
Guest Editorial

Hyperconnectivity: From Connected Things to Connected Intelligence

Welcome to this special issue containing some of the best papers presented at the Wireless World Research Forum (WWRF) meetings at Kuala Lumpur, Malaysia, in January 2021 and Paris, France, in December 2021. The Malaysia meeting had the theme *Hyperconnectivity (Beyond 5G, Opportunities & Challenges)* and the Paris meeting had the theme *From Connected Things to Connected Intelligence*. Both themes are well aligned with current technology trends and attracted a large number of high quality presentations and papers to the various plenary sessions and working groups.

Hyperconnectivity offers us the chance to reach for the goal of ubiquitous connectivity when everyone and everything can be part of an intelligently managed and limitless, yet sustainable, secure and reliable, Smart Connectivity System. At the same time, the widespread introduction of Artificial Intelligence (AI) and Machine Learning (ML) technology will provide a strong impetus towards improved network performance and cost-efficiency for current and even more for next generation mobile systems. Beyond 5G, services and networks will be managed more autonomously and are expected to offer increased flexibility and adaptability everywhere. Networks and applications will need to become more intelligent, self-learning and context dependent. AI's potential impact on consumer, society and industry-relevant aspects for end-to-end communication systems and use cases will be tremendous. Future Cognitive Communication Systems are envisioned to be continuously learning, self-optimizing and capable of transitioning from just connecting humans and things to connecting, sensing and actuating anything, intelligently and in a purpose driven manner.

From the highly successful WWRF meetings in 2021, authors of some of the most highly recommended submissions were invited to submit full-length journal papers. We are immensely delighted to bring to you four of these papers in this special issue, which cover a wide range of topics from implementation to innovative research to business models.

In the first paper, authored by Satya Gupta, a Wi-Fi Access Network Interface (WANI), called the PM-WANI (Prime Minister's WANI) framework, is described. It has been recommended by Telecom Regulatory Authority of India (TRAI) and approved by the Indian government in Dec 2020, and is a regulatory innovation which enables provision of broadband internet over Public Wi-Fi hotspots across the country through last mile Public Data Offices (PDOs) joined together with a roaming agreement. Other elements include a Public Data Office Aggregator (PDOA), App Provider (AP) and Central Registry (CR), with the CR playing a central role in provisioning and coordinating the various players in the unbundled value chain. All these elements act as independent entities in the value chain, and enable innovations independently. This unbundling of the Wi-Fi ecosystem provides opportunities for multiple players to participate, interoperate securely, and provide seamless internet connectivity at an affordable rate. The government has done away with any requirements to seek licenses or pay any fees before setting up the PDOs, thus making it attractive to anyone to establish these kiosks and scale quickly to hundreds of millions of hotspots across the country.

In the second paper by Waleed, Kosta, and Skouby, edge intelligent frameworks and their security issues are analyzed. Edge intelligence has emerged as a popular solution that has contributed to increase the overall system performance by reducing the burden of the cloud and the network. The basic idea of edge intelligent frameworks is that a massive amount of the data generated created in a given solution are not provided to the central cloud whereas the data analysis is carried out at the edge. Applying edge intelligence in IoT environments it has to be considered that they typically comprise numerous users and heterogeneous devices that communicate over the network where the exchange of sensitive data occurs. Therefore, security in such frameworks is crucial and a key challenge for reliable communication. The paper includes an analysis of popular AI/ML applications toward edge intelligence focusing on highlighting the critical security and privacy concerns desired in such systems. It is shown that although several promising edge intelligent frameworks have been developed to address energy and performance issues, they do not consider the security and privacy of the data as the researchers are more focused on the performance predicaments.

In the third paper by Gatara and Mzyece, *From QoS to QoE plus Quality of Task (QoT) in Beyond 5G Networks*, it is described that a paradigm shift from technical Quality of Service (QoS) oriented networks to user-centric Quality of Experience (QoE) centred network architectures is the trend. With this development, consideration of QoE user requirements into B5G networks will be critical to the emergence of ultra-reliable and ultra-low latency haptic-enabled Internet applications of the future, one such application being tele-haptic Internet. Thus, the authors discuss the linkages between network and user-centric QoS and QoE (with QoT) perspectives. In addition, the authors explain the emergence of a future B5G network and haptic-enabled Internet of Skills (IoS), and present an example of an architecture applied to the task-sensitive mission-critical use case of tele-haptic surgery. This is accomplished by developing the concept of Task-Technology Fit (TTF) models that can be empirically applied to this futuristic use case for a novel QoE/QoT perspective of future B5G communication networks.

