

**OUTAGE CHARACTERIZATION OF
OPPORTUNISTIC COOPERATIVE STRATEGIES IN
TWO-WAY RELAY NETWORKS**

by

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CERTIFICATE

This is to certify that the thesis entitled “**Outage Characterization of Opportunistic Cooperative Strategies in Two-Way Relay Networks**”, being submitted by **Prabhat Kumar Upadhyay** to the Indian Institute of Technology, Delhi, for the award of the degree of **Doctor of Philosophy**, is a bona fide record of the research work carried out by him under my supervision. The contents of this thesis have not been submitted elsewhere either in part or in full to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

Cooperative relaying has attracted a lot of recent research interest due to its potential advantages in enhancing coverage, reliability and throughput for wireless cellular, ad-hoc and sensor networks. Two-way relaying has emerged as a spectrally efficient scheme to facilitate bidirectional communication between two terminals via a half-duplex relay in only two time phases. Despite its high spectral efficiency, the outage performance of a two-way relaying protocol is degraded due to the absence of a direct link (which implies loss of diversity). The aim of this thesis is to improve the outage performance of an analog network coding (ANC) based two-way relaying protocol by harnessing the spatial diversity by exploiting the available network resources such as user and relay nodes, and the antennas deployed at each node. We develop opportunistic cooperative strategies by employing opportunistic selection with full diversity among available resources so as to simplify the richer functionality of a two-way relay network and to minimize the overall system outage probability.

To harness a multiuser diversity, we propose an outage optimal opportunistic scheduling strategy for a multiuser two-way relay network, wherein an ANC based relay serves multiple pairs of users. We also suggest a modified scheduler that ensures fairness among independent but not necessarily identically distributed (i.i.d.) user pairs of the considered system. Focusing on relay selection diversity, we develop an outage-optimal two-way opportunistic relaying (TWOR) strategy by considering a multi-relay network. In order to exploit antenna diversity, we propose an end-to-end antenna selection (E2E-AS) strategy for a multiple-input multiple-output (MIMO) two-way relay system, where each terminal is equipped with multiple antennas. In view of the great application potential of a two-way relaying protocol in cellular systems, we propose a user scheduling with antenna selection (USAS) strategy for a multiuser cellular two-way relay system, where a multi-antenna base station (BS) communicates bidirectionally with several mobile users via a single relay. We evaluate the performance of the aforementioned strategies in terms of overall system outage probability and er-

godic sum-rate, and establish that full diversity order can be achieved. For a Rayleigh flat-fading environment, we derive expressions for the overall outage probability of the considered schemes, which are shown to have simple closed-form representations at a high signal-to-noise ratio (SNR). More specifically, by assuming i.i.d. Nakagami- m fading channels over the two hops of the TWOR scheme, we derive an exact expression for overall system outage probability that is applicable for all values of SNR and for arbitrary integer values of the per-hop fading parameters. This helps us to gain insights into the overall system performance, especially in view of the unbalanced hops. Also, we highlight the impact of relay location and power allocation on the overall system outage performance. Further, we derive bound expressions for the ergodic sum-rate of the proposed cooperative strategies at a high SNR. One of the important contributions of the thesis is a comprehensive outage analysis of the two-way relaying protocol with an asymmetric traffic flow characteristic (typical of many practical links in applications like web browsing). Based on this analysis, we derive the optimal relay location and power allocation that minimizes the overall system outage probability. Our analytical and simulation results reveal that a significant performance gain can be realized with the proposed opportunistic cooperative strategies. The theoretical developments in this thesis provide guidelines to improve the system performance and service reliability in wireless networks.

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