Tutorial T-9: Backhaul/Fronthaul Technologies for Heterogeneous Small Cell Networks

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Tutorial Overview: Heterogeneous small-cell networks (HetNets) are considered as a striking solution to the challenging demands such as high spectral and energy efficiency of 5G mobile communication networks. HetNets are typically composed of multiple radio access technologies (RATs) where multiple low-power, low-cost user/operator deployed small cell base stations are complementing the existing macrocell network. Efficient and satisfactory operation of all these densely deployed small cells hinges on the economical and ubiquitous backhaul/fronthaul provisioning. Hence, there are considerable market interests on the development of innovative and smart backhaul/fronthaul solutions for ultra-dense HetNets. There is a wide range of backhaul/fronthaul solutions that together can address the transportation of heterogeneous-types of data between heterogeneous access nodes and core network.

In this tutorial, we will first study the backhaul/fronthaul requirements of HetNets (such as data rate, latency and implementation cost, etc.) and then present a comparative overview of several wireless backhaul/fronthaul technologies for HetNets. Free-space optical (FSO) and mm-wave technologies are considered as potential candidates to enable high capacity and low latency wireless backhauling/fronthauling. Hybrid backhaul/fronthaul approaches, such as usability of FSO and mm-wave with RF wireless backhaul/fronthaul systems, will then be presented and discussed in detail. The tutorial will also present smart solutions and novel frameworks to address the backhaul/fronthaul requirements and then discuss some recent industrial practices for fronthaul design in HetNets. This tutorial further targets to present some recommendations on underlying wireless backhaul/fronthaul solutions/frameworks by taking the associated deployment cost into consideration. Several simulation results and case studies will be presented to demonstrate the effectiveness of the emerging backhaul/fronthaul technologies and their comparison to the existing and other traditional technologies.

Specifically, this tutorial will provide answers for the following:

- What are the backhaul/fronthaul requirements for 5G networks (such as data rate, latency, etc.)?
- What are the emerging high data rate competitive technologies to build wireless backhaul/fronthaul network between RRUs and BBUs in HetNet (hybrid RF, FSO, mm-wave and UAVs)?
- What are the industrial practices and associated challenges for fronthauling/backhauling in HetNets?
- What are the backhaul/fronthaul relaxation approaches (traffic offloading, D2D, Wi-Fi and WiGig enabled HetNets)?

Biography of Presenters:

Muhammad Zeeshan Shakir is a Senior Researcher at Carleton University, Canada where he is serving as a project manager for Carleton-industrial collaborative R&D project on SDN-driven fronthauling for heterogeneous networks. He is also serving as a Consultant for R&D at Communications Theory Lab, KAUST and responsible for providing his expertise for the development of FSO-based sustainable fronthaul network for 5G communications. Previously, from July 2012 to July 2015, he was an Assistant Research Scientist at Texas A&M University at Qatar (TAMUQ), Qatar where he was a Co-Lead PI of 1M $ project awarded by Qatar National Research Fund (QNRF) on heterogeneous networks. Prior to joining TAMUQ, he was a Postdoctoral Research Fellow at King Abdullah University of Science and Technology (KAUST), Saudi Arabia where he received a collaborative research award from the KAUST Global Collaborative Research initiative for research project with University of Surrey. From September to December 2010, he was a Visiting Researcher at Institute for Communication Systems (ICS), University of Surrey, UK. He earned his PhD degree in electronic and electrical engineering from University of Strathclyde, Glasgow, UK in 2010. From January 2006 to September 2009, he was the joint recipient of an industrial research award and a prestigious overseas research scholarship by the University of Strathclyde.

Dr. Shakir's research interests include design and deployment of diverse wireless communication systems including hyper-dense heterogeneous small-cell networks with particular focus on Green communications, traffic offloading techniques and backhaul/fronthaul network design and emerging technologies for 5G communications. He is also interested in deriving emerging wireless application oriented unified frameworks for machine type communications, IoT, emerging cognitive radio communications and ubiquitous remote/mobile healthcare networks. He has published/produced more than 75 technical journal and conference papers and has contributed to 7 books, all in well reputed venues. He is co-author of 3 research monographs including one authored book.

Dr. Shakir has been/is giving tutorials on emerging wireless communication systems at IEEE flagship conferences such as IEEE ICUWB 2015, Montreal, IEEE GLOBECOM 2014/2015, Austin/San Diego, and IEEE ICC 2014, Sydney. He has been/is serving as Chair/Co-Chair of several special sessions/workshops and symposia in IEEE flagship conferences, such as ICC and GlobalSIP. He is the Founding organizer and Technical Chair of IEEE Workshop on Next Generation Backhaul/Fronthaul Networks - BackNets, collocated annually with IEEE ICC since 2015. He is an Associate Technical Editor of IEEE Communications Magazine and has served as a lead Guest Editor for IEEE Communications and IEEE Wireless Communications Magazines. He is serving as a Chair of IEEE ComSoc emerging technical committee on backhaul/fronthaul communications and networking (TCBNC). He is an active member of IEEE and IEEE Standard Association.

Mohamed-Slim Alouini received the Diplome d'Ingenieur from the École Nationale Supérieure des Télécommunications (TELECOM Paris Tech) and the Diplome d'Etudes Approfondies (D.E.A.) in Electronics with Highest Honors from the Université Pierre et Marie Curie in Paris, France, both in 1993. He received the M.S.E.E. degree from the Georgia Institute of Technology (Georgia Tech), Atlanta, Georgia, in 1995, and a PhD in Electrical Engineering from California Institute of Technology (Caltech), Pasadena, California, in 1998. He also received the Habilitation degree from the Université Pierre et Marie Curie, Paris, France, in 2003.

Dr. Alouini served as a faculty member in the University of Minnesota, Minneapolis, MN, USA, then in the Texas A&M University at Qatar, Education City, Doha, Qatar before joining King Abdullah University of Science and Technology (KAUST), Thuwal, Makkah Province, Saudi Arabia as a Professor of Electrical Engineering in 2009. His current research interests include design and performance analysis of emerging and future wireless communication/sensor systems & networks.

Dr. Alouini has published several papers on the above subjects, and he is co-author of the textbook Digital Communication over Fading Channels published by Wiley Interscience. He is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), a member of the Thomson ISI Web of Knowledge list of Highly Cited Researchers, an IEEE Distinguished Lecturer of the IEEE Communications Society (ComSoc), and a co-recipient of best paper awards in ten IEEE conferences (including ICC, GLOBECOM, VTC, PIMRC, and DySPAN).