# Guest Editorial Physical Layer Security for 5G Wireless Networks, Part I

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## I. Introduction

THE unprecedented growth in the number of mobile data and connected machines ever-fast approaches limits of fourth generation technologies to address this enormous data demand. Therefore, the development of the fifth generation (5G) wireless communication technologies is a priority issue currently. The evolution towards 5G wireless communications will be a cornerstone for realizing the future human-centric and connected machine-centric networks, which achieve near-instantaneous, zero distance connectivity for people and connected machines. On the other hand, wireless networks have been widely used in civilian and military applications and become an indispensable part of our daily life. People rely heavily on wireless networks for transmission of important/private information, such as credit card information, energy pricing, e-health data, command, and control messages. Therefore, security is a critical issue for future 5G wireless networks. Physical layer security techniques can be used to either perform secure data transmission directly or generate the distribution of cryptography keys for conventional cryptography techniques in the 5G networks. With careful management and implementation, physical layer security can be used as an additional level of protection on top of the existing security schemes. As such, they will formulate a well-integrated security solution together that efficiently safeguards the confidential and privacy communication data in 5G wireless networks. The main goal of this IEEE JSAC Special Issue on “Physical Layer Security for 5G Wireless Networks” is to bring together leading researchers in both academia and industry from diversified backgrounds to advance the theory and practice of physical layer security for 5G wireless networks.

There are total 39 accepted technical papers for our special issue, which will be published in two issues. In additional to technical papers, there is another survey paper “A survey of physical layer security techniques for 5G wireless networks and challenges ahead” in the first issue. This paper provides a latest survey of the physical layer security research on various promising 5G technologies.

## II. Accepted Technical Paper

The first issue has 19 technical papers with a broad range of topics as follows:

The first paper “Securing on-body IoT devices by exploiting creeping wave propagation” provides a good application example for the unified security strategy design across the network and the physical layers for the future Internet-of-Things vision. SecureTag is proposed to defend against active attacks for on-body devices by integrating physical layer information with upper-layer protocols. Once a suspicious transmission is detected, SecureTag initiates a physical layer-based challenge-response protocol to mitigate attacks.

The second paper “The secrecy capacity of Gaussian MIMO wiretap channels under interference constraints” studies the secrecy capacity of the multiple-input multiple-output (MIMO) wiretap channel with interference constraint. In other terms, how to characterise the amount of information two users equipped with multiple antennas can share with minimum leakage to eavesdroppers whilst minimising the interference generated at an other user. The authors show that the problem of finding the secrecy capacity can be expressed as a max-min problem so that a converging algorithm can be developed to find the solution. The optimal signaling directions are then characterised with and without interference constraint. In short, the feasibility of physical layer security with multiple antennas under interference constraint is investigated.

The third paper “Secure communication over finite state multiple-access wiretap channel with delayed feedback” analyzes the secrecy capacity region of a finite-state multiple-access wiretap channel with delayed feedback of the state and the channel output. Inner and outer bounds on the capacity region are derived for two cases: delay feedback of the state only, and delay feedback of both the state and the legitimate

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receiver's output. The main finding of this paper is that, delayed feedback of the channel output has two benefits: 1) allows the generation of secret keys between the transmitters and receiver; 2) allows coordination between the two transmitters. The bounds are evaluated for a degraded Gaussian fading channel.

The secure rate region of asymmetric multilevel diversity coding systems with $L$ encoders, $L+1$ sources, and security level $L2$ is investigated in the fourth paper "Fundamental limits on a class of secure asymmetric multilevel diversity coding systems". Upper bounds on the size of secrecy keys are derived. The authors prove that unlike in the symmetric multilevel diversity coding systems, superposition coding is not optimal for secure asymmetric multilevel diversity coding systems.

