



University
of Victoria

Graduate Studies

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

of

TIANQING WU

MEng (Beijing University of Posts and Telecommunications, 2010)

BEng (Beijing University of Posts and Telecommunications, 2007)

**“Cognitive Beamforming Transmission and Energy Harvesting with
Limited Primary Cooperation: Analysis and Design”**

Department of Electrical and Computer Engineering

Friday, September 15, 2017

2:30 P.M.

Engineering and Computer Science Building

Room 468

Supervisory Committee:

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(Supervisor)

Dr. Daler N. Rakhmatov, Department of Electrical and Computer Engineering, UVic (Member)

Dr. Kui Wu, Department of Computer Engineering, UVic (Outside Member)

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Dr. Bernie Pauly, School of Nursing, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

Cognitive radio improves radio spectrum utilization either by spectrum sharing or by opportunistically utilizing the spectrum of the licensed users. Cognitive beam-forming is a prominent technique that can further enhance the overall performance of the wireless communication systems through beamforming vector design and/or power allocation. Harvesting radio frequency (RF) energy from existing wireless communication systems is a promising potential solution for providing convenient, perpetual and green energy supply to wireless sensor networks (WSN). The amount of energy that can be harvested from existing RF energy sources over a short period of time can only support low data rate applications with simply transmission strategies. The main challenge for satisfying the energy requirement of WSN is the time-varying wireless fading channels. Low complexity cooperation between WSN and RF energy source can effectively enhance the stability of energy supply for the sensor node. While multiple transmission antennas are deployed at the existing RF energy source, judicious transmit beam selection can further improve the harvested energy at the sensor node, while simultaneously serving multiple users.

In this doctoral research, we present random unitary beamforming (RUB) cooperative beam selection schemes to ensure the QoS of primary system and reduce the hardware and software complexities of secondary system. We analyze the exact out-age performance of the primary system, and investigate the tradeoff between primary system outage probability versus secondary system sum-rate performance. We also study the performance of overlaid wireless sensor transmission powered by RF energy harvested from existing wireless system. We derive the exact distribution function of harvested energy over a certain number channel coherence time over Rayleigh fading channels with the consideration of hardware limitation, such as energy harvesting sensitivity and harvesting efficiency. We also analyze the average packet delay and packet loss probability of sensor transmission subject to interference from existing system, for both delay insensitive traffics and delay sensitive traffics. The optimal design of energy storage capacity of the sensor nodes is proposed to minimize the average packet transmission delay for delay insensitive traffics with two candidate transmission strategies. We further investigate the energy harvesting performance of a wireless sensor node powered by RF energy from an existing multiuser MIMO system. Specifically, we propose based cooperative beam selection schemes to enhance the energy harvesting performance at the sensor. We derive the exact distribution function of harvested energy in a coherence time and further investigate the performance tradeoff of the average harvested energy at the sensor versus the sum-rate of the multiuser MIMO system.