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RESEARCH ARTICLE

Capacity-Optimized Topology Control in Wireless Networks

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Abstract— Networks plays a vital role in networks communication that in terms of wired or wireless. The details are as Cooperative Communication become apparent as a new scheme of diversity in Mobile Ad hoc Networks. Topology control and Network capacity are important upper layer issues in considering the performances of a MANETs in Cooperative communication. In this article, we put forth the concern of topology control with aspiration of maximizing the network capacity by proposing a scheme called MSRCC(Spatial Reuse Maximizer in Cooperative Communication). We propose two algorithms that select the most energy efficient neighbor nodes, which assist a source to communicate with a destination node; an optimal method and a greedy heuristic. In addition, we consider a distributed version of the proposed topology control scheme. Our findings are substantiated by an extensive simulation study, through which we show that the Cooperative Bridges scheme substantially increases the connectivity while consuming a similar amount of transmission power compared to other existing topology control schemes.

Keywords: - Cooperative Communication; Topology; Control; Connectivity

I. INTRODUCTION

Wireless ad hoc networks are multi-hop structures, which consist of communications among wireless nodes without infrastructure. Therefore, they usually have unplanned network topologies. Wireless nodes need to save their power as well as sustain links with other nodes, since they are battery powered. Topology control deals with determining the transmission power of each node so as to maintain network connectivity and consume the minimum transmission power. Using topology control, each node is able to maintain its connection with multiple nodes by one hop or multi-hop, even though it does not use its maximum transmission power. Consequently, topology control helps power saving and decreases interferences between wireless links by reducing the number of links. As an example of topology control, the authors of [1-3] proposed a Minimum Spanning Tree (MST) based topology control algorithm in order to maintain the network connectivity and minimize the number of links.

Although some works have been done on cooperative communications, 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 wire- less networks attempt to create, adapt, and man- age a network on a maze of point-to-point noncooperative wireless links. Such architectures can be seen as complex networks of simple links. However, recent advances in cooperative communications will offer a number of advantages in flexibility over traditional techniques. Cooperation alleviates certain networking problems, such as collision resolution and routing, and allows for simpler networks of more complex links, rather than complicated networks of simple links.

The topology control scheme has been proposed for reduced power consumption using CC technology; however, it can be applied only when a strongly connected network topology is given at the initial step. A strongly connected network indicates a network where every node has a route to reach any other node. A wireless ad hoc network can be disconnected due to node mobility, low node density, and power constraint. The authors of have shown that CC technology enhances connectivity among disconnected networks, but there has been no definitive answer given to topology control research considering coverage expansion with CC.

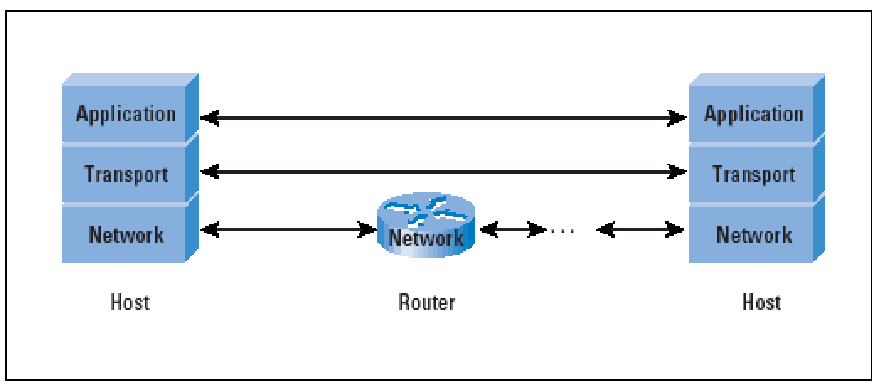
Therefore, we propose a centralized topology control scheme, which aims to increase network connectivity as well as reduce transmission power by minimizing the number of cooperative communication links (CC links) among disconnected networks. As a part of the proposed topology control scheme, we also suggest two helper decision algorithms to minimize transmission power for each CC link; an optimal method and a polynomial time heuristic algorithm.

The rest of this paper is organized as follows. Section 2 reviews the related work. Section 3 describes the network model and formulates our problems. Section 4 proposes our topology control algorithm including helper decision algorithms. Section 5 discusses the distributed version. In section 6, the results of simulation are presented. Finally, section 7 concludes this paper.

II. Related Work

In traditional multi-hop networks, intermediate nodes co- operate with a source node by forwarding the message to a destination node, which is performed on the network layer. Accordingly, the destination can receive only one copy of the message from the source or relay node. However, cooperative communication is different in that it originates from physical layer techniques; when a source node transmits a message, helper nodes around the source can overhear and retransmit it. There are two categories for this type of retransmission: amplify-and-forward and decode-and-forward. Under amplify-and-forward, a helper node receives a noisy signal and amplifies it before retransmission. Under decode- and-forward, on the other hand, a helper node must firstly decode the signal and then retransmit the detected data. A destination node combines several copies of the signal from a source node and helper nodes, and obtains the advantage of spatial diversity. The concept of combining partial signals has been traditionally known as maximal ratio combining.

