Editorial: Second Quarter 2021 IEEE COMMUNICATIONS SURVEYS AND TUTORIALS

WE WOULD like to welcome the readers to the second issue of the IEEE COMMUNICATIONS SURVEYS AND TUTORIALS in 2021. This issue includes 21 articles covering different aspects of communication networks. In particular, these articles survey and tutor various issues in "Wireless Communications," "Vehicular and Sensor Communications," "IoT and M2M," "Network Security," "Multimedia Communications," "Internet Technologies," "Network and Service Management," and "Optical Communications." A brief account for each of these articles is given below.

I. WIRELESS COMMUNICATIONS

In current 5G systems, with the increase of intelligent terminals, various service requirements of different communication environments are expected to be satisfied. How to improve system capacity and spectral efficiency becomes an urgent problem. To this end, heterogeneous network (HetNet) becomes an effective solution by developing small cells into traditional macrocell networks. In fact, the applications of HetNets are quite numerous. For example, HetNets have profound effects on Indoor coverage enhancement and edge user performance improvement, such as Home eNode, smart communities, large gymnasiums. In this context, the article titled "A Survey on Resource Allocation for 5G Heterogeneous Networks: Current Research, Future Trends, and Challenges" by Yongjun Xu, Guan Gui, Haris Gacanin, and Fumiyuki Adachi presents a survey, where the article overviews the resource allocation algorithm in 5G HetNets and presents its significant efforts. Moreover, the survey concludes with a comprehensive discussion that highlights the key challenges of future resource allocation techniques.

Due to the nature of the wireless transmission medium, wireless communications are characterized by notably larger losses of data packets than wired communications. The quality of wireless links is highly dependent on channel variations, interference and even transceiver imperfections. Such link uncertainty instigated the development of numerous techniques that can withstand uncertain conditions by adjusting the parameters of the wireless link to achieve higher reliability or selecting a more reliable alternative wireless link for data transmission. These techniques rely on effective wireless link quality estimation. For this reason, a plethora of research articles focus their attention on the quality aspects of wireless links.

In this context, the article titled "Machine Learning for Wireless Link Quality Estimation: A Survey" by Gregor Cerar, Halil Yetgin, Mihael Mohorčič and Carolina Fortuna provides a comprehensive analysis and comparison of wireless link quality estimators developed from empirical data, with focus on estimators that use machine learning algorithms. The work thoroughly analyzes and compares the existing estimators from two perspectives. Firstly, it focuses on addressing the quality requirements of their application. Secondly, it examines how others approach the standard design steps used in the machine learning community. The publication also considers available open-source datasets. It rounds up with lessons learned and design guidelines for link quality estimator development and dataset collection.

High Altitude Platform Station (HAPS) systems, located at an altitude around 20 km, will have an influential role in the (6G) network architecture by bridging the emerging satellite mega-constellations and the terrestrial networks. Although the use of HAPS systems has been limited to providing coverage to rural and remote areas, along with disaster relief scenarios, through the development of advanced materials and the realization of necessary technological leaps, it is expected that HAPS systems will emerge as an essential component of 6G networks due to their unique ability to serve densely populated metropolitan areas. The article titled "A Vision and Framework for the High Altitude Platform Station (HAPS) Networks of the Future" by Gunes Karabulut Kurt, Mohammad G. Khoshkholgh, Safwan Alfattani, Ahmed Ibrahim, Tasneem S. J. Darwish, Md Sahabul Alam, Halim Yanikomeroglu, and Abbas Yongacoglu presents a survey of the use of HAPS systems, along with proposing a vision highlighting their unexplored potential towards the networks of 2040s through the proposed use-cases. An overview of aviation and spectrum regulations that aim to harmonize the worldwide usage of HAPS is presented. The description of the main components of a HAPS communication system and the corresponding channel models are given. A comprehensive perspective on radio resource management, interference management, and handoff management of HAPS nodes is provided. Moreover, the indispensable role of artificial intelligence is detailed.

