Schotten, HD.; Uusitalo, MA.; Monserrat Del Río, JF.; Queseth, O. (2015). 5G Spectrum: enabling the future mobile landscape. IEEE Communications Magazine. 53(7):16-17. doi:10.1109/MCOM.2015.7158260.

GUEST EDITORIAL

5G SPECTRUM: ENABLING THE FUTURE MOBILE LANDSCAPE

The arrival of 5G is expected to come together with three important enablers. Firstly, the densification of access nodes will continue. Secondly, 5G networks must be highly flexible and adapt to the dynamism of the traffic location and patterns. For this, parts of the Radio Access Network (RAN) functionalities will run in large computer centers, able to dynamically assign more or less units of computation to the virtual cells distributed in the network. Finally, a complex landscape of spectrum availability and access will emerge where multiple frequency bands, subject to different regulations including various forms of shared spectrum, are expected to be available to wireless communication systems.

The discussions on spectrum demand in the ongoing preparation phase for the ITU World Radiocommunications Conference 2015 (WRC-15) are dominated by the dramatic increase in mobile data volume caused by the rapidly growing multimedia prosumption of end-users. Licensed Shared Access (LSA) and other concepts were developed to address the resulting challenges.

The preparation for WRC-19 and the long-term discussions on spectrum demand and usage concepts will be driven by 5G visions and, more specifically, the coherence of mobile communications solutions for many public and professional user groups within an overall mobile landscape. It is expected that this "5G" infrastructure will enable many new services in domains such as intelligent traffic systems, public safety, automation, e-health, transport and logistics, and will help them to become economically viable. This trend will not only increase the overall spectrum demand beyond the figures discussed at WRC-15, but it will result in additional requirements on spectrum resulting from the high coverage, reliability, and availability requirements of the new services to be supported.

This feature topic issue provides an overview of the major developments in the use of future 5G spectrum. The six papers included in this issue describe new approaches for the efficient use of spectrum as well as new band opportunities that will have an impact on the coming ITU-R discussions.

The first article “Spectrum Access System for the Citizen Broadband Radio Service” by Munawwar Sohul *et al.* presents a survey on the current discussions about LSA in the FCC framework. Special attention is paid to the concepts of Dynamic Frequency Assignment (DFA) and Interference Management (IM). Requirements, capabilities and minimum set of information are extracted for these two functionalities.

Once the general framework is provided from the U.S. regulation point of view, the next article entitled “Towards spectrum sharing: opportunities and technical enablers” by Konstantinos Chatzikokolakis *et al.*, presents the architectural framework and the challenges and opportunities observed from the European point of view. Moreover, this paper presents fuzzy logic-based mechanism to make the best decision concerning the type of authorization scheme. The proposed algorithm uses a number of measurements including, among others, network load, interference situation, and mobility patterns.

The third and fourth articles provide more specific mechanisms for spectrum sharing. In particular the third article “Coordination protocol for inter-operator spectrum sharing in co-primary 5G small cell networks” by Bikramjit Singh *et al.*, considers co-primary spectrum sharing among a limited number of co-located RANs belonging to different operators. In this framework, the authors propose a non-cooperative coordination protocol for mutual renting of spectrum in which operators agree on the set of negotiation rules. With low signaling overhead, no monetary transactions are involved; instead, spectrum sharing is based on a RAN-internal virtual currency. The protocol adapts to load and interference conditions and it has proven to be efficient in small cell scenarios.

On the other hand, the fourth article “Spectrum and licence flexibility for 5G networks” by Adrian Kliks *et al.*, discusses the idea of flexible licensing, which provides new opportunities for spectrum holders to make additional profit by renting portions of the locally

unused spectrum. Several concepts are analyzed in this framework, being of special relevance the pluralistic licensing concept, which is the focus of the paper. The paper also discusses about the necessary regulatory decisions made globally to facilitate these new spectrum usage approaches in the context of 5G networks.

The last two articles address two specific spectrum situations, those in the U.S and in China. The fifth article "Broadcast Television Spectrum Incentive Auctions in the U.S.: Trends, Challenges, and Opportunities" by David Gómez-Barquero and Winston Caldwell, presents an overview of the future TV broadcast spectrum incentive auction in the United States and reviews the main business, regulatory, and technical challenges for a successful auction. In this case, the U.S. could be the first country to make the upper portion of the 600 MHz band available for mobile broadband, and it will become one of the hot topics for the future WRC-19. The paper also proposes a new approach for a market-driven incentive auction, in which primary users may resell frequency packs to other interested players.

