Spatial Retreat of Net-Drones under Communication Failure

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***Abstract*—As a promising technology, drones are broadening its scope into various applications such as agriculture, delivery, broadcast, leisure, rescue, and many more. When drones experience communication failure due to interference, non-line-of-sight, or jamming, a possible solution is spatial retreat to evacuate drones from the communication failure area. In this paper, we propose a novel retreat technique that can provide resilient networking. Our approach called cooperative spatial retreat (CSR) significantly outperforms existing schemes by exploiting telemetry communication modules.**

***Keywords*—Aerial networks, drones, spatial retreat, topology management**

I. INTRODUCTION

Networking has become an essential element for our daily life. Consequently, it is of critical importance how to provide a reliable network infrastructure for various kinds of applications. However, in case of emergency networking such as disaster areas, it requires extensive time for service providers to deploy additional infrastructures.

A promising solution for significantly reducing deployment time is to reconstruct network infrastructure by drones as shown in Fig. 1, which is called aerial networks or more specifically *net-drones* [1]. Most of all, net-drones exploit the mobility of drones in the three-dimensional space that can overcome the limitation of two-dimensional mobility. However, net-drones may suffer from communication failure in case of interference, non-line-of-sight, or jamming.

In this paper, in order to overcome the communication failure of net-drones, we propose a novel spatial retreat mechanism, which can provide resilient networking service. Our method called *cooperative spatial retreat (CSR)* exploits additional telemetry communication modules and significantly outperforms existing schemes.

The remainder of the paper is as follows: In Section II, we describe the proposed spatial retreat algorithm of CSR. We evaluate the performance of CSR in Section III. Finally, our conclusion follows in Section IV.

II. COOPERATIVE SPATIAL RETREAT

A. Cooperative Spatial Retreat Algorithm

In the conventional spatial retreat scheme [2], [3], drones escape from the communication failure area in a random manner. However, random escape is obviously inefficient and may waste energy by longer movement and consequently reduce the battery lifetime.

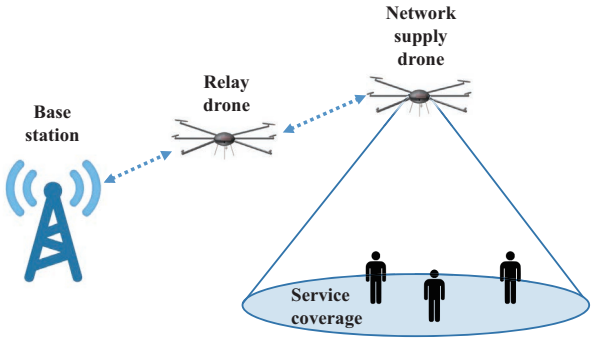


Fig. 1: Concept of net-drones.

The basic idea of the proposed cooperative spatial retreat (CSR) is shown in Fig. 2, whose procedure is given in detail in algorithm 1. In the proposed scheme, a drone that executes the algorithm is termed a target drone and the neighbor drones that send location information to the target drone are cooperative drones.

First, the target drone needs to detect whether it is located in the communication failure area or not by considering information such as the received signal strength indicator (RSSI), packet delivery ratio, carrier sense time, etc. Then, the target drone communicates with neighbor drones co-located in the communication failure area by using the additional communication module of telemetry. Consequently, the target drone can calculate the center of gravity of cooperative drones and itself. With this information, the target drone can evacuate exactly opposite direction from the center.

B. Difference between CSR and the previous schemes

One of existing strategies for escaping from the communication failure area is channel surfing [4], which is basically similar to frequency hopping. Another method is spatial retreat [2], [3]. When drones are interfered, they randomly escape from the area as shown in Fig. 2. The key difference between the proposed CSR and the conventional spatial retreat is that CSR further exploit information obtained from additional communication via telemetry.

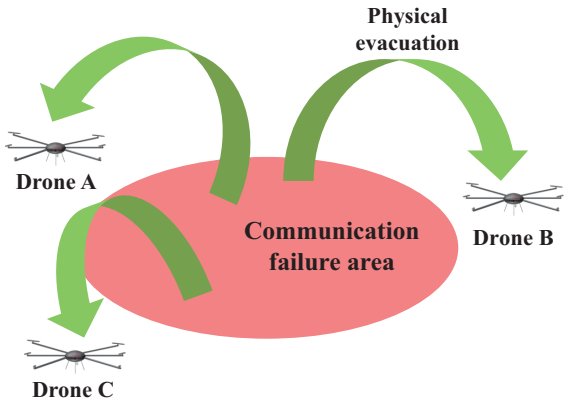


Fig. 2: Basic idea of spatial retreat.

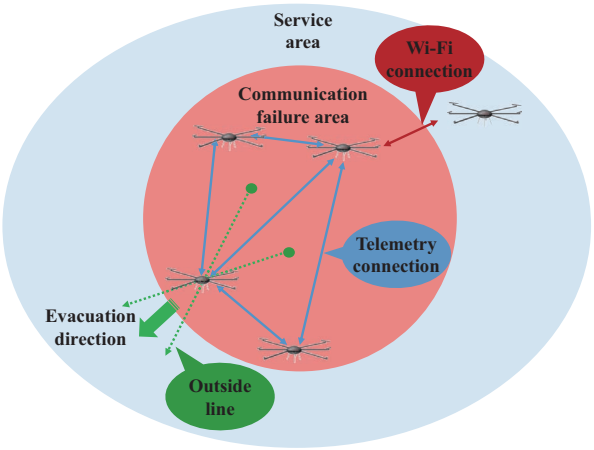


Fig. 3: Illustration of cooperative spatial retreat.

