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Critical Neighbor Scheme to Stabilize the Node in Topology Control with Cooperative Communication

V.veda Sahithi
Assistant Professor
Department of Computer Science and Engineering
Annamacharya Institute of Technology and Sciences
Hyderabad - India

B. Ratankanath
Associate Professor, H.O.D
Department of Computer Science and Engineering
Annamacharya Institute of Technology and Sciences
Hyderabad - India

Abstract: Cooperative communication is an important aspect in wireless network. As The demand for improving the speed in wireless network is continuously increasing. Recently, cooperative communication has received tremendous interests as an untapped means for improving the performance of information transmission operating over the ever-challenging wireless medium. The most of the existing research works on cooperative communication are focused on the capacity of MANET and it is also the major issue to transfer multi part data in wireless communications. In this paper, based on the recent research on topology control methods, I propose the critical neighbor (CN) scheme, which will adaptively adjust the transmission power of individual nodes according to specific route and traffic pattern. Hence it will improve the stability of the node, the performance of the network and minimize the interference .The simulation results of CRITICAL NEIGHBOUR scheme using AODV are included in this paper.

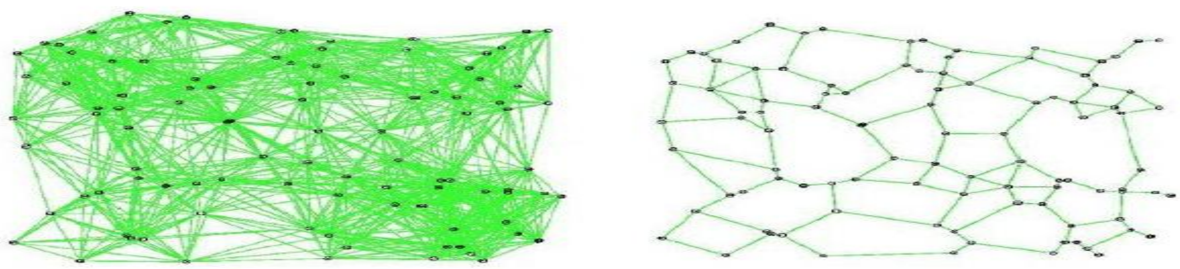
Keywords: Cooperative communication, Critical neighbour, MANET, Topology, Mobile Host.

I. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) are wireless networks that offer multi-hop connectivity between self-configuring and self-organizing mobile hosts. A MANET environment is characterized by energy-limited nodes (mobile hosts), band width – constrained, variable-capacity wireless links and dynamic topology, leading to frequent and unpredictable connectivity changes. The network size of a MANET is given by the total number of nodes in the network, which is a fixed number (assuming that no nodes enter or leave the network).Large networks are depicted by a sizeable number of nodes of up to 10 000, while small networks correspond to networks with very few nodes within the same environment size. While the number of nodes may be a good estimate of network density in homogenously distributed networks, this value may not be indicative of any specific network characteristics in a heterogeneous network where nodes are randomly positioned in the environment. I can identify a few key problems associated with network topology, that are faced by routing protocols in ad hoc networks with varying network sizes and densities. In sparse networks with low node densities, network partitions may be formed when mobile hosts move with contrasting patterns and cause the network to divide into two or more disconnected portions. This can lead to low connectivity and lack of routes to targeted destinations, resulting in higher packet loss and higher control overhead. Although path lengths might be comparatively shorter, this is because routes to further destinations cannot be discovered. The throughput is also lower in such partitioned networks. As node densities increase, it may be possible to establish path routes to destinations that are further away. Predictably, the frequency of link breakages within active routes will also increase.Dense networks are also characterized by higher node degrees, where each node has more neighbors' within its transmission range. This implies higher connectivity between nodes in the network, which can lower the mean number of hops needed between a source and its destination and improve the data delivery ratio. However, a high node degree can also result in more collisions between Neighboring nodes, which means that more energy is wasted at the radio level. But, the network size and density are often invariable parameters in an ad hoc environment. The main focus of previous work has been to reduce the routing overheads caused by routing protocols in dense networks that have uniform node densities and hierarchical routing methods which can incur additional overhead.

The main aim of topology control in this MANET is to save energy, reduce interference between nodes and extend Lifetime of the network control on some parameters of the network. 1. Transmission power of the nodes. 2. State of the nodes (active or sleeping). 3. Role of the node (gateway, regular, Cluster head). 4. Adding new nodes to the network. By modifying these parameters, the topology of the network can change. The demand for speed in wireless networks is continuously increasing. 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. Cooperative communication has emerged as a new dimension of diversity to enumerate the strategies designed for multiple antenna systems, since wireless mobile device may not able to support multiple antennas due to size ,cost or hardware limitations.

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 the network level upper layer issues ,such as topology control ,routing and network capacity ,are largely ignored .Indeed ,most of current works on wireless network attempts to create, adapt, and manage a network on a maze of point-to-point non cooperative wireless links.