Finally, the sixth article "5G Spectrum, is China Ready?" authored by Tan Wang *et al.*, presents the Chinese vision on 5G spectrum, including demands, potential candidate bands, and use of spectrum. Moreover, starting from the current framework of spectrum management in China, this paper offers an interesting classification of services and evaluates the specific needs of bandwidth.

We would like to thank Dr. Osman Gebizlioglu, Joseph Milizzo, Charis Scoggins and Jennifer Porcello for their continuous support and valuable comments to improve this feature topic issue. We hope that the articles in this issue will encourage the readers of the IEEE *Communications Magazine* to contribute to the discussions on the future design, development and adoption of 5G technologies.

HANS SCHOTTEN [M] (schotten@eit.uni-kl.de) is full professor and head of the Institute for Wireless Communications and Navigation at the University of Kaiserslautern and Scientific Director and member of the Management Board of the German Research Centre for Artificial Intelligence (DFKI GmbH). In 1997, he received a Ph.D. in Electrical Engineering from the Aachen University of Technology RWTH, Germany. He held positions as senior researcher, project manager, and head of research groups at the Aachen University of Technology, Ericsson Corporate Research, and Qualcomm Corporate R&D. At Qualcomm he has been a Director for Technical Standards and coordinator of Qualcomm's activities in European research programs. Prof. Schotten published over 200 technical papers, filed 15 patents, received several awards, and served as TPC co-chair of 20+ international workshops and conferences.

MIKKO A. UUSITALO [SM] (mikko.a.uusitalo@nokia.com) is Manager of Radio Research at Nokia Networks. He obtained a M.Sc. (Eng) and Dr.Tech. from Helsinki University of Technology in 1993 and 1997 and a B.Sc. (Economics) from Helsinki School of Economics in 2003 (Both of these currently known as Aalto University). Mikko has been at Nokia since 2000 with various roles, including Principal Researcher and Head of International Cooperation at Nokia Research. Mikko has about 95 pending or granted patents. Mikko was elected as chair of WWRF for the years 2004-2006, is one of the founding members of WWRF as well as WWRF Fellow. Mikko is also a founding member of the CELTIC EUREKA initiative. Mikko is a Senior Member of IEEE.

JOSE F. MONSERRAT [SM] (jomondel@iteam.upv.es) received his MSc. degree with High Honors and Ph.D. degree in Telecommunications engineering from the Polytechnic University of Valencia (UPV) in 2003 and 2007, respectively. He was the recipient of the First Regional Prize of Engineering Studies in 2003 for his outstanding student record receiving also the Best Thesis Prize from the UPV in 2008. In 2009 he was awarded with the best young researcher prize of Valencia. He is currently an associate professor in the Communications Department of the UPV. His current research focuses on the design of future 5G wireless systems and their performance assessment. He has been involved in several European Projects, being especially significant his participation in NEWCOM, PROSIMOS, WINNER+ and METIS where he is currently leading the simulation activities. He also participated in 2010 in one external evaluation group within ITU-R on the performance assessment of the candidates for the future family of standards IMT-Advanced. He co-edited the February 2011 special issue on IMT-Advanced systems published in IEEE Communications Magazine and is co-author of the Wiley book "Mobile and wireless communications for IMT-Advanced and beyond". Jose Monserrat is senior member of the IEEE, holds 6 patents and has published more than 40 journal papers.

OLAV QUESETH (olav.queseth@ericsson.com) received his MSc in computer engineering in 1995 from Chalmers, Sweden and a PhD degree in 2005 from KTH, Sweden in Radio Communications Networks. He is currently working at Ericsson as a master researcher. He joined the 5G research project METIS

in 2012 and since April 2014 he is the project coordinator. Prior to that he has worked with spectrum issues in the regulatory domain in CEPT and ITU and before that he worked with standardization of radio aspects in 3GPP. He joined Ericsson in 2007 after doing spectrum research in the Ambient networks EU research project.