Ph.D. DISSERTATION DEFENSE

Candidate:	Moh Khalid Hasan
Degree:	Doctor of Philosophy
School/Department:	Charles V. Schaefer, Jr. School of Engineering and Science / Electrical and Computer Engineering
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Title:	Toward Secure and Efficient Cognitive Radio Networks: Adaptive PHY Security and Learning-Driven Optimization
Chairperson:	Dr. Min Song, Department of Electrical and Computer Engineering, School of Engineering and Science
Committee Members:	Dr. Shucheng Yu, Department of Electrical and Computer Engineering, School of Engineering and Science
	Dr. Hongbin Li, Department of Electrical and Computer Engineering, School of Engineering and Science
	Dr. Ying Wang, Department of Systems and Enterprises, School of Engineering and Science

ABSTRACT

The exponentially increasing data traffic in wireless communication systems presents significant challenges for efficient radio spectrum usage, data security, and network performance optimization. In next-generation networks, especially 6G, these challenges are intensified due to the continued proliferation of connected devices. This dissertation addresses these issues through a comprehensive study involving cognitive radio networks with nonorthogonal multiple access (NOMA), PHY security, and learning-driven channel prediction for performance enhancement.

First, the study investigates cognitive radio networks, focusing on a cooperative NOMA-based spectrum leasing architecture designed to support multi-secondary user networks. A maximum ratio combining decoding scheme and an advanced successive interference cancellation (SIC) approach are proposed for decoding at both primary and secondary receiving ends. Under secondary transmitter power constraints, closed-form expressions for achievable rate and outage probability are derived. Simulations show that the proposed scheme outperforms conventional orthogonal multiple access-based spectrum leasing in both metrics.

Second, the research explores PHY security in NOMA-based overlay cognitive networks, particularly in antagonistic scenarios between primary and secondary networks. A novel channel-adaptive dual-phase cooperative jamming strategy is proposed using reverse SIC and dynamic top-down power allocation. Closed-form expressions for ergodic secrecy rate and its asymptotic form are derived using Taylor-McLaurin expansions and Gaussian-Chebyshev quadrature under Nakagami-*m* fading. This work is further extended to reconfigurable intelligent surface aided MIMO-NOMA networks, proposing a user-centric artificial noise (AN) based security design. The AN is nullified through singular value decomposition in the composite

channel. The study also examines the effects of fading and surface partitioning on uplink secrecy and discusses optimal power allocation.

Third, communication performance is optimized through advanced channel prediction and adaptive beamforming in autonomous MIMO-UAV networks. To address rapid channel fluctuations, MAPBNet, a new two-layer machine learning based framework, is proposed. It features a self-attention channel predictor and a learning-based adaptive beamforming strategy. Simulations show MAPBNet outperforms existing methods in prediction accuracy and transmission sum rate.

Additional ideas are presented to further optimize AN power in highly resource-constrained networks, introduce an interference-density-based user-grouping metric for underlay cognitive radio networks, validate the proposed frameworks through hardware and SDR testbeds, and extend spectrum-efficient, secure communication techniques to higher spectrum bands. Collectively, the contributions in this dissertation advance spectrum efficiency, PHY-layer confidentiality, and adaptability, offering a unified pathway toward resilient 6G cognitive networks.