IEEE ComSoc Emerging Technology Initiative Backhaul/fronthaul Networking & Communications (ETI-BNC) Blog

Issue 3, April 2019

Contents

Chair's Message

Muhammad Zeeshan Shakir

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Dear Members:

I am glad to distribute third issue of IEEE ETI-BNC Blog. In this issue, I would like to present our ETIs progress from past 4 years to demonstrate the contribution of our ETI to the technical areas. This issue also includes feature topic self-backhauling edited by Dr. Omid Semiari from Georgia Southern University, Dr. Syed Ali Raza Zaidi from University of Leeds and Dr. Abdellah Chehri from University of Quebec much thanks for their continued support to our ETI and members. You will also find call for participation to our ETIs Online meeting to be held on July 1, 2019 where we will present panel discussions on the use of flying platforms for future access and backhaul networks. Please find more detail here. You are also invited to contribute to JSAC Special Issue on Industry 4.0 with deadline currently set as July 1, 2019. For more future activities visit our website.

You know that our ETI-BNC has been a forum for industrial and academic researchers and practitioners to identify and discuss the wireless backhaul/fronthaul requirements for emerging technologies and smart cities, associated challenges, recent development and smart end-to-end solutions pertaining to fifth-generation (5G) and beyond of mobile communication networks and ad hoc networks. ETI-BNC has provided a prolific opportunity to educate about, promote and accelerate the evolution of next generation of backhaul/fronthaul networking and communications by fostering a variety of technical activities in the related area.

I am glad to say that with over 120 active members (doubled since early 2017 and mostly industrial members) ETI-BNC community has grown very much since recently. ETI has been organizing technical activities with consistency. So far, our members have organized 12 workshops/conference with IEEE BackNets alone published over 40 articles in IEEE GCC/ICC workshop proceedings over past 4 years; 7 Special Issues (JSAC, Communications Magazine, Access and Wireless Communications and Trans. Cognitive Communications); 3 Online newsletters; and 5 tutorials with very much active participation from industry to bridge the research and development of cross-cutting technologies for future smart backhaul and fronthaul networking, communications and signal processing. Recently, our ETI has published IEEE ComSoc Best Reading List: Backhaul and Fronthaul: Communications, Networking and Signal Processing, edited by myself, Prof Muhammad Imran from University of Glasgow and Prof

Walid Saad from VTech which is expected to provide several archival papers and other online resources on the backhaul/fronthaul and related networking, communication, and signal processing issues that are useful if you are doing research in this area or expected to build interest in this area. Stay tuned to our News and Activity sections for future events and activities and continue to participate in the ETIs activities in future.

Recently, our ETI-BNC has been evaluated by ETI Chair and members as part of IEEE ComSoc rules and policies. Our ETI has received positive feedback from the review panel. Some of the important feedback includes improvement of our members in following aspects of our organization and participation in ComSoc-wide activities:

- To broaden the participation from our members across academia and industry to our ongoing programs and activities
- To make effective measures for interaction with relevant standardization bodies.

For now, ETI-BNC will continue as ETI until next review cycle. As always, I welcome your suggestions and comments to improve involvement and participation from ETI-BNC members and also would like to invite you all to attend our next Online meeting to be held on July 1, 2019.

At the end as usual, a final reminder - the blog aims to highlight key achievements of community members. Consequently, if you would like to share your recent achievements or highlight successful proposal which are of relevance to the community, please get in touch with the editors. I would like to take this opportunity to welcome any suggestions from the community members to make ETI-BNC blog more informative and interesting. You are welcome to either write to me at muhamamd.shakir@uws.ac.uk or approach any of the editors.

