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RESEARCH ARTICLE

TOPOLOGY CONTROL IN MOBILE AD HOC NETWORKS WITH COOPERATIVE COMMUNICATIONS

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Abstract— Cooperative communication has received tremendous interest for wireless networks. Most existing works on cooperative communications are focused on link-level physical layer issues. Consequently, the impacts of cooperative communications on network-level upper layer issues, such as topology control, routing and network capacity, are largely ignored. In this article, 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.

Keywords— Include Capacity-Optimized Cooperative (COCO), MANETs, MIMO-CN, AF-Amplify forward, DF-Decode and forward

I. INTRODUCTION

The demand for speed in wireless networks is continuously increasing. Cooperative wireless communication has received tremendous interests as an untapped means for improving performance of information transmission operating over the ever-challenging wireless medium Cooperative communication has emerged as new dimension 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. Topology Capacity-Optimized Cooperative (COCO): A Capacity-Optimized Cooperative (COCO) 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. 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. Most existing woks 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. Therefore, many upper layer aspects of cooperative communications merit further research, e.g., the impacts on topology control and network capacity, especially in mobile ad hoc networks (MANETs), which 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. Instant conferences 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. The major activities involved in self organization are neighbor discovery, topology organization, and topology reorganization. Network topology describes the connectivity information of the entire network, including the nodes in the network and the connections between them. In this article, 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 (COCO) 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. The major activities involved in self-organization are neighbor discovery, topology organization, and topology reorganization. Network topology describes the connectivity information of the entire network, including the nodes in the network and the connections between them. 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. Using 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 article, 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 (COCO) 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. 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.

Cooperative diversity is a cooperative multiple antenna technique for improving or maximizing total network channel capacities for any given set of bandwidths which exploits user diversity by decoding the combined signal of the relayed signal and the direct signal in wireless multihop networks. A conventional single hop system uses direct transmission where a receiver decodes the information only based on the direct signal while regarding the relayed signal as interference, whereas the cooperative diversity considers the other signal as contribution. That is, cooperative diversity decodes the information from the combination of two signals. Hence, it can be seen that cooperative diversity is an antenna diversity that uses distributed antennas belonging to each node in a wireless network. Note that user cooperation is another definition of cooperative diversity. User cooperation considers an additional fact that each user relays the other user's signal while cooperative diversity can be also achieved by multi-hop relay networking systems. Actually we investigate that consideration the optimal power allocation at the source and each relay to maximize the end-to-end achievable rate of multi-relay MIMO-CN.now let us focus on the various relaying strategies like (AF-Amplify forward) and (DF-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 communication typically refers to a system where users share and coordinate their resources to enhance the information transmission quality. It is a generalization of the relay communication, in which multiple sources also serve as relays for each other. Recent tremendous interests in 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. In a simple cooperative wireless network model with two hops, there are a source, a destination, and several relay nodes. The basic idea of cooperative relaying is that some nodes, which overheard the information transmitted from the source node, relay it to the destination node instead of treating it as interference. Since the destination node receives multiple independently faded copies of the transmitted information from the source node and relay nodes, cooperative diversity is achieved. Relaying could be implemented using two common 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. Most existing works about cooperative communications are focused on physical layer issues, such as decreasing outage probability and increasing outage capacity, which are only linkwide metrics. However, from the network's point of view, it may not be sufficient for the overall network performance, such as the whole network capacity. Therefore, many upper layer network-wide metrics should be carefully studied, e.g., the impacts on network structure and topology control. Cooperation offers a number of advantages in flexibility over traditional wireless networks that go beyond simply providing a more reliable physical layer link. Since cooperation is essentially a network solution, the traditional link abstraction used for networking design may not be valid or appropriate. From the perspective of a network, cooperation can benefit not only the physical layer, but the whole network in many different aspects. With physical layer cooperative communications, there are three transmission manners in MANETs: direct transmissions (Fig. 1a), multihop transmissions (Fig. 1b) and cooperative transmissions (Fig. 1c). 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 multi-antenna transceivers.

