The international conference on wireless networks and mobile communications (WINCOM'16)
OCTOBER 26–29, 2016 \\ FEZ, MOROCCO

FULL DUPLEX COMMUNICATION FOR 5G: CHALLENGES, OPPORTUNITIES AND APPLICATIONS

By: Prof. Khalid Qaraqe, Imran S. Ansari and Nurul H. Mahmood

Type: Half day

Abstract:
Full duplex (FD) communication, i.e. simultaneous transmission and reception over the same frequency band, had generally been assumed infeasible in wireless communication due to the strong *loopback interference* from the transmission-end. Recent advances in self-interference cancellation (SIC) in both analog and digital domain have made FD communication appealing in practical systems with viable cost, thus promising a throughput (TP) enhancement and latency reduction of ideally up to 100% over conventional half duplex (HD) transmissions. In that respect, FD communication is considered as a potential 5G technology component.

The potential gains of FD communication with respect to HD transmission may be jeopardized by a number of factors. Simultaneous transmissions from both ends of a communication link inevitably result in additional network interference compared to conventional HD transmissions. Secondly, FD communication can only be exploited with traffic available at both uplink (UL) and downlink (DL) directions; whereas in practice, networks have a traffic profile skewed in favor of the DL direction. In addition, any residual loopback-interference following self-interference cancellation may still negatively affect the possibility of recovering the desired signal at the receiver end. Studies have shown that, ideally SIC of the order of 100 dB is required for satisfactory operation of FD nodes, which is still a practical challenge.

Although extensive research works on FD communication with theoretical promise and potentials have been established, practical implementations closing the gap between the theory and practice still need to be addressed. This tutorial will present a comprehensive overview of the challenges, opportunities and applications of full duplex communication for 5G systems. Moreover, the proposed tutorial will address the state-of-the-art in self-interference cancellation and challenges therein followed by challenges due to increased network interference. This will lead to thoughts on improving the MAC and RRM. Thereafter, the potential benefits of FD communication, namely throughput gain, reduced latency, and improving physical layer security issues among others, will be presented. The final part of the tutorial will be dedicated to presenting various applications of FD communication showcasing the potential gains and the challenges therein. The audience will be left with thought provoking applications inclusive of self-interference modeling; interaction of FD communication in small cell networks with RLC layer protocols like TCP; FD enabled backhaul & relaying solutions; and FD in D2D communications among others.

Objectives, Importance and Timeliness
A wide variety of new applications are expected to emerge in the fifth generation of cellular network (5G), contributing to new use cases requiring novel and disruptive techniques. FD communication is considered as such a potential 5G technology component owning to the different opportunities it offers in

terms of the TP and Physical layer security enhancements and latency reduction, among others. The objective of this tutorial is to provide a deeper insight into the challenges, opportunities and applications of FD communication. More specifically, through this tutorial, we aim to:

- Highlight the important role of FD communication in 5G systems,
- introduce various challenges involved with FD communication, and
- provide a comprehensive overview of the possible application areas of FD with pointers to the potential gains and related challenges involved therein.

The importance of this tutorial lies in the timeliness of treating FD as a potential 5G technology component. The first half of this decade saw the emergence of the 5G as a concept. However, the focus is now shifting towards turning the vision into a functioning reality. Evaluation of potential 5G solutions for standardization is expected to begin early this year, with detailed specification submission targeted by 2020. As such, this topic will attract significant attention in the coming 1-2 years, and has the potential to influence the 5G standardization process.

Intended audience

The design of a novel 5G radio access technology is a 'hot research topic' in wireless communication. Based on the current wireless communications systems and on the need of improving the resources to serve the greater issue of "x1000" capacity increase with 5G, this tutorial on FD communication and its applications in 5G systems is in-line with the near future improvements for the same. We therefore expect to attract a large audience of researchers and engineers working in the area of wireless systems design. PhD students in general, and those working with FD communication in particular, will also greatly benefit from this tutorial, especially from the comprehensive overview of FD applications. The audience may further obtain insights and inspiration for new research directions within this field.

Planned Presentation Style

We plan to present the tutorial in an interactive manner using ICT tools and delivery methods specifically designed for active learning.

Detailed outline of the tutorial

Introduction (30 mins)

- State of the art in 5G system design
- What is FD
- State of the art in self-interference cancellation
- FD and 5G: Outlook into the future (when will FD be commercially viable), and its importance as a potential technology component in 5G system design

Challenges (30 – 35 mins)

- Self-interference cancellation
- Increased network interference
- Need to have packets to transmit at both ends
- Need to rethink MAC and RRM

Opportunities (30 – 35 mins)

- Increase TP
- Reduce Latency
- Improve secrecy/PHY security

- Improve multiple access

Applications (45 – 50 mins):
- Self-interference modeling
- Increase TP and reduce latency in Small cells
- Latency reduction analysis
- PHY security
- Backhaul, cellular and microwave
- Relay
- FD for enhancing discovery in D2D communication

Conclusions and Future Outlook (5 mins):
- Key take away messages
- Future Outlook

Short biography of the instructor(s)

Professor Khalid Qaraqe – Professor, Electrical and Computer Engineering (ECEN) Department, Texas A&M University at Qatar (TAMUQ), Education City, Doha, Qatar, and Managing Director, Center for Remote Healthcare Technology at Qatar.

