# Unveiling 5G wireless networks: Emerging research advances, prospects, and challenges [Guest Editorial]

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# *Unveiling 5G Wireless Networks: Emerging Research Advances, Prospects, and Challenges*



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To cope with the high traffic volume demands spurred by the proliferation and penetration of 4G services, significant improvements to wireless access techniques have been made. Notable examples are massive multiple-input multiple-output (MIMO), coordinated multipoint (CoMP) transmission and reception, and D2D (device-to-device) incorporated in 3G and 4G specifications. Furthermore, to boost network coverage and capacity, mobile operators have also been increasingly deploying heterogeneous networks (HetNets), consisting of micro-, pico-, and small/femtocells. However, despite these advances in core wireless technologies, Third Generation Partnership Project (3GPP) mobile networks are still challenged to handle the ever increasing mobile traffic, particularly due to the use of specific-purpose networking equipment that can neither dynamically scale with mobile traffic nor easily be upgraded with new functions.

With the emergence of cloud computing as an important information technology in support of virtualized services, it is promising to design 5G wireless networks by exploiting recent advances in network function virtualization and benefiting from advanced virtualization techniques of cloud computing to build efficient and scalable networking infrastructures. Researchers have been designing new architectures for elastically composing and operating a virtual end-to-end network platform on demand on top of fragmented physical infrastructures provided by federated clouds. Software-defined networking (SDN) techniques have been seen as promising enablers for this vision of carrier cloud, which will likely play a crucial role in the design of 5G wireless networks.

In response to the Call for Contributions, we received 57 paper submissions. After a careful review process, seven outstanding papers were collected for this special issue.

The volume opens with an article on 5G wireless backhaul networks, "5G Wireless Backhaul Networks: Challenges and Research Advances," authored by Ge *et al.* The article presents potential wireless backhaul network solutions for future 5G mobile communication systems with massive backhaul traffic. Based on numerical results and analysis, the distribution solution is suggested for 5G wireless backhaul networks considering the throughput and energy efficiency constraints. Furthermore, some challenges, such as ultra-dense cell deployment, frequent handover in small cells, and energy efficiency, are discussed to satisfy requirements of 5G wireless backhaul networks. The second article, "Toward 5G: When Explosive Bursts Meet Soft Cloud," written by Zhou *et al.*, investigates explosive

bursts and their influence on next-generation 5G cellular networks, for which a software-defined cellular networking architecture has been proposed based on an interconnected cloud computing platform with open interfaces. In particular, this novel approach not only avoids the potentially negative influences of bursts, but also provides a software controlled end-to-end service management framework for future 5G cellular networks. Therefore, by taking advantage of the open interfaces of cloud based network elements, a unified intelligent (smart and soft) management across the RAN (radio access networks), core networks, bearer networks, and service platforms can also be achieved.

The demand for broadband network connectivity has dramatically increased in the last decade. It has gained additional momentum along with the increase in the number of Internet-connected mobile devices, ranging from smartphones, tablets, and laptops to sensor networks, and machine-to-machine (M2M) connectivity. This increasing demand, backed by always connected concepts of mobile applications, are pushing network infrastructure to the limit. 5G is the technology that will provide a solution by offering higher data rates with lower latency and much larger coverage radius. For 5G technology to be applicable and achieve its objectives, some of the challenges have to be overcome. As 5G networks will offer higher connectivity speeds with much higher support of mobile devices, the signaling traffic generated in the core network will be booming. In "NFV: State of the Art, Challenges and Implementation in Next Generation Mobile Networks (vEPC)," Hawilo *et al.* study network function virtualization (NFV) technology as a solution in the mobile core network. The article provides a glance into the state-of-the-art in NFV, one of the leading edge technologies that will bring the advantages of IT virtualization to the telecommunication industry. Moreover, the article discusses challenges in security, computing performance, VNF interconnection, portability, operation and management that hinder NFV adoption progress.

With the advent of 5G toward the end of the current decade, cellular operators may have to manage up to four different technologies — GSM, UMTS, 4G, and 5G — while deploying more network nodes to cope with the increasing user data demand. The resulting increase in operational complexity and expenditure poses one of the biggest challenges for next-generation broadband cellular systems. In the fourth article, "Challenges in 5G: How to Empower SON with Big Data for Enabling 5G," Imran *et al.* investigate self-organizing networks (SONs) to cope with challenges in 4G cellular networks. The article proposes to transform the state of the art reactive SON to proactive SON by empowering it with big data. More specifically, it proposes a systematic approach to exploit the deluge of control, signaling, and contextual data produced during routine operation of cellular networks thus far largely untapped, referred to as big data, to deduce unprecedented amounts of system-level intelligence that can then be fed into SON engines to make it proactive, thereby transforming it into a key enabler of 5G.