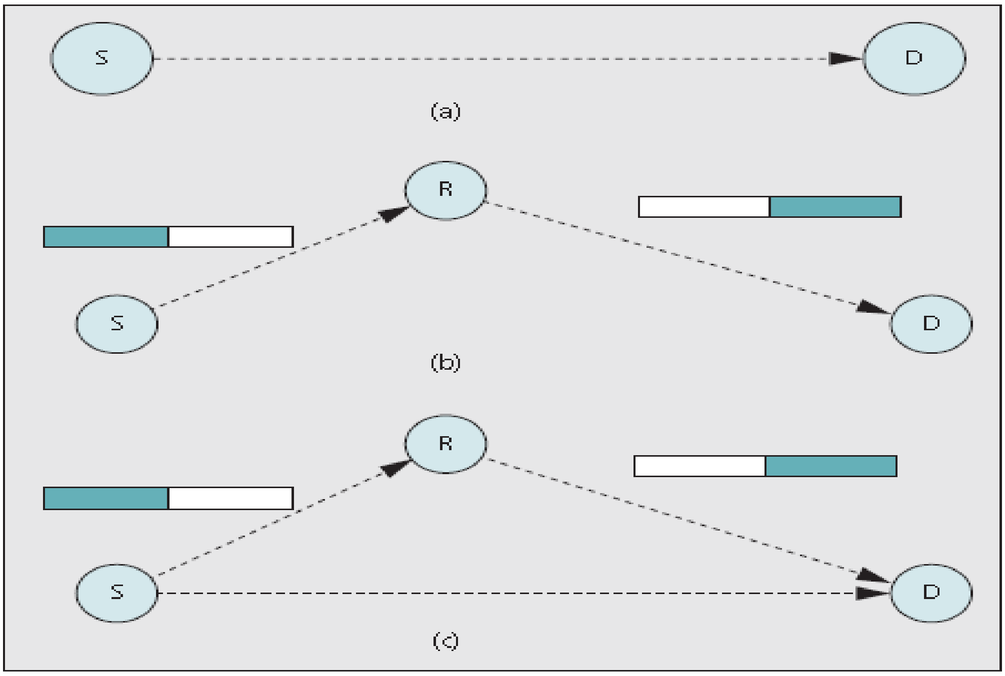

Fig 1. Three transmission protocols: a) direct transmissions via a point-topoint conventional link; b) multi-hop transmissions via a two-hop manner occupying two time slots; and c) cooperative transmissions via a cooperative diversity occupying two consecutive slots. The destination combines the two signals from the source and the relay to decode the information.

II. LITERATURE SURVEY

J. Laneman, D. Tse, and G. Wornell identified Cooperative Diversity in Wireless Networks with Efficient Protocols and Outage Behavior. And here they developed and analyzed low-complexity cooperative diversity protocols that combat fading induced by multipath propagation in wireless networks. The underlying techniques exploit space diversity available through cooperating terminals' relaying signals for one another. They outlined several strategies employed by the cooperating radios, including fixed relaying schemes such as amplify-and-forward and decode-and-forward, selection relaying schemes that adapt based upon channel measurements between the cooperating terminals, and incremental relaying schemes that adapt based upon limited feedback from the destination terminal.

P. H. J. Chong et al., proposed the Technologies in Multihop Cellular Network and his co-authors identified that Most existing works on cooperative communications are focused on link - level physical layer issues such as topology control, routing and network capacity are largely ignored Although there have been extensive studies on applying cooperative networking in multi-hop ad hoc networks, most works are limited to the basic three - node relay scheme and single antenna systems. These two limitations are interconnected and both are due to a limited theoretical understanding of the optimal power allocation structure in MIMO cooperative networks (MIMO - CN) In Proposed system we use Cooperative diversity. It is a cooperative multiple antenna technique for improving or maximizing total network channel capacities for any given set of bandwidths which exploits user diversity by decoding the combined signal of the relayed signal and the direct signal in wireless multi hop networks.

K. Woradit et al worked for Outage Behavior of Selective Relaying Schemes and and identified that Topology control and Network capacity are important upper layer issues in considering the performances of a MANETs in Cooperative communication. Also done probing on the concern of topology control with aspiration of maximizing the network capacity by proposing a scheme called MSRCC (Spatial Reuse Maximizer in Cooperative Communication). He performed the simulation using NS2.It combines both the Spatial Reuse Maximizer (MaxSR) that focuses on converging to an operating point minimizing network capacity and Capacity Optimized Cooperative Topology Control method that focuses on improving the network capacity by considering both physical layer cooperative communication and upper layer argument such as network capacity and topology control. Cooperative communication has emerged as a new dimension 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. By exploiting the broadcast nature of the wireless channel, cooperative communication allows single- antenna radios to share their antennas to form a virtual antenna array, and offers significant performance enhancements. This promising technique has been considered in the IEEE 802.16j standard, and is expected to be integrated into Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) multi-hop cellular networks.

III.EXPECTED OUTCOME OF THE PROPOSED WORK

Improve the network capacity in MANETs. Dynamic traffic pattern and dynamic network without a fixed infrastructure. There are a source, a destination and several relay nodes. Cooperation can benefit not only the physical layer, but the whole network in many different aspects.

A. 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. Power control and channel control issues are coupled with topology control in MANETs while they are treated separately traditionally. Although a mobile node can sense the available channel, it lacks of the scope to make network wide decisions. It therefore makes more sense to conduct power control and channel control via the topological viewpoint control is then to set up interference-free connections to minimizes the maximum transmission power and the number of required channels. It is also desirable to construct a reliable network topology since it will result in some benefits for the network performance.

