Optimal Coverage Control for Net-Drone Handover

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***Abstract*—Traditional aerial networks by UAV have several issues such as limited battery capacity and frequent handover caused by time-varying aerial environment. In particular, failure of resolving the handover issue will induce not only unsuccessful seamless handover but also frequent handover attempts. In this paper, an effective coverage decision algorithm is proposed, which aims at providing seamless handover and thus establishing a fully connected aerial network. We further calculate the seamless handover success probability and the false handover initiation probability to evaluate the proposed coverage decision algorithm. We conduct simulation study in order to evaluate the performance of the proposed scheme. Our simulation results show that the proposed scheme is promising for aerial networks.**

Keywords*—Seamless handover, Wireless LAN, Aerial network, Drone, topology management

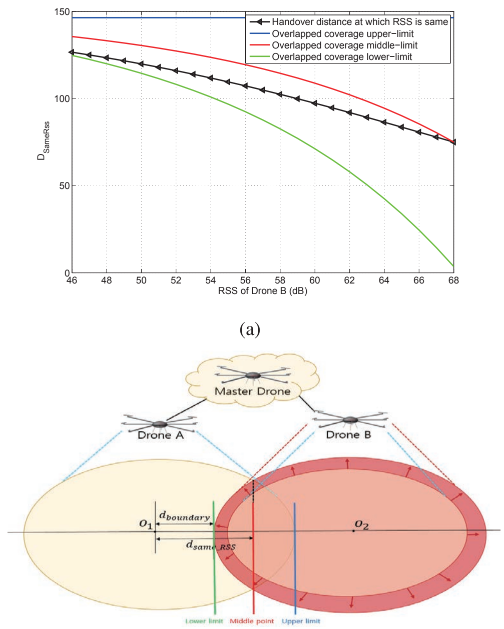
I. Introduction

These days, an hoc network construction without network infrastructure gains much attention. One promising solution is to construct an aerial Wi-Fi network by using Drones, which is so called *Net-Drone*. Each Net-Drone acts as an access point to ground users and can provide required network connection based on their mobility, which is especially useful for disaster areas where network infra is no longer available [1].

In Net-Drone, it is a crucial issue how to provide reliable handover for ground users. In particular, it is hard to resolve because Wi-Fi has narrow communication coverage compared to cellular networks. In addition, Drones have different coverage according to their different environment as well as their height. Consequently, traditional handover decision algorithms are not very effective because they assume the same coverage of the AP's [2].

In this paper, an RSS based efficient coverage decision algorithm is proposed that can determine the coverage of each Drone by controlling the height of each Drone and the distance between Drones. Ultimately, we aim at constructing a fully connected aerial Wi-Fi network by connecting all the Net-Drones. To this end, we calculate the seamless handover success probability and the false handover initiation probability. Then, by using these criteria, we evaluate the proposed coverage decision algorithm. Our simulation results confirms that the proposed algorithm can effectively provide improved handover performance.

In the next section, we introduce an efficient coverage decision algorithm. We denote P_s the seamless handover initiation probability and P_f the false handover initiation probability [3]. In Section III, we present the performance of the proposed scheme based on these criteria [4]. Finally, our conclusion is given in Section IV.



(a)

(b)

Fig. 1. Variation of the D_{Same_Rss} as the difference of Drone's coverage increases

II. Net-Drone topology management

A. Net-Drone in the three dimensional space

There exists a critical difference between the traditional handover problem and that of Net-Drone. Since Drones moves in the three dimensional space, the typical handover approach with two-dimensional viewpoint is no longer valid. If we let the coverage of a Drone as A, then A is given as

$$A = \pi d^2 = \pi(R^2 - h^2), \tag{1}$$

where h is the height of the Drone, R presents the radius of Drone's Wi-Fi coverage and d represents the radius of Drone's coverage on the ground.

A number of studies published earlier have surveyed handover decision algorithms, for example, [2]. In this paper, the optimal coverage decision algorithm is based on received signal strength (RSS). Here, RSS (in dB) is calculated as

$$RSS_{cur} = RSS_{min} - 10\beta log(d) + \epsilon. \tag{2}$$

In (2), RSS_{min} is the minimum level of the RSS required for the mobile terminal when the distance is one meter between the sender and the receiver, d is the path loss coefficient, d is the distance between the sender and the receiver (in meters), ϵ (in dB) is a zero-mean Gaussian random variable with a standard deviation that represents the statistical variation in RSS caused by shadowing. L3 handover is triggered at the point at which the two RSSs become the same, which is described by D_{Same_Rss} [5]. By using (1) and (2), D_{Same_Rss} is described by

$$D_{Same\_Rss} = \sqrt{\left(\frac{A \times D_{o1,o2}{}^2}{1-A}\right)^2 + \frac{A(D_{o1,o2}^2 + h^2) - h_2^2}{1-A}} + \frac{A \times D_{o1,o2}}{1-A}, \tag{3}$$

where A is $10^{\frac{P_1 - P_2}{5\beta}}$.