Best regards,
Muhammad Zeeshan Shakir
Chair IEEE ComSoc ETI-BNC

Muhammad Zeeshan Shakir is Reader at the University of the West of Scotland (UWS), UK. At UWS, he has been investigating commercial / non-commercial research projects in the areas of wireless communications of worth more than 900k funded by bodies such as Innovate UK, EU programmes such as ERASMUS and matched by UK industries. Recently, he has been awarded with UWS STARS (Staff Appreciation and Recognition Scheme) award 2018 for Outstanding Research and Enterprise performance at UWS. Before joining UWS, he has worked at Carleton University, Canada, Texas AM University, Qatar and KAUST, Saudi Arabia on various RD projects. He has published more than 100 technical journal and conference papers and has contributed to 12 books, all in reputable venues. He has been/is serving as a Chair of several symposiums/workshops in IEEE flagship conferences, including Globecom, ICC and VTC. He is an Editor of PHYCOM, IEEE Communications, IEEE Communications Letters, IEEE Wireless Communications and IEEE Access. He is a founding Chair of IEEE ComSoc emerging technical committee on backhaul/fronthaul. He is a Senior Member of IEEE and an active member of IEEE ComSoc.

Feature Topic Editors: Self-Backhauling in 5G and Beyond Cellular Networks

Omid Semiari and Syed Ali Raza Zaidi

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This issue presents self-backhauling as feature topic for future backhaul and fronthaul networks. We thank Dr. Abdellah Chehri form University of Quebec, Canada for presenting two interesting reviews on recently publsihed articles for ETI members to highlight key challenges for MIMO and mm-wave based self-backhauling systems. We would like to welcome any suggestions for our future issues. We also welcome reviews for future articles.

Omid Semiari is an Assistant Professor at the Department of Electrical and Computer Engineering at Georgia Southern University. He received the BS and MS degrees in electrical engineering from the University of Tehran, in 2010 and 2012, respectively, and the PhD degree from Virginia Tech, in 2017. His research interests include wireless networks, millimeter wave communications, ultra-reliable and low-latency communications, context-aware networks, matching theory, and applied machine learning. In 2014, Dr. Semiari has worked as a research intern at Bell Labs, in Stuttgart, on anticipatory, context-aware resource management in cellular networks. In 2016, he has joined Qualcomm CDMA Technologies for a summer internship, working on LTE-Advanced modem design. Dr. Semiari is the recipient of several research fellowship awards, including DAAD (German Academic Exchange Service) scholarship and NSF student travel grant. He has actively served as a reviewer for flagship IEEE Transactions and conferences and participated as the technical program committee (TPC) member for a variety of workshops at IEEE conferences.

Syed Ali Raza Zaidi Dr Syed Ali Raza Zaidi is currently a University Academic Fellow (Assistant Professor) in the broad area of Communication and Sensing for RAS. He was awarded J. W. and F. W. Carter Prize, was also awarded with COST IC0902, EPSRC, DAAD and Royal Academy of Engineering grants. He has published more than 95 technical papers in various top-tier IEEE Journals and conferences. His research interests include design and implementation of communication protocols for wireless networking specifically in the area of M2M.

Feature Topic: Self-Backhauling in Next Generation Wireless Cellular Networks

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Wireless communication has gone through decades of thriving advances. Compared to fourth-generation (4G) cellular systems, fifth-generation (5G) wireless communication systems face an ever-increasing demand for spectral efficiency and high data rates as required by new devices and applications. To meet the growing data traffic volume a number of emerging technologies are currently investigated. The idea of enhancing the capacity can be achieved by: 1) a higher frequency spectrum (e.g., mmWave), or by 2) advanced spectral-efficiency techniques such as massive MIMO and efficient modulation schemes or by 3) reducing the cell size through an ultra-dense small cell deployment [1].

This densification involves large numbers of cells, even for LTE, and the numbers will increase in 5G because of its increased capacity requirements, higher spectrum bands and support for new services such as smart city applications. Based on research conducted by the Small Cell Forum, both public and private enterprise small cell deployments will see a continuous growth through 2025 in support of LTE and 5G densification efforts. The industry group sees a peak in LTE small cell deployments around 2020, followed in 2024 by a shift in volume to 5G equipment [2].

The typical wired backhaul solution such as optical fiber is not always feasible due to the unconventional installation location of small cells and their incremental unplanned deployment. Therefore various hybrid backhaul architectures will be needed to accommodate the cost-efficient, backward compatible and dense deployment of network infrastructure which is necessary for providing for the broadband and low latency demands of 5G systems The wireless schemes employed in these hybrid backhaul solutions include self-backhaul [3], multiple-association [4], and millimeter-wave (mmWave) backhaul [5]. The wireless backhaul solutions discussed in literature can be categorized as self-backhaul (or in-band) and non-self-backhaul (or out-of-band) [6].