B. THE CAPACITY OF MANETS

As a key indicator for the information delivery ability, network capacity has attracted tremendous interests since the landmark paper by Gupta and Kumar [9]. There are different definitions for network capacity. Two types of network capacity are introduced in [9]. The first one is transport capacity, which is similar to the total one-hop capacity in the network. It takes distance into consideration and is based on the sum of bit-meter products. One bit-meter means that one bit has been transported to a distance of one meter toward its destination. Another 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. It has been shown that the capacity in wireless ad hoc networks is limited. In traditional MANETs without cooperative communications, the capacity is decreased as the number of nodes in the network increases. Asymptotically, the per-node throughput declines to zero when the number of nodes approaches to infinity. In this study, we adopt the second type of definition. The expected network capacity is determined by various factors: wireless channel data rate in the physical layer, spatial reuse scheduling and interference in the link layer, topology control presented earlier, traffic balance in routing, traffic patterns, etc. In the physical layer, channel data rate is one of the main factors. Theoretically, channel capacity can be derived using Shannon’s capacity formula. In practice, wireless channel data rate is jointly determined by the modulation, channel coding, transmission power, fading, etc. In addition, outage capacity is usually used in practice, which is supported by a small outage probability, to represent the link capacity. In the link layer, the spatial reuse is the major ingredient that affects network capacity. Link interference, which refers to the affected nodes during the transmission, also has a significant impact on network capacity. Higher interference may reduce simultaneous transmissions in the network, thus reduce the network capacity, and vice versa. The MAC function should avoid collision with existing transmission. It uses a spatial and temporal scheduling so that simultaneous transmissions do not interfere with each other. Nodes within the transmission range of the sender must keep silent to avoid destroying ongoing transmissions. In addition, there are some factors that prevent the channel capacity from being fully utilized, such as hidden and exposed terminals, which need to be solved using handshake protocols or a dedicated control channel in wireless networks. Routing not only finds paths to meet quality of service (QoS) requirements, but also balances traffic loads in nodes to avoid hot spots in the network. By balancing traffic, the network may admit more traffic flows and maximize the capacity. Since we focus on topology control and cooperative communications, we assume an ideal load balance in the network, where the traffic loads in the network are uniformly distributed to the nodes in the network. The study in shows that cooperative transmissions do not always outperform direct transmissions. If there is no such relay that makes cooperative transmissions have larger outage capacity, we rather transmit information directly or via multi-hops. For this reason, we need to determine the best link block and the best relay to optimize link capacity. On the other hand, other nodes in the transmission range have to be silent in order not to disrupt the transmission due to the open shared wireless media. The affected areas include the coverage of the source, the coverage of the destination, as well as the coverage of the relay.

C. IMPROVING NETWORK CAPACITY USING TOPOLOGY CONTROL IN MANETS WITH COOPERATIVE COMMUNICATIONS

To improve the network capacity 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. In order to derive the network capacity in a MANET with cooperative communications, we need to obtain the link capacity and inference model when a specific transmission manner (i.e., direct transmission, multi-hop transmission, or cooperative transmission) is used. When traditional direct transmission is used, given a small outage probability, the outage link capacity can be derived. Since only two nodes are involved in the direct transmission, the interference set of a direct transmission is the union of coverage sets of the source node and the destination node. In this article, we adopt the interference model in, which confines concurrent transmissions in the vicinity of the transmitter and receiver. This model fits the medium access control function well (e.g., the popular IEEE 802.11 MAC in most mobile devices in MANETs). Herein, interference of a link is defined as some combination of coverage of nodes involved in the transmission. Multihop 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. The transmission of each hop has its own interference, which happens in different slots. Since the transmissions of the two hops cannot occur simultaneously but in two separate time slots, the end-to-end interference. 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.

D. METHODOLOGY

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. Topology control focuses on network connectivity with the link information provided by MAC and physical layers. There are two aspects in a network topology: network nodes and the connection links among them. 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. A link is generally composed of two nodes which are in the transmission range of each other in classical MANETs. The topology of such a classical MANET is parameterized by some controllable parameters, which determine the existence of wireless line. 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)
s.t. network connectivity.

The problem Eq. 1 uses the original network topology G, which contains mobile nodes and link connections, as the input. 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 structure of resulting topology is strongly related to the optimization objective function, which is f(G) in Eq. 1 directly. It is difficult to collect the entire network information in MANETs. Therefore, it is desirable to design a distributed algorithm, which generally requires only local knowledge, and the algorithm is run at every node independently.

IV. CONCLUSIONS AND FUTURE WORK

In this article, we have introduced physical layer cooperative communications, topology control, and network capacity in MANETs. To improve the network capacity of MANETs with cooperative communications, we have proposed a Capacity- Optimized Cooperative (COCO) topology control scheme that 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. Future work is in progress to consider dynamic traffic patterns in the proposed scheme to further improve the performance of MANETs with cooperative communications.

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