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Improving Network Capacity Using Topology Control in Mobile Ad Hoc Networks with Cooperative Communication

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Abstract

In this paper we address the topology control with cooperative communication problem in ad hoc wireless communication. Cooperative communication has received tremendous interest for wireless networks. Cooperative communication is a novel model introduced recently that allows combining partial message to decode complete message. Most existing work on cooperative communications is focused on link level physical layer issues. The impacts of cooperative communication on network level upper layer issues, such as topology control, routing and network capacity are largely ignored. In this we propose a capacity optimized cooperative topology control scheme to improve the network capacity in MANETs by jointly considering both upper layer network capacity and physical layer cooperative communications. The proposed topology control scheme can substantially improve the network capacity in MANETs with cooperative communications.

1. Introduction

Now a day's every one demand for speed in wireless networks is continuously increasing. Now the 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. This cooperative communication has emerged as new dimensions of diversity to emulate the strategies designed for multiple antenna systems, since a wireless mobile device may not be able to support multiple transmit antennas due to size, cost or hardware limitations.

The broadcast nature of the wireless channel cooperative communication allows signal antenna radios to share their antennas to from a virtual antenna array, and offers significant performance enhancements. This technique it has been considered in the IEEE 802.16j standard and is expected to be integrated into third generation partnership project (3GPP) by using long term evolution (LTE) multi hop cellular network. In that some work have been done on cooperative communication most existing works are focused on link level physical layer issues such as outgoing probability and outage capacity. The impacts of cooperative communication on network level upper layer issues, such as topology control, routing and network capacity, are largely ignored. Most of current work on wireless network on a maze of point to point non cooperative wireless links. Finally many upper layer aspects of cooperative communications merit further research as the impacts on topology control and network capacity, essentially in mobile ad hoc networks (MANETs), it can establish a dynamic network without a fixed infrastructure. A node in MANETs can function both as a network router for routing packets from the other nodes and as a network host for transmitting and receiving data. MANETs are particularly useful when a reliable fixed or mobile infrastructure is not available. The conference between notebook PC users, military applications, emergency operations, and other secure sensitive operations are important applications of MANETs due to their quick and easy deployment. Due to the lack of centralized control MANETs nodes cooperate with each other to achieve a common goal. Network topology describes the connectivity information of the entire network including the nodes in the network and the connectivity information of the entire network, including the nodes in the network and the connection between them. The network topology control is very important for the overall performance of a MANET. For example to maintain a reliable network connectivity nodes in MANETs may work at the maximum radio power, which results in high nodal degree and long link distance but more interference is introduced into the network and much less throughput per node can be obtained. Topology control, a node carefully selects a set of its neighbors to establish logical data links and dynamically adjust its transmit power accordingly, so as to achieve high throughput in the network while keeping the energy consumption low.

In this paper we are considering both upper layer network capacity and physical layer cooperative communications, we study the topology control issues in MANETs with cooperative communications. We propose a capacity optimized cooperative topology control scheme to improve the network capacity in MANETs by jointly optimizing transmission mode selection relay node selection, and interference control in MANETs with cooperative communications.

2. Related work

In this article, we first introduce cooperative communications. Then the topology control problem in MANETs with cooperative communications is presented.

2.1 Cooperative Communications

Typically the cooperative communication refers to a system where users share and coordinate their resources to enhance the information transmission quality. The generalization of relay communication in which multiple sources also serve as relays for each other. Early study of relaying problems appears in the information theory community to enhance communication between the source and destination. Now a day's tremendous interests in

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cooperative communications are due to the increased understanding of the benefits of multiple antenna system. The 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 the cooperative communications allows 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. The basic idea of cooperative relaying is that some nodes which overheard the information transmitted from the source node and relay nodes the cooperative diversity is achieved. Relaying could be implemented using two common strategies.

i) Amplify and forward
ii) Decoding and forward

In amplifying and forwarding the relay nodes simply boost the strength 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. The cooperation between multiple nodes and their antennas are employing a space time code in transmitting the relay signals. The cooperation at the physical layer can achieve full levels of diversity similar to a MIMO system and hence to reduce the interference and then increase the strength of connectivity in wireless network.