- Drop long-range neighbors: Reduces interference and energy!

II. MANET WITH COOPERATIVE COMMUNICATIONS

In this section we first describe about role of cooperative communications. And then defining the topology control problem in MANETs with cooperative communications. 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 .Earlier study of relaying problems appears in the information theory community to enhance communication between the source and destination. Recent tremendous interest in cooperative communications is due to increased understanding of benefits of multiple antenna systems. Although multiple input and 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.

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 overhead 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,

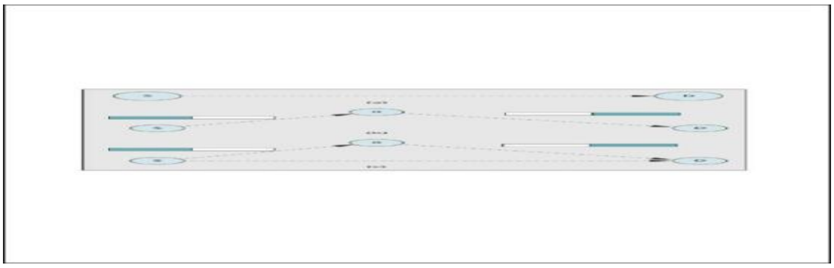
- Amplify and forward
- Decode and forward

Amplify-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. Where as 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 transmitting the relay signals. Three transmission protocols

a) Direct transmissions via a point-to-point 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.



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.

III. TOPOLOGY CONTROL

The network topology in a MANET is changing dynamically due to user mobility, traffic, node batteries. Meanwhile the topology in a MANET is controllable by adjusting some parameters such as transmission power, channel allocation etc. In general topology control is such a scheme to determine where to deploy the links and how the link works in wireless networks to form a good network topology, which will optimize the energy consumption, and to improve the capacity of the network, or end-to-end routing performance .Power control and channel allocation issues are coupled with topology control in MANETs while they are treated separately. Traditionally .the goal of the topology control is to set up interference free connections to minimize the maximum transmission power and the number of construct a reliable network topology since it will result in some benefits for the network performance.

There are two aspects in network topology network nodes and the connection links among them. In general, a wireless network 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 links directly. Usually, these parameters can be transmit power and antenna directions, etc. A general topology control problem can be expressed as

$G^* = \arg\max f(G)$ or $G^* = \arg\min f(G)$ eqn (1)

s.t. network connectivity

The above topology control problem consists of three elements, which can be formulated by a triple (M , P,O), where M represents network model, P represents the desired network property, which often refers to network connectivity for most of topology control algorithms, and O refers to the optimization objective . The eqn (1) uses the original network topology G, which contains mobile nodes and link connections, as the input. According to the objective function, a new good 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).

For MANETs, it is difficult to collect the entire network information. Therefore, the above centralized topology control should be solved using a distributed algorithm, which generally requires only local knowledge, and the algorithms run at every node independently. Consequently, each node in the network is responsible for managing the links to all its neighbors only. If all the neighbor connections are preserved, the end-to-end connectivity is then guaranteed via a hop-by-hop manner. The wireless links in cooperative communications are more complex than the conventional point-to-point wireless links. A cooperative link usually consists of three nodes: source (S), relay (R) and destination (D). As a result, the link is presented by (S,R,D) and the topology becomes GC (V, EC) in which

EC = { (S,R,D) |S,R,D ∈V}.

If the relay is changed, the link is then changed. Therefore, relay selection criteria can have significant impacts on the network topology. By considering three types of transmission protocols for a link: point-to-point direct transmissions, conventional multi-hop transmissions and cooperative transmissions. Direct transmissions and multi-hop transmissions can be considered as special types of cooperative transmissions. A direct transmission utilizes no relays while a multi-hop transmission does not combine signals at the destination. We assume that nodes can determine the best protocol for transmissions according to the objective of COCO.

IV. Critical Neighbor Algorithm to Stabilize the Node in Topology Control with Cooperative Communication

4.1)Preliminaries

We can classify the neighboring nodes of the interest into two categories:

- Critical nodes, C[x] = {set of nodes that are required to transmit data}
- Non-critical nodes, N[x] = {set of nodes that are not required to transmit data}

Therefore, the set of all neighboring nodes of an arbitrary node x can be given as the union of the set of critical and non-critical nodes:A[x] = C[x] U N[x]

Furthermore,

C[x] ∩ N[x] = Ø,

which means that the set of critical and non-critical nodes are two mutually exclusive sets.