To support the insatiable data demand, in addition to the existing licensed spectrum, cellular operators are considering to access spectrum in unlicensed and shared access spectrum bands. The article "Carrier Aggregation/Channel Bonding in Next Generation Cellular Networks: Methods and Challenges" by Khan *et al.* first reviews recent research efforts pertaining to the implementations of carrier aggregation/channel bonding techniques that can be used by cellular operators to offer unified services in licensed, unlicensed, and shared access bands. Then the article identifies challenges faced in the scenarios whereby multiple independent operators decide to combine channels simultaneously in the licensed, unlicensed, and shared access bands to obtain wider bandwidth and higher throughput.

The sixth article, "Visible Light Communication for 5G Wireless Networking Systems: From Fixed to Mobile Communications," targets visible light communication (VLC) as a potential access option for 5G wireless communications. This article investigates VLC's strengths in energy efficiency and ultra wide bandwidth, as well as its weakness in transmission range and obstacles in transmission paths. This paper aims at providing a conclusive investigation of the latest progress in research on VLC which can be used as part of 5G wireless communication systems. This work highlights the strengths and weaknesses of VLC in comparison with RF-based communications, especially in spectrum, spatial reuse, security, and energy efficiency. The article also investigates various lighting sources proposed for VLC systems. It summarizes the literature on VLC networking in two categories: fixed and mobile VLC communications.

The last article, "Heterogeneous Statistical QoS Provisioning Over 5G Mobile Wireless Networks" by Zhang *et al.*, proposes a novel heterogeneous statistical QoS provisioning architecture to support the transmission of highly bandwidth-intensive and time-sensitive multimedia services, including 3D immersive media services, over 5G systems. Observing that more than one type of multimedia traffic with different delay-bound QoS constraints coexist in 5G mobile wireless networks, this article develops a set of schemes to efficiently guarantee the heterogeneous statistical delay-bounded QoS requirements through employing three promising 5G-candidate wireless techniques: i) D2D; ii) full-duplex; and iii) cognitive radio, respectively, under their proposed heterogeneous statistical QoS provisioning architecture.

In closing, we would like to thank all the authors who submitted their research work to this Feature Topic. We would also like to acknowledge the contributions of many experts in the field, from both academia and industry, who participated in the review process, and provided helpful suggestions to the authors to improve the content and presentation of the articles. We would in particular like to thank Professor Xuemin "Sherman" Shen, Editor-in-Chief of *IEEE Network*, for his support and highly appreciated suggestions and comments during the delicate stages of concluding this Feature Topic. Last but not least, it is our hope that the readers will enjoy these articles.

## Biographies

VICTOR C. M. LEUNG (vleung@ece.ubc.ca) [S'75, M'89, SM'97, F'03] is a professor of electrical and computer engineering and holder of the TELUS Mobility Research Chair at the University of British Columbia (UBC). He has contributed some 750 technical papers, 29 book chapters, and 8 book titles

in the areas of wireless networks and mobile systems. He was a Distinguished Lecturer of the IEEE Communications Society. He has served/is serving on the editorial boards of *IEEE Transactions on Computers*, *IEEE Wireless Communications Letters*, and several other journals, and has contributed to the Organizing and Technical Program Committees of numerous conferences. He was a winner of the 2012 UBC Killam Research Prize and the IEEE Vancouver Section Centennial Award. He is a Fellow of the Royal Society of Canada, the Canadian Academy of Engineering, and the Engineering Institute of Canada.

TARIK TALEB (talebtarik@ieee.org) [S'04, M'05, SM'10] received his B.E. degree (with distinction) in information engineering, and M.Sc. and Ph.D. degrees in information science from Tohoku University, Sendai, Japan, in 2001, 2003, and 2005, respectively. He is a senior researcher and 3GPP standardization expert with NEC Europe Ltd., Heidelberg, Germany. He is leading the NEC Europe Labs Team, working on research and development projects on carrier cloud platforms. He is an IEEE Communications Society Distinguished Lecturer. He is a member of the IEEE ComSoc Standardization Program Development Board. He is serving as Vice Chair of the Wireless Communications Technical Committee, the largest in IEEE ComSoc. He founded and has been General Chair of the IEEE Workshop on Telecommunications Standards: From Research to Standards, which is a successful event that received the Best Workshop Award from IEEE ComSoc. He has received many awards including the IEEE ComSoc Asia Pacific Best Young Researcher award in June 2009. Some of his research work has also received Best Paper Awards at prestigious conferences.

