Semantic Communications for the Metaverse and Other Wireless Innovations

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First and foremost, I would like to take this opportunity to announce the 2022 Exemplary Technical Editors of IEEE Wireless Communications: Gabor Foder of Ericsson Research, Sweden, and Sukyoung Lee of Yonsei University, Korea. This recognition acknowledges their exceptional commitment to conducting timely reviews and providing constructive feedback. Their dedication and expertise in evaluating scholarly work have undoubtedly made a significant impact on the quality of our magazine. Their ability to offer valuable insights and suggestions to authors is commendable. Congratulations, Gabor and Sukyoung!

Furthermore, the elevated 2022 Impact Factor of 12.9, which continues to rank as the highest among ComSoc magazines, is the culmination of collectively contributions and unwavering efforts from readers, authors, reviewers, editors, and the ComSoc staff. This accomplishment signifies a noteworthy and meaningful progression from the prior rating of 12.777 recorded in 2021.

In this issue, we are pleased to present a timely Feature Topic: a collection of five articles on "Semantic Communications for the Metaverse," organized by guest editors Jiayi Zhang, Jiangtian Nie, Jiangming Jin, Tao Han, Dong In Kim, and Petar Popovski. For more details, please refer to the guest editorial and individual articles.

We are also delighted to include 15 articles from the open call, covering a diverse range of topics in the field of wireless communications systems, from mmWave Communications and Terahertz Communications to graphene-based wireless interconnects. Notably, two articles, "Realizing the Metaverse with Edge Intelligence: A Match Made in Heaven" and "The Roadmap of Communication and Networking in 6G for Metaverse," fall within the scope of the above Feature Topic, and are thus included in the Feature Topic.

Among the remaining 13 articles, the first four articles delve into mmWave Communications.

In the first article, "Beam Squint in Ultra-wideband mmWave Systems: RF Lens Array vs. Phase-Shifter-Based Array," by S.-H. Park *et al.*, the beam squint phenomenon of a phased array and an RF lens antenna in an ultra-wideband mmWave system is investigated. The study shows that the beam squint problem of the RF lens system can be effectively mitigated by utilizing stable permittivity materials.

The second article, "A Framework to Address Mobility Management Challenges in Emerging Networks," authored by A. Zaidi *et al.*, highlights the unique network management challenges posed by key drivers of emerging cellular networks, such as densification and mmWave usage. The article advocates for a proactive approach to mobility management, introducing the Advanced Mobility Management and Utilization Framework (A-MMUF), which leverages Mobility Prediction Models for enhanced automation and handover processes. Case studies underscore A-MMUF's potential in transforming mobility management for improved network performance.

In the third article, "Reconfigurable Intelligent Surfaces: Performance Assessment Through a System-Level Simulator," B. Sihlbom *et al.* explore the utilization of Reconfigurable Intelligent Surfaces (RISs) to enhance wireless network performance. The study presents a system-level simulation of RIS deployment in an urban 5G network, analyzing coverage and rates at different frequencies. The results indicate significant improvements in coverage probability and rate, particularly in millimeter-wave bands. While suggesting potential benefits of RIS deployment in real-world networks, the study acknowledges the need for further research to optimize RIS integration and consider various deployment scenarios.

The fourth article, "Deep Learning for mmWave Beam-Management: State-of-the-Art, Opportunities and Challenges," authored by K. Ma *et al.*, delves into the application of deep learning (DL) to address challenges in narrow beam management. The article provides a comprehensive review of DL methods for beam prediction, tracking, and adaptive beam-management, highlighting future research opportunities and design insights in the context of DL.

