# STATISTICAL CHANNEL KNOWLEDGE BASED TRANSMISSION STRATEGIES FOR ENERGY-CONSTRAINED AD-HOC WIRELESS RELAY NETWORKS

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by


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# Certificate

This is to certify that the thesis entitled **"Statistical channel knowledge based transmission strategies for energy-constrained ad-hoc wireless relay networks"** being submitted by **Mr. Sabyasachi Gupta** to the Bharti School of Telecommunication Technology and Management, Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy** is the record of bonafide research work carried out by him under my supervision. In my opinion, the thesis has reached the standards fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted either in part or in full to any other University or Institute for the award of any degree or diploma.

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Date:
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Sabyasachi Gupta

# Abstract

Reliable transmission of signal and energy efficiency are crucial design issues in wireless networks. With nodes helping each other to transmit message through multiple independent fading paths, user cooperation reduces the probability of erroneous message reception, improves reliability and reduces the transmit power consumption . The requirement to transmit the source messages from multiple independent channel may not be always be fulfilled. A conventional multihop transmission scheme is an effective method to transmit source messages to the destination when direct connection between source or relay nodes to the destination is not feasible or power efficient. Energy efficiency in multihop or cooperative networks can be improved by choosing an appropriate path to forward the source data at the network layer, as well as the transmit power allocation among the nodes at the physical layer. In this thesis, we investigate the statistical channel knowledge based energy efficient transmission schemes for multihop networks and cooperative networks with end-to-end quality of service (QoS) constraint. Particularly, we consider four different network setups: multihop networks with end-to-end error probability constraint, mutihop networks with end-to-end outage probability constraint, source-relay pairing based cooperative networks with end-to-end error probability constraint and pairwise cooperative networks with end-to-end error probability constraint. We solve the joint route selection and power allocation problem for each of these network setups according to two network objectives: minimizing overall transmit power and maximizing lifetime of the networks.

For the multihop networks with end-to-end error probability constraint and outage probability constraint setups, we propose minimum total power (MTP) strategy which is optimal for minimizing overall transmit power consumption in the network. To max-

imize the lifetime for these network setups, we have developed two residual energy aware joint routing and power allocation strategies: path lifetime maximization (PLM) strategy and minimum weighted total power (MWTP) strategy. Distributed implementation for these strategies is also presented for each network setups. Simulation results demonstrate that the MWTP and PLM strategies achieve significant network lifetime improvement over MTP strategy. It has been shown that, at reasonably low route refresh interval, the MWTP strategy performs the best in terms of network lifetime while at very high route refresh interval, the PLM strategy is optimal for network lifetime maximization.

Next, we investigate the relay assignment and power allocation problems for source-relay pairing based cooperative networks. The MTP policy aims at minimizing overall power in the network. To maximize network lifetime, we propose group lifetime maximization (GLM) and MWTP policies. We solve the power allocation solution optimally for each policy. Then, we solve the the optimal relay assignment for MTP and MWTP policies using minimum weighted bipartite matching (MWBM) algorithm and optimal relay assignment for GLM policy using bottleneck bipartite matching (BBM) algorithm. We propose a novel minimum bottleneck bipartite matching (MBBM) algorithm to solve the relay assignment problem optimally for GLM policy which is more power efficient compared to the relay assignment with BBM algorithm. We further propose suboptimal relay selection (SRS) algorithm with lower time complexity compared to the optimal relay selection schemes. Simulation results demonstrate that with derived power allocation solution, relay assignment with SRS algorithm has performance very close to optimal relay assignment with bipartite graph matching strategy in terms of power minimization and lifetime maximization. The proposed relay selection and power allocation strategies based on GLM policy have better network lifetime performance over the strategies based on MWTP policy and achieve significant lifetime improvement over strategies based on MTP policy. We show that relay assignment based on MBBM algorithm achieves maximum network lifetime performance.

With the aim of lifetime maximization in pairwise cooperative wireless networks, we investigate the partner selection and power allocation problem for two different network power management policies: GLM and MWTP. With optimal power allocation solution derived according to each policy, we show that the optimal partner selection can be

obtained using the bottleneck matching (BM) algorithm and the maximum weighted matching (MWM) algorithm for GLM and MWTP policies, respectively. Since partner selection with BM algorithm is not power efficient, we propose a novel minimum bottleneck matching (MBM) algorithm to solve the optimal partner selection problem for GLM policy. We further propose a suboptimal partner selection (SPS) algorithm for these policies with lower time complexity compared to the optimal partner selection schemes. Simulation results demonstrate that the proposed partner selection and power allocation strategies based on GLM policy have better network lifetime performance over the strategies based on MWTP policy and achieve significant network lifetime improvement over conventional strategies of minimizing the total power per transmission with and without equal power constraint. We show that partner selection based on MBM algorithm achieves the maximum network lifetime performance and partner selection with SPS algorithm has performance very close to it.

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# List of Abbreviations

| | |
|---|---|
| **ACSI** | Average channel state information |
| **AF** | Amplify-and-forward |
| **AODV** | Ad hoc on-demand distance vector |
| **AWGN** | Additive white Gaussian noise |
| **BBM** | Bottleneck bipartite matching |
| **BER** | Bit Error Rate |
| **BM** | Bottleneck matching |
| **BPSK** | Binary phase-shift keying |
| **BS** | Base station |
| **CDF** | Cumulative distribution function |
| **DF** | Decode-and-forward |
| **DSDV** | Destination-sequenced distance vector |
| **EGC** | Equal gain combining |
| **FA** | Flow augmentation |
| **FDD** | Frequency-division duplex |
| **GLM** | Group lifetime maximization |
| **ICSI** | Instantaneous channel state information |
| **KKT** | Karush-Kuhn-Tucker |
| **MAC** | Medium access control |
| **MBBM** | Minimum bottleneck bipartite matching |
| **MBM** | Minimum bottleneck matching |
| **MIMO** | Multiple-input multiple-output |
| **MRC** | Maximal ratio combining |
| **MTP** | Minimum total power |
| **MWBM** | Minimum weighted bipartite matching |

| | |
|---|---|
| **MWM** | Maximum weighted matching |
| **MWTP** | Minimum weighted total power |
| **PLM** | Path lifetime maximization |
| **QoS** | Quality of service |
| **SC** | Selection combining |
| **SER** | Symbol error rate |
| **SNR** | Signal-to-noise ratio |
| **SPS** | Suboptimal partner selection |
| **SRS** | Suboptimal relay selection |
| **TDD** | Time-division-duplex |
| **TDMA** | Time division multiple access |
| **UWB** | Ultra-wideband |
| **WLF** | Worst link first |