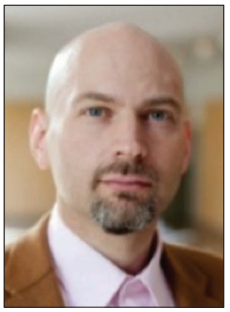
MOBILE CONVERGED NETWORKS



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Driven by the ever increasing popularity and demand of multimedia contents, wireless traffic is expected to increase 1000 times in the next 10 years. A looming problem is how to identify a frequency band, from the already scarce spectrum resources, to fulfill this requirement. A feasible cost-efficient solution is to integrate several existing network resources, which have been allocated for different services, to form a single mobile converged network. These existing networks operate independently on different frequency bands, including the cellular network, video broadcast, wireless sensor network (WSN), and wireless local area network (WLAN). Each of them, alone, has its own historic justification, but suffers certain drawbacks in one way or another. For instance, the cellular network was originally designed to offer voice service, lacking an efficient means of broadcasting multimedia contents. Clearly, integrating these heterogeneous networks will constitute a much more powerful unified framework able to fully exploit the capability and radio resources of all the individual networks, provide a platform for the Internet of Things, and enable users to enjoy a uniform service everywhere by using a software-defined radio device. The benefits of converged networks are promising; however, the road to success is filled with challenges. The networks integration necessitates a harmonious interaction among heterogeneous networks at different levels, thus requiring a careful design of network architecture, coordination protocols, and resource allocation algorithms for efficient operation of the converged network.

This Feature Topic consists of 14 papers addressing recent research advances on mobile converged networks from different aspects such as converged network architecture, air interface convergence design, unified protocols for integration of heterogeneous systems, as well as coexistence solutions for converged networks.

In the first article, "CONCERT: A Cloud-Based Architecture for Next-Generation Cellular Systems," Liu *et al.* propose Convergence of Cloud and Cellular Systems (CONCERT), a converged edge infrastructure for future cellular communications and mobile computing services. Moreover, they introduce new designs for physical resource placement and task scheduling so that CONCERT can overcome the drawbacks of the existing baseband-up centralization approach and better facilitate innovations in next-generation cellular networks. These advantages are demonstrated with application examples on radio access networks (RANs) with C/D decoupled air interface, delay-sensitive machine-type communications, and real-time mobile cloud gaming.

In the second article, "A Unified Protocol Stack Solution for LTE and WLAN in Future Mobile Converged Networks," Cui *et al.* propose a new converged base station (CBS) solution, which integrates different radio access technologies (RATs) at layer 2 in the true sense of convergence. They design a unified protocol stack that includes all the original functions of both LTE and WLAN systems. Then a convergence architecture is proposed, the RATs multiplexing control (RMC) sublayer, for joint management of these two RATs. The proposed CBS solution can support seamless offloading through soft handover, guaranteed quality of service (QoS), forwarding management by a single IP address, and customized bandwidth aggregation service.

In the third article, "Mobile Converged Networks: Framework, Optimization, and Challenges," Han *et al.* propose a new framework of mobile converged networks for flexible resource optimization over multi-tier wireless heterogeneous networks. Moreover, they also present mobile converged network models based on interference coordination and energy efficiency, and develop the corresponding optimization algorithms.

In the fourth article, "Networks of Learning Automata for Vehicular Environment: A Performance Analysis Study," Kumar *et al.* analyze the performance of networks of learning automata (LA) using the concepts of the Bayesian coalition game in the vehicular environment. The performance of the proposed scheme is also evaluated in different network conditions in a real environment by varying the learning rates of the automaton. Moreover, a 20–30 percent enhancement of successful packet delivery ratio

has been observed using the proposed scheme in the vehicular environment.

In the fifth article, "Network Convergence: Theory, Architecture, and Applications," Zhang *et al.* introduce crucial issues arising from network convergence including its information-theoretic foundation, architectures, and feasible schemes for various application scenarios.

In the sixth article, "A Survey of Converging Solutions for Heterogeneous Mobile Networks," Jo *et al.* provide an overview of converged mobile networks, investigating different converged mobile network types, different types of convergence, and the current problems and solutions. They also propose potential research topics in converged mobile networks.

In the seventh article, "Coexistence of Digital Terrestrial Television and Next Generation Cellular Networks in the 700 MHz Band," Fuentes *et al.* introduce the new spectrum allocated to mobile communications, the 700 MHz band. Then they analyze the coexistence problem in the 700 MHz band and evaluate the interference of LTE signals into DTT services. Moreover, they consider several coexistence scenarios and perform laboratory tests to measure interference protection ratios.

In the eighth article, "SoftMobile: Control Evolution for Future Heterogeneous Mobile Networks," Chen *et al.* first briefly review the control planes of 2G to 4G cellular networks, and then identify their constraints to support heterogeneous mobile networks (HMNs). Then they analyze the complexity of HMNs and examine enabling control technologies for them. Furthermore, they propose an SDN-based control framework, SoftMobile, to coordinate complex radio access in HMN. The important research problems in SDN for mobile networks are also highlighted.

In the ninth article, "SDN Enabled Converged Networks," Tan *et al.* propose an SDN-enabled convergent network for efficient resource management, E2E QoS enforcement, and the achievement of flexibility and scalability for future network evolutions. The system architecture and protocol, as well as key technical challenges are also investigated. Some promising applications of the proposed network are implemented and evaluated based on their established open test platform to show its superiority to current network architecture and techniques.

