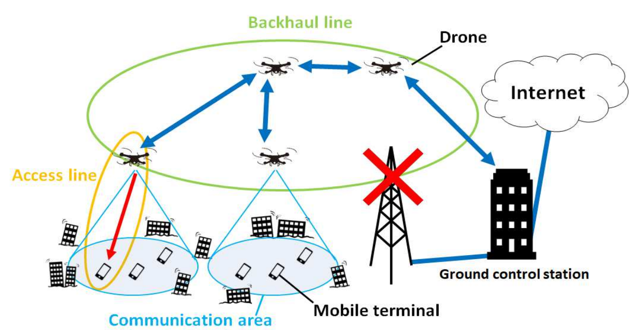

Figure 1 An image of a drone multi-hop wireless network.

Ⅱ. 3-DIMENSIONAL DRONES' ALLOCATION CONTROL

In this paper, the "communication area" is defined as the range of communication on the ground. The communication area is calculated from radio propagation attenuation. Figure 2 shows an image of the drones' allocations by the conventional and proposed schemes. (a) is the initial drones' allocation. (b) is the conventional scheme. (c) is the proposed scheme. The mobile terminals' received bit rate are represented by 3 colors, from yellow, blue, to green according to received bit rate from the drones. The mobile terminals' received bit rate are higher near the center of the communication area. This is because the distance between drones and mobile terminals becomes shorter.

(a): The starting point for drones' allocation control is pointed out.

(b): The conventional schemes control only-height of the drone. When the distribution of mobile terminals is constant, reduce radio propagation attenuation by lowering drones' height. This leads higher mobile terminals' received bit rate. This has increased the number of mobile terminals in the yellow area. This has increased the number of mobile However, many mobile terminals are still in the blue area.

(c): The proposed scheme controls the 3D drones' allocation control. More mobile terminals to be covered in the yellow area by controlling the drone horizontally in addition to height. In this way, all mobile terminals will receive a higher of received bit rate.

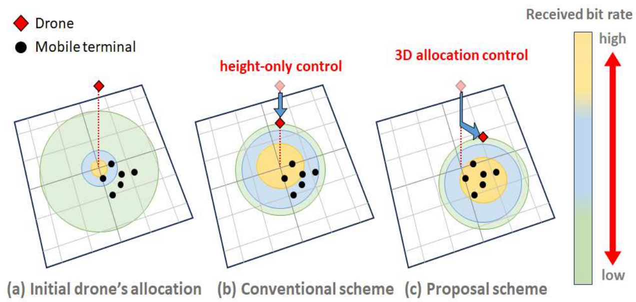

Figure 2 Image of the drones' allocations by the conventional and proposed schemes.

Ⅲ. RECEIVED BIT RATE CHARACTERISTICS

In this paper, the wireless communication standard for the access lines is assumed to be IEEE802.11a. Figure 3 derives the " Received bit rate characteristics between drone mobile terminals as a function of distance" based on link adaptation [6], when the antenna beam width of the drone is 45 [°].

Figures 4 to 6 are the communication area and received bit rate when changing drone's height with a beam width of 45 [°], using Figure 3. Figure 4 shows the communication area and received bit rate for a drone's height of 500 [m]. This figure shows that the communication area is 207 [m] in radius and the modulation scheme is QPSK (r=3/4). Figure 5 shows the communication area and received bit rate for a drone's height of 375 [m]. In this figure, the communication area of QPSK (r=3/4) is smaller to a radius of 155 [m] and transitions to 16QAM (r=1/2) at a radius of 76[m] from the center. Figure 6 shows the communication area and received bit rate for a drone's height of 330 [m]. In this figure, the communication area of QPSK (r=3/4) is eliminated and the communication area of 16QAM (r=1/2) expands to a radius of 136 [m]. These figures show the communication area expands when the drone's height rises, but the received bit rate decreases. Conversely, the communication area will be smaller when the drone's height is lowered, but the received bit rate increases.

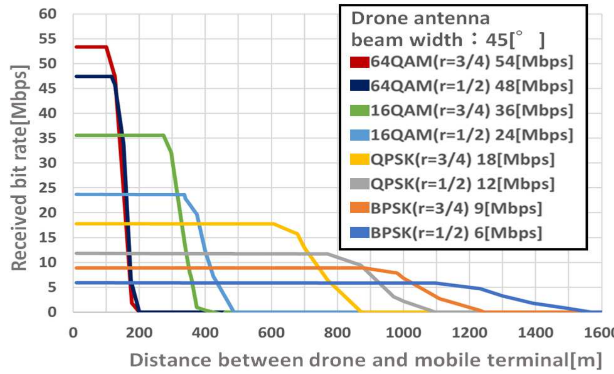

Figure 3 Received bit rate characteristics between drone mobile terminals as a function of distance.

