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Special Issue on Integrated Sensing and Communications

The 6G networks are anticipated to be instrumental in powering a wide array of upcoming applications, including smart cities and homes, interconnected vehicles, intelligent factories, and the industrial Internet of Things (IoT). These applications need advanced wireless connectivity and robust, precise sensing abilities. A consistent aspect of future 6G plans is the increased importance of sensing, set to play an unprecedented role. By incorporating sensing capabilities, 6G networks will expand beyond traditional communication boundaries, offering pervasive sensing services to analyze and potentially map out the environments they operate in. This capability to collect environmental sensory data is seen as essential for nurturing intelligence in the upcoming era of smart environments. This necessitates a concurrent focus on developing communication and sensing technologies within 6G networks, which has prompted recent explorations in integrated sensing and communications (ISAC).

Technological advances are propelling ISAC toward practical application. Recent innovations in using expansive antenna arrays and signals in the millimeter-wave/terahertz bands are aligning the structural, channel, and processing characteristics of sensing and communication systems closer than ever. This evolution is diminishing the distinctions between these two domains, leading to a unified hardware and spectrum use that encourages a shift in design strategy. This strategy promotes the co-design of sensing and communication systems to efficiently leverage resources, balance functional tradeoffs, and foster synergies that benefit both fields. Integrating sensing with wireless communication networks equips IoT devices and cellular infrastructures with essential sensing functions swiftly and affordably. Conversely, gathering various types of sensory data helps pinpoint the precise locations of communication devices, thereby boosting the performance of communications.

Given the recent surge in interest in ISAC, this special issue (SI) is established as a forum for researchers, industry experts, and practitioners in related fields to share their innovative ideas, recent discoveries, and cutting-edge results. The call for articles attracted a robust turnout, yielding 33 high-quality submissions. These submissions underwent a rigorous, multistage peer review process. Due to the limited number of available spots and a stringent publication timeline, we ultimately selected seven outstanding articles for inclusion in this issue. We provide summaries of each of the articles that were accepted.

In the first article [A1], Yang et al. discuss the development of ISAC channel models and measurement methodologies for 6G networks. They highlight the need for new ISAC-specific channel models that can account for both communication and sensing functionalities within a single framework. This includes a novel ISAC channel model that integrates deterministic multiscattering-center models of sensing targets with stochastic propagation models. The article also details two channel measurement approaches, one using a vector network analyzer and another based on a dual-sensor system, aimed at supporting future 6G standardizations.

In the second article [A2], Liu et al. also concentrate on channel modeling of ISAC and highlight the need for hybrid channel models that can handle the complex requirements of ISAC. These models must account for various elements such as targets, clutter, and interference to effectively simulate real-world scenarios. The article also suggests performance enhancement methods using real-time 3D environment reconstruction and artificial intelligence to improve the accuracy and efficiency of channel models. The goal is to support the dynamic and high-precision requirements of future wireless networks, enabling more effective planning and operation of 6G systems.

In the third article [A3], Hamidi-Sepehr et al. explore the integration

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of radar sensing capabilities into cellular networks, particularly focusing on the Open Radio Access Network (O-RAN) architecture. It introduces a framework for analyzing the radio and signal processing techniques necessary to embed sensing functions within the RAN, addressing the specific needs for fronthaul throughput and the functional split between the radio unit and the distributed unit. The feasibility of incorporating wideband sensing across disjoint bandwidths within this framework is demonstrated, showing potential for enhanced detection performance in applications like smart transportation and intelligent cities.

In the fourth article [A4], Wan et al. focus on the emerging field of multiband sensing for ISAC systems, particularly using orthogonal frequency division multiplexing-based signals across multiple noncontiguous bands to enhance resolution and performance. They introduce the multiband signal model and discuss how phase distortions affect sensing accuracy, requiring careful calibration. The article outlines the resolution limits of multiband sensing, showing how additional frequency bands can improve sensing resolution beyond single-band capabilities. It also reviews various algorithmic approaches to optimize multiband sensing and identifies open challenges and future directions in the field, highlighting the need for further research on robustness against interference and the potential benefits of machine learning in multiband ISAC systems.