Frequency spectrum is becoming increasingly congested due to the rapid growth of wireless devices and mobile services. As a result, the price of the wireless spectrum has

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experienced a sharp rise during recent years. This enables the spectrum sharing between wireless communication systems and radar systems that leads to a convergence trend of the radar and the communication, namely joint radar and communication (JRC). In particular, JRC allows the radar and communication systems to share the spectrum. Also, JRC enables a single hardware platform, e.g., an autonomous vehicle, to simultaneously perform the communication function and radar function. Consequently, JRC is able to improve the efficiency of resources, i.e., spectrum and energy, reduce the system size and minimize the system cost. As a result, JRC as a promising technology for several applications such as military applications, e.g., shipborn systems, airborne system, and civilian applications, e.g., autonomous vehicle systems. In this context, the article titled "Radio Resource Management in Joint Radar and Communication: A Comprehensive Survey" by Nguyen Cong Luong, Xiao Lu, Dinh Thai Hoang, Dusit Niyato, and Dong In Kim presents a survey and tutorial on JRC. First, the article gives fundamental concepts of JRC, important performance metrics used in JRC systems, and applications of the JRC systems. Then, the article reviews and analyzes resource management approaches, i.e., spectrum sharing, power allocation, and interference management, for JRC. In addition, the article presents security issues to JRC and provides a discussion of countermeasures to the security issues. Finally, the article highlights important challenges in the JRC design and discusses future research directions related to JRC.

II. Vehicular and Sensor Communications

Autonomous underwater vehicles (AUVs) can be used to discover new sources from deep-ocean, ship-hull inspection, fishing, etc. In many situations, a single AUV is difficult to finish complex tasks in an unknown underwater environment. Therefore, researchers attempt to utilize AUV formation techniques to accomplish tasks with high efficiency and good stability. Current AUV formation methods mainly focus on control studies and lack the interdisciplinary aspects of AUV performance, formation control, and communication capability. In this context, the article titled "Survey of Autonomous Underwater Vehicle Formation: Performance, Formation Control, and Communication Capability" by Yue Yang, Yang Xiao, and Tieshan Li presents a tutorial and a survey to satisfy interdisciplinary audiences. First, the article overviews AUV formation with three dimensions, including AUV performance, formation control, and communication capability. Second, the article focuses on the interdisciplinary relationships of the above three aspects, e.g., formation architecture with communication constraints. Finally, the article identifies and discusses a series of common misconceptions and questionable research for AUV formation control related to communication.

In recent years, robotic applications are broadly adopted in building smart Cyber-Physical Systems (CPSs) to enhance automation and operational performance, which possess an inherent demand of faster processing for their data-heavy and compute-intensive tasks. The concept of multi-agent cloud robotics enables robotic cooperation and supports the robots in executing large-scale applications with the help of the edge and cloud resources. Since this paradigm is a complex synthesis of robotics, tele-operation, edge computing and core cloud technologies, the performance of such system depends on proper management and co-ordination among heterogeneous resources. Therefore, efficient resource allocation and service provisioning mechanisms are required to fully exploit the benefits of multi-agent cloud robotics. In this context, the article titled "Resource Allocation and Service Provisioning in Multi-Agent Cloud Robotics: A Comprehensive Survey" by Mahbuba Afrin *et al.* conducts a comprehensive survey on resource allocation and service provisioning in multi-agent cloud robotics. It identifies the domain specific challenges compared to contemporary computing paradigms and discusses the promising use cases. A complete taxonomy on resource allocation is presented together with the discussion of resource pooling, computation offloading, and task scheduling for efficient service provisioning. A summary of lessons learned from the existing works in literature is given to identify the research gaps in addressing the challenges. Furthermore, a holistic framework for efficient resource allocation and service provisioning is also provided to open directions for future research.

