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A Novel Cooperative Opportunistic Routing Scheme in Mobile Ad Hoc Networks

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Abstract:

Cooperative communication (CC) is a technique that exploits spatial diversity allowing multiple nodes to cooperatively relay signals to the receiver so that it can combine the received signals to obtain the original message. CC can be combined with topology control to increase connectivity at the cost of a small increase in energy consumption. This work focuses on exploring CC to improve the connectivity with a sink node in ad hoc wireless networks. More precisely, this work proposes a new technique, named CoopSink, that combines CC and topology control techniques to increase connectivity to a sink node while ensuring energyefficient routes. Simulation results show that connectivity and routing to the sink cost can be improved up to 6.8 and 2.3 times, respectively, when compared with other similar strategies. The first algorithm uses a distributed decision process at each node that makes use of only 2-hop neighborhood information. The second algorithm sets up the transmission ranges of nodes iteratively, over a maximum of six steps, using only 1-hop neighborhood information. We analyze the performance of our approaches through extensive simulation.

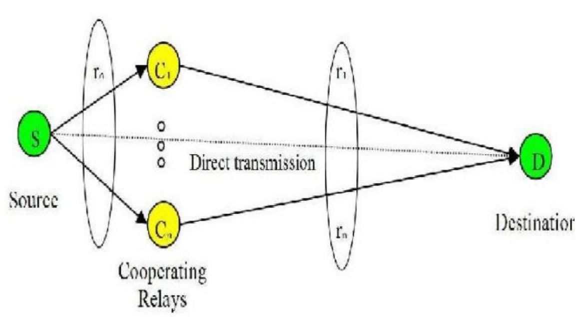
Keywords: Topology Control; Wireless Networks; Network Protocols; Cooperative Communication

Introduction:

Ad hoc wireless networks consist of wireless nodes that can communicate with each other in the absence of a fixed infrastructure. Wireless nodes are battery powered and therefore have a limited operational time. Recently, the optimization of the energy utilization of wireless nodes has received significant attention [9]. Different techniques for power management have been proposed at all layers of the network protocol stack. Power saving techniques can generally be classified into two categories: by scheduling the wireless nodes to alternate between the active and sleep mode, and by adjusting the transmission range of wireless nodes. In this paper, we deal with the second method. To support peer-to-peer communication in ad hoc wireless networks, the network connectivity must be maintained at any time. This requires that for each node there must be a route to reach any other node in the network. Such a network is called strongly-connected. In this paper, we address the problem of assigning a power level to every node such that the resulting topology is strongly-connected and the total energy expenditure for achieving the strong connectivity is minimized.

In traditional multiple-hop wireless networks, intermediate nodes cooperate with each other to assist in the task of relying data packets from a source node to the desired destination. Note that this process occurs at the network layer. Cooperative communication (CC), on the other hand, is a physical layer technique that allows single antenna devices to benefit from some advantages of Multiple-Input Multiple Output (MIMO) systems by exploring the spatial diversity [28]. This technique allows nodes to improve signal quality and transmission range. In CC, when a source node transmits a packet, a set of helper nodes in the vicinity of the source overhear the signal and, simultaneously, relay independent copies of the same signal to the destination node. The destination node then combines the received signals to obtain the original packet. Recent works have explored CC with topology control techniques to reduce energy consumption [5]. Ways to increase network connectivity and improve network lifetime has been investigated [35,33]. However, to the best of our knowledge, no work so far explored CC to increase the connectivity to the sink in ad hoc wireless networks. Link failure due to battery depletion and node failure may prevent wireless nodes to reach the sink. In this context, CC can be explored to improve network connectivity and to allow the establishment of alternative routes to the sink node. This work presents a new technique, named CoopSink, that combines CC and topology control in an ad hoc wireless network to increase connectivity to the sink while ensuring energy efficient routes. This proposal could be applied to the environment described in [4], where there is a sink node equipped with a large range radio for query broadcast and the nodes cooperate to overcome link failures and report information to the sink. This scenario is similar to that found in the Amazon Tall Tower Observatory (ATTO) project, where the objective is to position a high central tower in the middle of the Amazon forest and, with the help of smaller and strategically placed sensors, to obtain reliable estimates of sources of greenhouse gases.

Architecture:



Related Works:

Topology Control is a technique that alters the network topology based on some given conditions. For instance, topology control can be used to optimize network power consumption, reduce routing cost and the number of control messages, improve throughput or meet certain QoS requirements [5,15,11]. According to [5], topology control protocols can be classified as: (i) centralised; or (ii) distributed. Centralised protocols consider that global information is available, such as topological information, routing information, global memory status, and so on. However, even when global information is at hand, it has been proven that finding strongly connected topologies with minimum total energy consumption is a NP-complete problem [6]. Among centralised protocols, Ramanathan et al. [27] proposed alternatives to optimize network connectivity while improving network lifetime. Distributed protocols consider k-hop neighbouring information, where k is typically one or two. Li et al. [20] propose a cone-based algorithm for TC that aims to optimize energy consumption while maintaining network connectivity. To achieve this, each node adjusts its transmitting power to cover a number of neighbouring nodes, under the condition that they lay at most α degrees apart from each other. The authors show that a degree of α = 5π 6 is enough to preserve network connectivity. Several optimized solutions of the basic algorithm are also discussed and a beacon-based protocol is defined for topology maintenance. In a more recent work, Li et al. [21] proposed a Localised Minimum Spanning Tree (LMST) algorithm. The LMST works by having each node building a localised MST based on 1-hop neighbouring information. The final topology is constructed so that the maximum node degree is 6. Comprehensive surveys can be found in [22,14].