Figure 1: The Three Layers of the Internet Protocol Stack



Network layer research usually considers simple physical characteristics for CC instead of variations of channel state. In , a hitch-hiking model based on decode-and- forward and maximal ratio combining is employed, and shows a simpler CC model. Our research is also based on a similar model. In and, a topology control and broadcasting algorithm is proposed, respectively, which reduce average power consumption by utilizing the CC technique after a strongly connected network is given at the initial step. In , the proposed algorithm selects a smaller number of forwarding nodes for broadcasting by CC. Observing that the CC technique extends the transmission range and it can link disconnected networks, analyzes the improvement of network connectivity via percolation theory when CC is applied. None of the existing topology control research acknowledges that coverage extension with CC results in linking disconnected networks. We propose a novel topology control algorithm that minimizes average transmission power as well as maximizes the connectivity of divided networks.

III. Model and Problem Formulation

In this section, we describe a cooperative communication model and a network model for our topology control scheme. In addition, we define two problems: 1) Topology Control considering Extended Links caused by CC and 2) Energy- Efficient Extended Link with CC.

A. Cooperative Communication Model

Our model is similar to those of [12][15]. Every node has a maximum transmission power limit Pmax,pi is the transmission power of node i. α is the path loss exponent and τ is the minimum average SNR for decoding received data.

Ω denotes the set of a source node and helper nodes. If nodes in Ω transmit simultaneously, i.e., use cooperative communication, the following formula must be satisfied for correct decoding at destination node j.

B. Network Model

The wireless network topology is modeled as a 2- dimensional graph: graph G = (V, E). V = (v1 , ..., vn) is a set of randomly distributed nodes and E is a set of pairs of nodes (vi , vj), with vi, vj ∈ V . The notations V (G) and E(G) are used for the vertex- and edge-set of G. The weight of a directional link from u to v is denoted as w(u → v). Edge

(u, v) has weight, w(u, v), which means the average power consumption for maintaining a bi-directional link (u, v). The average weight for bi-directional CC link, weight w(u, v), is (w(u → v) + w(v → u))/2. N (v) is the set of neighbor nodes within the maximum transmission range of node v.

All elements in N (v) are the candidate nodes, which are eligible as helper nodes for v. The power set of N (v) signifies

C. Problem Formulation

The existing topology control [1][2][12] tried to minimize the transmission power of nodes and preserve the given connectivity. However, the goal of this paper is to minimize the transmission power while increasing the connectivity. We formally define this problem as follows.

IV. Sample Code

```
function validateForm()
{
var x=document.forms["myForm"]["fname"].value;
if (x==null || x=="")
{
alert("First name must be filled out");
return false;
}
}
<form name="myForm" action="demo_form.asp" onsubmit="return validateForm()" method="post"> First
name: <input type="text" name="fname">
<input type="submit" value="Submit">
</form>

function validateForm()
{
var x=document.forms["myForm"]["email"].value;
var atpos=x.indexOf("@");
var dotpos=x.lastIndexOf(".");
if (atpos<1 || dotpos<atpos+2 || dotpos+2>=x.length)
{
alert("Not a valid e-mail address");
return false;
}
}
```


<form name="myForm" action="demo_form.asp" onsubmit="return validateForm();" method="post"> Email: <input type="text" name="email">
<input type="submit" value="Submit">
</form>

V. Simulation Results

We have proposed novel ideas, which ensure energy efficiency by assigning proper CC links, and which increase and maintain the network connectivity. In this section, we perform extensive simulations to compare the performance of the proposed energy-efficient topology controls using cooperative communication (Coop. Bridges, Coop. Bridges + DTCC) with other schemes. Coop. Bridges is the topology control applying the greedy heuristic in step 2 of section 4 and the MST algorithm within each cluster in step 4 of section 4. Coop. Bridges + DTCC is based on Coop. Bridges, but the DTCC algorithm [12] is used within each cluster in step 4 of section 4. The compared schemes are as follows: a scheme that maintains direct links to all neighbor nodes without using CC (Max- Power-w/o-CC) and a topology control scheme maintaining all possible direct links and CC links (Max-Power-w/-CC). In Max-Power-w/-CC, each source node selects all neighbor nodes as its helper nodes. In addition, DTCC [12] and a MST topology scheme without using CC (MST) are also compared. Since there is no existing topology control scheme using an extended transmission range with CC, we select MST.

VI. Conclusion

In this paper, we have proposed a novel centralized topology control scheme to minimize the transmission power of nodes and increase connectivity for separated networks, considering coverage expansion of cooperative communication technology. Our present study is the first to investigate this approach. Our solution constructs an MST-based network connectivity graph with minimal CC links selected from possible candidates of CC links to reduce transmission power. Furthermore, two helper-node selection schemes to maintain energy-efficient CC links were suggested; the optimal method and the greedy heuristic method. We also applied MST (or DTCC) to each cluster for direct links and it achieved further power reduction. Next, we discussed a distributed version of the proposed topology control scheme. Via simulations, we concluded that our algorithms lead to greater enhancements (up to 50%) in connectivity than other topology control schemes.

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