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On the positioning likelihood of UAVs in 5G networks

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ABSTRACT

An increment in the number of User Equipment (UE) demands network replanning or introducing incipient devices which can provide dynamic support to the subsisting networks. One of these devices can be the Unmanned Aerial Vehicles (UAVs). However, being prodigiously dynamic and autonomous in some scenarios, these vehicles require an efficient mechanism for their deployment in currently operating wireless networks. In this paper, an efficient approach is proposed which utilizes the properties of the self-healing neural model and the concept of matrix-coloring in order to maximize the UAVs positioning likelihood for optimized throughput coverage and maximum UE to UAV mapping. The efficacy of the proposed approach is demonstrated in terms of amelioration in the throughput coverage and mapping of the UAV to subdivisions at low consumption of energy and memory by using numerical simulations.

1. Introduction

With the magnification of 5G networks, the number of Access Points (APs) and service units are growing in deployment density [1]. These networks would require an astronomically immense number of sites for the deployment of incipient infrastructure. This is not practical at the moment since most of the regime sites are pre-occupied and other private units are not facilely accessible. Further, the subsisting heterogeneous wireless networks do not sanction direct deployment of nodes as this would require replanning of the entire network. This network replanning arises Capital Expenditure/ Operating Expenditure (CAPEX/OPEX) issues which would increment the overall operating cost of the network as well as the total cost of ownership.

The increment in the number of users in a macrocell would require either deployment of smaller cells or entire network replanning [2]. An alternative solution to this quandary of handling extra users along with the maximization of throughput coverage and accommodations to User Equipment (UE) can be the deployment of UAVs, as shown in Fig. 1. UAVs are flexible and autonomously operable, which sanctions them to be utilized in prodigious types of scenarios according to the network demand and requisites [3–5].

Researchers have additionally fixated on the utilization of UAVs to enhance the operations of the wireless networks, such as utilizing UAVs for enhancing the WiFi connectivity, data acquisition over wireless sensor networks, and can be utilized in layers to handle the adversities of heterogeneous wireless networks [6–9]. Support for other types of networks such as ad hoc formations is additionally one of the crucial applications of UAVs. All the aspects cognate to the utilization of UAVs have dependency over one mundane feature, i.e. placements of UAVs. This is an optimization problem and requires a solution which can place UAVs optimally in any type of networks. Further, efficient scheduling can be considered as another consequential quandary with the utilization of UAVs [10–13].

UAVs help to extend the application of traditional cellular networks by incorporating the features of dynamic and flexible transmissions between the core and the UE [14–17]. Despite being advantageous, it is required to understand the network formations for UAVs while fully following the extent of connectivity and coverage supported by them. UAVs can be used for supporting fronthaul as well as backhaul depending on the range of connectivity and payload mounted on them. For backhaul, heavy equipment is to be mounted on UAVs, which requires considerable planning before deploying the network, whereas for UAV fronthaul, mini-base stations can help to serve the purpose. Despite in clarity of role of UAVs in 5G networks, drone cells still require backhauling for improvised connectivity to its core [18–20]. Such a facility can be attained either directly connecting the UAVs with Base Band Unit (BBU) or depending on Macrocell Base Station (MBS) for supporting backhaul to drone/UAV cells, as shown in Fig. 2. This

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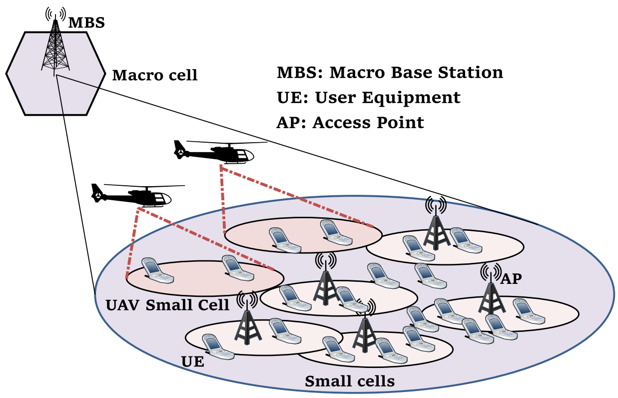

Fig. 1. An exemplary illustration of UAVs deployment over heterogeneous networks as fronthaul with MBS.