Self-backhaul offers a flexible and cost-efficient solution as the access and backhaul links share the same spectrum and have identical radio access technology. These solutions are also referred to as in-band backhaul. The term “in-band” means that the access link (BS-MS link) and backhaul link (BS-BS links or BS-network links) are multiplexed on the same frequency band. The capacity and resource allocation between access and backhaul links are major concerns in self-backhaul solutions, and several studies have addressed these issues.

In this special issue, we focus on self-backhauling in next generation wireless networks as the feature topic and overview two key papers in the field. We hope that this effort be useful for our readers, especially to those who are new in this field of research.

References:

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Abdellah Chehri is an assistant professor at the University of Quebec in Chicoutimi. He received his M.A.Sc. Degree in signal and digital communication from the University Sophia-Antipolis at Nice-France. In Sept. 2004, he joined the department of electrical and computer engineering of Laval University, Quebec, Canada. He received his Ph.D. in Electrical Engineering in June 2009. From 2007 to 2009, he worked as a project member at the Bell-Aliant Research Laboratory, Quebec, Canada and served as a lecturer in the Information Technologies Graduate Program of UQAT. He joined the University of Ottawa in July 2009 as a postdoctoral fellow and then research associate. From 2012 to 2014, he was with BLiNQ Networks where he was involved in the development and testing of dual-carrier sub-6 GHz backhaul. In Feb 2014, he Dr. Chehri worked as a manager of Next-Generation Network (NGN) /VoIP & Emerging Technologies at Bell Canada. He served as guest editor and severed as a technical reviewer for several international conferences and journals (IEEE, Elsevier, Springer). Dr. Chehri received many prestigious awards, including, Deans scholarship award, postdoctoral studies (University Ottawa), a scholarship fund to support success (Laval University), Japan Society for the Promotion of Science, NSERC postdoctoral fellowship.

Review of "Point-to-Multipoint In-Band mmWave Backhaul for 5G Networks"

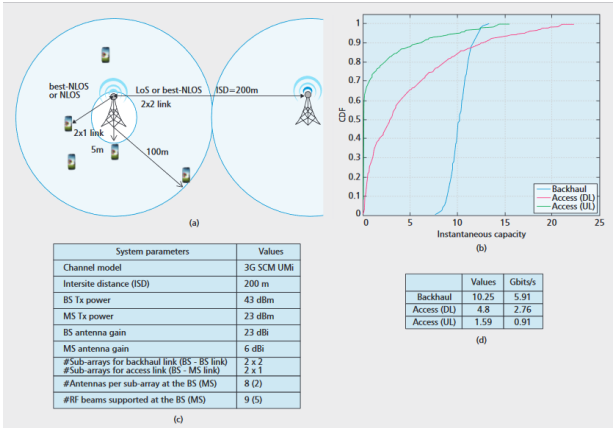
IEEE Communications Magazine, January 2015

Authors: R. Taori and A. Sridharan

The feasibility of in-band backhaul at mmWave frequencies was investigated in this work. It was shown that the access link capacity was not significantly affected by the availability of larger bandwidths in a mmWave spectrum. The authors started their investigation by providing a persuasive analysis to establish that an in-band backhaul solution at mmWave is feasible. As mentioned previously, in the in-band wireless backhaul system, the resources used for backhaul are taken from the access links resources regardless of the multiplexing method used. An important task, therefore, is to analyze whether enough resources are available for backhauling without compromising the access needs.

Based on the deployment scenario and using a Monte Carlo simulation, the cumulative distribution function (CDFs) of the instantaneous cell capacity was calculated. The average link capacities tabulated in Fig.1 show that the backhaul links capacity is about 2.1 times higher than the access links capacity. Based on these capacity numbers, The authors investigated the feasibility of the proposed in-band mmWave backhaul solution.

Furthermore, the authors provided the link capacity results for the best NLoS path on the BL and NLoS path for the AL (Table 1), where "DL/UL" indicates the downlink-to-uplink ratio for resource allocation in a time-division duplex (TDD) system. Based on their simulation, the authors observed that using only 25 percent of the AL resources for the BL is sufficient to support user data rates as high as 0.8 Gb/s.



