Guest Editorial Special Issue on UAV Communications in 5G and Beyond Networks—Part II

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I. Introduction

WIRELESS communication is an essential technology to unlock the full potential of unmanned aerial vehicles (UAVs) in numerous applications and has thus received unprecedented attention recently. Although technologies such as direct link, WiFi, and satellite communications are still useful in some remote scenarios where cellular services are unavailable, it is believed that exploiting the thriving 5G and beyond cellular networks to support UAV communications is the most promising and cost-effective approach, especially when the number of UAVs grows dramatically. On the one hand, to guarantee safe and efficient flight operations of multiple UAVs, it is of paramount importance to provide secure and ultra-reliable communication links between the UAVs and their ground pilots or control stations for conveying command and control signals, especially in beyond-visual-line-of-sight (BVLOS) scenarios. On the other hand, because of advances in communication equipment miniaturization as well as UAV manufacturing, mounting compact and lightweight base stations (BSs) or relays on UAVs becomes increasingly feasible. This has led to two promising research paradigms for UAV communications, namely, UAV-assisted cellular communications and cellular-connected UAVs, where UAVs are integrated into cellular networks as aerial communication platforms and aerial users, respectively. As such, integrating UAVs into cellular networks is believed to be a win-win technology for both UAV-related industries and cellular network operators, which not only creates plenty of new business opportunities but also benefits the communication performance of 3-D wireless networks. In addition, UAV related sensing and computing are also helpful for achieving efficient and reliable communication (e.g., in avoiding coverage holes) as well as smart UAV coordination, positioning, and trajectory design. However, 5G and beyond wireless networks with UAVs significantly differs from traditional communication systems, because of the high altitude and high maneuverability of UAVs, the unique UAV-ground channels, the diversified quality of service (QoS) requirements for downlink command and control (C&C) and uplink mission-related data transmission, the stringent constraints imposed by the size, weight, and power (SWAP) limitations of UAVs, as well as the new design degrees of freedom enabled by joint UAV mobility control and communication resource allocation.

This special issue (SI) aims to advance the research on UAV communications in 5G and beyond networks. It led to a strong response from the research community of UAV communications and attracted more than 130 high-quality submissions from researchers all over the world. Due to the space limitation, only 39 original contribution papers were eventually selected for publication in a double-issue. In addition, an overview paper from the Guest Editors was reviewed by the team of Senior Editors of IEEE Journal on Selected Areas in Communications. All submissions received at least three reviews, and the accepted articles went through at least one revision round.

The second part of the double issue covers the latest research advances of edge computing, security and other applications in UAV communications in 5G and beyond networks.

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The contributions of the accepted articles are categorized as follows.

II. Edge Computing in UAV Communication Networks

The article "Let's trade in the future! A futures-enabled fast resource trading mechanism in edge computing-assisted UAV networks" studies an interesting computing resource trading problem in mobile edge computing-enabled UAV networks by introducing the idea of futures. Specifically, aiming to relieve the onsite negotiation latency and cost among players, and the unexpected trading failures as well as unfairness incurred by price fluctuation, the authors propose a bilateral negotiation mechanism for the mobile edge computing (MEC) as a seller and the UAV as a buyer. It helps reach a consensus on resource amount and price associated with a forward contract which will be fulfilled in the future. Additionally, a power optimization algorithm to reduce the buyer's energy consumption is presented.

The article "Hybrid beamforming design and resource allocation for UAV-aided wireless-powered mobile edge computing networks with NOMA" investigates the emerging wireless powered MEC systems by considering hybrid beamforming and NOMA together with UAV communications. For MEC offloading, the authors consider the binary and partial offloading models based on task partitionality. By maximizing the sum computation rate of all the devices, this article employs alternating-optimization approaches to optimize UAV position, hybrid beamforming, and computation offloading decisions in order to obtain suboptimal solutions.

The article "Service provisioning for UAV-enabled mobile edge computing" studies a fundamental and critical problem in UAV-enabled MEC, i.e., how to provide on-demand service deployed on UAVs for terrestrial users. The authors propose novel suboptimal solutions to the studied problem. Besides a traditional solution based on branch-and-bound method and SCA, they also propose a novel approximation solution to solve the challenging integral service placement and task scheduling subproblem. The performances of both solutions are rigorously analyzed and validated by extensive simulations.

