Reviews on UAV-Enabled Wireless Communication Networks with AI-Driven Management

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***Abstract*—Unmanned aerial vehicles (UAVs) are revolutionizing wireless communication networks, enabling diverse applications in military, public safety, and wireless communication. UAV-enabled networks, at the intersection of aerial robotics and communications, address accessibility and scalability issues. Increased demand for enhanced communication solutions in disaster response and underserved areas drives interest in UAV-assisted networks. UAVs, equipped with communication gear, bridge communication gaps and transform information sharing, offering flexible and rapid solutions in previously inaccessible regions. Through AI-based network management, these UAV-enabled networks provide efficient operation and optimization. This paper provides a comprehensive overview of UAV-enabled networks, highlighting performance factors, relationships, and optimization methods. Configurable for connectivity and coverage improvement, mobility, energy efficiency, and 5G integration, these networks expand and collect data in IoT and wireless sensor networks using multiple UAVs. UAVs are transforming communication networks, with diverse applications in various sectors. This paper explores the potential of UAV-enabled networks, including AI-driven network management, to reshape the telecommunications industry and inspire innovations in this rapidly evolving field.**

***Index Terms*—Unmanned aerial vehicles (UAVs), Wireless communication networks, Wireless Sensor Networks (WSN), Internet of Things (IoT), Data collection**

I. Introduction

Unmanned aerial vehicles (UAVs), commonly known as drones, have emerged as versatile tools with a wide range of applications in today's technological environment. Unmanned aerial vehicles have been used for military purposes, including surveillance, reconnaissance and attack, or in the public sector for traffic management and public safety. But now, beyond their traditional role, they are increasingly being used to revolutionize wireless communications networks. Unmanned aerial vehicle-enabled networks represent an interesting convergence of aerial robotics and communications, offering innovative solutions to resolve a variety of issues in communication networks such as accessability and scalability [1].

The concept of UAV-assisted networks has garnered considerable attention in recent years, spurred by the pressing need for enhanced communication solutions in diverse scenarios. These scenarios encompass emergency response in disaster-stricken regions, connectivity provisioning in remote and underserved areas, and augmenting existing network infrastructure to meet growing demands for data services. UAVs, equipped with communication equipment and advanced capabilities, have the potential to bridge these communication gaps and transform the way we connect and share information [2], [3].

The importance of UAV-enabled networks lies in their ability to provide flexible and rapidly deployable communications solutions that can adapt to a variety of scenarios and challenges. Integrating UAVs into communications networks opens up new possibilities for providing connectivity to places previously considered inaccessible. As such, this paper seeks to provide a comprehensive view of the state-of-the-art in UAV-enabled networks and explain the performance factors considered in the network and the relationships between them along with optimization methods [4].

A UAV-enabled network can be configured according to several scenarios. Various UAV-enabled network configurations can be classified according to several characteristics. Depending on the performance improvement goal of the proposed network, it can be divided into connectivity and coverage improvement [5], mobility and relay strategy, energy efficiency of sensor nodes in wireless sensor networks (WSN) [6], [7], and integration with 5G or higher networks [8]. And depending on the number of UAVs utilized in the network, combinations of various components can be considered, including single or multiple UAV systems and the convergence of edge computing and UAVs [9]–[11]. By analyzing along these aspects, we aim to highlight the development directions that UAV-enabled networks can offer and their potential to reshape the telecom-

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munications industry.

The following sections examine each relevant research trend according to the characteristics identified above to provide insight into the current UAV-enabled network and potential directions for further exploration. Specifically, we will classify this into research on ways to expand networks using multiple UAVs and research on data collection in IoT or WSN using a small number of moving UAVs. In doing so, we contribute to the broader discussion on the role of UAVs for the advancement of wireless communication networks, and the paper seeks to inspire new ideas and innovations in this exciting and rapidly developing field.

II. UAV-Assisted wireless networks considering various communication scenarios

Many recent studies are underway that utilize moving UAVs to collect data from sensor nodes in IoT and WSN. Zhu *et al.* [12] introduced a study to minimize minimizes the total energy consumption of the UAV-IoT system by simultaneously selecting the trajectory of UAV and the cluster head (CH) of the IoT network. The authors view the UAV's trajectory planning problem as a sequential decision-making problem and propose a sequential-sequential neural network that uses a sequential model to express the UAV's policy.

In [13], the authors modify the Voronoi diagram by considering the maximum horizontal communication distance of each sensor and use it to find a stopping position for the UAV where the UAV can collect data from as many adjacent sensors as possible. Then, connect each stopping location to obtain the shortest UAV path. The initially obtained UAV path is adjusted to maximize the remaining energy of the sensor. To this end, the stopping position of the UAV is changed by reducing the horizontal communication distance of each sensor. This process is repeated until the UAV's movement distance constraints are satisfied.

Wang *et al.* [14] aim to optimize the UAV trajectory and the transmission schedule of the devices to minimize the maximum energy consumption of all devices, while ensuring the reliability of data collection and the required 3D localization accuracy. The authors design a data collection process in a UAV-assisted IoT network and derive the transmission rates of the ground-to-ground and ground-to-air channels and the energy consumption of the devices.

When constructing a wireless network using multiple UAVs to transmit data, several challenges must be addressed. UAV networks face limitations in terms of communication resources, non-permanent nodes, intermittent connectivity, and potential channel impairments. To tackle these issues, various studies have been conducted. Ku *et al.* [15] proposed the use of SDN [16], a method that enables network programmability, allowing for the deployment and management of new protocols, applications, and services while facilitating the coordination of network policies and performance. Dely *et al.* [17] demonstrated the potential of leveraging the aggregated network knowledge of SDN controllers by implementing the integration of wireless mesh networks with OpenFlow on a small scale within a testbed. Although these studies did not actually assume a wireless mesh network composed of UAVs, the possibility of a UAV-based wireless mesh network through SDN can be considered.

Sahingoz *et al.* [18] proposed multi level hierarchical routing (MLHR). It addresses scalability issues in large-scale vehicular networks, which typically have flat structures leading to performance degradation as the network size grows. To improve this, hierarchical organization is employed, increasing the network's size and operation area. Similarly, UAV networks can be grouped into clusters, where only the cluster head maintains connections outside the cluster.

III. Conclusion

This paper reviewed studies that solve the limitations of existing wireless networks using UAVs. We can see that various studies are underway regarding how to collect data from the sensor nodes of IoT and WSN. These studies utilize machine learning techniques to optimize parameters related to energy efficiency and data transmission.

When building a wireless network that uses multiple UAVs to transmit data, it has been proposed as a way to enable network programming and facilitate coordination of network policies and performance while deploying and managing new protocols, applications, and services, taking into account the various challenges of communication resources, non-persistent nodes, intermittent connections, and potential channel failures. These studies cover various aspects of networks using UAVs and utilize AI-driven network management methods to efficiently utilize UAVs and improve network performance in wireless communication environments. These studies highlight the importance of AI-driven management for UAV utilization and network optimization in future network environments.

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