New Advances in Non-Orthogonal Multiple Access


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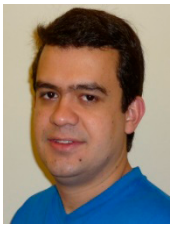
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Multiple access is one of the core technologies in wireless communications, which enables wireless base stations to support a large number of terminal users and serve them simultaneously under stringent spectrum constraints. Orthogonal multiple access (OMA), as one multiple access method, has been prevailing since the first generation (1G) cellular system. However, the number of active users allowed access to the OMA system is strictly limited by the number of available orthogonal resources, since as required by OMA the communication resources allocated to different users are orthogonal in at least one radio resource dimension, e.g., frequency, time, code, etc. Nowadays, with the rapid growth of mobile network and Internet of Things (IoT) this problem becomes more and more critical.

Non-orthogonal multiple access (NOMA), as another multiple access method, arises as a promising solution to the aforementioned problem. In contrast to OMA, NOMA simultaneously accommodates a multitude of users with the same radio resource via superposition coding and successive interference cancellation (SIC), achieving high spectral efficiency, massive connectivity, and enhanced user fairness. Owing to its promising features, NOMA has been highlighted in many fifth generation (5G) white papers produced by industrial and academic bodies. However, there are still a number of open issues remaining to be solved before NOMA can be successfully applied in practical systems.

This feature topic aims to bring together leading researchers in both academia and industry from diversified backgrounds to unlock the potential of NOMA for beyond 5G networks. The Call for Papers generated considerable interest in the research community, and 11 out of in total 31 submissions were accepted after a thorough review process.

The feature topic begins with the article by Dong *et al.*, "NOMA-based energy-efficient task scheduling in vehicular edge computing networks: A self-imitation learning-based approach." This article first introduces related mobile edge computing (MEC) technologies in vehicular networks. Then, it proposes an energy-efficient approach for task scheduling in vehicular edge computing networks based on deep reinforcement learning, with the purpose of both guaranteeing the task latency requirement for multiple users and minimizing total energy consumption of MEC servers. Numerical results demonstrate that the proposed algorithm outperforms other methods from various aspects.

The article by Cai *et al.*, "Active user and data detection for uplink grant-free NOMA systems," considers active user detection (AUD), channel estimation (CE) and multi-user detection (MUD) for both uplink single-carrier and multi-carrier NOMA systems. In this article, an alternating direction method of multipliers based algorithm to detect the active users for single-carrier NOMA is first proposed. Then, the proposed algorithm for AUD is extended to multi-carrier case by exploiting the block sparse structure. A low complexity MUD detection algorithm based on alternating minimization to estimate the active users' data is also proposed, which avoids computing the inverse of the Hessian matrix. Simulation results show that the proposed algorithms have better performance in terms of AUD, CE and MUD.

The article by Wei *et al.*, "Secure Performance Analysis and Optimization for FD-NOMA Vehicular Communications," focuses on the security performance of the full duplex (FD) NOMA based vehicle to vehicle system, where FD and NOMA are allied to enhance the secrecy

performance. By analyzing the ergodic secrecy capacity of the considered system, the authors propose a secrecy sum-rate optimization scheme, which is formulated as a non-convex optimization problem. Based on the differential structure of the non-convex constraints, the original problem is approximated and solved by a series of convex optimization programs. Simulation results validate the analytical results and the effectiveness of the secrecy sum-rate optimization algorithm.

The article by Liu *et al.*, "Robust Artificial Noise-Aided Beamforming for A Secure MISO-NOMA Visible Light Communication System," studies the resource allocation optimization in NOMA assisted visible light communication system, which can enhance the secure performance. Specifically, the artificial noise jamming and beamforming are jointly designed to satisfy the quality of service (QoS) requirement of the desired users and the maximum tolerable data rate of the eavesdropper under the practical imperfect channel state information. Moreover, the influence of the light emitting diode (LED) height and number on this system is investigated.

