UTS UNIVERSITY OF TECHNOLOGY SYDNEY

New Signaling Techniques for Energy and Information Deliveries

by Hongwen Yu

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Doctor of Philosophy

under the supervision of Prof. Tuan D. Hoang and Prof. Eryk Dutkiewicz

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Hongwen Yu declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree at any other academic institution except as fully acknowledged within the text. This thesis is the result of a Collaborative Doctoral Research Degree program with Shanghai University.

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Publications

The contents of this thesis are based on the following papers that have been published, accepted, or submitted to peer-reviewed journals and conferences.

Journal Papers:

1. H. Yu, H. D. Tuan, A. A. Nasir, T. Q. Duong and H. V. Poor, "Joint Design of Reconfigurable Intelligent Surfaces and Transmit Beamforming under Proper and Improper Gaussian Signaling". *IEEE Journal on Selected Areas in Communications*, 2020, 38(11): 2589-2603.

2. H. Yu, H. D. Tuan, T. Q. Duong, H. V. Poor and Y. Fang, "Optimization for Signal Transmission and Reception in a Macrocell of Heterogeneous Uplinks and Downlinks". *IEEE Transactions on Communications*, 2020, 68(11): 7054-7067.

3. H. Yu, H. D. Tuan, T. Q. Duong, Y. Fang and L. Hanzo, "Improper Gaussian Signaling for Integrated Data and Energy Networking". *IEEE Transactions on Communications*, 2020, 68(6): 3922-3934.

4. H. Yu, H. D. Tuan, A. A. Nasir, T. Q. Duong and L. Hanzo, "Improper Gaussian Signaling for Computationally Tractable Energy and Information Beamforming". *IEEE Transactions on Vehicular Technology*, 2020, 69(11): 13990-13995.

5. H. Yu, H. D. Tuan, E. Dutkiewicz, H. V. Poor and L. Hanzo, "Maximizing the Geometric Mean of User-Rates to Improve Rate-Fairness: Proper vs. Improper Gaussian Signaling". *IEEE Transactions on Wireless Communications*, 2021,21(1):295-309.

6. H. Yu, H. D. Tuan, A. A. Nasir, M. Debbahd and Y. Fang, "New Generalized Zero Forcing Beamforming for Serving More Users in Energy-Harvesting Enabled Networks". *Physical Communication*, 50(2022): 101500.

7. H. Yu, H. D. Tuan, E. Dutkiewicz, H. V. Poor and L. Hanzo, "RIS-aided Zero-Forcing and Regularized Zero-Forcing Beamfoming in Integrated Information and Energy Delivery". *IEEE Transactions on Wireless Communications*, 2021. (Early Access)

8. H. Yu, H. D. Tuan, E. Dutkiewicz, H. V. Poor and L. Hanzo, "Hybrid Beamforming with Analog Finite-Resolution for Millimeter-wave Multi-user Communications". *IEEE Transactions on Communications*, 2021. (Under review)

Conference Papers:

1. H. Yu, H. D. Tuan, A. A. Nasir, M. Debbah and Y. Fang, "Regularized Zero Forcing Beamforming for Serving More Users in Energy-Harvesting Enabled Networks". *Proceedings of 2020 IEEE Tenth International Conference on Communications and Electronics (ICCE)*, Vietnam, 2020: 51-56.

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Abstract

The 6th-generation networks aim to further increase the average data rate and the edge rate, decrease in energy consumption and cost, and be able to transfer the energy at the same time. Precoding technology is one of the core technologies to achieve above goals. This thesis conducts in-depth research on uplink and downlink synchronous transmission scenarios, spectrum efficiency in energy-harvesting (EH) communication scenarios and Reconfigurable Intelligent Surfaces (RIS)-aided communication scenarios under precoding optimization methods.

Firstly, we propose a joint design of precoding matrix for base station and uplink users, and optimize the coefficient of time fraction in the same time. We also propose a joint design of precoding matrix for base station and uplink users, and optimize the allocation of downlink and uplink bandwidth in the same time.

Secondly, this dissertation considers multi-cell and multi-user communication scenario with EH, combining the fractional time method and the improper Gaussian signaling (IGS) precoding, an iterative algorithm is designed to optimize the user's max-min throughput in the optimization of spectrum efficiency. Furthermore, a simplified improper Gaussian signaling precoding optimization algorithm is proposed, the algorithm reduces the complexity of the algorithm under improper Gaussian signaling.

Thirdly, in the RIS-aided communication scenario, this dissertation proposes a joint design of RIS and transmit beamforming under proper and improper Gaussian signaling, and introduces the unit-modulus constraints (UMC) of RIS reflection coefficients into the objective function which reduces the complexity of the algorithm.

Fourthly, a joint design of linear transmit beamformers and the programmable reflecting coefficients of an RIS to maximize the geometric mean of the users' rates is

proposed. We also consider the joint design of widely linear transmit beamformers and the programmable reflecting coefficients to further improve the GM of the users' rates.

Finally, this dissertation considers RIS-aided wireless communication system with EH network where the RIS links the connection between the IUs and the BS as there is no direct path between the former and the latter. Joint optimization algorithms for information transfer beamforming, energy transfer beamforming and reflecting coefficients of the RIS based on transmit time-switching approach are developed. The superiority of the proposed algorithm is verified in the simulation section.

In summary, the optimization of precoding for wireless communication systems is studied, and method proposed in this thesis has certain significance for the theoretical research and technical realization of wireless communication systems.