The article "5G-enabled UAV-to-community offloading: Joint trajectory design and task scheduling" constructs a UAV-enabled 5G offloading framework, which jointly utilizes orthogonal frequency division multiple access (OFDMA) and NOMA techniques. First, an optimization problem is formulated. Due to its complexity, it is solved by some effective methods. For the trajectory design subproblem, an auction-based algorithm is developed to compete for the computing resources of UAVs. While for the task scheduling subproblem, considering the constraints of task deadline and atomicity, a dynamic task admission algorithm is proposed to maximize the system throughput. Performance evaluations illustrate that the presented solution works well with respect to the system throughput and the number of users benefiting from edge computing.

III. Security in UAV Communication Networks

The article "Optimal transmit power and flying location for UAV covert wireless communications" jointly optimizes the flying location and wireless communication transmit power for a UAV conducting covert operations. This article tackles the question of maximizing the communication quality to a legitimate ground receiver outside the surveillance region, subject to a covertness constraint, a maximum transmit power constraint, and a physical location constraint determined by the required surveillance quality. An explicit solution to the optimization problem considering practical constraints is presented.

The article "Robust 3D-trajectory and time switching optimization for dual-UAV-enabled secure communications" studies the problem of joint 3-D trajectory design and time-sharing allocation in a dual UAV-assisted secure communication scenario under a limited flying time constraint. An optimization problem is formulated to maximize the minimum secrecy throughput between the UAVs and the mobile ground users over all time slots. An iterative algorithm is proposed for solving the original optimization problem which can converge to a local minimum.

The article "UAV-enabled covert wireless data collection" studies the problem of single UAV wireless data collection under covertness constraints from ground users. Through the use of its jamming capability, the UAV's goal is to hide transmission between scheduled users and itself from unscheduled ones. The proposed approach consists of jointly designing the UAV's trajectory, jamming transmit power, and user scheduling through a penalty successive convex approximation scheme (P-SCA) and compared to a heuristic successive hover-and-fly (SHAF) solution, which is also used as an initialization to the P-SCA approach.

The article "Joint resource, trajectory, and artificial noise optimization in secure driven 3D UAVs with NOMA and imperfect CSI" aims to improve the secure energy efficiency by designing the energy resources, communication trajectory, and artificial noise in UAV NOMA networks. The Markov inequality, Marcum Q-function, and first-order Taylor expansion are introduced to solve the nonconvex optimization problem. Simulations results are carried out to verify the advantage of the proposed algorithm.

IV. Other Applications

The article "Multi-UAV trajectory optimization considering collisions in FSO communication networks" considers a network consisting of multiple UAVs that are connected to multiple ground terminals (GTs) via FSO links. Various optimization criteria are considered in the article. The corresponding optimization problems are transformed into convex problems that can be solved using commercial solvers such as CVX. A comprehensive set of simulation results are provided which are interesting and report insightful observations.

The article "Resource allocation for 5G-UAV based emergency wireless communications" analyzes the ergodic capacity and the optimum resource allocation of UAV-based EWC systems over realistic fading channels. A useful formulation of the realistic considered model is provided along with useful insights in terms of energy efficiency and the impact of fading parameters on the performance.

The article "Joint optimisation of real-time deployment and resource allocation for UAV-aided disaster emergency communications" deals with the joint optimization of real-time deployment and resource allocation scheme for UAV-aided relay systems in mission-critical scenario. The authors utilize a fast K-means algorithm for user clustering model and jointly optimize the power and time transferring allocation which can be applied in the real system by using UAVs as flying base stations for real-time recovering and maintaining network connectivity during and after disasters.

The article "AoI-driven statistical delay and error-rate bounded QoS provisioning for mURLLC over UAV-multimedia 6G mobile networks using FBC" gives out a significant research on massive ultra-reliable and low latency communications (mURLLC), which is considered as a new and dominating 6G use case. This article proposes the AoI-driven statistical delay and error-rate bounded QoS provisioning schemes to efficiently support mURLLC over UAV-enabled 6G mobile wireless networks in the finite blocklength regime. The joint UAV power allocation and UAV trajectory planning are also investigated. Simulations are conducted to verify the effectiveness of the proposed scheme.