With the development of the emerging multimedia technology, such as augmented reality (AR) and virtual reality (VR), the wireless networks need to provide higher bandwidth and lower latency for video applications. Multi-access edge computing (MEC) is a key technology in the 5th generation (5G) network, which can provide compute-/storage- intensive services for video applications. Furthermore, MEC provides an information service environment and cloud-computing capabilities at the edge of the mobile network, within the radio access network (RAN) and near mobile subscribers. In this context, the article titled "A Survey on Multi-Access Edge Computing Applied to Video Streaming: Some Research Issues and Challenges" by Xiantao Jiang, F. Richard Yu, Tian Song, and Victor C. M. Leung presents a tutorial and survey. First, the article starts by providing an overview of the multi-access edge computing and video streaming. Second, the article summaries the resource allocation approaches for multi-access edge computing for video streaming. Then, the article discusses the enabled technologies, including caching, computing, and networking. Finally, the survey concludes with a discussion that highlights the challenges and future research direction.

III. IoT and M2M

The Internet of Underwater Things (IoUT) is an emerging technological ecosystem developed for connecting objects in maritime and underwater environments. The domain of IoUT influence is quite wide, ranging from an underwater observatory to maritime cities and to covering global oceanic trade. Although the IoUT has many technical similarities with its terrestrial IoT counterpart, it also has numerous differences arising from its more challenging communication environment, computational limitations, information security

issues, and limited energy resources. In this context, the article titled "Internet of Underwater Things and Big Marine Data Analytics—A Comprehensive Survey" by Mohammad Jahanbakht, Wei Xiang, Lajos Hanzo, and Mostafa Rahimi Azghadi presents a survey critically appraising the differences and similarities between the IoT and IoUT. The article starts by providing a comprehensive analysis of the challenges faced in underwater communication due to the hostile environment. Specifically, it discusses the network architecture, link reliability, network protocols, signal routing, software-defined networks, and edge computing in IoUT. Then, the issues of Big Marine Data (BMD) acquisition and processing are surveyed. The article provides insight into the employment of distributed and cloud-based systems for BMD processing and the associated challenges, followed by the benefits of machine learning techniques that can be used for BMD processing. Finally, a suite of IoUT solutions and future research directions are discussed.

Internet of Things (IoT) plays a significant role in the realization of smart life concept dominating over diverse applications. Internet connectivity is a critical requirement in IoT, however the network requirements of different IoT applications are diverse. The heterogeneity and the exponential growth of IoT applications challenge the traditional telecommunication networks, which holds the concept of "one size fits all." Network slicing is an emerging technology in future telecommunication networks that divides the physical network into multiple logical networks with diverse network characteristics. Slicing has the potential to mitigate the staticity of conventional telecommunication networks. In these circumstances, the article titled "Survey on Network Slicing for Internet of Things Realization in 5G Networks" by Shalitha Wijethilaka and Madhusanka Liyanage, investigates how network slicing supports to overcome the challenges in the IoT realization. The article discusses the technical aspects that can be provided by slicing to the IoT ecosystem, the utilization of slicing in a set of key IoT applications, and the technical challenges that can be risen due to IoT in the slicing ecosystem. Furthermore, the impact of novel technologies in a slicing enabled IoT ecosystem is examined. Finally, the article summarizes a range of potential research directions related to the article content.

Radio-based sensing has advanced the conventional human sensing applications for the past decade and still remains an active area of research. Many new radio frequency (RF)-based modalities such as WiFi, RFID, and radar-based sensing have dominated the mainstream research but scaling this technology to large scale deployments has been challenging. Classical machine learning approaches have addressed this to a level but deploying such models to unseen environments were not always successful. Recent advancements in Deep Learning have furthered the performance in RF based sensing models which were previously not viable. Therefore, recent years have seen a spike of Deep Learning based RF sensing applications. In this context, the survey titled "Deep Learning for Radio-Based Human Sensing: Recent Advances and Future Directions" by Isura Nirmal, Abdelwahed Khamis, Mahbub Hassan, Wen Hu, and Xiaoqing Zhu presents a taxonomy of the current state-of-the art of deep learning applications in RF based sensing supported by a comprehensive review. It also reviews publicly released RF sensing datasets which can further help future research in this area. The survey concludes by reviewing the lessons learned followed by a discussion of the current limitations and future directions of Deep Learning as an enabler of RF-based sensing.