System parameters	Values
Channel model	3G SCM UMi
Intersite distance (ISD)	200 m
BS Tx power	43 dBm
MS Tx power	23 dBm
BS antenna gain	23 dBi
MS antenna gain	6 dBi
#Sub-arrays for backhaul link (BS - BS link) #Sub-arrays for access link (BS - MS link)	2 x 2 2 x 1
#Antennas per sub-array at the BS (MS)	8 (2)
#RF beams supported at the BS (MS)	9 (5)

	Values	Gbits/s
Backhaul	10.25	5.91
Access (DL)	4.8	2.76
Access (UL)	1.59	0.91

Figure 4.1: Monte Carlo simulation setup for evaluating wireless backhaul feasibility and observations: a) Monte Carlo simulation scenario for evaluating feasibility of in-band wireless backhaul; b) CDFs of the instantaneous capacities on the BL and ALs (uplink, UL, and downlink, DL); c) parameters used for the Monte Carlo simulations; d) average link capacities obtained using Monte Carlo simulations.

After this first step of investigation (i.e. the feasi-

(Unit: Mb/s)	BL (best NLoS)	AL (NLoS)		
		DL/UL = 1	DL/UL = 2	DL/UL = 3
Link Capacity *C*	3,301	DL 1,817/UL 343		
Data Rate *R*	3,136	784	968	1,061
Data (α = 1/5)	627	627	775	849
Data (α = 1/4)	784	588	726	796
Data (α = 1/3)	1,045	522	646	707

Figure 4.2: . Feasible AL and BL rates assuming non-line-of-sight (NLoS) conditons on the AL and best NLoS conditions on the BL for various downlink to uplink ratios. Best NLoS condition can be assumed on the BL as there is ample time to choose the best NLoS setting (which does not change very often) compared to the AL.

bility of in-band backhaul at mmWave frequencies), the authors discussed the deployment assumptions and system design constraints applicable in a practical system. Then, they outlined a BS-to-BS scheduling scheme for the BL that can be multiplexed with the usual BS-to-MS scheduling for in-band backhaul and access deployment scenario. Finally, the authors open the door for other avenues of interest (e.g. investigations into Spatial division multiple access (SDMA) and full-duplexing capabilities) for further spectral efficiency enhancements.

Review of "Small Cell In-Band Wireless Backhaul in Massive MIMO Systems: A Cooperation of Next- Generation Techniques"

IEEE Transactions on Wireless Communications, December 2015

Authors: B. Li, D. Zhu, and P. Liang

Massive multiple-input-multiple-output (MIMO) systems, dense small-cells (SCs), and full duplex are three candidate techniques for next-generation communication systems. The cooperation of next-generation techniques could offer more benefits.

In this work, in-band wireless backhaul using massive MIMO systems was studied. In addition, various duplex techniques for improving throughput over in-band backhaul links were investigated. This work mainly focuses on analyzing the average achievable sum rate for backhaul transmission and data transmission with the allocated in-band bandwidth. The authors discussed the potential throughput improvement introduced by SC in-band wireless backhaul in massive MIMO systems. After providing an overview of massive MIMO system, three strategies of dense small-cells (SCs), in-band wireless backhaul in massive MIMO systems were introduced and compared.

The first one is Complete TDD (CTDD), which further divides the communication between the BS and SCs and the data exchanges between SCs and their associated User Equipment (UEs) in the time division. The second strategy is based on zero-division duplex (ZDD), which requires that SCs are capable to do self-interference cancellation thus could transmit and receive signals in the same time-frequency resource. The third one is called ZDD with interference rejection (ZDD-IR). ZDD-IR is actually an enhanced version of ZDD, which has an additional requirement that the BS can apply the IR procedure. Then the authors calculated the average achievable sum rate values of downlink and uplink for the three strategies. In their work, uncorrelated Rayleigh fading is applied as the channel model and perfect channel state information is assumed for simulations. To exploit the advantages of multiple antennas, the authors use the Non-Line-of-Sight (NLoS) models with shadowing at the carrier frequency $f_c = 2$ GHz. Based on the simulations, the authors attested that among the three strategies, CTDD is the simplest one and could achieve a decent throughput gain for an in-band wireless backhaul in massive MIMO systems.