The traditional RSS based handover decision algorithms usually assume that the AP's coverage is the same. In this case, D_{Same_Rss} is the midpoint of the overlapped area. However, as mentioned above, Drones have different coverage. The issue is that D_{Same_Rss} gradually moves toward on the outskirts of the overlapped area which is not a midpoint as the difference of the Drone's coverage decreases. Fig. 1 illustrates the variation of D_{Same_Rss} as the difference of Drone's coverage increases when Drone A's RSS is fixed at 68 dB and we change the Drone B's RSS. The green line is the overlapped coverage's lower limit, while the red line is midpoint and the blue line is upper limit of overlapped coverage. Fig. 1 shows that D_{Same_Rss} gradually approaches the red line as Drone B's RSS increases. In order to guarantee the seamless handover, every Drone should adjust Drone's height and location to get the same RSS, which moves D_{Same_Rss} from the original location to the midpoint.

B. Seamless handover success probability

The coverage decision algorithm uses P_s and P_f to search the optimal overlapped coverage which minimizes the interference among Drones and makes every RSS the same. Here, P_s is calculated as the taken time which mobile terminal (MT) initiates handover process and escapes from the current service area divided by the time taken to complete the whole handover process. If MT's moving direction is in the range $(-\pi, \pi]$, and the maximum distance which MT can move during T_h is described by $D_h = V_{mt} \times T_h$. Here, V_{mt} is the maximum velocity and T_h presents L3 handover completion time. Also, P_s is the coverage overlapped area between two Drones divided by the green area which can move during T_h in Fig. 2. Here, P_s is given as

$$P_s = \frac{W_{overlap}}{\pi D_h^2 + 4D_h \times r_1 \times \sin\theta_1},$$

where $W_{overlap}$ means the width of the coverage overlapped area.

C. False handover initiation probability

During the course of MT's movement, when the MT reaches the point P, the RSS from the old Drone (OD) drops below S_{th} and L2 handover initiation request is triggered. Also, L2 handover is initiated when the MT reaches P [6]. If the MT does not move to the new Drone (ND) when L2 handover initiation request is triggered during a certain period of time, L2 handover initiation request is considered as an incorrect report. It is the false handover initiation probability [3]. If the MT has the equal probability that can move to all

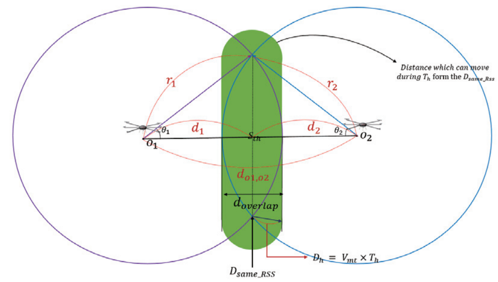


Fig. 2. Analysis of the seamless handover success probability.

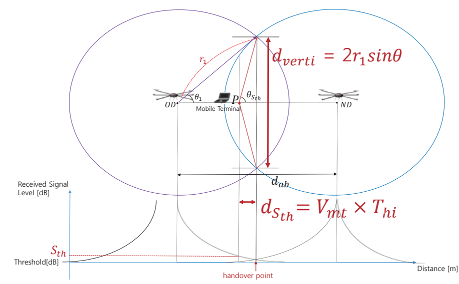


Fig. 3. Analysis of the false handover initiation probability.

directions when the MT is located at point P as shown in Fig. 3, the pdf of MT's direction of motion is given as

$$f_\theta(\theta) = \frac{1}{2\pi}, -\pi < \theta < \pi.$$

In Fig. 3, if MT's direction of motion from P is in the range except (-$\theta_{S_{th}}, \theta_{S_{th}}$], P_f is described by

$$P_f = 1 - \frac{1}{\pi}\arctan\left(\frac{2r_1 \sin\left(\cos^{-1}\frac{d_{o1,o2}}{2r_1}\right)}{2d_{S_{th}}}\right),$$

where $\theta_{S_{th}} = \arctan(d_{verti}/2d_{S_{th}})$.