The Internet of Things (IoT) connects a wide range of entities and types of environments, and several entities such as users, devices, and information resources are interconnected with services. Thus, interoperability is essential for accomplishing interworking among different entities, and it must consider security-related factors to protect data and privacy and prevent malicious activities. Therefore, we should consider both security and interoperability together to implement IoT in the real world. In information and communication technology (ICT) fields, international standards provide guidance and protocols to help with the production and utilization of information technologies; several international standard organizations are developing IoT-related standards, such as architecture, framework, network protocols, and definitions. Therefore, the adoption of standards can support interoperability and security that are guaranteed by these standards. In this context, the article titled "A Survey on Standards for Interoperability and Security in the Internet of Things" by Euijong Lee, Young-Duk Seo, Se-Ra Oh, and Young-Gab Kim presents a survey, where the article overviews interoperability and security-related international standards for IoT. The article provides a summary of IoT-related international standards for interoperability and security. Furthermore, international standards and its subcommittees responsible for developing IoT-related standards are investigated. Finally, the article discusses challenges and future research directions related to interoperability and security standards for IoT.

IV. Network Security

Previsions for 2025 estimate nearly 64 billion IoT devices connected to each other into diverse cutting-edge environments, such as Smart Cities, Industry 4.0, or crowdsensing. In this context, as the number of interconnected devices grows exponentially, their diversity, malfunctions, and cybersecurity threats are increasing at the same rate. Then, to guarantee the correct functioning and performance of these novel environments, it is crucial to identify the capabilities of their devices and detect potential misbehavior that may arise due to cyberattacks, system faults, or misconfigurations. To meet this challenge, the advancement of communication networks and computing paradigms has influenced that behavioral data science evolution from studying theoretical and empirical issues related to human behaviors, its initial scope, to conquer the cyberworld and offer a promising alternative to model device behaviors. In this context, the article titled "A Survey on Device Behavior Fingerprinting: Data Sources, Techniques, Application Scenarios, and Datasets" by Pedro Miguel Sánchez Sánchez, José María Jorquera Valero, Alberto Huertas Celdrán, Gérôme Bovet, Manuel Gil Pérez, and Gregorio Martínez Pérez presents a survey. It details the main

application scenarios, device types, behavioral data sources, and processing and evaluation techniques by summarizing and comparing the most representative research works in the area. This survey also reviews the principal datasets containing behavioral data, as most of the novel processing techniques are based on Machine Learning and Deep Learning. Finally, the article gives a set of lessons learned, current trends, and future research challenges to guide new solutions in the area.

Multi-Access Edge Computing (MEC) is an emerging edge computing paradigm that has the potential to overcome the disparity between the prevailing and envisioned networking architectures suited to realize the 5G based applications. In MEC, security is a paramount conundrum due to its intricate interoperability and compatibility concerns emanated with underlying driving technologies. The edge of the mobile network, being a critical juncture for the ingress traffic of Radio Access Network (RAN), infuses the weakest points of the entire network in terms of security. Privacy, integrity, and trust management assurances are prime requirements with MEC deployments despite the attributed locational and context awareness facilitated for the users. Emerging aspects of service migration, mobile offloading, and virtualization are opening the prevailing network interfaces for unforeseen threats that compromise the MEC environment. In this context, the article titled "Survey on Multi-Access Edge Computing Security and Privacy" by Pasika Ranaweera, Anca Delia Jurcut, and Madhusanka Liyanage presents a tutorial and a survey, where the technological overview of MEC and its ETSI based standardization landscape were presented as the tutorial content. The article first specifies the conventional security aspects of MEC with stated possible violations and mitigation approaches. MEC specific security aspects are specified in terms of various threat vectors, elaborated considering the real-world deployment scenarios of MEC. Current issues, objectives of preservation, and prevailing solutions for Privacy are then classified and presented for MEC. The insights of the research are stated along with the future directives at the concluding stage of the article.

