University of Victoria | Graduate Studies

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

of

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"Signal Design for Multi-Way Relay Channels"

Department of Electrical and Computer Engineering

Friday, December 2, 2016
2:00 P.M.
Engineering and Computer Science Building
Room 468

Supervisory Committee:
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Dr. Xiaodai Dong, Department of Electrical and Computer Engineering, UVic (Member)
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Dr. Lindsay Tedds, School of Public Administration, UVic

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Abstract

Today's communication systems are in need of spectral efficient and high throughput techniques more than ever because of high data rate applications and scarcity and expensiveness of bandwidth. In order to cope with the increased data rate and capacity demand, more base stations are needed which is not a very cost and energy efficient method in cellular networks. It has been shown that wireless relay networks can provide higher network throughput and increase power and spectral efficiency with low complexity and cost. Furthermore, network resources can be utilized more efficiently by the use of network coding at the top of relay networks.

A wireless relay network in which multiple user nodes exchange information with one another with the help of relay node(s) is called a multi-way relay channel (MWRC). MWRCs are expected to be an integral part of the next generation wireless standards.

The main focus of this dissertation is studying transmission schemes in an MWRC to improve its throughput and performance as well as analyzing its error performance. For that, an MWRC with no direct links between the communicating nodes is assumed, in which a half-duplex relay station (RS) is the enabler of communication. Also, it is assumed that full data exchange is desired between users i.e. every user has a message and wants to transmit its message to all other user nodes.

One of the challenges with the signal demodulation in MWRCs is the existence of ambiguous point(s) in the received constellation at the relay. The first part of the thesis investigates a transmission scheme for full data exchange that benefits from ambiguous point(s) and improves the throughput of an MWRC compared to the traditional relaying scheme. The power efficiency and error performance of the proposed scheme are also compared with plain routing to show there is a trade-off between them in selecting a relaying scheme.

Then an MWRC where a RS assists multiple communication clusters is considered. Each cluster consists of multiple user nodes who intend to exchange messages among themselves. Here a different approach is taken to avoid the ambiguous point(s) in the

superposition of symbols from different users of a cluster which are simultaneously received at the relay. This can be achievable by employing complex field network coding (CFNC) which results in full data exchange in two communication phases. CFNC may lead to small Euclidean distances between constellation points at the relay resulting in poor performance. A precoding vector is designed to be employed by the users such that the reception of a rectangular quadrature amplitude modulation (QAM) is ensured at the relay when channel state information are available at the users. Then a more general problem is considered in which each user can employ an arbitrary pulse amplitude modulation (PAM) or rectangular QAM constellation and the optimal precoding values are derived such that the power efficiency of the relay QAM constellation is highest. The error performance of each user in such an MWRC is also analyzed and compared with other relaying schemes.

Finally, focusing on the uplink of multi-way relay systems, the performance of MWRC is studied in which users can employ arbitrary modulation schemes and the links between the users and the relay have different gains. For instance, in a Rayleigh fading environment, different users most likely have channels with different gains resulting in different received energy. Analytical expressions for exact average pairwise error probability of such MWRCs are derived, the probability density function (PDF) and mean of the minimum Euclidean distance of the relay constellation are closely approximated and a tight upper bound on the symbol error probability is developed.