The article by Feng *et al.*, "NOMA-Based UAV-Aided Networks for Emergency Communications," establishes an emergency communications framework of NOMA-based UAV-aided networks, where the disasters scenarios can be divided into three broad categories including emergency areas, wide areas and dense areas. For the case of emergency areas, a deep-Q-learning (DQL) based path planning scheme has been established to gather information from IoT devices. For the case of wide areas, a multi-UAV enabled NOMA network has been investigated to extend the UAV coverage for IoT devices. For the case of densely distributed areas, a joint 3D trajectory and power optimization scheme is designed to provide wireless service for IoT devices.

The article by Xiang *et al.*, "Secure Transmission for NOMA Systems with Imperfect SIC," investigates the secure transmission for NOMA systems adopting imperfect SIC for both of the legitimate users and eavesdropper. In this article, the closed-form expressions for connection outage probability, secrecy outage probability, and effective secrecy throughput are derived over Nakagami-m fading channels in both NOMA and benchmark OMA systems. The results verify the analysis and show a better secrecy performance.

The article by Bai *et al.*, "Contention-Based Nonorthogonal Massive Access with Massive MIMO," proposes a new contention-based scheme for CS-based massive access to support the sporadic access of massive devices with limited resources, where an advanced receiver algorithm is designed to utilize various prior information to enhance the performance. In this article, the joint sparsity between the channel and data is used to improve the accuracy of pilot detection, and the information of modulation and cyclic redundancy check is exploited for channel correction to improve the performance of data recovery.

The article by Ji *et al.*, "Power Allocation for Cooperative Communications in Non-Orthogonal Cognitive Radio Vehicular Ad-Hoc Networks," investigates an effective power allocation scheme considering the interference to the main system in a controllable range for the cooperative communication in non-orthogonal cognitive radio vehicular ad-hoc networks (CR-VANETs). In this article, the end-to-end SNR in overlay and underlay cognitive communication systems are analyzed including decode-and-forward (DF) and amplify-and-forward (AF) protocols. The corresponding optimal power allocation (PA) factor is obtained via seeking the minimum value of overall system outage probability in an approximate way to show the superiority compared with the average PA and other existing PA schemes.

The article by Yu *et al.*, "AI-Enhanced Constellation Design for NOMA System: A Model Driven Method," proposes a human intelligence (HI)-guided artificial intelligence (AI)-enhanced signature/constellation design method for NOMA system, which not only has smaller size of deep neuron network (DNN) and less training data, but also has stronger interpretability. Particularly, the performance in terms of bit-error-ratio (BER) and computational complexity of decoders are provided to show the advantages of the proposed scheme compared with conventional NOMA systems.

The article by Huang *et al.*, "Performance Analysis of NOMA-Based Cooperative Networks with Relay Selection," investigates the performance of dual-hop NOMA-based cooperative relaying networks. In this article, both DF and AF protocols are applied to the selected relay for the considered NOMA-based cooperative system, and the metrics of ergodic sum-rate and outage probability are analyzed to evaluate the efficiency and reliability of the corresponding protocols.

Finally, the article by Li *et al.*, "NOMA-Aided Generalized Pre-Coded Quadrature Spatial Modulation for Downlink Communication Systems," proposes a novel generalized pre-coded quadrature spatial modulation (GPQSM)-based NOMA scheme, which incorporates the GPQSM scheme into the multi-user communication networks with aid of NOMA. Low-complexity detection is

proposed to mitigate the high detection complexity of the maximum-likelihood detection in successive interference cancellation method for all users by NOMA-GPQSM. Simulation results show that near users and far users achieve relatively good and acceptable performance by proper power factors of all users in NOMA-GPQSM, respectively.

In conclusion, the Guest Editors of this feature topic would like to thank all the authors for their contributions, and the anonymous reviewers for their constructive comments and suggestions. We also would like to acknowledge the guidance from Ms. Nie.

Biographies

Miaowen Wen, received the Ph.D. degree from Peking University, Beijing, China, in 2014. From 2012 to 2013, he was a Visiting Student Research Collaborator with Princeton University, Princeton, NJ, USA. He is currently an Associate Professor with South China University of Technology, Guangzhou, China, and a Hong Kong Scholar with The University of Hong Kong, Hong Kong, China. He has published a book Index Modulation for 5G Wireless Communications (Springer, 2017) and more than 100 IEEE journal papers. His research interests include a variety of topics in the areas of wireless and molecular communications. Dr. Wen was the recipient of four Best Paper Awards from IEEE ITST'12, IEEE ITSC'14, IEEE ICNC'16, and IEEE ICCT'2019. He has served on the Editorial Boards of IEEE Access and EURASIP Journal on Wireless Communications and Networking. He served as a Guest Editor for IEEE Journal on Selected Areas in Communications and for IEEE Journal of Selected Topics in Signal Processing. He is currently serving as an Editor for IEEE Transactions on Communications, IEEE Communications Letters, and Physical Communication (Elsevier).

