Coexistence of Drone and Terrestrial Networks




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While drones have found use in military applications for decades, they have recently entered the commercial application arena, with substantial market investments coming up over the next decade. They are prevalent in application domains like public safety, surveillance, package/goods delivery, and first responders, to name a few. They are being seen as wireless services on the fly that can augment or complement the capabilities of the current terrestrial wireless communication networks. Drones require a radio frequency spectrum to connect and communicate with the ground base stations, irrespective of the underlying application. Terrestrial wireless networks can support low-altitude drone communications and can thereby help improve the reliability, security, and safety of drone operations. However, transmission from drones to terrestrial networks has the potential to interfere with a large number of terrestrial nodes because of their larger coverage footprint. This leads to a plethora of research challenges related to the coexistence of drone and terrestrial networks. Primarily, we need to understand the rules and regimes under which it makes sense for drone networks to share spectrum with terrestrial networks. Likewise, it is also essential to study situations in which it will be suitable for drones to operate over licensed frequency bands. Therefore, even though integrating drones with terrestrial networks is inevitable and will likely inspire a new suite of applications, many challenges must be tackled before this becomes a reality. For example, existing cellular networks were not designed or optimized to serve or support aerial devices, which demands a significant rethinking in the design and operation of these networks if we are to support these new aerial services reliably.

Looking into the complex nature of these challenges, we envisioned this Special Issue (SI) to provide a platform for the researchers related to different sectors (e.g., academia, industry, and government) to submit their latest research ideas and case studies focused on the coexistence of drone and terrestrial networks. This Special Issue of *IEEE Wireless Communications* is aimed at showcasing and highlighting the critical open research dimensions and future directions on the coexistence of drone and terrestrial networks. The Call for Papers received a good response from the research community with 33 high-quality submissions, further supporting the need for attention to the critical challenges in this research area. After passing through a multi-phase and highly competitive peer review process, we have accepted five high-quality papers that were foreseen to depict their research practicality and merits over time while being particularly relevant for our current readership. Therefore, the acceptance rate for this special issue was about 15 percent. A summary of all the accepted articles is presented here.

In the first article, "Deep Reinforcement Learning Assisted Spectrum Management in Cellular-Based Urban Air Mobility," Han *et al.* focus on cellular-based urban air mobility (cUAM), which can support reliable air-ground communications in urban air transportation. First, the authors introduce communication requirements and highlight spectrum management challenges. Then deep reinforcement learning is proposed for spectrum management in cUAM to minimize mission completion time. Extensive experiments clearly demonstrate the benefits of the proposed spectrum sharing optimization with significantly lower mission completion time than the baseline.

The second article, "Opportunities for Physical Layer Security in UAV Communication Enhanced with Intelligent Reflective Surfaces" by Khan *et al.*, discusses the opportunities related to the adoption of the intelligent reflective surface (IRS) to extend/enhance wireless coverage through reconfiguration of the propagation environments. In this article, the authors discuss various aspects concerning the use of IRS for improving the physical layer security of unmanned aerial vehicle (UAV) networks. Further, different use cases related to physical layer security for IRS-supported UAV communications are also discussed in the article. A case study is also presented that focuses on maximizing the UAV environment's secrecy capacity in this setting. Finally, various open research directions and potential challenges concerning IRS-improvised UAV communications are highlighted.

In the third article, "AI-Based Energy-Efficient UAV-Assisted IoT Data Collection with Integrated Trajectory and Resource Optimization," Haider *et al.* propose a data gathering and optimal scheduling paradigm assisted by UAVs for intelligent farms. This paradigm considers a hybrid optimization technique based on lion mated with cats optimization (LMCO) and cat-mouse-based optimization. In this technique, the UAV creates a collision-free path using the optimization algorithm that enables data collection from all clusters in a specific region. The proposed model is validated by using simulations based on several performance metrics.

The fourth article, "Near Space Communications: A New Regime in Space-Air-Ground Integrated Network" by Xiao *et al.*, presents a comprehensive overview of the near-space communication (NS-COM) network for next-generation space-air-ground integrated network (SAGIN). First, the authors compare NS-COM with the existing terrestrial cellular networks, followed by a discussion on the current state of development of NS-COM. This is followed by exploring the unique attributes of NS-COM platforms and propagation systems for near space. The authors identify the main limitations concerning NS-COM and then explore the possible application scenarios of NS-COM con-

cerning different considerations. The coexistence of NS-COM and ground networks as interferers or collaborators is also discussed in this article. Finally, various technologies for NS-COM based on spectrum usage are highlighted, alongside exploring the potential technical challenges for future research.

