EXTREMELY DENSE WIRELESS NETWORKS


Claudio Cicconetti


Antonio de la Oliva


David Chieng


Juan Carlos Zúñiga

The ever growing demand from mobile network users is pushing the current wireless technologies toward their limits. As a matter of fact, not even the most optimistic promises from emerging standards, such as LTE-Advanced and IEEE 802.11ac/ad/af, will be able to satiate the huge appetite for bandwidth of the future users of 5G networks — at least, unless the size of cells is reduced dramatically. This situation will soon create a desperate need for extremely dense wireless networks (DenseNets).

Unfortunately, merely shrinking the cell size is not sufficient due to several technical and economic factors. On the technical side we find interference, which is a real challenge as the number of cells deployed nearby increases, and energy consumption, which also becomes important due to much more irregular usage patterns. Among the business/deployment issues, we mention the availability of sufficient backhaul capacity everywhere, the current lack of very low-cost/very small base stations, and the need for economically viable operation, administration, and management (OAM) activities.

In brief, low-hanging fruits will not be there to be grabbed by the telecom industry. Rather, a new ecosystem of solutions, possibly characterized by the use of cooperative approaches, will be required to take full advantage of the new opportunities brought by extremely dense wireless networks. The nine articles in this Feature Topic deeply investigate some of the hottest research challenges in this context.

The first challenge addressed is related to the deployment of future mobile networks. In "Spectral and Energy Efficiency of Ultra-Dense Networks under Different Deployment Strategies" by Syed Fahad Yunas *et al.*, it is shown how extremely dense indoor femtocells and outdoor distributed antenna systems both outperform a densified macrocell deployment in terms of capacity and energy efficiency. Therefore, to meet the 5G requirements, alternative paths to the long-standing processes of cellular network provisioning must be experimented.

The second article, "Interference Coordination for Dense Wireless Networks" by Beatriz Soret *et al.*, presents the problem of interference in dense scenarios: as the density of cells increases, so does interference. This article revisits the options on the table for LTE and LTE-Advanced, proposing two algorithms to apply time domain and frequency domain small cell interference coordination in a DenseNet.

The third article, "Understanding Channel Selection Dynamics in Dense Wi-Fi Networks" by Akash Baid and Dipankar Raychaudhuri investigates the impact of increasing enterprises' or service providers' access points (APs) with centralized channel assignment on the performance of typical residential APs and vice versa. A parametric approximation scheme is proposed for estimating the AP's throughput.

The fourth article, "Per-Node Throughput Enhancement in Wi-Fi DenseNets" by Kyungseop Shin *et al.*, proposes a joint dynamic sensitivity control (DSC) and transmit power control (TPC) approach to control interference in dense residential, enterprise, or indoor hotspot deployments. The simulation results show that significant per-node throughput improvements can be achieved regardless of the deployment type.

The fifth article, "On the Efficient Utilization of Radio Resources in Extremely Dense Wireless Networks" by Arash Asadi *et al.*, tackles the joint utilization of WiFi relays to improve the performance of LTE. This work proposes a resource allocation mechanism opportunistically exploiting network density as a resource. Results show that intracell opportunistic relay can reduce the complexity and boost efficiency of intercell interference coordination in LTE.

The sixth article, "Toward 5G DenseNets: Architectural Advances for Effective Machine-Type Communications over Femtocells" by Massimo Condoluci *et al.*, presents a novel architecture to handle the growing MTC traffic by the use of small cells to handle the massive and dense MTC rollout. This work introduces a novel 3GPP-compliant architecture that absorbs the MTC traffic via home evolved NodeBs (HeNBs), providing significant reduction of congestion in radio access and core networks.

Efficient mobility management is a firm but challenging requirement in future extremely dense scenarios of mobile networks. In the seventh article, "Distributed Mobility Management for Future 5G Networks: Overview and Analysis of Existing Approaches" by Fabio Giust *et al.*, the authors propose a novel and highly scalable mobility management architecture based on the distributed mobility management concept currently under study at the Internet Engineering Task Force (IETF).

C-RAN is a promising technology to increase the density of the network at reduced cost. This topic is investigated in the eighth article, "Software-Defined Networking in Cellular Radio Access Networks: Potential and Challenges" by Mustafa Y. Arslan *et al.*, where the concept of SDN is applied to the fronthauling in C-RAN deployments. The results can also be applied to extended support for coordinated multipoint approaches.

Finally, the ninth article, "Scalability of Dense Wireless Lighting Control Networks" by Conrad Dandelski, addresses an interesting technological alternative for DenseNets, that is, the use of LED-based lighting networks already deployed in buildings for broadcasting messages and collecting sensor data, thus providing a control system for the lighting network increasing its scalability.

ACKNOWLEDGMENT

Putting together this Feature Topic has been challenging but rewarding. We would like to thank all authors for their invaluable contributions. This Feature Topic would not be possible without the timely and professional support of all the reviewers. Last but not least, we would also like to record our sincere thanks to Dr. Sean Moore, Editor-in-Chief of *IEEE Communications Magazine*, Charis Scoggins, and Jennifer Porcello for their relentless support throughout the whole publication process.

BIOGRAPHIES

CLAUDIO CICCONETTI (ccicconetti@mbigroup.it) holds a Laurea degree (2003) and a Ph.D. (2007) in information engineering from the University of Pisa. He worked at Intecs as an R&D Manager until 2013 and is now working at MBI S.rl. (Italy) on satellite communications. He has been involved in several projects co-funded by the European Commission (EuQoS, SANDRA, CROWD, MOTO, BETaaS) and the European Space Agency (SAT4NET, ACCORD). He has co-authored 50+ scientific papers and two international patents.

ANTONIO DE LA OLIVA (aoliva@it.uc3m.es) obtained a degree (2004) and his Ph.D. (2008) in telecommunication engineering at the University Carlos III of Madrid, where he is an assistant professor. He has been involved in many European projects (DAIDALOS, ONELAB, CARMEN, MEDIEVAL, CROWD). He has published 30+ papers and submitted several patents on mobility management and wireless networks. He has served as Vice-Chair of the IEEE 802.21b task group and Technical Editor of IEEE 802.21d.

DAVID CHIENG (ht.chieng@mimos.my) is currently the head of the HetNet Lab in Mimos, Malaysia. From 2006 to 2010, he led broadband wireless research in BT MRC and also served as a WP manager in the EU FP7 CARMEN project. From 2003 to 2006, he was with the Faculty of Engineering, Multimedia University. He received his Ph.D. in communication networks from Queen's University of Belfast, Northern Ireland, in 2002. He has authored and co-authored more than 40 publications and filed 14 patents.

JUAN CARLOS ZÚÑIGA (JuanCarlos.Zuniga@interdigital.com) received his engineering degree from the UNAM, Mexico, and his M.Sc. from Imperial College London, United Kingdom. He has worked with Harris Canada, Nortel Networks UK, and Kb/Tel Mexico, and is now a principal engineer at InterDigital. He chairs the IEEE 802 Privacy SG and IETF Internet Area WG. He is the inventor of 30+ granted patents and has several publications. He has been granted the BoD Chairman's Award and the British Council Fellowship.