The fifth paper "An LDPC code based physical layer authentication scheme with prefect security" studies multiple-message authentication over noiseless main channel case and noisy main channel case, respectively. For the noiseless main channel case, a multiple-message authentication is proposed by leveraging a novel $\epsilon$-$\mathrm{AU}_2$ hash function family and the dual of large-girth LDPC codes. For the noisy main channel case, an authentication scheme is proposed by reducing the noisy main channel case to noiseless main channel case through public discussion and stochastically degraded channel technique. The proposed schemes are proved to be perfectly secure if the number of attacks by Eve is upper bounded by a polynomial times in terms of n.

A secrecy capacity achieving polar coding scheme for the cognitive interference channel with confidential messages under the strong secrecy criterion is proposed in the sixth paper "Polar coding for the cognitive interference channel with confidential messages". It is shown that the whole secrecy capacity region of the cognitive interference channel with confidential messages can be achieved by simple point-to-point polar codes, and the proposed scheme requires the minimum rate of randomness at the encoder.

The seventh paper "Robust beamforming for physical layer security in BDMA massive MIMO" proposes a robust beamforming desgin to achieve physical layer security for a multi-user beam division multiple access massive multiple-input multiple-output (MIMO) system with imperfect channel state information (CSI). The proposed design reduces the computational complexity by obtaining a closed form solution for the optimal beamforming direction and the optimal beamforming power allocation.

The eighth paper "Exploiting inter-user interference for secure massive non-orthogonal multiple access" studies the secure massive access in a single-cell multiuser downlink communication system with massive MIMO and non-orthogonal multiple access. The non-orthogonal channel estimation is performed to reduce the length of training sequence and the inter-user interference is exploited as AN signal to confuse the eavesdroppers, especially in the scenario of active eavesdropping.

The ninth paper "Secure massive MIMO with the artificial noise-aided downlink training" proposes two AN-aiding schemes to enhance the secrecy performance of massive MIMO networks in presence of a passive eavesdropper. The authors develop the analytical expressions and tight approximations for the achievable secrecy rate to investigate the performance of the two proposed AN-aiding schemes. The results reveal that deploying AN in the downlink training phase of massive MIMO networks does not affect the downlink channel estimation process at users while enabling the system to suppress the downlink channel estimation process at eavesdropper.

The tenth paper "Optimal transmit antenna selection for massive MIMO wiretap channels" investigates the secrecy performance of a massive MIMO wiretap channel when the transmitter selects a subset of antennas corresponding to the strongest channels. Confidential messages are then transmitted to a multi-antenna legitimate receiver while a multi-antenna eavesdropper overhears the channel. For this setup, an accurate large-system approximation of the instantaneous secrecy rate is derived and this approximation is used to investigate the performance under active and passive eavesdropping.

The eleventh paper "Physically securing energy-based massive MIMO MAC via joint alignment of multi-user constellations and artificial noise" considers the optimality of jointly aligning multi-user constellations and artificial noise to secure a multiple access communication in a massive MIMO setup, i.e., the base station and the eavesdropper are equipped with large antenna arrays and each user is equipped with multiple transmit antennas. The authors start by discussing a distance optimal constellation and show that its structure can be specifically used to design a PAM alignment scheme. At this stage, the secrecy constraint is taken into consideration. Then, by exploiting the power domain freedom of the used constellation, they present a stepped water-Filing power allocation scheme that utilizes the remaining power to transmit artificial noise.

The twelfth paper "Constant envelope hybrid precoding for directional millimeter-wave communications" studies physical layer security for mmWave massive MIMO systems by considering joint hybrid analog and digital precoding and constant envelope modulation to address the challenges caused by limited number of radio frequency chains and high peak to average power ratio. Considering two specific hybrid MIMO architectures, optimization problems are formulated to minimize the power leakage to eavesdroppers while ensuring the legitimate users can correctly receive the desired data symbols. To solve these problems, the authors exploit penalty method and block coordinate descent-type algorithms, which is shown to find the stationary points of the optimization problems.

The thirteenth paper "Multiple antennas secure transmission under pilot spoofing and jamming attack" provides a scheme to counteract pilot spoofing attacks and pilot jamming attacks in a base station with multiple antennas, in time division duplex mode. The idea is to let the terminal use a random channel training, in which the pilot used by the terminal is drawn randomly from a subset of all pilots. The base station can then, without a priori knowledge, detect what pilot was transmitted, and use this to estimate both the channel to the legitimate terminal and to the malicious terminal. The paper finds closed-form expressions and approximations to measure performance in terms of error decision rate and secrecy rate.

