Integrated Sensing and Communications for 6G


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6G networks have been envisioned as key enablers for numerous emerging applications, including smart cities and homes, intelligently connected vechiles, smart manufactoring, and industrial Internet-of-Things (IoT). These applications require both extreme wireless connectivity as well as highly accurate and reliable sensing capability. Indeed, among many 6G visions, a common theme is that sensing will play a more significant role than ever before. By equipping wireless systems with the sensing functionality, 6G networks will go beyond classical communication and provide ubiquitous sensing services to measure, or to image, surrounding environments. This sensing functionality and the corresponding ability of the network to collect sensory data from the environment are seen as the foundation for building intelligence in the future smart world. Toward that end, there is a strong need to jointly design sensing and communication operations in 6G networks, which motivates the recent research of Integrated Sensing and Communications (ISAC).

Technological trends are now driving ISAC into a reality. With recent developments, the combined use of large-scale antenna arrays and Millimeter Wave (mmWave)/Terahertz (THz) band signals results in a striking resemblance between sensing and communications systems in terms of the hardware architecture, channel characteristics, and signal processing algorithms. Hence, the boundary between sensing and communications is becoming blurred, and the hardware and spectrum convergence has led to a design paradigm shift, where the two systems can be co-designed for efficiently utilizing resources, offering tunable trade-offs between them, and introducing unprecedented synergies between them to enable mutual benefits. On one hand, integrating radio sensing into wireless communications endows native sensing capability to ubiquitous IoT devices and cellular infrastructures in a fast and economical manner. On the other hand, multi-modal sensory data can be used to extract important information, such as the relative locations of communication devices, which can improve communication performance.

In light of the recent growing research interests in ISAC, we envisioned this special issue (SI) to provide a platform for the researchers, industry practitioners, and individuals working on the related areas to share their new ideas, latest findings, and state-of-the-art results. The call for papers (CFP) led to a strong response from the research community with 26 high-quality submissions in total. After passing through a multiphase and highly competitive peer review process, and given the limited available slots and tight publication schedule, we have accepted six high-quality papers for publication. Therefore, the acceptance rate is about 23 percent. A summary of all the accepted articles is presented here:

In the first article, "Collaborative Sensing in Perceptive Mobile Networks: Opportunities and Challenges," Xie *et al.* provides a comprehensive overview on the design of perceptive mobile networks (PMNs), which incorporate accurate sensing capability into existing wireless networks. The article covers various facets of PMNs, including the popular network architectures, sensing protocols, standing research problems, and available solutions. Finally, several future research directions that are critical for the development of PMNs are identified and discussed.

The second article, "Self-Adaptive RISs Beyond Free Space: Convergence of Localization, Sensing and Communication under Rich-Scattering Conditions" by Saigre-Tardif *et al.*, discusses the need for a confluence of localization, sensing, and communications for the future important 6G deployment scenarios where the reconfigurable intelligent surfaces (RISs) are to be deployed in a self-adaptive manner in the dynamically evolving rich scattering settings. The authors pointed out that in such problems, the rich scattering wireless channels are subject to highly nonlinear deterministic double parametrization through both the RIS and uncontrolled moving objects. The article illustrates the essential steps for operating a self adaptive RIS under such environments, and reveals that self adaptive RIS's outperform their context-ignorant counterparts below certain noise thresholds.

In the third article, "Over-the-Air Integrated Sensing, Communication, and Computation in IoT Networks," Li *et al.* proposes a novel technique that combines the ISAC and over the air computation (AirComp), namely, over the air integrated sensing, communication, and computation (Air-ISCC). The proposed Air-ISCC approach is able to facilitate the development of IoT services in a highly efficient manner, through collecting data via the wireless network, and passing it to the server for further processing. This article introduces the fundamentals and advanced techniques of the Air-ISCC, and identifies a number of potential applications.

The fourth article, "Multi-Domain Cooperative SLAM: The Enabler for Integrated Sensing and Communications" by Yang *et al.*, focuses on implementing the simultaneous localization and mapping (SLAM) through the deep integration between sensing and advanced communication networks with ultra wide band, multiple antennas, and massive connections. The article presents efficient mechanisms for cross-sensing, cross-user, cross-frequency, and cross-device SLAM. It also discusses research opportunities and challenges in such a multi-domain SLAM context. The authors prove that the multi-domain SLAM may considerably improve the accuracy of localization and mapping in complex multipath propagation environments through both numerical and experimental results.

In the fifth article, "Integrated Sensing and Communication with Reconfigurable Intelligent Surfaces: Opportunities, Applications, and Future Directions," Liu *et al.* provides an overview on RIS-assisted ISAC, with a particular focus on the potential of deploying RIS to improve the sensing performance and enhance the tradeoff between communication and sensing. The article first reviews the fundamentals of RIS and its applications in conventional systems, and then overviews existing contributions on RIS-assisted ISAC, followed by a case study to verify the superiority of using RIS in ISAC systems. Finally, several open challenges and future directions in this research area are presented.

The last article, "Toward Trusted and Swift UAV Communication: ISAC-Enabled Dual Identity Mapping" by Cui *et al.*, discusses the intersection of ISAC and the future intelligent and efficient UAV network. The authors first describe the motivating scenario and present a novel framework of ISAC-enabled dual identity solution, followed by the detailed analysis on the identity production, mapping, management, and authentication. On top of that, three typical applications of the proposed approaches are further elaborated. Finally, a series of key enabling techniques, open challenges, and potential solutions of ISAC-enabled dual-domain identity are presented.

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Biographies

Christos Masouros [SM] (chris.masouros@ieee.org) received his degree in Electrical and Computer Engineering from the University of Patras, Greece, in 2004, M.Sc. by research, and Ph.D. in Electrical and Electronic Engineering from the University of Manchester, UK in 2006 and 2009, respectively. In 2008, he was a research intern at Philips Research Labs, UK. Between 2009–2010, he was a research associate in the University of Manchester, and between 2010–2012, a research fellow in Queen's University Belfast. In 2012, he joined University College London as a lecturer. He has held a Royal Academy of Engineering Research Fellowship between 2011–2016. Since 2019, he has been a Professor of Signal Processing and Wireless Communications in the Information and Communication Engineering research group, Dept. Electrical and Electronic Engineering, and affiliated with the Institute for Communications and Connected Systems, University College London. His research interests lie in the field of wireless communications and signal processing with particular focus on Green Communications, Large Scale Antenna Systems, Integrated Sensing and Communications, interference mitigation techniques for MIMO, and multicarrier communications. He was the co-recipient of the 2021 IEEE SPS Young Author Best Paper Award. He was the recipient of the Best Paper Awards in the IEEE GlobeCom 2015 and IEEE WCNC 2019 conferences, and has been recognized as an exemplary editor for the *IEEE Communications Letters*, and as an exemplary reviewer for the *IEEE Transactions on Communications*. He is an editor for *IEEE Transactions on Communications*, *IEEE Transactions on Wireless Communications*, the *IEEE Open Journal of Signal Processing*, and an editor-at-large for *IEEE Open Journal of the Communications Society*. He has been an associate editor for *IEEE Communications Letters*, and a guest editor for a number of *IEEE Journal on Selected Topics in Signal Processing* and *IEEE Journal on Selected Areas in Communications* issues. He is a founding member and vice vhair of the IEEE Emerging Technology Initiative on Integrated Sensing and Communications, vice chair of the IEEE Special Interest Group on Integrated sensing and communications (ISAC), and chair of the IEEE Special Interest Group on Energy Harvesting Communication Networks.

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