# UAV5GB: UAV Communications for 5G and Beyond

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***Abstract*—This editorial sums up relevant topics on recent developments for enabling UAV-assisted and cellular-connected UAV communications covered by five presentations at the track entitled "UAV5GB: UAV Communications for 5G and Beyond". The topics include the assessment of the viability of cellular-connected UAV communications, the latest advances on precise characterization of the electromagnetic signal propagation for that kind of scenarios, and applications for sensing and location of transmitting sources, which are all declared scenarios of interest for 5G and Beyond (B5G) systems. The contents in this session are of utmost relevance for the practical development of a reliable, scalable and safe technology to give support to UAV communications and the broad scope of applications associated to them.**

## I. Introduction

Due to the decrease in the cost and size, Unmanned Aerial Vehicles (UAVs) are being more accessible for general-purpose civil and commercial applications, such as search and rescue operations, precision farming and transportation, among others. Most of the mentioned applications rely on a stable Air-to-Ground (A2G) communications link between a ground Base Station (BS) and the UAV. For example, they can be exploited as aerial base stations to quickly provide wireless connections for rescue after disasters or be utilized as relays to enable energy-efficient sensing by leveraging the nearly LoS (Light of Sight) radio channels between UAV relays and ground sensors. Meanwhile, UAVs are becoming a new type of user equipments (UEs) in cellular networks. UAV communications can imply different kinds of traffic, such as the one for control signaling and safety-related communications and that for non-critical data transmission, which exhibit very different requirements in terms of throughput, end-to-end delay and Quality of Service (QoS). It is expected that ultra-reliable command and control (C2) communication links for beyond visual-LoS missions and high-throughput uplink communication links for, e.g., video streaming can be enabled for UAV-UEs.

The above use cases, among others, are closely related to the vision of 5G and beyond (B5G) communications either utilizing UAVs to assist the enhanced mobile broadband (eMBB), massive machine-type communications (mMTC), and ultra-reliable and low latency communications (URLLC); or providing these fancy services to UAVs. However, there are many challenges to be tackled.

Although the nearly-LoS links are favorable for UAVs, leading to high received power values, UAVs can in turn cause severe interferences to the ground UEs or other UAVs in the air. This motivates the necessity of designing sophisticated scheduling, interference management and power control schemes, etc. On the other hand, UAVs usually have limited battery life. Thus, it is important to maximize the energy usage efficiency as much as possible via, e.g., flight trajectory optimization, coordination, more efficient communication schemes, etc. Moreover, novel technologies, such as millimeter waves (mmWave), massive multiple-input-multiple-output (MIMO) and large intelligent surfaces (LIS) can provide UAVs with a higher level of integration in the B5G global communication scope. Hence, in this special track, we focus on recent developments in enabling various UAV-assisted and cellular-connected UAV communications or added value UAV applications.

## II. Submissions

When one talks about design or evaluation of communication systems, the channel modeling is always the basis to start with. Channel modeling is not only essential for the design and optimization of transceivers, but also for network deployments planning. When a new scenario or application is under study, its inherent propagation characteristics may be carefully studied, giving especial relevance to the empirical results. Hence, this special track starts revisiting the propagation characteristics for low-height A2G and Air-to-Air (A2A) communications.

Cai et.al [4] complete the small-scale part of the A2G channel characterization by analyzing the delay, Doppler frequency and complex amplitude of the channel Multi-Path Components (MPCs) by means of a High-Resolution Parameter Estimation (HRPE) method. Based on the obtained estimates, the fast-fading characteristics of the propagation channel are investigated, and corresponding statistical models are proposed. It was found, by analyzing actual captured data in a suburban scenario, that the Rician distribution represents a good model for the fast fading in more than 70% of the cases and that large Ricean K-factors are ensured in general. However, the provided results also show that, different from the common belief, the A2G channel does not always become more LoS-alike with larger flight heights, especially for suburban or urban scenarios.

Song et.al. [5] focus on the system-level modeling and analysis of ultra-dense UAV-to-UAV communications. In particular, a bounded path-loss model is introduced to avoid the singularity issue created by conventional power decaying unbounded path-loss model. With aid of the analytical tools behind stochastic geometry and point processes, a tractable mathematical framework of coverage probability and capacity is proposed for system-level analysis and optimization. Furthermore, a closed-form formulation of coverage probability is provided to gain further insights under the impact of different system parameters. The analytical results are verified and in a good agreement with Monte-Carlo simulations.

