Guest Editorial: Signal Processing for Wireless Physical Layer Security

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THE ONGOING advances in wireless technologies (e.g., cognitive radio, device-to-device communications, social networking services, etc.) have introduced new security challenges in next-generation networks. Despite the proven efficiency of cryptographic techniques, the associated overhead and complexity make it difficult to implement encryption algorithms in future large-scale, heterogeneous, and distributed wireless networks. Indeed, the emergence of highly decentralized wireless architectures without an infrastructure that supports key management and authentication imposes new challenges on classical security measures such as cryptography. Motivated by these issues, substantial recent research has been dedicated toward seeking novel information-theoretic techniques that can secure wireless networks without the computational overhead that accompanies standard cryptographic techniques. The main idea of this work is to exploit physical characteristics of the wireless channel such as fading or noise, traditionally seen as impediments, to improve the transmission reliability against eavesdropping attacks with relatively low computational overhead. This approach is known as wireless *physical layer security*. At the heart of this formalism lies the concept of a *secrecy capacity* which is defined as the maximum wireless transmission rate that achieves perfect secrecy - the eavesdropper cannot do better than a guessing-based exhaustive search for data detection and, thus, it achieves the worst-case bit error rate during signal detection. Indeed, if well designed, physical layer security mechanisms can provide a robust solution for boosting wireless security and can act as either an alternative or as a complement that can strengthen traditional encryption techniques.

The emergence of physical layer security as a potential technique for securing wireless transmission has significantly captured the attention of researchers in both the signal processing and communications communities. In this context, developing advanced signal processing techniques for optimizing and enhancing the secrecy rate of wireless links has become an issue of considerable interest in the design and analysis of future wireless networks. As is the case with any novel technology, reaping the benefits of physical layer security is contingent upon meeting several key challenges. The main goal of this special issue is to gather state-of-the-art contributions that address such challenges as they pertain to the design, analysis, and optimization of physical layer security in next-generation networks. In particular, the selected papers are aimed at addressing the following challenges in physical layer security: 1) design of multiple antenna and cooperative techniques for maximizing the achievable secrecy rate, 2) development of new signal processing techniques that exploit channel randomness for secret key generation, 3) development of advanced algorithms at the physical layer for treating security primitives such as authentication and privacy, 4) waveform and signal designs for boosting the secrecy rate and combatting active and passive eavesdropping, 5) novel coding techniques that are tailored toward physical layer secrecy, and 6) fundamental limits and novel optimization approaches for wireless secrecy.

The special issue begins by focusing on contributions that address physical layer enhancements, such as multiple antenna and cooperative techniques, that are tailored toward improving secrecy rate. One fundamental problem in this area is to develop secrecy-enhancing transmission techniques in dense networks with multiple antennas at the transmitter and, possibly, at the receivers. The related contributions include fundamental results on optimal secrecy-achieving precoding techniques, novel beamforming schemes for optimizing secrecy rates, and relay-assisted cooperative schemes for characterizing and optimizing secrecy rates in a variety of multi-antenna settings.

Wireless physical layer security is not limited to characterizing and optimizing secrecy rate, but also extends to utilizing channel characteristics for developing novel authentication and key extraction techniques. In this respect, the next group of papers address the major problems in secret key generation and authentication using physical layer techniques. The contributions encompass solutions to several open problems such as deriving fundamental results for extracting secret keys from various wireless channels (reciprocal, frequency selective, etc.), key agreement schemes in multiple access channels, and a number of physical layer-based authentication

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protocols for different applications that include body area networks as well as more traditional wireless systems.

Next, the special issue focuses on signal designs for enhancing wireless secrecy and combatting eavesdroppers with various capabilities. Indeed, exploiting different properties at the eavesdropper's side such as receiver characteristics or eavesdropper behavior (active/passive) can provide interesting dimensions for optimizing secrecy. The papers in this group cover diverse topics such as the use of non-linear conversion operation at an eavesdropper's receiver to maintain a positive secrecy capacity, the derivation of fundamental results on the ergodic secrecy capacity under partial channel state information at the transmitter, and the development of new signal processing techniques for optimizing secrecy under two scenarios: the presence of active and passive eavesdroppers as well as in the case of multicasting.

In order to deploy and operate physical layer security mechanisms, it is necessary to understand the prospective performance and potential limitations of these techniques. This is important for both key generation and secrecy optimization. In this regard, the next collection of papers focuses on fundamental results pertaining to modeling and analysis of wireless physical layer security scenarios. These results are expected to enhance our understanding of the performance of physical layer security mechanisms, subsequently providing the much needed theoretical foundations for such protocols. These contributions include the development of foundational measures for characterizing the performance of physical layer-based secret key generation mechanisms, the introduction of novel coding and performance analysis techniques, as well as the derivation of fundamental information-theoretic bounds and metrics for characterizing and analyzing physical layer secrecy and its limits.

Last but not least, this special issue provides two papers that focus on cross-layer approaches to combining physical layer secrecy with higher layer performance measures. To this end, the first paper introduces novel control-theoretic techniques that neatly link evading eavesdropping at the physical layer and networking issues such as packet arrivals, queuing, and admission control. Then, the final paper in this special issue develops a detection-theoretic method for optimizing packet reordering at routers or proxy servers, so as to prevent eavesdroppers from tracking the flow of packets, under both throughput and memory constraints.

In a nutshell, despite the significant advances in physical layer security that accompanied the past decade, this special issue provides novel solutions to a variety of open physical layer security problems that have emerged in the past few years, particularly from the signal processing and optimization perspectives. We believe that these contributions will also provide a solid basis for future research developments towards introducing physical layer security schemes in practical scenarios.

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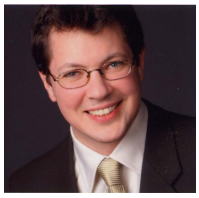

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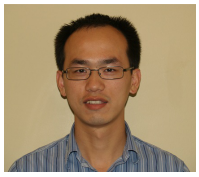

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