Wei Duan, received the Ph.D. degree from Chonbuk National University, Jeonju, South Korea, in 2017. He is currently an associate professor with Nantong University, Nantong, China. He had participated in the World Class University Project, sponsored by the National Research Foundation of Korea Grant funded by the Korean Ministry of Education Science and Technology, as a Vice Head Researcher. He has authored more than 30 journal papers. His research interests include wireless communications, reconfigurable intelligent surface and non-orthogonal multiple access techniques.

Zhiguo Ding, received his B.Eng in Electrical Engineering from the Beijing University of Posts and Telecommunications in 2000, and the Ph.D degree in Electrical Engineering from Imperial College London in 2005. From Jul. 2005 to Apr. 2018, he was working in Queen's University Belfast, Imperial College, Newcastle University and Lancaster University. Since Apr. 2018, he has been with the University of Manchester as a Professor in Communications. From Oct. 2012 to Sept. 2020, he has also been an academic visitor in Princeton University. Dr Ding' research interests are 5G networks, game theory, cooperative and energy harvesting networks and statistical signal processing. He is serving as an Area Editor for the IEEE Open Journal of the Communications Society, an Editor for IEEE Transactions on Communications, IEEE Transactions on Vehicular Technology, and Journal of Wireless Communications and Mobile Computing, and was an Editor for IEEE Wireless Communication Letters, IEEE Communication Letters from 2013 to 2016. He received the best paper award in IET ICWMC-2009 and IEEE WCSP-2014, the EU Marie Curie Fellowship 2012-2014, the Top IEEE TVT Editor 2017, IEEE Heinrich Hertz Award 2018, IEEE Jack Neubauer Memorial Award 2018 and IEEE Best Signal Processing Letter Award 2018.

Daniel Benevides da Costa, was born in Fortaleza, Ceará, Brazil, in 1981. He received the B.Sc. degree in Telecommunications from the Military Institute of Engineering (IME), Rio de Janeiro, Brazil, in 2003, and the M.Sc. and Ph.D. degrees in Electrical Engineering, Area: Telecommunications, from the University of Campinas, SP, Brazil, in 2006 and 2008, respectively. His Ph.D thesis was awarded the Best Ph.D. Thesis in Electrical Engineering by the Brazilian Ministry of Education (CAPES) at the 2009 CAPES Thesis Contest. From 2008 to 2009, he was a Postdoctoral Research Fellow with INRS-EMT, University of Quebec, Montreal, QC, Canada. Since 2010, he has been with the Federal University of Ceará, where he is currently an Associate Professor. Prof. da Costa is currently Executive Editor of the IEEE Communications Letters, Area Editor of IEEE Open Journal of the Communication Society - Area: Green, Cognitive, and Intelligent Communications and Networks, and Specialty Chief Editor of the Frontiers in Communications and Networks - Wireless Communications Section. He is also Editor of the IEEE Communications Surveys and Tutorials, IEEE Transactions on Communications, IEEE Transactions on Vehicular Technology, and IEEE Transactions on Cognitive Communications and Networking. From Jan. 2012 to May 2020, he served as Associate Technical Editor of the IEEE Communications Magazine. From 2012 to 2017 and from Mar. 2019 to Aug. 2019, he was Editor and Senior Editor, respectively, of the IEEE Communications Letters. He has served as Lead Guest Editor and Guest Editor of several Journal Special Issues. He has been involved on the Organizing Committee of several conferences. He is currently the Latin American Chapters Coordinator of the IEEE Vehicular Technology Society. Also, he acts as a Scientific Consultant of the National Council of Scientific and Technological Development (CNPq), Brazil, and he is a Productivity Research Fellow of CNPq. From 2012 to 2017, he was Member of the Advisory Board of the Ceará Council of Scientific and Technological Development (FUNCAP), Area: Telecommunications. Currently, he is Vice-Chair of Americas of the IEEE Technical Committee of Cognitive Networks (TCCN), Director of the TCCN Newsletter, and Chair of the Special Interest Group on ``Energy-Harvesting Cognitive Radio Networks'' in IEEE TCCN. He is also Vice-Chair of the SIG on "REconFigurabLE Intelligent Surfaces for Signal Processing and Communications" (REFLECTIONS) in Signal Processing and Computing for Communications Technical Committee (SPCC). Prof. da Costa is the recipient of four conference paper awards. He received the Exemplary Reviewer Certificate of the IEEE Wireless Communications Letters in 2013 and 2019, the Exemplary Reviewer Certificate of the IEEE Communications Letters in 2016, 2017, and 2019, the Certificate of Appreciation of Top Associate Editor for outstanding contributions to IEEE Transactions on Vehicular Technology in 2013, 2015