MIN CHEN (minchen@ieee.org) [M'08, SM'09] is a professor in the School of Computer Science and Technology at Huazhong University of Science and Technology (HUST). He was an assistant professor in the School of Computer Science and Engineering at Seoul National University (SNU) from September 2009 to February 2012. He worked as a post-doctoral fellow in the Department of Electrical and Computer Engineering at UBC for three years. Before joining UBC, he was a post-doctoral fellow at SNU for one and a half years. He has more than 180 paper publications. He received the Best Paper Award from IEEE ICC 2012 and Best Paper Runner-Up Award from QShine 2008. He has been a Guest Editor for *IEEE Network*, *IEEE Wireless Communications*, and other publications. He was Symposium Co-Chair for IEEE ICC 2012 and IEEE ICC 2013, and General Co-Chair for IEEE CIT 2012. He is a TPC member for IEEE INFOCOM 2014. He is a Keynote Speaker for CyberC 2012 and Mobiquitous 2012.

THOMAS MAGEDANZ is actively performing R&D in the field of converging networks and ICT for more than 25 years. Since 2000 he has been the director of the Next Generation Network Infrastructures division of the Fraunhofer Institute FOKUS, where he is responsible for the development of the globally recognized OpenXXX testbed toolkits enabling industry and academia to prototype the newest network and service platform technologies. Since 2004 he is also a full professor in the electrical engineering and computer sciences faculty at the Technische Universität Berlin, Germany, leading the chair for Next Generation Networks and educating Master and Ph.D. students.

LI-CHUN WANG [F'10] received his B.S. degree from National Chiao Tung University, Taiwan, R.O.C., in 1986, his M.S. degree from National Taiwan University in 1988, and Ms. Sci. and Ph. D. degrees from the Georgia Institute of Technology, Atlanta, in 1995, and 1996, respectively, all in electrical engineering. His IEEE Fellow grade was given for his contributions in cellular architecutures and radio resource management techniques in wireless networks.

RAHIM TAFAZOLLI is the Director of the Institute for Communication Systems (ICS) and 5G Innovation Centre (5GIC), The University of Surrey in the UK. He has published more than 500 research papers in refereed journals, international conferences and as invited speaker. He is the editor of two books on "Technologies for Wireless Future" published by Wiley's Vol.1 in 2004 and Vol.2 2006. He was appointed as Fellow of WWRF (Wireless World Research Forum) in April 2011, in recognition of his personal contribution to the wireless world. As well as heading one of Europe's leading research groups.

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**BACKGROUND**

In order to tackle future exponentially increased traffic demands and ever-increasing quality of experience (QoE) requirements, telecommunications providers are currently rethinking their network architecture from one consisting of a multitude of "black boxes" with specialized network hardware and software to a new architecture consisting of "white box" hardware running a multitude of specialized network software. This network software may be data-plane software providing network function virtualization (NFV), or control-plane software providing centralized network management - software defined networking (SDN). It is expected that these architectural changes will permeate networks as wide ranging in size as the internet core networks, to metro networks, to enterprise networks and as wide ranging in functionality from converged packet-optical networks, to wireless core networks, to wireless radio access networks.

SDN problems will be especially pronounced in future carrier wireless networks, which will rely on the co-existence of multiple deployment scenarios, on diverse radio access specifications, and support a rich variety of services and applications. This requires a new wireless network architecture which directs flexible, dynamically configurable network elements to provide on-demand customized services to traffic demands which may be dynamic in time and space. The special issue aims to bring together tutorials of the state-of-the-art on the design, specification, and implementation of architectures, algorithms and protocols conceived for software defined carrier wireless networks (SD-CWN). We aim to draw original, unpublished contributions in all aspects of SD-CWN. **SUBMISSIONS**

With regard to both the content and formatting style of the submissions, prospective authors should follow the IEEE Network submission guidelines available athttp://www.comsoc.org/netmag/paper-submission-guidelines. Authors should submit their manuscripts via Manuscript Central, choosing "Software Defined Wireless Networks" from the drop-down menu on the submission page. The corresponding author is also requested to send the title of the submission and the list of authors by email to the Guest Editors.

**SCHEDULE FOR SUBMISSIONS**

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