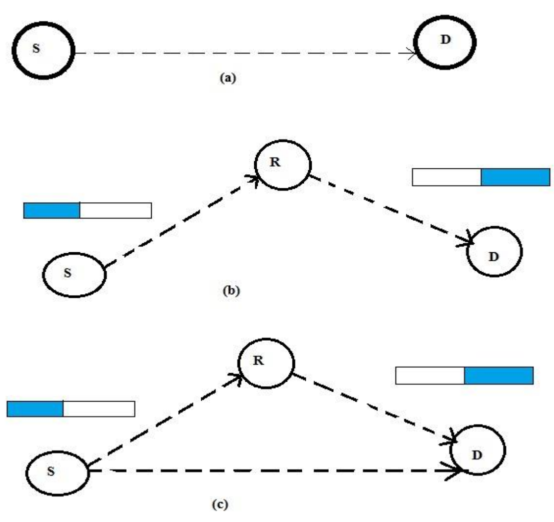

Fig.2.1.1. Three transmission protocols: a) direct transmission via a point to point conventional link. b) Multi – hop transmission via a two- hop manner occupying two time slots. c) Cooperative transmission via a cooperative diversity occupying two consecutive slots. The destination combines the two signals from the source and the relay to decode the information.

2.2 Topology Control

Topology control is a technique used in distributed computing to alter the understanding network in order to reduce the cost of distributed algorithms if ran over the new resulting graphs. The term topology control is consumed mostly by the wireless Ad Hoc and sensor network research community. The main aim of topology control in this domain is to save energy, reduce interference between nodes and extended lifetime of the network. The network topology in a MANET is changing dynamically due to user mobility, traffic, node batteries, and so on. A MANET is controllable by adjusting some parameters such as the transmission power, channel assignment. Generally topology control is such a scheme to determine where to deploy the links and how the links work in wireless networks to form a good network topology which will optimize the energy consumption, the capacity of the network or end to end routing performance/ A Mobile Ad hoc Network is self configuring infrastructure network of mobile devices connected by wireless. Each device in a MANET is free to move independently in any direction and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the large internet. MANETs are a kind of wireless as hoc network that usually has a routable networking environment on top of a link layer ad hoc network. The growth of laptop and 802.11/Wi-Fi wireless networking has made MANETs a popular research topic. Power control and channel control issues are coupled with topology control in MANETs while they are treated separately traditionally. Even though a mobile node can sense the available channel, it lacks of the scope to make network-wide decisions. Therefore it makes more sense to conduct power control and channel control via the topological viewpoint. Aim of topology control is then to set up interference- free connections to minimize the maximum transmission power and the number of required channels. The topology control focus on network connectivity with the link information provided by MAC and physical layers. In general a MANET can be mapped into a graph G(V,E), where V is the set of nodes in the network and E is the edge set representing the wireless links. As topology control is to determine the existence of wireless links subject to network connectivity, the general topology control problem can be expressed as $G^*=\arg\max f(G)$, (1) According to the objective function a better topology $G^*(V, E^*)$ will be constructed as the output of the algorithm. G* should contain all mobile nodes in G, and the link connections E^* should preserve network connectivity without partitioning the network. The objective function F(G) in Eq.1 is critical to topology control problems.

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3. Methodology (Topology control for network capacity improvement in MANETs with cooperative communications)

In this section firstly we describe the capacity of MANETs. Then we present the proposed COCO topology control scheme for MANETs with cooperative communications.

3.1 The capacity of MANETs

Here two types of network capacity are introduced. The first one is transport capacity, which is similar to the total one hop capacity in the network. A second type of capacity is throughput capacity, which is based on the information capacity of a channel. Obviously it is the amount of all the data successfully transmitted during a unit time. The routing not only find paths to meet quality of service (QoS) requirements but also balances traffic load in nodes to avoid hot spots in the network. When we balancing traffic, the network may admit more traffic flows and maximize the capacity. Since we focus on topology control and cooperative communications, assume an ideal load balance in the network, where the traffic loads in the network are uniformly distributed to the nodes in the network.

3.2 Improving Network capacity using topology control in MANETs with cooperative communications

The network capacity improvement in MANETs with cooperative communications using topology control, we can set the network capacity as the objective function in the topology control problem in Eq.1. When cooperative network is used, a best relay needs to be selected proactively before transmission. In this study, we adopt the decode and forward relaying scheme. The source broadcasts its message to the relay and destination in the first slot. They relay node and destination in the first slot. The relay node decodes and re-encodes the signal from the source and then forwards it to the destination in the second slot. The maximum instantaneous end to end mutual information, outage probability, and outage capacity can be derived. The interference model in the broadcast period of both the covered neighbors of the source and the covered neighbors of the relay and the destination have to be silent to ensure successful reception.