Dr Khalid A. Qaraqe (SM'00) was born in Bethlehem. Dr Qaraqe received the B.S. degree in EE from the University of Technology, Bagdad, Iraq in 1986, with honors. He received the M.S. degree from the University of Jordan, Jordan, Amman, Jordan, in 1989, and earned his Ph.D. degree from Texas A&M University, USA, in 1997. From 1989 to 2004 Dr Qaraqe has held a variety positions in many companies and has over 12 years of experience in the telecommunication industry. Dr Qaraqe has worked on numerous GSM, CDMA, and WCDMA projects and has experience in product development, design, deployments, testing and integration. Dr Qaraqe joined the department of Electrical and Computer Engineering of Texas A&M University at Qatar, in July 2004, where he is now a professor.

Prof. Qaraqe has been awarded 15 research projects consisting of more than USD 9.0 M from local industries in Qatar and the Qatar National Research Foundation (QNRF). He has published 90 journal papers in top IEEE journals, and published and presented 194 papers at prestigious international conferences. He has 13 book chapters published, two books slated to appear, four patents, and presented five tutorials and talks. Dr. Qaraqe received the Itochu Professorship award, 2013-2015, best researcher award, QNRF 2013, several best paper awards in top notch conferences and workshops, and TAMUQ Research Excellence award in April, 2010.

Prof. Qaraqe's research interests include communication theory and its application to design and performance analysis of cellular systems, and indoor communication systems. Particular interests are in mobile networks, broadband wireless access, cooperative networks, cognitive radio, diversity techniques, and 5G systems.

Imran Shafique Ansari – Postdoctoral Research Associate (PRA), Electrical and Computer Engineering (ECEN) Department, Texas A&M University at Qatar (TAMUQ), Education City, Doha, Qatar

Imran Shafique Ansari (S'07-M'15) was born in India in 1987. He completed his B.Sc. in Computer Engineering from King Fahd University of Petroleum and Minerals (KFUPM) in 2009 (with First Honors) and M.Sc. and PhD from King Abdullah University of Science and Technology (KAUST) in 2010 and 2015, respectively. Currently, he is a Postdoctoral Research Associate (PRA) with Texas A&M University at Qatar (TAMUQ). From May 2009 through Aug. 2009, he was a visiting scholar with Michigan State University (MSU), East Lansing, MI, USA, and from Jun. 2010 through Aug. 2010, he was a research intern with Carleton University, Ottawa, ON, Canada.

He has been affiliated with IEEE and IET since 2007 and has served in various capacities. He is serving on the IEEE ComSoc Young Professionals (YP) Board since April 2016. He has served on IET CC-EMEA (Communities Committee-Europe, Middle-East and Africa) for a complete term from Oct. 2010-Sep. 2013 and has been re-elected to serve for another term from Oct. 2015-Sep. 2018. He is an active reviewer for various IEEE Transactions and various other journals. He has served as a TPC for various IEEE conferences. He is a recipient of TAMUQ Research Excellence Award 2016, a recipient of recognized reviewer certificate by Elsevier Optics Communications in 2015, a recipient of recognized reviewer certificate by OSA Publishing in 2014, a recipient of appreciation for an exemplary reviewer for IEEE Wireless Communications Letters (WCL) in 2014, a recipient of post-doctoral research award (PDRA) (first cycle) with Qatar national research foundation (QNRF) in 2014, a recipient of KAUST academic excellence award (AEA) in 2014, and a recipient of IEEE Richard E. Merwin student scholarship award in Jul. 2013.

Imran has authored/co-authored around 35 journal and conference publications. He has co-organized the GRASNET'2016 workshop in conjunction with IEEE WCNC'2016. His current research interests include free-space optics (FSO), channel modeling/signal propagation issues, relay/multihop communications, physical layer secrecy issues, full duplex systems, and diversity reception techniques among others.

Nurul Huda Mahmood – Post-doctoral fellow, Wireless Communication Networks Section, Aalborg University, Aalborg, Denmark.

Nurul Huda Mahmood (S'05-M'13) was born in Chittagong, Bangladesh. He received the M.Sc. degree in Mobile Communications from Aalborg University, Denmark in 2007 and the Ph.D. degree in communication theory from Norwegian University of Science and Technology (NTNU), Norway in 2013. Since then, Nurul is serving as a post-doctoral fellow at Aalborg University involved in teaching and research activities, and an external research contractor with Nokia Bell Labs in Aalborg. He is currently involved in the European 5G-PPP Project *fantastic-5G* as the WCN section lead.

Nurul is an active reviewer for a number of journals and has served as a TPC for various IEEE conferences. He has authored/co-authored more than 35 journal and conference publications, including 10 publications on the modeling and performance evaluation of Full Duplex systems. His research interests include communication theory, full duplex communication, radio resource optimization techniques and modelling & performance analysis of wireless communication systems.