Moving on to the theme of unmanned aerial vehicles (UAVs) in wireless networks, the fifth article, "UAV-aided RF Mapping for Sensing and Connectivity in Wireless Networks," authored by D. Gesbert *et al.*, discusses the deployment of UAVs as flying radio access network (RAN) nodes for wireless networks. The advantages of using UAVs for optimal network throughput and sensing in 3D space are emphasized, along with challenges related to UAV trajectory design and optimization for enhanced connectivity and sensing. Map-based techniques are proposed to improve UAV placement and path planning, showcasing the potential of UAV-aided communications through practical prototypes like Rebot (Relay Robot).

The sixth article, "iTUAVs: Intermittently Tethered UAVs for Future Wireless Networks," by N. Cherif *et al.*, introduces the concept of intermittently tethered unmanned aerial vehicles (iTUAVs) as a hybrid solution combining the benefits of tethered UAVs (TUAVs) and untethered UAVs. iTUAVs leverage flexible tethers to connect to ground anchors, providing cellular connectivity while maintaining mobility. The study showcases comparative advantages of iTUAVs over existing UAV-based cellular systems in terms of coverage, mobility, reliability, and infrastructure reuse. A case study further demonstrates the potential of iTUAVs in sustaining reliable cellular connectivity, while discussing challenges, such as tether design and integration with 5G technologies.

Shifting the focus to Terahertz (THz) Communications, the seventh article, "THz Precoding for 6G: Challenges, Solutions, and Opportunities," authored by Tan and Dai, offers insights into THz precoding techniques for 6G networks. The article addresses challenges associated with THz communications, including distance-dependent path loss, beam split, power consumption, mixed propagation, and blockage. Five THz precoding techniques are examined, providing a comparison of hardware structures, design considerations, and their respective advantages and disadvantages. The article emphasizes open issues and future research directions to empower THz precoding in future networks.

The eighth article, "Molecular Absorption Effect: A Double-edged Sword of Terahertz Communications," authored by C. Han *et al.*, delves into the molecular absorption effect in THz communications, presenting both challenges and oppor-

tunities. THz communications is gaining importance for 6G and beyond due to its potential to handle high data traffic. The article explores the impact of molecular absorption on signal power and noise in various communication scenarios, highlighting both negative effects, such as reduced signal power and degraded data rates, and positive effects, including secure and covert communication. The article provides guidelines for system design and proposes secure communication schemes in light of the molecular absorption effect.

Continuing our exploration, we turn to the realm of Vehicular Communications and Security:

The ninth article, "A DDPG Hybrid of Graph Attention Network and Action Branching for Multi-Scale End-Edge-Cloud Vehicular Orchestrated Task Offloading," authored by Y. He *et al.*, introduces an efficient system for orchestrating task offloading in vehicular networks. The proposed system integrates cloud clusters, edge nodes, and cybertwin components within a graph-based model, optimizing task offloading using a hybrid deep deterministic policy gradient (DDPG) approach. The article highlights improved performance achieved through this approach and addresses challenges related to resource allocation, dynamic system modeling, and feature extraction. The study envisions potential future directions, including the exploration of novel graph neural networks and addressing ultra-dense multi-to-multi relational systems.

The tenth article, "Security and Privacy in Vehicular Digital Twin Networks: Challenges and Solutions," authored by C. He *et al.*, delves into security and privacy concerns in the emerging concept of Vehicular Digital Twin (VDT) networks. These networks encompass both intra-twin and inter-twin communication, enabling enhanced services for autonomous vehicles. The article explores the architecture, applications, security, and privacy issues of VDT networks. It proposes countermeasures such as identity authentication and privacy-preserving techniques, while underscoring the need for ongoing research in this field. Intra-twin and inter-twin security challenges are discussed, including attacks like replay, message tampering, Sybil attacks, and privacy leakage. The potential for DDoS attacks and privacy compromise in information sharing is also explored.