and 2016, the Exemplary Editor Award of IEEE Communications Letters in 2016, and the Outstanding Editor Award of IEEE Access in 2017, and the Certificate of Appreciation for notable services and contributions to IEEE Access in 2018 and 2019. He is a Distinguished Lecturer of the IEEE Vehicular Technology Society. He is a Senior Member of IEEE, Member of IEEE Communications Society, IEEE Vehicular Technology Society, and Brazilian Telecommunications Society.

Ioannis Krikidis, received the Diploma degree in computer engineering from the Computer Engineering and Informatics Department (CEID), University of Patras, Greece, in 2000, and the M.Sc. and Ph.D. degrees from Ecole Nationale Supérieure des Télécommunications (ENST), Paris, France, in 2001 and 2005, respectively, all in electrical engineering. From 2006 to 2007, he worked as a Post-Doctoral Researcher with ENST, Paris. From 2007 to 2010, he was a Research Fellow of the School of Engineering and Electronics, The University of Edinburgh, Edinburgh, U.K. He also has held research positions at the Department of Electrical Engineering, University of Notre Dame; the Department of Electrical and Computer Engineering, University of Maryland; the Interdisciplinary Centre for Security, Reliability and Trust, University of Luxembourg; and the Department of Electrical and Electronic Engineering, Niigata University, Japan. He is currently an Associate Professor at the Department of Electrical and Computer Engineering, University of Cyprus, Nicosia, Cyprus. His current research interests include wireless communications, cooperative networks, 5G communication systems, wireless powered communications, and secrecy communications. He serves as an Associate Editor for IEEE TRANSACTIONS ON COMMUNICATIONS, IEEE TRANSACTIONS ON GREEN COMMUNICATIONS AND NETWORKING, and IEEE WIRELESS COMMUNICATIONS LETTERS. He was a recipient of the Young Researcher Award from the Research Promotion Foundation, Cyprus, in 2013, and a recipient of IEEE ComSoc Best Young Professional Award in Academia, 2016. He has been recognized by the Web of Science as a Highly Cited Researcher for 2017, 2018, and 2019. He has received the prestigious ERC Consolidator Grant.

Yifei Yuan, received his Bachelor & Master degrees from Tsinghua University of China, and a Ph. D from Carnegie Mellon University, USA. He was with Alcatel-Lucent from 2000 to 2008, working on 3G/4G key technologies. From 2008 to 2020, he was with ZTE as technical director and chief engineer responsible for standards research on LTE-Advanced and 5G. Since January 2020, he has been with China Mobile Research Institute as Chief Expert, responsible for advanced technologies of 6G air interface. His research interests include MIMO, channel coding, non-orthogonal multiple access (NOMA), internet-of-things (IoT), resource scheduling. He has extensive publications, including 7 books on LTE-Advanced relay, LTE-Advanced key technologies & system performance, narrow-band (NB) IoT, 5G channel coding, 5G ultra-dense networks (UDN), and 5G non-orthogonal multiple access, respectively. He has over 50 granted patents. He is the rapporteur of NOMA study item in 3GPP. He is the recipient of Best Paper Award by IEEE Communications Society Asia-Pacific Board for co-authoring a paper on NOMA in IEEE Communications Magazine. He serves as the editors of IEEE Communications Letters, and China Communications, and the Chief Editor of Hans Wireless Communications.