In the fifth article [A5], Zhang et al. propose the design of perceptive mobile networks (PMNs) for effective unmanned aerial vehicle (UAV) surveillance. They highlight the utility of cooperative sensing among interconnected base stations (BSs) to enhance surveillance accuracy by overcoming limitations like network clutter and sensing coverage. The challenges addressed include ensuring extensive sensing coverage, managing interference from network clutter, and balancing the tradeoffs among communication and sensing functionalities. Additionally, the article outlines strategies for cooperative sensing, emphasizing spatial diversity gains from multiple BSs and proposing future directions to further refine UAV surveillance through PMNs.

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In the sixth article [A6], Zhang et al. discuss the integration of communication, sensing, and computing within space-air-ground integrated networks to enhance the QoS across various user applications. They present a new system architecture and handover procedure that considers the joint capabilities of these networks, aiming to provide seamless global connectivity. The approach includes designing QoS-aware handover selection schemes that account for end-to-end latency, communication rate, sensing accuracy, and computing capability. Simulation results are provided to demonstrate the effectiveness of the proposed handover strategies, and several open research challenges are identified, highlighting areas for further exploration in integrating these multifunctional networks.

In the last article [A7], Guan et al. investigate the aerial ISAC networks using UAVs to enhance 6G network capabilities. They propose a network slicing approach that optimizes the 3D positioning and bandwidth allocation of UAVs to maximize the service level agreement satisfaction ratio. This involves dynamic UAV placement and resource distribution to efficiently provide ISAC services across varying user demands and conditions. Extensive simulations validate the effectiveness of this approach in terms of resource management, cost efficiency, and energy savings, demonstrating potential improvements in both sensing and communication tasks within these complex networks.

The "From the Guest Editors" column team would like to express their sincere gratitude to all authors for their high-quality submissions and all reviewers for their precious time invested in improving the articles. The guest editors are also grateful to the editor in chief, Prof. Javier Gozalvez, for his generous support and contribution toward the organization and success of this SI. Finally, the guest editors would like to convey their gratitude to the administrative staff of the magazine for their timely support.

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Appendix: Related Articles

[A1] W. Yang et al., "Integrated sensing and communication channel modeling and measurements: Requirements and methodologies toward 6G standardization," *IEEE Veh. Technol. Mag.*, vol. 19, no. 2, pp. 22–30, Jun. 2024, doi: 10.1109/MVT.2024.3383654.

[A2] T. Liu et al., "6G integrated sensing and communications channel modeling: Challenges and opportunities," *IEEE Veh. Technol. Mag.*, vol. 19, no. 2, pp. 31–40, Jun. 2024, doi: 10.1109/MVT.2024.3373930.

[A3] F. Hamidi-Sepehr, T. Hewavithana, R. Vannithamby, and A. Merwaday, "Integrating sensing into cellular systems: Architectural requirements and performance enhancements," *IEEE Veh. Technol. Mag.*, vol. 19, no. 2, pp. 41–50, Jun. 2024, doi: 10.1109/MVT.2024.3382831.

[A4] Y. Wan, Z. Hu, A. Liu, R. Du, T. X. Han, and T. Q. S. Quek, "OFDM-based multiband sensing for ISAC: Resolution limit, algorithm design, and open issues," *IEEE Veh. Technol. Mag.*, vol. 19, no. 2, pp. 51–59, Jun. 2024, doi: 10.1109/MVT.2024.3368205.

[A5] Y. Zhang, H. Shan, H. Chen, D. Mi, and Z. Shi, "Perceptive mobile networks for unmanned aerial vehicle surveillance: From the perspective of cooperative sensing," *IEEE Veh. Technol. Mag.*, vol. 19, no. 2, pp. 60–69, Jun. 2024, doi: 10.1109/MVT.2024.3373931.

[A6] Y. Zhang, J. Wang, Q. Li, J. Chen, H. Feng, and S. He, "Joint communication, sensing and computing in space-air-ground integrated networks: System architecture and handover procedure," *IEEE Veh. Technol. Mag.*, vol. 19, no. 2, pp. 70–78, Jun. 2024, doi: 10.1109/MVT.2024.3371420.

[A7] Y. Guan, Q. Song, T. Chen, W. Qi, L. Guo, and A. Jamalipour, "Slicing-aware aerial networks for integrated sensing and communication: 3D placement and adaptive allocation of resource," *IEEE Veh. Technol. Mag.*, vol. 19, no. 2, pp. 79–88, Jun. 2024, doi: 10.1109/MVT.2024.3372509.

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