Guest Editorial >>>

Special Topic on Integrated Sensing and Communication (ISAC) Technologies for Future Wireless Communication

Guest Editors

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The radio communication division of the International Telecommunication Union (ITU-R) has recently adopted Integrated Sensing and Communication (ISAC) as a key usage scenario for IMT-2030/6G. The synergy of these two functionalities can facilitate a wide array of applications such as autonomous driving, smart cities, and industrial automation, where simultaneous data transmission and environmental sensing are crucial. The rationale of the ISAC is that a radio emission can simultaneously convey communication data from the transmitter to the receiver and extract environmental information from the scattered echoes. From a research perspective, ISAC opens new avenues for innovation in signal processing, hardware design, and network architecture, facilitating efficient utilization of system spectrum/power/hardware resources and pursuit of mutual benefits. It is anticipated that ISAC can improve spectral efficiency, reduce hardware costs, and enhance overall system capabilities. Despite the promising advantages above, ISAC imposes unique technical challenges on future wireless communications, including the dual-functional signaling strategy, the low-complexity sensing and communication reception technique, the potential resource management and protocols tailored for the ISAC network, the information-theoretic limits of ISAC, etc.

The call-for-paper of this special issue has attracted high-quality submissions. After two-round reviews, eight papers are presented to address some of the aforementioned challenges, and innovative solutions to facilitating the ISAC technology are proposed. These papers cover a wide range of topics, including the signaling design, resource allocation design, and reception algorithm design.

The first paper titled "Kullback-Leibler Divergence Based ISAC Constellation and Beamforming Design in the Presence of Clutter" presents a novel approach to constellation and beamforming design for ISAC systems in the presence of clutter, employing the Kullback-Leibler divergence (KLD) as the unified ISAC performance metric. The constellation design problem is solved via the successive convex approximation (SCA) technique, while the optimal beamforming in terms of sensing KLD is proven to be equivalent to maximizing the signal-to-interference-plus-noise ratio (SINR) of echo signals. The proposed scheme achieves significant clutter suppression and higher SINR of echo signals compared with the conventional schemes.

The second paper titled "Joint Beamforming Design for Dual-Functional Radar-Communication Systems Under Beampattern Gain Constraints" proposes a joint beamforming design to maximize the sum rate of multi-user communication while ensuring the beampattern gain at specific sensing

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angles of interest under the transmit power budget constraint. Utilizing fractional programming and semidefinite relaxation, the study introduces an iterative algorithm that balances the performance of both communication and sensing. The results demonstrate significant performance gain in terms of communication sum rate and radar detection capability.

The third paper titled "On Normalized Least Mean Square Based Interference Cancellation Algorithm for Integrated Sensing and Communication Systems" addresses the co-site interference issue for practical ISAC systems by proposing an interference cancellation scheme using a normalized least mean square (NLMS) algorithm. The scheme reconstructs the interference from the local transmitter and cancels it from the received signal. The proposed NLMS algorithm effectively cancels co-site interference and achieves a good balance between computational complexity and convergence performance.

The fourth paper titled "Trajectory Tracking for MmWave Communication Systems via Cooperative Passive Sensing" proposes a cooperative passive sensing framework for millimeter wave (mmWave) communication systems and demonstrates it in the presence of a mobile signal blocker. A gradient-descent-based algorithm is proposed to track the blocker's trajectory, localize the transmitters, and detect the potential link blockage jointly. The study demonstrates that the system can achieve decimeter-level localization and trajectory estimation, and predict the blockage time with an error of less than 0.1 s.

The fifth paper titled "Integrated Sensing and Communication: Who Benefits More?" examines the benefits of communication-assisted sensing and sensing-assisted communication in the context of ISAC. The paper reveals that communication-assisted sensing may offer greater development potential due to the wide coverage and cost-effectiveness of wireless infrastructure in a large range of applications. As an instance, the paper presents a channel knowledge map (CKM)-assisted beam tracking scheme and demonstrates the practical advantages of incorporating CKM in enhancing beam tracking accuracy.

The sixth paper titled "Low-Complexity Integrated Super-Resolution Sensing and Communication with Signal Decimation and Ambiguity Removal" introduces a low-complexity method for super-resolution sensing based on communication signals. The proposed scheme performs signal decimation in the frequency domain to reduce the computational complexity and uses the collocated subcarrier data to remove the pseudo peaks due to range ambiguity. The proposed scheme reduces computational complexity by two orders of magnitude while maintaining the range resolution and unambiguity.