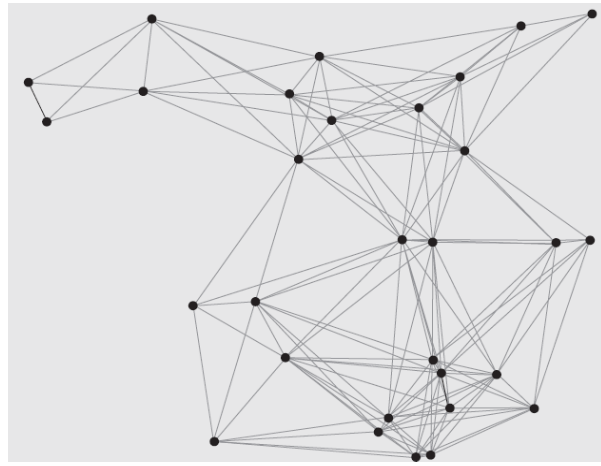

Fig.3.2.1. The original topology: A MANET with 30 nodes randomly deployed in 800 x 800 m^2 area

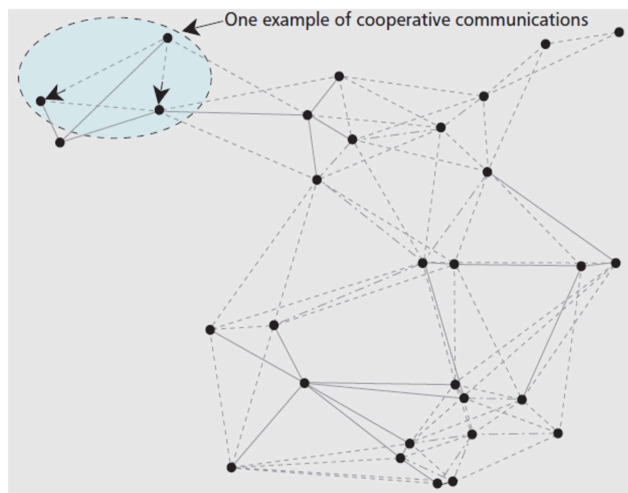

Fig.3.2.2 The final topology generated by COCO. The solid lines denote traditional direct transmissions and multihop transmissions. The dashed lines denote the links involved in cooperative communications.

4. Simulation results and discussions

We consider a MANET with 30 nodes randomly deployed in a 800 x 800 m^2 area. The number of nodes is changed simultaneously. We compare the performance of the proposed scheme with that of an existing well known topology control scheme called LLISE, which only considers traditional multi-hop transmissions without cooperative communications and preserves the minimum interference path for each neighbor link locally. we also show the worst network capacity among all the topology

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configurations for comparison. The original topology is shown in Fig. 2, where links exist whenever the associated two end nodes are within transmission range of each other. It is clear that this topology lacks any physical layer cooperative communications. Fig.3. shows the resulting topology using the proposed COCO topology control scheme. In Fig.3 the solid lines denote links involved in cooperative communication. We can see from Fig.3. to maximize the network capacity of the MANET, many links in the network are involved in cooperative communication. One example of two-phase cooperative communications is shown in the top left corner of the figure. The Fig.4 shows the network capacity per node in different topology control schemes with different numbers of nodes in the MANET. The proposed COCO scheme has the highest network capacity regardless of the number of nodes in the network. Similar to COCO, LLISE is executed in each node distributed. Nevertheless COCO can achieve a much higher network capacity than LLISE, since LLISE only considers multi hop transmission. The gain performances of this proposed scheme comes from the joint design of transmission mode selection, relay node selection, and interference minimization in MANETs with cooperative communication.

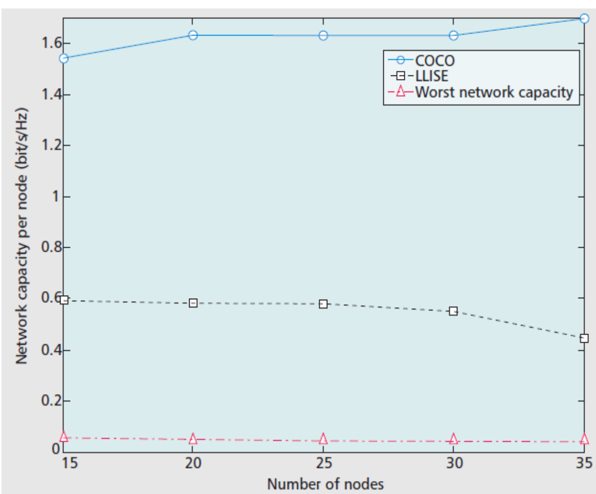

Fig.4.1 Network capacity versus different numbers of nodes in the MANET.

5. Conclusion

In this article we are introduced the physical layer cooperative communication, topology control, and network capacity in MANETs. To improve the network capacity of MANETs with cooperative communications, we are proposed a capacity optimized cooperative topology control scheme that consider the upper layer network capacity and physical layer relay selection in cooperative communications techniques have significant impacts on the network capacity, and proposed topology control scheme can substantially improve the network capacity in MANETs with cooperative communications.

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