In the fourth paper by Lindgren and Ek, the Green Business Model Innovation (GBMI) in Symbiosis Business Value Networks is addressed and the profitability and achievements of Green Symbiosis Business Value Networks (GSBVN) are investigated. The GSBVN seems to be a promising initiative to accelerate transformation of business models into green business models, facilitated by means of advanced wireless and sensing technologies. The paper presents some initial studies on the definition of green business model innovation in symbiosis and impact of innovations in future wireless technologies on GSBVN. An overview of different GSBVN approaches, origins, and views is provided and the role of future wireless technologies in designing, reconfiguring, developing and operating GSBVNs is discussed.

We hope you will find the papers published in this Special Issue interesting. Most of the topics raised are the subject of continuing research and development by WWRF members and others, leading to a better understanding of the many open issues that still remain to be addressed. We encourage you to join in this process by contributing to or attending WWRF meetings, or joining WWRF as a member. This will enable you to take part in guiding the development of the evolving hyper-connected world we all live in. We would also welcome any comments or suggestions you may have on this issue or any others relating the future Wireless World.

Guest Editors

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Sudhir Dixit is a Co-Founder and Senior Fellow at the Basic Internet Foundation in Oslo, Norway, and heads its US operations. He is also associated with the Academy of Finland Flagship 6G Project, led by the Centre for Wireless Communications, University of Oulu, Finland where he is a Docent since 2010. From 2015 to 2017 he was the CEO and Co-Founder of a start-up, Skydoot, Inc. From 2009 to 2015, he was a Distinguished Chief Technologist and CTO of the Communications and Media Services for the Americas Region of Hewlett-Packard Enterprise Services in Palo Alto, CA, and the Director of Hewlett-Packard Labs India in Palo Alto and Bangalore. Before joining HP, he held various engineering and leadership positions at BlackBerry, Nokia, NSN and NYNEX (currently Verizon Communications). He has been a technical editor of IEEE Communications Magazine, and is presently a Board Member, Working Group Chair and Vice Chair for America at the Wireless World Research Forum (WWRF). He was on the editorial board of IEEE Spectrum Magazine, and is presently on the editorial board of Springer's Wireless Personal Communications Journal. He is a Co-Chair of the CTU Working Group at INGR in the IEEE Future Network Initiative. Dr. Dixit has published nine books, holds 21 U.S. patents and published extensively in numerous peer-reviewed journals and conferences. In 2018, he was appointed a Distinguished Lecturer by the IEEE Communications Society. From 2010 to 2012, he was an Adjunct Professor of Computer Science at the University of California, Davis, and, since 2022 he is also a VAJRA Adjunct Professor at the Indian Institute of Science, Bangalore. A Life Fellow of the IEEE, Fellow of IET and IETE, Dixit holds a Ph.D. from the University of Strathclyde, Glasgow, U.K. and an M.B.A. from the Florida Institute of Technology, Melbourne, Florida.



Nigel Jefferies is the Chairman of the Wireless World Research Forum, a global partnership between industry and academia to develop a research agenda for mobile communications. Previously he was Standards Development Manager at Huawei Technologies, Head of Academic Relationships for Vodafone Group Research & Development and a Principal Mathematician at Racal Research Ltd. He has led a number of research projects including the European-funded IST project SHAMAN, which studied the security of future mobile systems, and ran the Secure Applications Steering Group for Mobile VCE. Other collaborative research projects on various aspects of security for mobile communications include 3GS3 in the UK-funded LINK programme, and ASPeCT and USECA in the European ACTS programme. His research interests include cryptography, security of systems and applications of mathematics to telecommunications. He was a member of the UK government's 5G advisory committee. He received a PhD in functional analysis from Goldsmith's College, London, and an MA in mathematics from the Queen's College, Oxford. He is a Senior Member of the IEEE, a member of the IET and a Fellow of the Institute of Mathematics and its Applications and a Chartered Mathematician.



