Rate Optimization and Resource Allocation in Cooperative Cognitive Radio Networks

By

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CIIT/SP12-PEE-008/ISB

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This is to certify that the research work presented in this thesis, entitled "Rate Optimization and Resource Allocation in Cooperative Cognitive Radio Networks" was conducted by Mr. Bakhtiar Ali, under the supervision of Dr. Muhammad Fasih Uddin Butt. No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the Department of Electrical Engineering, COMSATS Institute of Information Technology, Islamabad, in the partial fulfilment of the requirement for the degree of Doctor of Philosophy in the field of Electrical Engineering.

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ABSTRACT

Rate Optimization and Resource Allocation in Cooperative Cognitive Radio Networks

Cognitive radio enables the cognitive nodes or Secondary Users (SUs) to sense any opportunity for transmission without degrading the Primary Users (PUs) transmission. This helps in efficient utilization of the available radio spectrum. Cooperation among PUs and SUs can greatly enhance the performance of the cognitive radio network. In this thesis, we have considered various spectrum access strategies in Cooperative Cognitive Radio Networks (CCRNs) using distributed matching algorithms in order to optimize the PU and/or SU sum-rate. SUs cooperatively relay PUs messages based on Amplify-and-Forward (AF) and Decode-and-Forward (DF) cooperative techniques, in exchange for accessing some of the spectrum for their secondary communications. From the literatures, we found that the Conventional Distributed Algorithm (CDA) and Pragmatic Distributed Algorithm (PDA) aim to maximize the PU sum-rate resulting in a lower sum-rate for the SU. In this contribution, we have investigated a suit of distributed matching algorithms. More specifically, we investigated SU-based CDA (CDA-SU) and SU-based PDA (PDA-SU) that maximize the SU sum-rate. We have also proposed the All User-based PDA (PDA-ALL), for maximizing the sum-rates of both PU and SU groups. All schemes are investigated under the idealistic scenario involving perfect coding and perfect modulation, as well as under practical scenario involving actual coding and actual modulation. Explicitly, our practical scenario considers the adaptive coded modulation based DF schemes for transmission flexibility and efficiency. More specifically, we have considered the Self-Concatenated Convolutional Code (SECCC), which exhibits low complexity, since it invokes only a single encoder and a single decoder. Furthermore, puncturing has been employed for enhancing the bandwidth efficiency of SECCC. As another enhancement, physical layer security has been applied to our system by introducing a unique Advanced Encryption Standard (AES) based puncturing to our SECCC scheme.

Furthermore, we present a secrecy sum-rate maximization based matching algorithm between PUs and SU cooperative jammers in the presence of an eavesdropper. We present the achievable secrecy regions by employing friendly jammers which transmit noise to impair the eavesdropper's ability to decode the message. The cooperative jammers are allocated a fraction of the bandwidth in compensation for their help to transmit jamming signals towards the eavesdropper, which in our case is an untrusted relay node. We provide results for the secrecy rate regions, where we consider only relaying link between the source and the destination. We also provide results for the secrecy rate regions when we consider a direct link between the source and destination in addition to the relaying link. The Conventional Distributed Algorithm (CDA) and the Pragmatic Distributed Algorithm (PDA), which were originally designed for maximizing the user's sum rate, are modified and adapted for maximizing the secrecy sum-rate for the primary user.

In the end we considered a scenario such that a single PU can acquire help from multiple SUs. More explicitly, we consider an untrusted relay scenario, where the relay is a potential eavesdropper. The transmission of the proposed scheme is divided into three time slots, i.e., broadcast and jamming phase, relaying phase and the jammer's secondary transmission phase or utility phase. We employ multiple jammers where we first fix the position of the first jammer at the point where maximum secrecy is achieved and study the behavior of introducing a second jammer to maximize the secrecy further. Then we fix the locations of the first two jammers and add another jammer to assist in improving the secrecy further. We consider a leader-follower game theoretic model where the primary user (source) is the leader and the secondary users (jammers) are the followers. To facilitate the behavior of cooperative jammers, a Nash equilibrium based power control mechanism is employed. We consider two scenarios for our power control mechanism, where in the first case the jammers simultaneously transmit their information (non-orthogonal) during the jammer's utility phase, while in the second case the jammer's utility time slot is divided equally among the participating jammers (orthogonal) to mitigate interference caused by the participating jammers.

LIST OF PUBLICATIONS

1. **Bakhtiar Ali**, N. Zamir, S. X. Ng and M. F. U. Butt, "Distributed Matching Algorithms for Spectrum Access: A Comparative Study and Further Enhancements",*KSII Transactions on Internet and Information Systems*, eISSN 1976-7277, [Under review] [Chapter 3].

2. **Bakhtiar Ali**, N. Zamir, S. X. Ng and M. F. U. Butt, "Distributed Matching Algorithms: Maximizing Secrecy in the Presence of Untrusted Relay",*Radioengineering Journal*, ISSN 1210-2512 [Accepted for publication] [Chapter 4].

3. N. Zamir, **Bakhtiar Ali**, M. F. U. Butt and S. X. Ng, "Further Improving secrecy rate via cooperative jamming based on Nash Equilibrium",*IEEE Communications Letters*, [Under review] [Chapter 5].

4. **Bakhtiar Ali**, N. Zamir, S. X. Ng and M. F. U. Butt, "Physical layer security: Friendly jamming in an untrusted relay scenario",*2016 24th European Signal Processing Conference (EUSIPCO)*, Budapest, 2016, pp. 958-962.

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Additional Research Work

6. J. Mirza, **Bakhtiar Ali**, S. S. Naqvi, S. Saleem, "Hybrid Precoding via Successive Refinement for Millimeter Wave MIMO Communication Systems,",*in IEEE Communications Letters*, vol.PP, no.99, pp.1-1.

7. H. M. F. A. Madni, **Bakhtiar Ali** and M. F. U. Butt, "Study and Analysis of Channel Estimation Techniques for OFDM Based Wireless Communication Systems",*2014 12th International Conference on Frontiers of Information Technology*, 2014, pp. 56-60.

8. K. Naveed, **Bakhtiar Ali** and M. T. Akhtar, "A variable step size affine projection algorithm based on the principle of orthogonality,",*2016 IEEE 59th International Midwest Symposium on Circuits and Systems (MWSCAS)*, Abu Dhabi, 2016, pp. 1-4

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