Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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"Cross-Layer Design for Multi-Hop Two-Way Relay Network"

Department of Electrical and Computer Engineering

Wednesday, June 14, 2017
1:00 P.M.
Engineering and Computer Science Building
Room 468

Supervisory Committee:
Dr. Lin Cai, Department of Electrical and Computer Engineering, University of Victoria (Supervisor)
Dr. T. Aaron Gulliver, Department of Electrical and Computer Engineering, UVic (Member)
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Dr. Carolyn Crippen, Department of Education Psychology & Leadership Studies, UVic

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Abstract

Physical layer network coding (PNC) is proposed under the two-way relay channel (TWRC) scenario, where two sources target to exchange information aided by a relay. PNC allows the two sources to transmit to the relay simultaneously, where the superimposed signals at the relay can be mapped to a network-coded symbol and then broadcast instead of being treated as the interference. The concurrent transmissions achieve a higher spectrum efficiency compared to the time division and network coding solutions. Existing research mainly focused on the symmetric PNC designs, where the same channel coding and modulation configurations are applied by both sources. When the channel conditions of the two source-relay links are asymmetric or an unequal data exchange ratio is required, heterogeneous modulation PNC designs are necessary. In additional, the design and optimization of multi-hop PNC, where multiple relays are scheduled to support the data exchange between two sources remains an open issue, which motivates the study of this dissertation.

This dissertation investigated the design of heterogeneous modulation physical layer network coding (HePNC), the integration of channel error control coding into HePNC, the combination of HePNC with hierarchical modulation and the design and generalization of multi-hop PNC. The contributions of this dissertation are four-fold.

First, under the asymmetric TWRC, where the channel conditions of the two source-relay links are asymmetric, we designed a HePNC protocol, including the optimizations of the adaptive mapping functions and the bit-symbol labeling, to minimize the end-to-end BER. In addition, we developed an analytical framework to derive the BER of HePNC theoretically. HePNC can substantially enhance the throughput compared with the existing symmetric PNC under the asymmetric TWRC.

Second, we investigated channel coded HePNC and integrated the channel error control coding into HePNC in a link-to-link coding, where the relay tries to decode the superimposed codewords in the multi-access stage. A full-state sum-product decoding algorithm is proposed at the relay based on the repeat-accumulate codes to guarantee the reliable end-to-end communication.

Third, we proposed hierarchical modulation PNC (H-PNC) under asymmetric TWRC, where additional data exchange between the relay and the source with the relatively better channel condition is achieved in addition to that between the two end sources, benefiting from superimposing the additional data flow on the PNC transmission. In the scenarios that the relay also has the data exchange requirement with the source with a better source-relay channel, H-PNC outperforms HePNC and PNC in terms of the system's sum throughput.

Fourth, we designed and generalized multi-hop PNC, where multiple relays located in a linear topology are scheduled to support the data exchange between two end sources. The impacts of the error propagation and the mutual interference among the nodes are addressed and optimized. The proposed designs outperform the existing ones in terms of the end-to-end BER and end-to-end throughout.