Smart devices such as smartphones, smart watches, smart home appliances, etc. have become ubiquitous offering a wide range of features and user-centric services to improve our daily lives. With the advancements of the Internet of Things, modern smart devices can interact with users as well as surrounding physical world. In this context, sensors in smart devices act as a bridge between the users and the physical world. Sensors enable smart devices to accurately identify any changes in the surroundings and automate tasks based on physical parameters and customized user inputs. While the use of sensors in smart devices surely increases the functionalities, attackers can use sensors as a mean of intrusion and perform malicious activities. Indeed, recent years have seen exponential growth in sensor-based attacks to smart devices. The diverse nature of sensor activities in smart devices make the situation worse making existing security tools and sensor management systems obsolete. In this context, the article titled "A Survey on Sensor-Based Threats and Attacks to Smart Devices and Applications" by Amit Kumar Sikder, Giuseppe Petracca, Hidayet Aksu, Trent Jaeger, and A. Selcuk Uluagac presents a comprehensive survey. The article provides a detailed overview of smart device ecosystem and list the pitfalls of existing sensor management systems. Then the article presents a comprehensive taxonomy of sensor-based threats detailing the attack mechanisms and effectiveness based on known vulnerability metrics. Finally, the article provides a detailed taxonomy of proposed solutions to address sensor-based threats and outlines open-issues and future research directions.

V. Multimedia Communications

The recent technological advancements in wireless communications, especially the emergence of 5G systems, eliminate the limitations that hindered realizing the true potential of Mobile Augmented Reality (MAR). MAR enhances human perception by augmenting virtual content on the real space in the form of visual, audio, and haptic. MAR technology which is supported by 5G wireless communication systems and complementary technology MEC will enable a wide range of use cases in different applications areas including Industry 4.0, healthcare, education, travel and tourism, smart cities and smart homes, automotive, and aviation. To satisfy the extreme communication requirements of MAR use cases, proper utilization of 5G systems is a necessity, thus needs extensive research. The article titled "A Survey on Mobile Augmented Reality With 5G Mobile Edge Computing: Architectures, Applications, and Technical Aspects" by Yushan Siriwardhana, Pawani Porambage, Madhusanka Liyanage and Mika Ylianttila, is presented in this context. First, the survey provides an overview of MAR technology in the future and elaborates on various architectural options for MAR systems supported by edge and cloud computing technologies. Then it discusses how the key distinguishing characteristics of 5G systems can revolutionize the future MAR systems. The article presents a number of existing and emerging application areas of MAR focusing on their realization in 5G networks. Key technical aspects that play an essential role in 5G MAR systems are also discussed. Finally, an extensive discussion on research problems, preliminary solutions, and future research directions are presented.

VI. Internet Technologies

Witnessing the rapid 5G commercialization recently with multiple advantages for emerging user service requirements, people look forward to seeing an emerging innovation in the next-generation mobile networks, 6G. As a demand response, the 6G additionally integrates an aerial radio access network (ARAN) as an expansion of mobile coverage from the sky toward a comprehensive access infrastructure. ARANs are constituted by multiple aerial base stations including aircraft and airships such as UAVs, drones, balloons, and airplanes equipped with wireless transceiver antennas to provide a radio access medium from the sky to end users for Internet services.

In this context, the article titled "Survey on Aerial Radio Access Networks: Toward a Comprehensive 6G Access Infrastructure" by Nhu-Ngoc Dao, Quoc-Viet Pham, Ngo Hoang Tu, Tran Thien Thanh, Vo Nguyen Quoc Bao, Demeke

Shumeye Lakew, and Sungrae Cho presents a survey, where the article provides an overview about ARAN architectures in a comprehensive 6G access infrastructure. In addition, the survey investigates emerging technologies and applications of ARANs in 6G context. Moreover, the survey concludes with a discussion about research challenges for ARAN development.