Among distributed and localized protocols, Li et al [12] propose a cone-based algorithm for topology control. The goal is to minimize total energy consumption while preserving connectivity. Each node will transmit with the minimum power needed to reach some node in every cone with degree α. They show that a cone degree α = 5π/6 will suffice to achieve connectivity. Several optimized solutions of the basic algorithm are also discussed as well as a beaconing-based protocol for topology maintenance. Li, Hou and Sha [13] devise another distributed and localized algorithm (LMST) for topology control starting from a minimum spanning tree. Each node builds its local MST independently based on the location information of its 1-hop neighbors and only keeps 1-hop nodes within its local MST as neighbors in the final topology. The algorithm produces a connected topology with a maximum node degree of 6. An optional phase is provided where the topology is transformed to one with bidirectional links. Among probabilistic protocols, the work by Santi et al [19] assumes all nodes operate with the same transmission range. The goal is to determine a uniform minimum transmission range in order to achieve connectivity.

Existing System:

Most existing works are focused on link-level physical layer issues, such as outage probability and outage capacity. Consequently, the impacts of cooperative communications on network-level upper layer issues, such as topology control, routing and network capacity, are largely ignored. Indeed, most of current works on wireless networks attempt to create, adapt, and manage a network on a maze of point-to-point non-cooperative wireless links. Such architectures can be seen as complex networks of simple links.

Disadvantages:

1. Low Network Capacity.

2. Communications are focused on physical layer issues, such as decreasing outage probability and increasing outage capacity, which are only link-wide metrics.

Proposed System:

We propose a Capacity-Optimized Cooperative (COCO) topology control scheme to improve the network capacity in MANETs by jointly considering both upper layer network capacity and physical layer cooperative communications. Through simulations, we show that physical layer cooperative communications have significant impacts on the network capacity, and the proposed topology control scheme can substantially improve the network capacity in MANETs with cooperative communications.

Modules:

1. Transmission in MANETs

2. Network Constraints

3. Relaying Strategies

4. Cooperative Communications

5. Multi-hop Transmission

With physical layer cooperative communications, there are three transmission manners in MANETs: direct transmissions, multi-hop transmissions and cooperative transmissions. Direct transmissions and multi-hop transmissions can be regarded as special types of cooperative transmissions. A direct transmission utilizes no relays while a multi-hop transmission does not combine signals at the destination. In Fig. 1c, the cooperative channel is a virtual multiple-input single-output (MISO) channel, where spatially distributed nodes are coordinated to form a virtual antenna to emulate multiantenna transceivers. Two constraint conditions need to be taken into consideration in the proposed COCO topology control scheme. One is network connectivity, which is the basic requirement in topology control. The end-to-end network connectivity is guaranteed via a hop-by-hop manner in the objective function. Every node is in charge of the connections to all its neighbors. If all the neighbor connections are guaranteed, the end-to-end connectivity in the whole network can be preserved. The other aspect that determines network capacity is the path length. An end-to-end transmission that traverses more hops will import more data packets into the network. Although path length is mainly determined by routing, COCO limits dividing a long link into too many hops locally. The limitation is two hops due to the fact that only two-hop relaying is adopted.

Relaying Strategies:

• Amplify-and-forward

• Decode-and-forward

In amplify-and-forward, the relay nodes simply boost the energy of the signal received from the sender and retransmit it to the receiver. In decode-and forward, the relay nodes will perform physical-layer decoding and then forward the decoding result to the destinations. If multiple nodes are available for cooperation, their antennas can employ a space-time code in transmitting the relay signals. It is shown that cooperation at the physical layer can achieve full levels of diversity similar to a MIMO system, and hence can reduce the interference and increase the connectivity of wireless networks.

Cooperative transmissions via a cooperative diversity occupying two consecutive slots. The destination combines the two signals from the source and the relay to decode the information. Cooperative communications are due to the increased understanding of the benefits of multiple antenna systems. Although multiple-input multiple-output (MIMO) systems have been widely acknowledged, it is difficult for some wireless mobile devices to support multiple antennas due to the size and cost constraints. Recent studies show that cooperative communications allow single antenna devices to work together to exploit the spatial diversity and reap the benefits of MIMO systems such as resistance to fading, high throughput, low transmitted power, and resilient networks.

Multi-hop Transmission:

Multi-hop transmission can be illustrated using two-hop transmission. When two-hop transmission is used, two time slots are consumed. In the first slot, messages are transmitted from the source to the relay, and the messages will be forwarded to the destination in the second slot. The outage capacity of this two-hop transmission can be derived considering the outage of each hop transmission.

Conclusions :

In this paper, we have addressed the NP-complete problem on Topology Control with Cooperative Communication (TCC) in ad hoc wireless networks, with the objective of minimizing the total energy consumption while obtaining a strongly-connected topology. Power control impacts energy usage in wireless communication with an effect on battery lifetime, which is a limited resource in many wireless applications. We have proposed two distributed and localized algorithms that can be applied to any symmetric, strongly-connected topology in order to reduce the total power consumption. The first one uses a distributed decision process at each node that makes use of only 2-hop neighborhood information. The second uses the cooperative communication of nodes within a 1-hop neighborhood in order to set nodes' transmission ranges iteratively, in at most six rounds. We have analyzed the performance of our algorithms through simulations. Our future work is, by starting from DTCC or ITCC algorithm, to design an efficient topology maintenance mechanism that effectively adapts to a dynamic and mobile wireless environment.

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