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Capacity Optimized Topology Control for MANET with Cooperative Communication

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Abstract

Cooperative communications enables efficient utilization of system communication resources, thereby allowing nodes or terminals participating in a communication network to collaborate with each other during information transmission. Cooperative communication schemes have advantageous in improving node capacity and diversity Cooperative Communication (CC) is a technology that allows multiple nodes to simultaneously transmit the same data. It is also used in improving enhancing power, network connectivity, improving communication reliability and spectrum efficiency. The three basic cooperation protocols in cooperative relaying are decode-and-forward (DF) and compress-and-forward (CF) and amplify-and-forward (AF). But these existing works on cooperative communications are mainly focused on the link level physical layer issues. In this paper a brief analyze is made on Capacity-Optimized Cooperative (COCO) a novel topology scheme to improve the network capacity in MANET by considering both the upper layer network capacity and the physical layer cooperative communications.

Keywords

Cooperative Communication, COCO, MANET, network capacity, relay nodes

I. Introduction

A MANET is a type of ad-hoc network that can change locations and self configuring. These networks can exist without a fixed infrastructure i.e., infrastructure less and they can work in an autonomous manner. As nodes are mobile, the connection link between two devices can break depending on the spatial orientation of the mobile nodes. The mobile wireless devices which are out of communication range can use the other devices within their communication range to forward the packets. Thus reliability can be ensured in MANET. Cooperative communication has derived an interest for wireless network. Cooperative communications refer to a type of communication system or technique that allows users to transmit each other's messages to the intended destination. Cooperative communication typically refers to a system where the users can share and coordinate their resources to improve the information transmission quality. Recently, cooperative wireless communication has received tremendous interests as an untapped means for improving the performance of information transmission operating over the ever challenging wireless medium. The demand for the speed in the wireless networks is also rapidly increasing. Most existing works on cooperative communications are focused on link level physical layer issues. Direct transmissions and multi hop transmissions can be regarded as special types of the cooperative transmissions. A direct transmission uses no relays, while a multi hop transmissions does not combine signals at the destination.

The relay nodes play a vital role in cooperative communication. The possible ways of realizing cooperation are using extra relay nodes (RNs) to assist the communications between sources and their corresponding destinations. And the next is to allow the communication nodes in a network to help each other in order to communicate with their corresponding destinations. The Systems which using the first way of cooperation is often referred to as relay systems. The systems using the second way of cooperation are often referred to as cooperative systems. The cooperative communication mainly deals with the physical layer issues. Cooperative communication typically refers to a system allows users to share and coordinate their resources in order to enhance the data transmission quality. This is a generalization of the relay communication, where multiple sources also serve as relays for each other.

The impacts of cooperative communications on network-level upper layer issues, such as the topology control, routing and network capacity are largely avoided. In Figure 1, S indicates source node, R is the relay node and D is the destination node. This diagram represents the simplest cooperative scenario having only three nodes. In time slot1, the source transmits data to the destination node. At the same time the relay overhears the transmission from source to destination. Then in the time slot2, the relay forwards the message to the destination which uses both of the received messages and jointly decodes the data through maximal ratio.

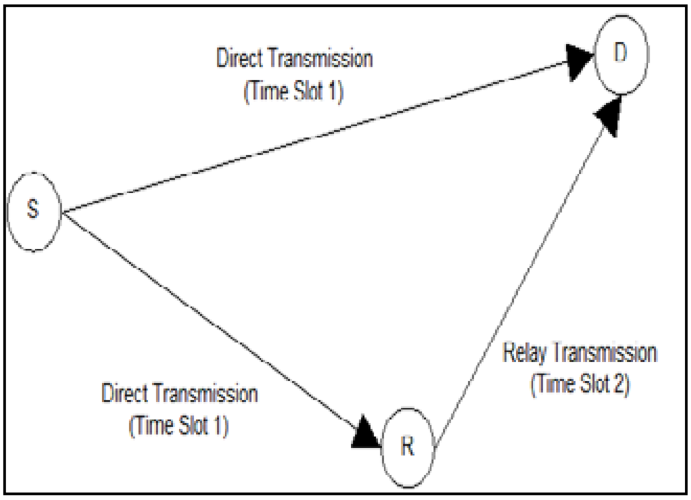

Fig. 1: Simple Cooperative Communication

II. The Topology Control Problem in MANET

Topology control have been widely studied and applied in wireless ad hoc networks. It is considered as one of the key energy saving technique. In order to extend lifetime and save energy of networks topology control, each wireless node to select certain subset of neighbors or adjust its transmission power at the same time to maintain network connectivity. Chen and Huang first made analyzes in strongly connected topology control problem, which aims to

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find a connected topology such that the total energy consumption is minimized. NP complete is proved to be one of such problem. Several following works have focused on finding the minimum power assignment so that the induced communication graph has some "good" properties such as connectivity or fault-tolerance and disjoint paths.