Future wireless networks are characterized by a huge increase of connected edge devices and a proliferation of services and applications such as Internet-of-Things (IoT), e-health, and extended reality. Artificial Intelligence (AI) and Machine Learning (ML) are the key enabling technologies of the future wireless systems to achieve scalability, context-awareness, and energy efficiency along with a massive capacity and connectivity. DNN-based techniques such as Convolutional Neural Networks (CNNs), Deep Reinforcement Learning (DRL), Generative Adversarial Networks (GANs) have led to tremendous successes in different real-world applications from medicine to robotics. In this context, the article titled "Single and Multi-Agent Deep Reinforcement Learning for AI-Enabled Wireless Networks: A Tutorial" by Amal Feriani and Ekram Hossain provides a detailed overview of model-free/model-based single-agent Deep Reinforcement Learning (DRL), and deep cooperative Multi-Agent Reinforcement Learning (MARL) frameworks along with a review of recent MARL-based contributions in MEC systems, UAV networks, distributed beamforming, cooperative spectrum sharing, etc. With an emphasis on MARL, the tutorial presents key insights and observations from the literature review. For instance, few works focused on proposing efficient communication protocols to share information between the agents. Furthermore, the importance of designing a unified benchmarking framework is highlighted to ensure a fair and constructive comparison between the proposed methods. The authors conclude by discussing open problems for future research directions.

Communication networks have become a critical infrastructure of the digital society. In order to meet the increasingly stringent dependability requirements of applications, most packet-switched networks (e.g., backbone networks, datacenter networks, or enterprise networks) support fast failure recovery mechanisms in the data plane. These data plane mechanisms typically allow to react to link failures orders of magnitude faster than control plane mechanisms. However, implementing fast recovery in the data plane is challenging. In this context, the article titled "A Survey of Fast-Recovery Mechanisms in Packet-Switched Networks" by Marco Chiesa, Andrzej Kamisiński, Jacek Rak, Gábor Rétvári, and Stefan Schmid, presents a systematic, tutorial-like overview of packet-based fast-recovery mechanisms in the data plane, focusing on concepts but structured around different networking technologies, from traditional link-layer and IP-based mechanisms, over BGP and MPLS to emerging software-defined networks and programmable data planes. The article examines the evolution of fast-recovery standards and mechanisms over time and identifies and discusses the fundamental principles and algorithms underlying different mechanisms. It further presents a taxonomy of the state of the art, summarizes the main lessons learned, and proposes a few concrete future directions.

VII. Network and Service Management

The fifth-generation (5G) and beyond of mobile technologies will bring new and challenging paradigms for cellular network operations. This will result in new requirements for network capacity, enhanced data rates, new services, and the merge of different and new radio access technologies. Network coverage is a crucial factor to accomplish all these objectives and its quality highly impacts the overall network performance and the end-user experience. It is of great importance to understand how future cellular networks can be deployed respecting the coverage-capacity trade-off that can be extended to latency or transmission reliability considering the upcoming use cases. Additionally, network coverage has its specific requirements, such as ubiquitous and seamless coverage, and reaching most environments including rural or isolated areas, and deep indoor service. In this direction, the article titled "A Survey on Coverage Enhancement in Cellular Networks: Challenges and Solutions for Future Deployments" by Ruben Borralho, Abdelrahim Mohamed, Atta Ul Quddus, Pedro Vieira, and Rahim Tafazolli presents an exhaustive and extensive literature review of coverage in mobile networks. It explores and studies the coverage as a concept and how it can be defined in different contexts. An overview of the main key performance indicators (KPIs) and requirements related to coverage is provided. It defines a new taxonomy for coverage in cellular networks, dividing potential solutions for its enhancement into three main groups: Network deployments, the influence of frequency bands on coverage, and interference management for coverage enhancement. Finally, a discussion of open issues and work directions concludes the article.