However, there are various open questions which still need to be addressed, such as consideration of the interference from macro and the inter-SC interference. For interference in co-channel deploy-

ment, it is usually the macro cells that are interfering with the small cells/backhauls due to the large transmit power disparity between the macro and small cells. Coordinated architecture can be explored through cloud computing for better interference management. To reduce the inter-SC interferences, a coordinated cell switch off methods might need to be investigated. The authors also kept the doors open for further investigation using more realistic assumptions such as realistic channel models and channel estimation errors.

IEEE ETI-BNC Online Panel 2019 Networked-Flying Platforms: Paving the Way Towards Global Wireless Connectivity

Call for Participation

Join us for IEEE ETI-BNC 4th Meeting: Online Panel: Networked-Flying Platforms: Paving the Way Towards Global Wireless Connectivity

Monday, 1 Jul, 2019 14:00 — 1 hour — (UTC+00:00) Dublin, Edinburgh, Lisbon, London Meeting number: 590 693 294

Agenda: Driven by an emerging use of Networked Flying Platforms (NFPs) such as unmanned aerial vehicles (UAVs) and unmanned balloons in future network applications and the challenges that the 5G and beyond networks exhibit, the focus of this Panel discussions is to demonstrate the evolution of the NFPs as a novel architectural enabler for radio access network (RAN) and their integration with the future cellular access and backhaul/fronthaul networks. NFPs are networked, flying and a potential way to offer high data rate, high reliability and ultra-low latent access and backhaul/fronthaul to future wireless networks. Specifically, this panel will provide answers for the following:

- How NFPs can offer a reliable, high data rate and scalable solution to fronthaul the ultra-dense small cell deployment (NFPs deployment architecture, potential high data rate technologies, and NFP-small cell association)?
- How NFPs can enhance capacity and coverage for users and access networks (NFP placement, resource allocation and network and user/network centric approaches)?
- What are the economic, regulatory and industrial perspectives of deploying NPFs for cellular access and backhaul networks (total cost of operation and some latest regulations)?

Panelists

- University of the West of Scotland, UK
- KAUST, SA
- FACEBOOK, USA
- University of Glasgow, UK
- Carleton University, Canada

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Call for Papers: IEEE JSAC Design and Analysis of Communication Interfaces for Industry 4.0

Publication Date
First/Second Quarter 2020
Manuscript Submission Deadline July 1, 2019

Call for Papers

The fourth industrial revolution also referred to as Industry 4.0 aims to integrate advanced manufacturing techniques with the Internet-of-Things (IoT) to create an agile digital manufacturing ecosystem. The key idea is to provide a higher level of automation by combining technologies such as Industrial IoT (IIoT), cloud computing, machine learning (ML) and advanced robotics to enable the creation of interconnected, responsive, intelligent and self-optimizing manufacturing processes and systems. The increased automation can:

- Significantly enhance operational efficiency through real-time process analytics or even end-to-end process control.
- Significantly enhance overall productivity by realizing zero-downtime through proactive maintenance via the implementation of "digital twins".

Implementation of either real-time process analytics or digital twining is geared to generate a huge volume of heterogeneous data flows. Consequently, the design of communication interfaces to support interconnectivity must be optimized to enable convergence between legacy operations technology (OT) and next-generation IIoT.

This special issue solicits original research papers focused on Design and Analysis of:

- Ultra-reliable Low-Latency Connectivity Interfaces for IIoT Networks
- Spectrum Management and Coexistence Issues for IIoT Networks
- Architecture and Protocols for IIoT Networks
- Novel ML methods for implementing Self-X capabilities in IIoT Networks
- Resource Allocation and Management for IIoT Networks
- Security, Privacy and Trust issues in IIoT deployments
- Interoperability and Convergence Issues for legacy OT and IIoT Networks
- Application and Deployment Specific Issues for IIoT Networks

Submission Guidelines

All submissions have to be prepared according to the Information for Authors as published in the Journal website and must be submitted via EDAS.

Important Dates

Manuscript Due: 1 July 2019
Acceptance Notification: 30 September 2019
Final Manuscript Due: 15 November 2019
Expected Publication of the Special Issue: First/Second Quarter 2020

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