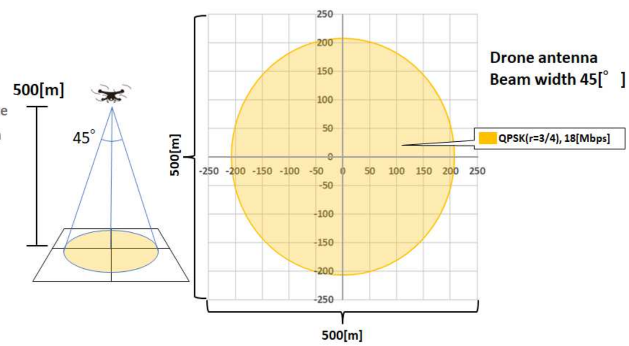

Figure 4 Communication area and received bit rate when drone's height is 500 [m].

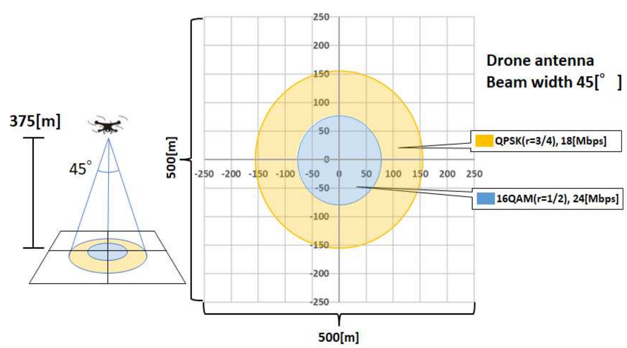

Figure 5 Communication area and received bit rate when drone's height is 375 [m].

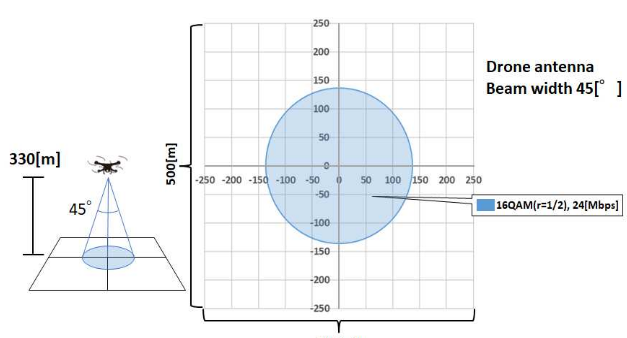

Figure 6 Communication area and received bit rate when drone's height is 330 [m].

Ⅳ. SIMULATION PARAMETERS

To evaluate the effectiveness of the proposal scheme, we simulated conventional and proposed schemes. In the simulations, we compared average mobile terminal throughputs with the constraint that all mobile terminals are covered by the conventional and proposed schemes. The simulation parameters are shown in Table 1 and the initial drones' allocation is shown in Figure 7. In an area of 500 x 500 [m^2], 25 mobile terminals were randomly allocated. Two drones' allocation were controlled, drone A and drone B. The initial drones' allocation for drone A is (-125,-125,1000) and for drone B is (125,125,1000). The wireless communication standard was IEEE802.11a, and each drone used a separate channel. The proposal scheme uses machine learning Kmeans++. K-means is a non-hierarchical clustering method that divides data into K clusters [7]. It starts by setting the center (centroid) for the K clusters. Then, it assigns data points to the closest centroid and updates the centroids. It repeats this assigning and updating until the clusters don't change anymore, making the centroids settle. We simulated the conventional and the proposed schemes with these parameters.

Table 1 Simulation parameters of the proposed scheme.

Area size	**500×500[m^2]**
Initial drones' allocation	**DroneA(−125, −125,1000) DroneB(125,125,1000)**
Drones	**2**
Terminals	**25 (Random distribution of terminals)**
Wireless communication standard	**IEEE802.11a**
Frequency	**5[GHz]**
Channel width	**20[MHz]**
Transmission power	**8[dBm][8]**
Antenna width	**45[°]**
Machine learning for 3D drones' allocation control	**Kmeans++**

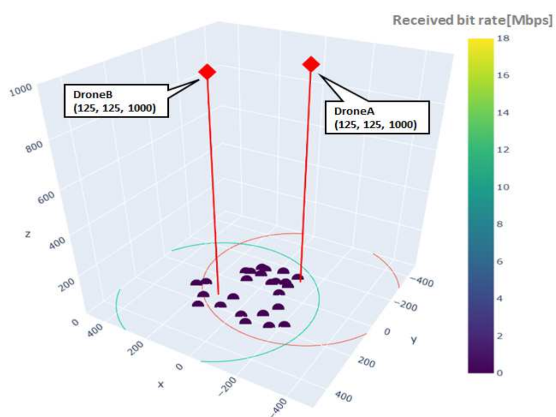

Figure 7 Initial drones' allocation of drone A and drone B in the simulation.