The seventh paper titled "Tensor Decomposition-Based Channel Estimation and Sensing for Millimeter Wave MIMO-OFDM V2I Systems" utilizes tensor decomposition techniques for channel estimation and sensing in millimeter-wave MIMO-OFDM vehicle-to-infrastructure (V2I) systems. A CANDECOMP/PARAFAC (CP) decomposition-based method is proposed for time-varying channel parameter extraction and then a nonlinear weighted least-square problem is proposed to accurately recover the location, heading and velocity of vehicles. The proposed methods are effective and efficient in time-varying channel estimation as well as vehicle sensing in mmWave MIMO-OFDM V2I systems.

The eighth paper titled "Sensing and Communication Integrated Fast Neighbor Discovery for UAV Networks" addresses the challenge of fast neighbor discovery in UAV networks through integrated sensing and communication. The learning automata (LA) is applied to interact with the environment and continuously adjust the probability to select beams to accelerate the convergence speed of ND algorithms. The method reduces the neighbor discovery (ND) time by up to 32% compared with the conventional scan-based algorithm (SBA).

To conclude, the papers presented in this special issue underscore some fundamental challenges of ISAC technology for future wireless communication systems. The diverse research contributions provide valuable insights and innovative solutions, serving as a valuable resource for researchers, practitioners, and students who are interested in ISAC. We also hope this special issue inspires further research and collaboration in this exciting and rapidly evolving field. Finally, we would like to express our sincere gratitude to all the authors and reviewers who have contributed to the success of this special issue.

Biographies

YUAN Jinhong received his BE and PhD degrees in electronics engineering from Beijing Institute of Technology, China in 1991 and 1997, respectively. From 1997 to 1999, he was a research fellow at the School of Electrical Engineering, University of Sydney, Australia. In 2000, he joined the School of Electrical Engineering and Telecommunications, The University of New South Wales, Australia, where he is currently a professor and the Acting Head of the School. He has published two books, five book chapters, over 300 papers in telecommunications journals and conference proceedings, and 50 industrial reports. He is a co-inventor of one patent on MIMO systems and four patents on low-density-parity-check codes. His current research interests include error control coding and information theory, communication theory, and wireless communications. He has coauthored four Best Paper Awards and one Best Poster Award, including the Best Paper Award from the IEEE International Conference on Communications, Kansas City, USA in 2018, the Best Paper Award from IEEE Wireless Communications and Networking Conference, Cancun, Mexico in 2011, and the Best Paper Award from the IEEE International Symposium on Wireless Communications Systems, Trondheim, Norway in 2007. He served as the IEEE NSW Chapter Chair of Joint Communications/Signal Processing/Ocean Engineering Chapter from 2011 to 2014 and served as an associate editor for the *IEEE Transac-*

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FEI Zesong received his PhD degree in electronic engineering from Beijing Institute of Technology (BIT), China in 2004. He is currently a professor with the Research Institute of Communication Technology, BIT. His research interests are in the area of wireless communications and signal processing, including integrated sensing and communications, physical layer security, UAV communications, intelligent reflecting surface, channel coding, and multiple access. He has authored or co-authored over 200 journal and conference papers, and was the co-receipt of the Best Paper Award in WCSP 2012, Chinacom 2012, Chinacom 2013, and PIMRC 2015. He serves as an associate editor for *IEEE Open Journal of the Communications Society*.

WEI Zhiqiang received his BE degree in information engineering from Northwestern Polytechnical University (NPU), China in 2012, and PhD degree in electrical engineering and telecommunications from The University of New South Wales (UNSW), Australia in 2019. From 2019 to 2020, he was a postdoctoral research fellow with UNSW. From 2021 to 2022, he was a Humboldt postdoctoral research fellow with the Institute for Digital Communications, Friedrich-Alexander University Erlangen-Nuremberg (FAU), Germany. He is currently a professor with the School of Mathematics and Statistics, Xi'an Jiaotong University, China. He is the founding co-chair (publications) of the IEEE ComSoc special interest group on OTFS (OTFS-SIG). He received the Best Paper Award at the IEEE ICC 2018 and IEEE WCNC 2023. He was the organizer/chair for several workshops and tutorials on related topics of orthogonal time frequency space (OTFS) in IEEE flagship conferences, including IEEE ICC, IEEE WCNC, IEEE VTC, and IEEE ICCC. He also co-authored the IEEE ComSoc Best Readings on OTFS and Delay Doppler Signal Processing. He is now serving as the associate editor of the *IEEE Open Journal of the Communications Society*. His current research interests include delay-Doppler communications, resource allocation optimization, and statistic and array signal processing.