The fourteenth paper "Mapping-varied spatial modulation for physical layer security: transmission strategy and secrecy rate" proposes a physical layer secure transmission scheme based on spatial modulation, which is termed mapping-varied spatial modulation. The scheme varies the mappings of antenna indices and constellation points according to the legitimate CSI, which is unknown by Eve. In this way Eve cannot directly decode the information and the security is improved. Furthermore, the paper studies the achievable secrecy rates of the proposed scheme under both finite-alphabet and Gaussian input.

The fifteenth paper "Secure and precise wireless transmission for random-subcarrier-selection-based directional modulation transmit antenna array" joint utilizes random subcarrier selection based on OFDM, phase alignment/beamforming, artificial noise, and directional modulation to achieve secure precise transmission of confidential messages. In addition, the average signal-to-interference-and-noise ratio (SINR) and its upper bound are derived.

The sixteenth paper "Optimization or alignment: secure primary transmission assisted by secondary networks" proposes, analyzes, and compares two schemes, i.e., optimal transceiver design scheme and interference alignment-based scheme, to achieve secure transmission of primary user assisted by secondary users in cognitive radio networks.

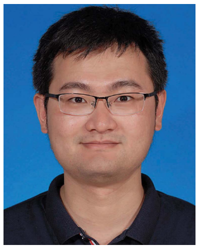
The seventeenth paper "Artificial noise aided secure cognitive beamforming for cooperative MISO-NOMA using SWIPT" investigates the beamforming design for the artificial noise aided jamming of cognitive radio multiple-input single-output non-orthogonal multiple access with simultaneous wireless information and power transfer by using a nonlinear energy harvesting model. The beamformer is designed to minimize the transmission power for given harvested energy level and secrecy rate under perfect CSI and a bounded CSI error model.

The eighteenth paper "Robust secure beamforming for 5G cellular networks coexisting with satellite networks" studies the robust beamforming schemes for the physical layer security techniques in a scenario where a 5G cellular system uses the millimeter wave frequency and coexists with a satellite network. By developing a new physical layer security framework, and formulating a constrained optimization problem to maximize the secrecy rate at the second user while satisfying the interference level constraint at the primary user, this paper proposes two beamforming schemes, namely, heuristic beamforming scheme and iterative penalty function-based beamforming algorithm associated with the cases of coordinated and uncoordinated Eves, respectively.

The nineteenth paper "Resource management for device-to-device communication: a physical layer security perspective" studies the resource management of device-to-device (D2D) communication links underlaying cellular networks from a physical layer security perspective. Aiming to improve both security of the cellular users and spectral efficiency of D2D links, the authors have formulated the joint optimization of the power allocation and channel assignment as difficult mixed integer problem. Then, two algorithms are proposed for single-D2D and multi-D2D communications respectively. Finally, simulation results are provided to show that the win-win situation can be achieved by the proposed algorithms.

## Acknowledgment

The authors want to thank all the authors who submitted their works to this special issue as well as their technical merits. They provided both the Reviewers and Editors with a fascinating snapshot of the range of ongoing research in the area. Owing to the highly selective nature of JSAC, many interesting papers were not selected for our special issue, but we hope that these papers might appear elsewhere. They also thank all the Reviewers, who were very responsive to our repeated reminders about staying on schedule. Their critical comments and suggestions to the Authors contributed substantially to our special issue. They also thank Prof. M. Medard, JSAC Editor-in-Chief, the Executive Editor Laurel Greenidge, and the Senior Editor Prof. A. Jukan, for the effort and help they have provided for our special issue.



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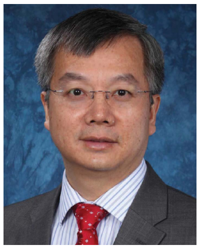

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