In the conventional spatial retreat scheme, drones choose the evacuation direction in a random manner. On the contrary, the proposed scheme exploits information from other drones and move to the direction with a high probability of improving the channel condition.

C. Discussion on CSR

We can think of some situations when the proposed CSR algorithm may not properly work as shown in Fig. 4. For example, situation (A), (B), and (C) corresponds to the cases when there exist no cooperative drones. Situation (D) is when the target drone is in the middle of the interference area and CSR trivially becomes random escape. Situation (E) is the case when drones are densely located on the boundary of the interference area. In this case, the performance of CSR may not significantly outperform random escape. In case of situation (F), there could be flooded information from too many cooperative drones that may result in extensive overhead.

III. Simulation Study

In this section, we compare the performance of CSR with the random spatial retreat. In particular, we compare the moving distance for evacuation from the communication failure are as shown in Fig. 4. In our simulation study, the performance of random spatial retreat is shown in green while that of CSR is given in blue. For comparison purpose, performance of the perfect movement with full information is shown in red.

Algorithm 1 Cooperative spatial retreat of net-drones

```
procedure COOPERATIVE SPATIAL RETREAT
    if DETECT_FAILURE = true then
        if DRONE_MOVING = true then
            move_toward_mission_area()
        else
            turn_on_telemetry()
            for each_drone(i) < number_of_drone do
                get_other_drone_location()
            end for
            set_midpoint()
            evacuate()
            reconstruct_phase()
        end if
    else
        normal_phase()
    end if
end procedure
```

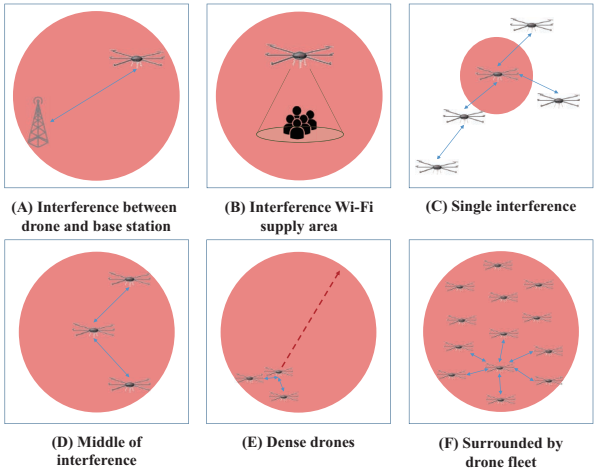


Fig. 4: Limitations of the CSR algorithm.

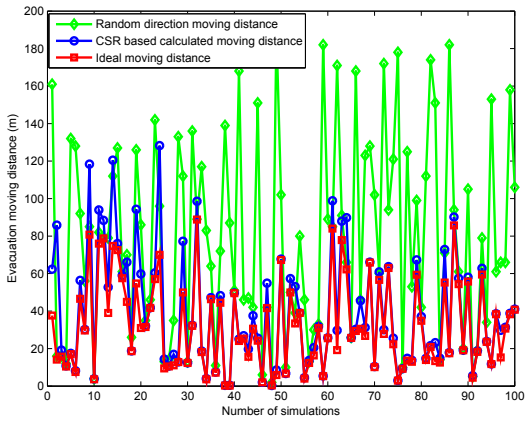
As given in Fig. 4, the moving distance of the proposed CSR is much shorter than that of the conventional random spatial retreat. On average, the moving distance of CSR is less than a half of that of the conventional scheme. Furthermore, the performance of CSR is comparable to that of the optimal scheme with full knowledge of the communication failure area.

IV. Conclusions

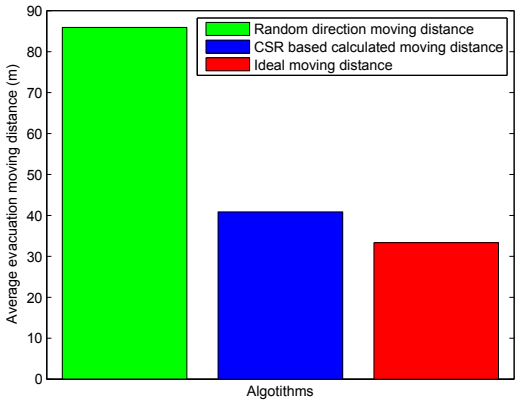
In this paper, we have proposed an efficient spatial retreat scheme entitled cooperative spatial retreat algorithm (CSR) to enhance the reliability of net-drones for providing network service. By using the proposed scheme, net-drones are able to

TABLE I: Parameters used in the simulation study.

Parameter	Value
Simulation tool	MATLAB (R2013a 8.1.0.604)
Simulation dimension	Two dimensional plane
Shape of the failure area	Circle
Radius of the failure area	100 (m)
Maximum evacuation distance	200 (m)
Number of drones	3 drones



(a) Comparison of the moving distance for evacuation per each simulation run.



(b) comparison of the average moving distance for each algorithm.

Fig. 5: Comparison of the moving distance required for evacuation.

get out of the communication failure area and provide reliable network service.

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