D. Coverage management algorithm

First, in case of P_s, if the overlapped area $(D_{overlap})$ is bigger than $2 \times D_h$, the seamless handover probability will be increased, but the interference among Drones is increased and the distance among Drones is reduced as well. As a result, the overall Net-Drone topology needs more Drones to cover the same service area. Therefore, the optimal probability is attained when $\frac{D_{overlap}}{2}$ is the same as D_h as shown in Fig. 2.

In case of P_f, $d_{S_{th}}$ is determined in accordance with V_{mt} and T_{hi}, where T_{hi} is time needed for L2 handover. If $d_{S_{th}}$ is bigger than $\frac{D_{overlap}}{2}$, the L2 handover initiation point is triggered on the outside of the overlapped area. Also, the L2 handover process including the cell scanning and channel allocation fails [6]. Therefore, $\frac{D_{overlap}}{2}$ has to be selected as a value bigger than $d_{S_{th}}$.

The coverage decision algorithm adjusts all Drone's heights to match r_{max} which is the smallest coverage at H_{min} (which is the smallest height of Drone due to physical constraint). Then, the distance between the Drones is adjusted to make the overlapped coverage satisfying the L3 handover time and the L2 handover time by using P_f and P_s.

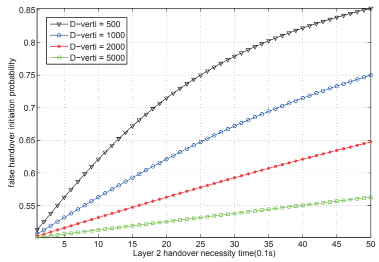


Fig. 4. Relationship between false handoff initiation probability and vertical distance of the overlapped area.

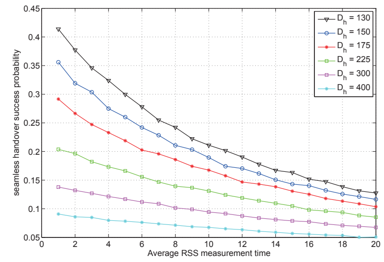


Fig. 6. Relationship between average RSS measurement time and the seamless handover success probability.

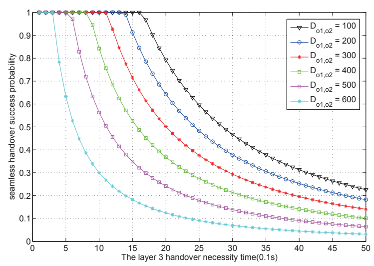


Fig. 5. Relationship between the seamless handover success probability and the L3 handover necessity time.

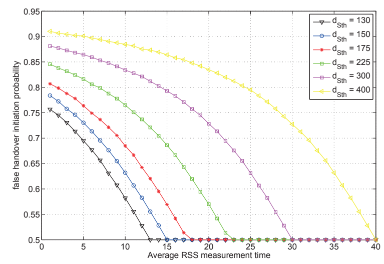


Fig. 7. Relationship between average RSS measurement time and false handover initiation probability.

III. Performance Evaluation

In this section, several simulation scenarios are considered to show that how P_f and P_s is changed by various factors. Fig. 4 shows the relationship between the false handoff initiation probability and the vertical distance of the overlapped area. In Fig. 4, we can know that P_f increases as the L2 handover necessity time increases, and the overlapped area's vertical distance decreases. Fig. 5 gives the relationship between the seamless handover success probability and the L3 handover necessity time. Here, it is shown that P_s decreases as the L3 handover necessity time increases and the overlapped area decreases in accordance with the distance between the Drones increases.

Generally, the RSS is fluctuated by the measurement error of the receiver, the attenuation by the various noises in the wireless environment and so on. Consequently, the mean value of RSS during the RSS's measurement time is used instead of the RSS's instantaneous value. However, stable RSS value can be obtained as RSS's measurement time increases because the MT's movement direction and the MT's rate can be changed during the RSS's measurement time, P_s and P_f are changed. In the Fig. 6, the seamless handover success probability is decreased as average RSS measurement increases. On the other hand, the Fig. 7 shows that the false handover initiation probability is decreased as the average RSS measurement time increases because the MT is getting close to the point at which L3 handover is initiated.

IV. Conclusion

This paper proposes an efficient coverage decision algorithm to establish a fully connected aerial network by the so-called Net-Drone. The key point is to control the height for Drones in order to guarantee seamless handover. In addition, an efficient coverage decision algorithm uses the seamless handover success probability and the false handover initiation probability to search the proper overlapped coverage that minimizes the interference between Net-Drones and makes RSS of every Net-Drone the same.

Acknowledgments

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