Federated learning is revolutionizing the way machine learning can be trained without jeopardizing the privacy of users' local data. This is because it enables a collaborative on-device training of a single machine learning using each user's own data, as opposed to the traditional machine learning approach in which the data must be transmitted from the user's device to a central cloud server. Technically speaking, federated learning enables a number of edge devices to locally train (over many iterations) a single machine learning model on their own data and then send model updates to an edge server, which employs some aggregation technique to aggregate the contributions from all the devices. This contributes in (1) protecting users' privacy as the data never leaves the user's device and (2) reducing the communication overhead since only model updates (instead of raw data) need to be communicated. In this context, the article titled "Federated Machine Learning: Survey, Multi-Level Classification, Desirable Criteria and Future Directions in Communication and Networking Systems" by Omar Abdel Wahab, Azzam Mourad, Hadi Otrok and Tarik Taleb provides a comprehensive survey and tutorial on federated learning and its connections with the state-of-the-art technologies such as edge computing, Internet of Things and 5G/6G networks. We design a multi-level classification scheme that first considers the high-level challenges of federated learning, then

the low-level challenges within each high-level challenge and finally the techniques used to address each underlying low-level challenge. We finally uncover some novel research directions in federated learning.

VIII. Optical Communications

Future 6G wireless communication systems aim to converge different wireless domains and technologies. Among them, the convergence of Light Fidelity (LiFi) and WiFi networks well combines their complementary advantages in spectrum and coverage. This forms the hybrid LiFi and WiFi network (HLWNet), which has great potential to fulfill the future demands for data rates in the range of 10-1000 Gbit/s. So far, LiFi has been officially included in the same standard series as WiFi (IEEE 802.11), laying solid foundation for HLWNets. The development of HLWNets will not only advance the network capacity for the purpose of communications, but also provide a new network paradigm for a wide range of application services such as virtual reality, hologram display, localization, communications security, the Internet of Things (IoT), etc. In this context, the article titled "Hybrid LiFi and WiFi Networks: A Survey" by Xiping Wu, Mohammad Dehghani Soltani, Lai Zhou, Majid Safari, and Harald Haas presents a tutorial and survey. The article starts by providing a framework of system design for HLWNets. Then, performance metrics and recent achievements are reviewed to demonstrate the superiority of HLWNets against stand-alone networks. Further, the article elaborates the research advances on four key topics: user behavior modeling, interference management, handover, and load balancing. Moreover, the article studies the potential of HLWNets in the application areas, exemplified by indoor positioning and physical layer security. Finally, the article discusses a range of hot spot challenges to be tackled by future research.

We hope that the readers enjoy reading this issue and find the articles useful. At last, we are truly sorry to learn about the loss of one of our associate editors, Dr. Artur Ziviani, who passed away of Covid-19 complications on March 24th, 2021 at the age of 47. Dr. Artur Ziviani was a Senior Researcher at the Brazilian National Laboratory for Scientific Computing (LNCC). He was a leader at the Data Extreme Lab (DEXL) research group and current Coordinator of LNCC's Graduate Program in Computational Modeling. He was senior member of both IEEE and ACM, a member of the Brazilian Computer Society (SBC) and an affiliated member of the Brazilian Academy of Sciences (ABC). He held an Electronic Engineer degree from the Polytechnic School of UFRJ, Master in Electrical Engineering (with emphasis on Teleinformatics) from COPPE/UFRJ and Doctor in Computer Science from Université Paris VI, Sorbonne Universités, France. He was a visiting researcher at INRIA, France, for 5 months between 2008 and 2009. He held a merit research fellowship from CNPq - Brazilian equivalent of NSF, the distinction of Scientist of the State of Rio de Janeiro (CNE), award given by FAPERJ - Rio de Janeiro State R&D funding agency. Dr. Artur was the head of the Special Commission on Computing Applied to Healthcare (CE-CAS) of the Brazilian Computer Society (SBC) from 2011 to 2013 and he was the Vice-Coordinator of the virtual research network National Institute of Science and Technology in Medicine Assisted by Scientific Computing (INCT-MACC) from 2008 to 2016. He was a member of the Steering Committee of the IEEE Smart Cities initiative representing IEEE ComSoc. His research contributions include the characterization, modeling and analysis of computer networks, as well as network science, data science, machine learning, and interdisciplinary data science research with a networking approach applied to areas such as digital health, energy, biodiversity, and bioinformatics.

Dr. Artur was a true academic leader dedicated to make this world a better place. He was also a very positive, lighthearted, always smiling person, continuously spreading waves of happiness around him. Again, we would like to extend the deepest condolences to his wife, two children, family, friends and colleagues.

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