In the last article, "Blockchain and AI Enabled Configurable Reflection Resource Allocation for IRS-Aided Coexisting Drone-Terrestrial Networks," Pan *et al.* propose a configurable mechanism based on blockchain and artificial intelligence (AI) to provide a secure intelligent reflecting surface (IRS) reflection resource allocation for coexisting drone-terrestrial networks (CDTNs). In this mechanism, a drone-mounted IRS is first used to enhance *spatial freedom* for data transmission. Then the transactions for allocation are designed using a hierarchical blockchain structure for resource trading. Finally, deep reinforcement learning is used to configure the reflection coefficient and assign intelligent reflection elements. The experimental evaluations are used to verify the validity of the proposed mechanism, followed by a discussion on the key challenges and open directions in the research domain.

We would like to convey our gratitude to all the authors (irrespective of whether their papers were accepted or rejected) for their high- quality submissions that made this Special Issue a success. We would also like to acknowledge the contributions of highly qualified reviewers who participated in the multi-round review process voluntarily and gave their constructive feedback. Without their support, it would not have been possible to wrap up this Special Issue in such a tight timeline. We are also grateful to the former Editor-in-Chief, Professor Yi Qian, and the current Editor-in-Chief, Professor Nirwan Ansari, for understanding the importance of this timely topic and allowing us to organize this Special Issue, and for their continuous support and guidance throughout the review process. Last but not the least, we would like to thank the administrative staff of the magazine for their timely support since the inception of this Special Issue. We hope that this Special Issue will be useful for our research community. In particular, we hope that this will contribute to the ongoing dialogue on the multitude of research problems related to the coexistence of drone and terrestrial networks.

Biographies

Gagangeet Singh Aujla [SM] (gagangeet.s.aujla@durham.ac.uk) is an assistant professor of computer science at Durham University, United Kingdom, and a Fellow of the Durham Energy Institute. He received his Ph.D. in computer science and engineering from Thapar Institute of Engineering and Technology, Patiala, Punjab, India, in 2018. He received his B.Tech and M.Tech. degrees in computer science and Engineering from Punjab Technical University, Jalandhar in 2003 and 2013, respectively. He was awarded the 2018 IEEE TCSC Outstanding Ph.D. Dissertation Award of Excellence. He is the recipient of the 2021 *IEEE Systems Journal* Best Paper Award. He received the 2022 IEEE TCSC Award of Excellence (Early Career Researcher). Some of his research findings have been published in top cited publications such as the *IEEE TKDE*, *IEEE TDSC*, *IEEE Transactions on Vehicular Technology*, *IEEE TITS*, *IEEE TSC*, *IEEE TCC*, *IEEE TNSM*, *IEEE TII*, *IEEE TGCN*, *IEEE TSuSC*, the *IEEE Journal on Selected Areas in Communications*, the *IEEE Internet of Things Journal*, and the *IEEE System Journal*. He has also published his vision articles in top magazines including *IEEE Wireless Communications*, *IEEE Communication Magazine*, *IEEE Network*, *IEEE Internet Computing*, and *IEEE Consumer Electronics Magazine*. His work has been published in the top-tier conferences such as IEEE WOWMOM, ACM Mobicom Workshops, ACM MobiHoc Workshops, IEEE INFOCOM Workshops, IEEE GLOBECOM, IEEE ICC, IEEE WiMob, and IEEE IC2E, among others. He is leading several workshop series (BlockCPS, BlockSecSDN) in conjunction with top conferences like IEEE INFOCOM, IEEE GLOBECOM, IEEE ICC, IEEE/ACM UCC, and IEEE/ACM CCGrid. He is the Co-Secretary, IEEE UK and Ireland Diversity, Equality and Inclusion Committee. He is an Area Editor for *Ad Hoc Networks* (Elsevier) and an Associate Editor of *IET Smart Grid* and *Frontiers in Internet of Things*. He is a Member of the ACM.

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