The propagation channel characterization results like those in [4], [5] are of utmost relevance for the design and optimization of transmission techniques and for network planning. However, the realistic evaluation of current communication systems requires much more than an accurate characterization of the propagation at link level. The communication protocols themselves impact noticeably the overall performance of large-scale wireless networks. Moreover, the BSs can use cooperative strategies among them. This way, the entire system needs to be evaluated as a whole, taking into account both the network deployments and the users, since the communication resources are shared among users and hence one user impacts the others. In [2], Fiebig proposes a realistic communication scenario, supported by data, in which thousands of UAVs are autonomously flying in the scope of typical medium-sized cities. By presenting an analogy with the current car usage pattern and the controlling mechanisms for commercial aviation nowadays, it shows that manual controlling systems are not feasible for this application. Hence, based on simplified yet still realistic data, the author proposes a de-centralized control system for scenarios with massive UAVs. The range for the de-centralized communications, as well as the number of simultaneous users to be considered for each UAV for the communication, is considered and it is suggested that even the current technology could afford such a scenario.

However, especially talking about communications related with flight control or safety-related procedures, stringent reliability and latency requirements have to be met. In plain words, it is not only necessary that a message arrives the receiver, but it needs to arrive on time. The requirements for different kind of UAV communications, such as the payload-oriented ones and those involving critical data transmission, are well established by the 3GPP in terms of availability, end-to-end delay and throughput. However, the evaluation of these kind of figures of merit, especially the end-to-end delay, leads to complex simulations involving the consideration of not only the direct link (i.e., that from the transmitter to the receiver), but also the feedback one (from the receiver to the transmitter) and the whole implementation of the communications protocol at both ends of the communication chain. In [1], Zhu et.al propose a way of reducing the cost and complexity of this kind of evaluations. Firstly, the end-to-end delay, the packet success rate and the throughput of A2G communications for UAVs are evaluated based on realistic channel models obtained from a measurement campaign. The measurement campaign, conducted in a suburban environment, includes both Line-of-Sight (LoS) and Obstructed Line-of-Sight (OLoS) scenarios. From the results, it can be seen that architectural elements close to the flight route can severely decrease the communications performance even when the visibility between the BS and the UAV is permanently ensured. Most importantly, the authors show that that the Quality of Service (QoS) requirements for critical communications proposed by 3GPP can be fulfilled by establishing a threshold on the received Signal-to-Interference and Noise Ratio (SINR). This way, the SINR can be used as a condensed performance metric for the design of safe flight routes for critical communications for UAVs. This severely reduces the cost of assessment of UAV communications since it does not require to consider the evaluation of the feedback link.

Finally, it must be noted that, with the last advances of the communication systems, paving the road for the B5G, especial relevance is given to the joint communication and environment sensing by using a single signal. In other words, more interest is given in taking advantage of the communication signal itself for environment sensing purposes. In particular, localization technology based on Direction of Arrival estimation is proved to be promising for UAV channel due to limited angular spread in the air. In [3], Chen et.al propose a method to estimate the direction of a ground radio frequency transmitter by using an UAV equipped with a single antenna, which is critical when considering the form factor and computational capabilities of a UAV. By considering the received signal at several points along its trajectory, the receiver implicitly creates a virtual multi-antenna array, which can be used to estimate the direction of the transmitter. The authors need to face technical challenges such as accurately estimating the relative positions of the UAV and compensate the offset between the local oscillators of the transmitter and receiver, which adds an additional cumulative phase offset to the received signal at each antenna of the virtual array. The provided simulation results show the feasibility of the proposals of the authors.

## III. Final Remarks

The “UAV5GB: UAV Communications for 5G and Beyond” special track, included in the 17th International Conference on Wireless and Mobile Communications (ICWMC 2021), focuses on recent developments in enabling various UAV-assisted and cellular-connected UAV communications, as well as added value UAV applications. Different from most of the sessions focused on UAV communications, these are not considered solely from the propagation point of view, but a whole picture of the needs and a technical analysis of the feasibility of the solutions is given.

This way, two contributions are provided to characterize both the large-scale [5] and small-scale [4] propagation characteristics for UAV communications; whereas other two contributions study the feasibility of communications on massive scenarios [2] and for critical and safety-related communications [1]. Furthermore, with the aim of considering the latest needs for B5G communications, a methodology for environment sensing from a flying UAV is provided in [3].

We believe that the technical contributions presented in this special track will pave the road for the development of reliable, scalable and safe technologies to give support to UAV communications in the scope of B5G for the next few years.

## REFERENCES


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