The article "A UAV-assisted ubiquitous trust communication system in 5G and beyond networks" constructs a UAV-assisted ubiquitous trusted communication system to provide trusted data collection and communication for IoT-based applications. The system contains two trust evaluation models. On the one hand, it uses UAVs to obtain baseline data and evaluates the correctness of the data uploaded by mobile data collectors (MDCs). On the other hand, the UAV distributes the data verification hash code to assist in the mutual trust assessment between MDCs. This article also proposes an algorithm for selecting winning MDCs based on incentive mechanism and conducted simulation experiments and analysis.

The article "MPC-based UAV navigation for simultaneous solar-energy harvesting and two-way communications" develops a new predictive model control over a receding horizon, which exploits the channel state information (CSI) of A2G and G2A channels at the initial point only and their statistics in all subsequent points of the receding horizon. The considered online optimization problem for the receding horizon control problem is nonconvex due to the involvement of various optimization variables. A novel rapidly converging path-following algorithm is proposed. Simulation results demonstrate that its performance matches that of the benchmark non-MPC and offline-MPC approaches.

The article "Hybrid satellite-UAV-terrestrial networks for 6G ubiquitous coverage: A maritime communications perspective" focuses on the connectivity issue in the smart ocean scenario, in which the UAVs are deployed to provide a wireless connection for vessels on the ocean. In particular, a hierarchical satellite-UAV-terrestrial network on the ocean is investigated, in which the joint link scheduling and rate adaptation problem is formulated and efficient solutions are proposed based on Min-Max transformation and iterative problem relaxation techniques.

The article "UAV-LEO integrated backbone: A ubiquitous data collection approach for B5G internet of remote things networks" focuses on the data collection in B5G IoRT networks, where the UAVs are dispatched to collect data from distributed sensors. Due to the limited caching capacity at the UAV, the data is uploaded to the low orbit satellite via the UAV-LEO link. The UAV trajectory, UAV power allocation, bandwidth allocation to IoT sensors, satellite selection methods are jointly optimized.

The article "UAV trajectory and communication co-design: Flexible path discretization and path compression" proposes a new and general framework to reduce the computational complexity for the UAV trajectory and communication co-design over the existing space or time discretization schemes. The proposed scheme is novel compared to the existing literature for UAV trajectory design, which significantly reduces the computational complexity. The fundamental communication utility approximation bound is derived for the discretization of the UAV's trajectory. Moreover, it proposes a flexible path discretization scheme and further a path compression scheme.

The article "Novel optimal trajectory design in UAV-assisted networks: A mechanical equivalence-based strategy" represents the objective function by the artificial potential field (APF), and represents the UAV trajectory by a physical rope with specific density carrying UAV speed information. Thus, the UAV trajectory design problem is transformed into a mechanical problem, which is finding the shape of the rope at the minimum of the total potential field energy. In order to find an optimal solution, mechanical characteristics are added to APF.

The article "Joint subchannel allocation and power control in licensed and unlicensed spectrum for multi-cell UAV-cellular network" considers the resource and interference management problem in a novel scenario, in which multiple UAV-BSs provide cellular services to UAV users, via reusing both licensed and unlicensed spectrum. In order to solve the considered joint problem, alternating optimization techniques are used in the article.

The article "Time and energy minimization communications based on collaborative beamforming for UAV networks: A multi-objective optimization method" uses a swarm of UAVs to collectively beamform to different base stations sequentially. Optimizing the position, speeds and current weights to minimize the total transmission and performance time. This has been done by designing a swarm intelligence algorithm capable of solving complex systems. The simulation results are compared to existing works employing similar methods.

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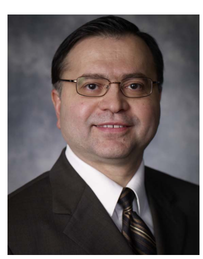

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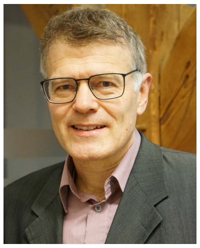

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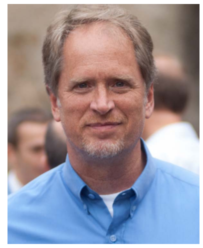

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