In the 10th article, "Intelligent Access Network Selection in Converged Multi-Radio Heterogeneous Networks," Andreev *et al.* focus on interworking within the radio access network and detailed feasible options for intelligent access network selection. Their system-level simulation results indicate that load-aware user-centric schemes, which augment SNR measurements with additional information about network loading, could improve the performance of conventional WiFi-preferred solutions based on minimum SNR threshold. Then comparison with more advanced network-controlled schemes has also been completed to confirm attractive practical benefits of distributed user-centric algorithms. Moreover, they also propose novel analytical space-time methodology for assisted network selection capturing user traffic dynamics together with spatial randomness of multi-radio heterogeneous networks.

In the 11th article, "Device-to-Device Communication Underlaying Converged Heterogeneous Networks," Gamage *et al.* investigate how to leverage device-to-device (D2D) communication to further improve the performance of a converged network which consists of an LTE-Advanced (LTE-A) cellular network and IEEE 802.11n WLANs. Then three main technical challenges that complicate the resource allocation are identified. To address these challenges, they propose a resource allocation scheme that performs mode selection, allocation of WLAN resources, and allocation of LTE-A network resources in three different timescales. Moreover, simulation results demonstrate the achievable performance improvements.

In the 12th article, "Cooperative Small Cell Networks: High Capacity for Hotspots with Interference Mitigation," Jiang *et al.* propose a cooperative small cell network (CSCN) architecture, which jointly utilizes several advanced techniques to enhance the capacity of hotspots. By examining the existing solutions for capacity enhancement and hotspots, they then present the basic concept of the proposed CSCN architecture, and discuss the related technical aspects. Moreover, several open problems for future research based on the CSCN architecture are also presented.

In the 13th article, "On Content-Centric Wireless Delivery Networks," Liu *et al.* investigate the problem of massive content delivery over wireless networks and present a systematic view on content-centric network design and its underlying challenges. Then they describe a network architecture that enables wireless network crowdsourcing for content delivery, followed by an exemplary campus wireless network that encompasses the proposed concepts.

In the 14th article, "Heterogeneous Cloud Radio Access Networks: A New Perspective for Enhancing Spectral and Energy Efficiencies," Peng *et al.* propose heterogeneous cloud radio access networks (H-CRANs) as cost-efficient potential solutions through incorporating cloud computing into heterogeneous networks (HetNets). They also discuss issues of system architectures, spectral and energy efficiency performance, and promising key techniques. The major challenges and open issues in terms of theoretical performance with stochastic geometry, fronthaul constrained resource allocation, and standard development that may block the promotion of H-CRANs are discussed as well.

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 contribution of many experts in the field who have participated in the review process, and provided helpful suggestions to the authors on improving the content and presentation of the articles. In addition, we would like to extend our sincere thanks to Dr. Hsiao-Hwa Chen, Editor-in-Chief of *IEEE Wireless Communications*, for his support and help in bringing forward this Feature Topic. We hope you enjoy the articles in this collection.

BIOGRAPHIES

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YUN RUI [M'11, SM'14] (ruiy@sari.ac.cn) received his B.S. degree from Southeast University (SEU) in 2004 and his Ph.D. degree from the Chinese Academy of Sciences (CAS) in 2009, all in telecommunications engineering. From February 2011 to August 2011, he was a visiting fellow at the Department of Electronic Engineering, City University of Hong Kong. Since September 2011, he has been an associate professor in the Shanghai Advanced Research Institute, CAS. His current research interests include green communication networks, mobile converged networks, and software defined wireless networks. He is an Associate Editor for *Wireless Communications and Mobile Computing* and a Guest Editor for *IEEE Wireless Communications*, Feature Topic on Mobile Converged Networks. He is serving as General Chair for the IEEE IWCMC 2014 Workshop on Software Defined Wireless Networks and IEEE ICC 2015 Workshop of Heterogeneous Converged Networks. He also served as TPC Co-Chair for the IEEE WCNC 2013 Workshop on Convergence of Broadcast and Broadband Communication. He was a recipient of the International Conference Award of the K. C. Wong Education Foundation. He was elected a member of the Youth Innovation Promotion Association of CAS.

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KARI PEHKONEN [M]received hisMaster of Science, Licentiate in Technology, and Doctor of Technology degrees from the University of Oulu in 1987, 1989, and 1993, respectively. After graduation, he joined the Computer Technology Laboratory of the Technical Research Centre of Finland in 1987, involved in research on parallel programming and parallel computers. During 1989–1990 he was a visiting researcher at the Computer Vision Laboratory of the Center for Automation Research of the University of Maryland, doing research on computer vision algorithms. Upon his return to Finland, he continued at the Technical Research Centre further studying the algorithms developed during his visit to the United States. In December 1993, he joined Nokia, first as a research engineer and then holding various managerial positions within the company, doing research on WCDMA systems and standardization. In 1998–2001 he was with Nokia Japan, responsible for ARIB standardization activities. From the beginning of 2001 until December 2010, he was leading the systems research at Nokia. From December 2010 until September 2013, he was head of Systems Research and Standardization at Renesas Mobile Corporation with global responsibility for system research and standardization activities. In October 2013 he joined Broadcom Communications Finland, responsible for global standardization activities. He has published 23 papers in international conferences and journals, and holds 81 patents covering different areas of radio interfaces.