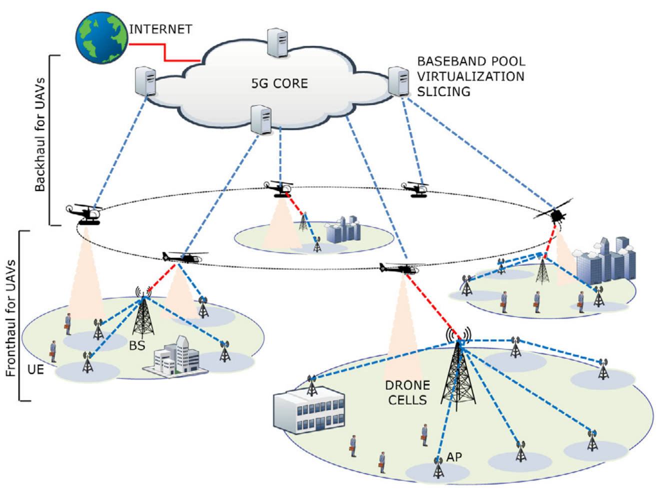

Fig. 2. An exemplary illustration of backhaul and fronthaul formations for UAV-cells.

type of connectivity is dependent on the service provider as well as on the initial planning of the network.[1]

The proposed approach uses the concept of matrix-coloring, which is inspired by graph coloring approach [21], in order to maximize the UAVs positioning likelihood for optimized throughput coverage and maximum UE to UAV mapping. Moreover, for enhancing the efficiency of the proposed approach, the initial system modeling is performed by utilizing the properties of self-healing neural model [22], which helps in failure avoidance along with position optimization. Simulations are shown to present the efficiency of the proposed approach in terms of capacity enhancement, the number of iterations used for allocation of UAVs, cost consumption, positioning likelihood, and energy consumption.[2]

The rest of the paper is structured as follows: Section 2 presents the general problem statement and key highlights of our proposed solution. Section 3 gives the details on related works. Section 4 discusses the proposed solution. Section 5 provides the performance evaluations. Finally, Section 6 concludes the article.

2. Problem statement and our contributions

The positioning of UAVs is very much crucial for any network which fixates to avail any of their properties for enhanced connectivity. Any solution, which performs optimization for the positioning of UAVs, but involves a complex mechanism, is of no use as it may generate considerable overheads in real scenarios.[3] Thus, it is desired to build a model which is not only low on cost in terms of energy and memory but should also be able to enhance the performance factors that are considered by existing solutions.

The paper resolves the positioning issues of multiple UAVs while providing an effective strategy for cell-based allocations. The contributions of this article are listed below:

- The paper provides a network setup for considering issues related to the positioning likelihood of UAVs.
- Matrix coloring is applied through backtracking to solve the defined problem.
- Factors like throughput coverage, capacity, and iterative evaluations are considered along with the proposed solution.
- With the proposed approach, the overall positioning likelihood is improved with almost zero isolated area.
- The proposed solution causes fewer burdens on energy resources and operates with a low complexity and fewer overheads in terms of CPU utilization and memory consumption.

3. Related works

The utilization of energy-constrained UAVs for wireless communications has grown rapidly. Despite being advantageous, the wireless communication through UAVs faces lots of challenges related to positioning, energy conservation, and resource optimization. Kandeepan et al. [23] proposed an adaptive cooperative scheme which enables the survivability of the battery-operated aerial–terrestrial communication links. The authors present the analysis of hybrid aerial–terrestrial systems for an uplink Rayleigh fading channel. The relaying information imposes the delay due to the traffic at the relay nodes. In the era of wireless communications with UAVs, Zeng et al. [32] discuss the challenges and opportunities related to the network of UAVs. The adaptability of UAVs provides cost-effective wireless connectivity for devices without infrastructure coverage. The authors highlighted the issues pertaining to UAV deployment and path planning. As studied by the authors, a useful method for path planning is to approximate the UAV dynamics by a discrete-time state space, with the state vector typically consisting of the position and velocity in a three-dimensional (3D) coordinate system.

Efficient deployment of multiple UAVs is directly proportional to the range of connectivity in the desired coverage area. Considering this, the positioning of UAVs is of paramount importance as it highly impacts the energy consumption as well as the interference generated by neighboring UAVs. Mozaffari et al. [24] proposed a framework of 3D locations finder for UAVs which focuses on the deployment of multiple UAVs by considering the maximum downlink coverage performance with a minimum transmit power. The coverage requirement and the size of the area reflect the optimal number of UAVs for efficient system design. The complexity of the channel model imposes difficulties in the UAVs deployment for the 3D environment. Bor-Yaliniz et al. [25] discuss the drone cell placement problem and focus on the network coverage maximization. The problem is solved mathematically and verified with analytical derivations through numerical simulations. The effect of interference and using several drone-cells is still an open challenge

[1] This paper deals with positioning aspect of UAVs while considering their fronthaul connectivity with MBS and does not focus on mobile backhaul for MBS or drone/UAV cells.

[2] Moreover, it is required that positioning likelihood of UAVs must be balanced for its tradeoff with the energy and memory requirements.

[3] A low complex solution that consumes less amount of energy is the key to positioning optimization.