On the other hand, several geometrical structures have been proposed which are used as underlying network topologies. These geometrical structures are usually kept as few links as possible from the original communication graph and can be easily constructed using location information. Recently, a new class of communication techniques, cooperative communication (CC) has been introduced to allow single antenna devices to take the advantage of the multiple-input-multiple-output (MIMO) systems which is shown in fig 2. This cooperative communication explores the broadcast nature of the wireless medium and allows nodes that have received the transmitted signal to cooperatively help relaying data for other nodes. Recent study has shown significant performance gain of cooperative communication in various wireless network applications: energy efficient routing and connectivity improvement.

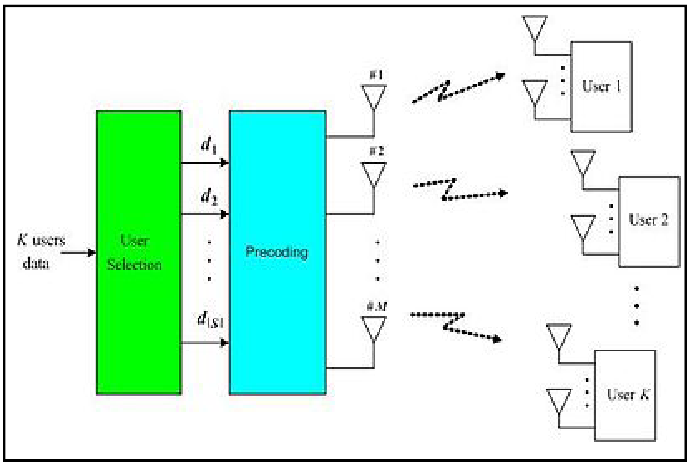

Fig. 2: Multiuser MIMO System

The cooperative communication techniques can also be used in topology control. The topology control problem under cooperative model, aims to obtain a strongly-connected topology with minimum total energy consumption. NP-complete is the first problem and then proposed two algorithms that start from a connected topology assumed to be the output of a traditional (without using CC) topology control algorithm and reduce the energy consumption using CC model. The first algorithm (DTCC) uses 2-hop neighborhood information of each node to reduce the overall energy consumption within its 2-hop neighborhood without hurting the connectivity under CC model. The second algorithm (ITCC) starts from a minimum transmission power, and it repeatedly increases its power until all nodes within its 1-hop neighborhood are connected under CC model. Finding that the CC technique can also extend the transmission range and thus link disconnected components.

In mobile ad hoc wireless communication, each node of the network has a potential of varying the topology through the adjustment of its power transmission in relation to other nodes in the neighborhood. In contrast, wired networks have fixed established pre-configured infrastructure with centralized network management system structure in place. Therefore, the fundamental reason for the topology control scheme in MANET is to provide a control mechanism that maintains the network connectivity and performance optimization by prolonging network lifetime and maximizing network throughput.

III. Background

A. Relay Nodes

In a relay system, sources first transmit their data to the receiver nodes. Each receiver node then processes and forwards its received data information to the destination nodes following some cooperation protocols. With the received signal from the Receiver nodes, the destinations decode the data from their corresponding sources. Some basic cooperation protocols are amplify-and-forward (AF), decode-and-forward (DF), and compress-and-forward (CF). For the amplify-and-forward protocol, each receiver node simply scales its received signal according to its transmit power constraint and forwards the scaled signal in the next transmission slot. The decode-and-forward protocol, each RN decodes the source message from its received signal, re-encodes it into a new codeword, and transmits it in the next transmission slot. For the compress-and-forward protocol, each RN first maps its received signal into another signal in a reduced signal space, then encodes and forwards the "compressed" signal as a new codeword by taking the signal received at the destination as side information. AF and CF based cooperation schemes can be viewed as "analog" cooperation schemes. DF based cooperation schemes can be viewed as "digital" cooperation schemes. Depending on the network topology and the quality of the backhaul link between the source and the RN, one protocol may outperform the other in terms of system capacity or diversity.