Wrapping up the series of articles, the eleventh article, "Graphene-based Wireless Agile Interconnects for Massive Heterogeneous Multi-chip Processors," authored by S. Abadal *et al.*, proposes the use of graphene-based antennas and transceivers to address challenges in wireless communications within massive heterogeneous multi-chip processors. With traditional wired interconnects facing limitations in data-hungry architectures, graphene antennas offer high bandwidth and frequency reconfigurability. The article outlines technological integration, communications protocols, and architectural implications. Challenges related to realizing graphene antenna performance, integrating graphene within chips, designing protocols, and simulating wireless-enabled architectures are discussed. The vision put forth suggests that graphene-based wireless interconnects have the potential to enhance chip-scale communications with agility, high bandwidth, and adaptability.

In the twelfth article, "Communication Beyond Transmitting Bits: Semantics-Guided Source and Channel Coding," authored by J. Dai *et al.*, a novel approach termed "semantic communications" is introduced. This approach injects semantic meaning into the design of source and channel coding for wireless communications, aiming to convey meaning and improve communication effectiveness beyond traditional bit transmission. The article introduces the architecture, methodologies, and implementations of semantic coded transmission (SCT), which combines source coding, semantic analysis, and channel coding to enhance system performance. The article also outlines challenges and future research directions in theoretical and technical aspects, underscoring the potential impact of semantic communications.

Finally, the thirteenth article, "Self-Evolving and Transformative (SET) Protocol Architecture for 6G," authored by L. Cai *et al.*, addresses the fusion of real and digital realms in 6G wireless systems. The proposed Self-Evolving and Transformative (SET) protocol architecture for 6G enables adaptive control functions, distributed intelligence, and enhanced services to support diverse communication modes and user-centric applications. Challenges, such as protocol stack decomposition, monitoring strategy definition, control policy optimization, and security and privacy considerations are discussed. The article emphasizes the need for further research to successfully implement the SET framework and facilitate the integration of real and digital elements in 6G wireless systems.

Don't forget to explore the following columns:

- Industrial Perspectives: "Device Centric Compute, Orchestration and Networking."
- Spectrum Policy and Regulatory Issues: "The Importance of Spectrum Measurements."
- Book Reviews: "5G Backhaul and Fronthaul."
- Scanning the Literature: Highlights of four articles recently published in IEEE Transactions on Wireless Communications and IEEE Journal on Selected Areas in Communications.

We hope you find this issue of IEEE Wireless Communications informative and engaging.

Biography

Nirwan Ansari [S'78, M'83, SM'94, F'09] (nirwan.ansari@njit.edu), a Distinguished Professor of Electrical and Computer Engineering at the New Jersey Institute of Technology (NJIT), received his Ph.D. from Purdue University, his M.S.E.E. from the University of Michigan, and his B.S.E.E. (summa cum laude with a perfect GPA) from NJIT. He is also a Fellow of the National Academy of Inventors. He has published three books and (co-)authored more than 700 technical publications, over half published in widely cited journals/magazines. He has guest edited a number of Special Issues covering various emerging topics in communications and networking. He is the Editor-in-Chief of *IEEE Wireless Communications* and has served on the Editorial/Advisory Boards of over 10 journals. His current research focuses on green communications and networking, cloud computing, drone-assisted networking, and various aspects of broadband networks. He was elected to serve on the IEEE Communications Society (ComSoc) Board of Governors as a Member-at-Large, has chaired some ComSoc Technical and Steering Committees, and is currently the Director of ComSoc's Educational Services Board. He has served on many committees, such as the IEEE Fellow Committee, and has actively organized numerous IEEE international conferences/symposia/workshops. Some of his recognitions include several excellence in teaching awards, a few best paper awards, the NCE Excellence in Research Award, several ComSoc Technical Committee technical recognition awards, the NJ Inventors Hall of Fame Inventor of the Year Award, the Thomas Alva Edison Patent Award, the Purdue University Outstanding Electrical and Computer Engineering Award, the NCE 100 Medal, the NJIT Excellence in Research Prize and Medal, and designation as a ComSoc Distinguished Lecturer. He has also been granted more than 40 U.S. patents.