Ⅴ. SIMULATION RESULTS

The conventional and proposed schemes in the simulation are shown in Figures 8 and 9. Figure 8 shows the simulation results of the conventional scheme. In the conventional scheme, the drones' allocation is decided by the mobile terminals farthest from directly below the drone. The result shows that the drones' allocations for Drone A was (-125,-125,750) and Drone B was (125,125,725), and the average mobile terminal throughputs was 11.64 [Mbps]. Figure 9 shows the simulation results of the proposal scheme. The proposal scheme uses machine learning to derive the high average mobile terminal throughputs allocation by moving the drones' allocation in 3D. The result shows that the drones' allocations for Drone A was (-1.2,-81.3,293) and Drone B was (15.3,164.4,562.5), and the average mobile terminal throughputs was 22.15 [Mbps].

Figure 10 shows the average mobile terminal throughputs for the conventional and proposed schemes. The figure shows that the proposal scheme increases the average mobile terminal throughputs by 10.51 [Mbps] compared to the conventional scheme. This happened because the proposal scheme can move drones horizontally in addition to height, making the distance to each mobile terminals reduced than the conventional scheme. As a result, the received bit rate between each terminal and drone could be increased, and the average mobile terminal throughputs could be increased.

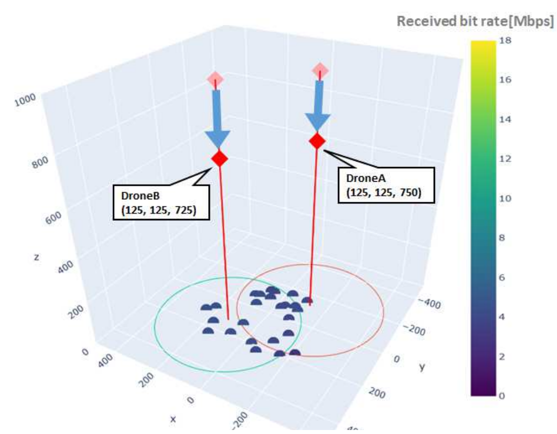

Figure 8 Simulation results of conventional scheme.

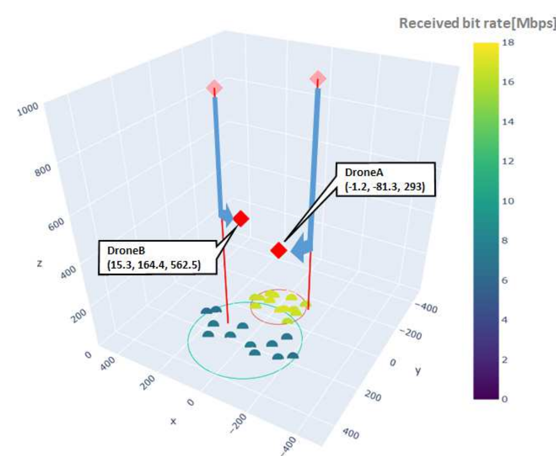

Figure 9 Simulation results of proposal scheme.

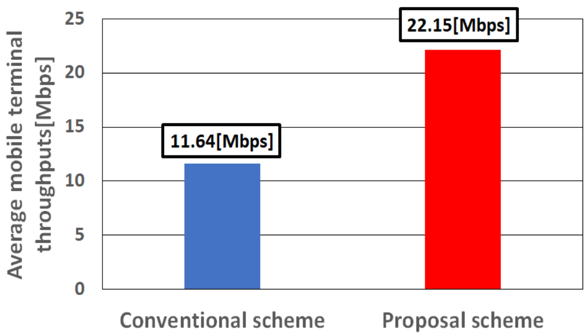

Figure 10 Comparison of average mobile terminal throughputs between conventional and proposed schemes.

VI. CONCLUSION

In this paper, simulations were performed for conventional and proposed schemes with the constraint that all mobile terminals are covered. The simulation results show that the proposal scheme increases the average mobile terminal throughputs by 10.51 [Mbps] compared to the conventional scheme. The results show that the proposal scheme is more effective in increasing average mobile terminal throughputs than the conventional scheme. These results prove that the proposal scheme effective in increasing average mobile terminal throughputs.

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