B. Phases of Cooperative Transmissions

Most cooperative communication schemes involve two transmission phases [1]

1. Phase 1 refers to a coordination phase. This is the phase where users exchange their own source data and control messages with each other and/or the destination.
2. Phase 2 refers to a cooperation phase. This is the phase where the users cooperatively retransmit their messages to the destination.
3. In Phase I, the source user broadcasts its data to both the relay and the destination
4. In Phase II, the relay forwards the source's data either by itself or by cooperating with the source to enhance reception at the destination

IV. COCO: Capacity Optimized Cooperative topology

The COCO (Capacity-Optimized Cooperative topology control scheme) extends the physical layer cooperative communications from the link-level perspective to the network-level perspective in MANETs. The Energy Efficient path is chosen between the source, the relay and the destination nodes. Then the path is checked for the less number of interference on the relay nodes using the COCO Topology scheme. The main work of the COCO topology scheme is to establish a path via relay nodes with less number of interferences.

The extensive research has been done on cooperative communications; most existing works are focused on physical layer issues, such as decreasing outage probability and increasing outage capacity, which are only link-wide metrics. However, from the network's point of view, it may not be sufficient for

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the overall network performance, such as the whole network capacity. Therefore, many upper layer aspects of cooperative communications merit further research, e.g., the impacts on network structure and topology control, especially in mobile ad hoc networks (MANETs). Indeed, most current studies on MANETs attempt to create, adapt, and manage a complex network based on traditional simple point-to-point non-cooperative wireless links. Considering upper layer network capacity and physical layer relay selection, this paper proposes a Capacity- Optimized Cooperative (COCO) topology control scheme for MANETs with cooperative communications. Most existing topology control schemes assume that the wireless channel is well-known and organized. But, in practice, it is difficult to have the good knowledge of a dynamic channel.

In this sense, COCO only requires the channel estimate. Accordingly, the topology control problem in MANETs is formulated as a discrete stochastic optimization problem, and it can be solved using a stochastic approximation approach, which is proven to move toward a better solution iteratively until converging to the optimal solution by analysis and simulation in the paper. One of the main advantages of this iterative approach is that it can track the changing mobile environment to reconfigure the network topology dynamically The main advantageous of COCO model is to avoid the packet loss level and to stop the traffic condition on the network, to improve the network performance on the delivery level. The final topology generated by COCO. The solid lines denote traditional direct transmissions and multi hop transmissions. The dashed lines denote the links involved in cooperative communications. The network performance and the relay performance of the capacity optimized cooperative topology control scheme is depicted in fig. 3 and fig. 4 for simulation results.

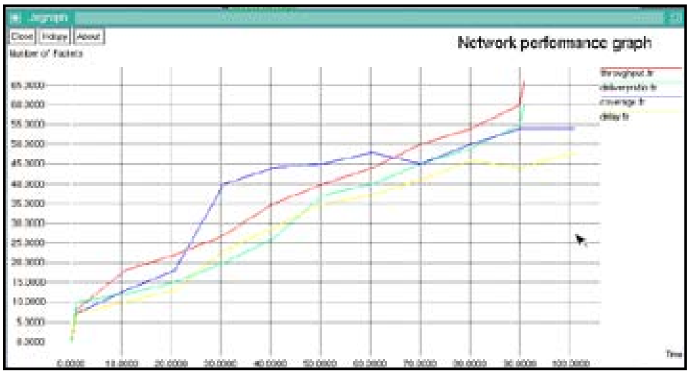

Fig. 3: Network Performance Graph

Fig. 4: Relay Performance Graph

V. Conclusion

A dynamic traffic congestion method with co-operative control scheme called COCO considers both upper layer network capacity and physical layer relay selection in cooperative communications. Simulation results have shown that physical layer cooperative communications techniques have significant impacts on the network capacity, and the proposed topology control scheme can substantially improve the network capacity in MANETs with cooperative communications. By using this method we can reduce the delay of data delivery, reduces the end-to-end delay and the number of route discovery requests, and balances the traffic Load. And that our proposed technique attains high delivery ratio and throughput with reduced delay when compared with the existing technique. To the best of our knowledge, COCO is the first topology control scheme for MANETs with cooperative communications and noisy channel estimates.

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