Mérouane Debbah is Chief Researcher at the Technology Innovation Institute in Abu Dhabi. He is an Adjunct Professor with the Department of Machine Learning at the Mohamed Bin Zayed University of Artificial Intelligence. He received the M.Sc. and Ph.D. degrees from the Ecole Normale Supérieure Paris-Saclay, France. He was with Motorola Labs, Saclay, France, from 1999 to 2002, and also with the Vienna Research Center for Telecommunications, Vienna, Austria, until 2003. From 2003 to 2007, he was an Assistant Professor with the Mobile Communications Department, Institut Eurecom, Sophia Antipolis, France. In 2007, he was appointed Full Professor at CentraleSupélec, Gif-sur-Yvette, France. From 2007 to 2014, he was the Director of the Alcatel-Lucent Chair on Flexible Radio. From 2014 to 2021, he was Vice-President of the Huawei France Research Center. He was jointly the director of the Mathematical and Algorithmic Sciences Lab as well as the director of the Lagrange Mathematical and Computing Research Center. He is an IEEE Fellow, a WWRP Fellow, a Eurasip Fellow, an AAIA Fellow, an Institut Louis Bachelier Fellow and a Membre émérite SEE.



Knud Erik Skouby is professor emeritus, Aalborg University. Founding director of center for Communication, Media and Information technologies, Aalborg University-Copenhagen (2007–17). Has a career as a university teacher and within consultancy since 1972; focus on ICT since 1987. Working areas: *Techno-economic Analyses; Development of mobile/wireless applications and services; Regulation of telecommunications.*

Project manager and partner in a number of international, European and Danish research projects. Served on public committees within telecom, IT and broadcasting; member of boards of professional societies, member of organizing boards, evaluation committees and as invited speaker on international conferences; published a number of Danish and international articles, books and conference proceedings. Member of EUs Economic and Social Council 1994–98. Past dep. chair IEEE Denmark. Editor in chief of Nordic and Baltic Journal of Information and Communication Technologies (NBICT); Chair of WGA in Wireless World Research Forum.



Angeliki Alexiou is a professor of Broadband Communications Systems at the department of Digital Systems, ICT School, University of Piraeus, Greece. She received the Diploma in Electrical and Computer Engineering from the National Technical University of Athens in 1994 and the PhD in Electrical Engineering from Imperial College of Science, Technology and Medicine, University of London in 2000. Since May 2009 she has been a faculty member at the Department of Digital Systems, where she conducts research and teaches undergraduate and postgraduate courses in Broadband Communications and Advanced Wireless Technologies. Prior to this appointment she was with Bell Laboratories, Wireless Research, Lucent Technologies, (later Alcatel-Lucent, now NOKIA), in Swindon, UK, first as a member of technical staff (January 1999-February 2006) and later as a Technical Manager (March 2006-April 2009). Professor Alexiou is a co-recipient of Bell Labs President's Gold Award in 2002 for contributions to Bell Labs Layered Space-Time (BLAST) project and the Central Bell Labs Teamwork Award in 2004 for role model teamwork and technical achievements in the IST FITNESS project. Professor Alexiou is the Chair of the Working Group on Radio Communication Technologies and of the Working Group on High Frequencies Radio Technologies of the Wireless World Research Forum. She is a member of the IEEE, the IEEE ComSoc, Core member of the IEEE ComSoc SIG on TeraHertz Communications, the IEEE SP Society, member of the IEEE SP Society SAM TC and member of the Technical Chamber of Greece. Her current research interests include radio interface for 6G systems, MIMO, THz wireless communication technologies, Reconfigurable Intelligent Surfaces, cooperation and coordination for Ultra Dense wireless networks, 'cell-less' architectures and machine learning for wireless systems. She is the project coordinator of the H2020 TERRANOVA project (ict-terranova.eu) and the technical manager of H2020 ARIADNE project (ict-ariadne.eu).