We use the Ground Reflection (or Two-Ray) model in our simulations, which considers both the direct path and the ground reflected propagation path between the transmitter and the receiver:

$$Pr = Pt \times \frac{h_t^2 \times h_r^2}{d^4} \times G_t \times G_r$$

where Pr= Received power; Pt= Transmitted power; G_t=Antenna gain at the transmitter ;G_r= Antenna gain at the receiver; h_t= Height of the transmitter antenna; and h_r=Height of the receiver antenna. Hence we derive the estimated distance between node xand its i^th critical neighbor as:

$$E_{dist}[xi] = 4\sqrt{\frac{P_t \times h_t^2 \times h_r^2 \times G_t \times G_r}{P_r}}$$

Taking Gt = Gr = 0 dBm = 1,

$$E_{dist}[xi] = 4\sqrt{\frac{P_t \times h_t^2 \times h_r^2}{P_r}}$$

While evaluating the estimated distance as above, we keep in mind that this value may not be a true reflection of the actual distance between any two nodes. This is because two nodes in close proximity may also be subject to interferences from the noise in the environment, as well as from surrounding nodes that are transmitting data or control packets.

We can also define the critical transmission range of an arbitrary node as the minimum distance required to keep the set of critical nodes C[x] within connectivity:

$$C_{txn}[x] = Max(E_{dist}[x_i], E_{dist}[x_{i+1}], \ldots, E_{dist}[x_n]), 1 \le i \le n$$

Where n is the total number of nodes belong to the setC[x]; and $E_{dist}[xi]$ is the estimated critical distance between node x and its i^{th} critical neighbor.

4.2 CRITICAL NEIGHBOUR ALGORITHM

Nodes in wireless networks are subject to interference from neighboring nodes within the transmission and interference ranges. These neighboring nodes may cause higher delay due to contention of bandwidth, as well as higher packet loss due to collisions.

The CN scheme (see Figure 2) attempts to reduce the interference caused by adjacent nodes that are not part of the forwarding routes of a particular node. This is commonly known as the hidden/exposed terminal problem as shown in Figure 1,where a receiving node may experience interferences from other adjacent nodes, resulting in packet loss. There have been attempts to solve this problem in the literature, one of which includes the RTS/CTS dialogue – which necessitates handshake between the transmitting and receiving nodes that precedes the actual transmission. In the RTS/CTS scheme, a node that wants to transmit data has to send a Request To Send(RTS) control packet, which defers all nodes that hear the RTS from accessing the channel for a specified time period. The destination node responds with a Clear To Send (CTS) control packet upon reception of the RTS. However, the use of the RTS/CTS dialogue will only eliminate collusions caused by nodes within the transmission range and not the interference range.

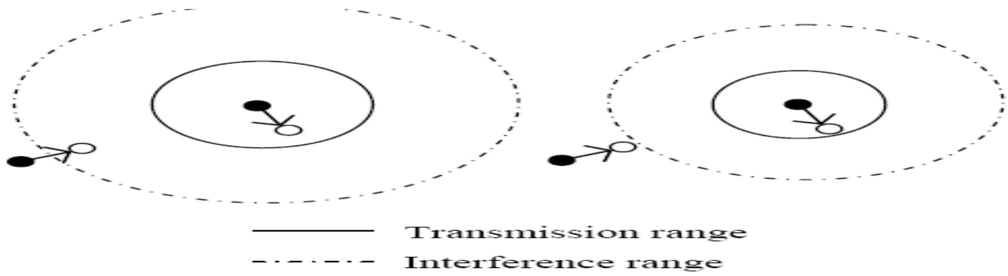


Figure 1: Hidden/Exposed Terminal Problem

Figure 2: Critical Neighbour (CN) scheme

The Critical Neighbor scheme complements the RTS/CTS dialogue to reduce the collisions within the interference range. By reducing the transmission range of nodes such that they reach the minimum distance required to maintain connectivity with the neighboring nodes that are part of the active routes, unnecessary interference experienced by other neighboring nodes can be minimized.

The adaptive Critical Neighbor (CN) scheme comprises of three main components:

- Measurement of estimated critical range
- Estimation of the ideal power; and

- Adjustment of the ideal power based on constraints.

When periodic beacons such as Hello packets in AODV are received, the node will calculate the critical transmission rang e $C_{txn.}$ This is then used to estimate and adjust the transmission power so that the performance of the routing protocol can be improved.

As such, we estimate the corresponding ideal transmission power as follows:

$$P_{ideal} = P_{min\_r} \times \frac{C_{txn}^4}{ht^2 \times hr^2 \times G_t \times G_r} \times \text{tolerance\_factor}$$

Since $G_t = G_r = 0$ dBm = 1,

$$P_{ideal} = P_{min\_r} \times \frac{C_{txn}^4}{h_t^2 \times h_r^2} \times \text{tolerance\_factor}$$

where P_{min_r} is the minimum signal strength for a packet tobe received correctly; and tolerance factor is a percentage which allows for node mobility, as well as some noise and interferences in the environment.After obtaining the ideal power, we need to make sure that the node must have significant power, so that node can able to route the packet to the destination. Otherwise node has to be bypass in routing.

```
/* Handling of Hello packets */
FOR each Hello packet received {
IF it is received from a critical neighbor
 {
Determine the critical transmission range Ctxn;
Determine the ideal transmission power P ideal;
IF P ideal is within constraints
Adjust the transmission power accordingly;
}
Update routing and neighbor tables;
}
```

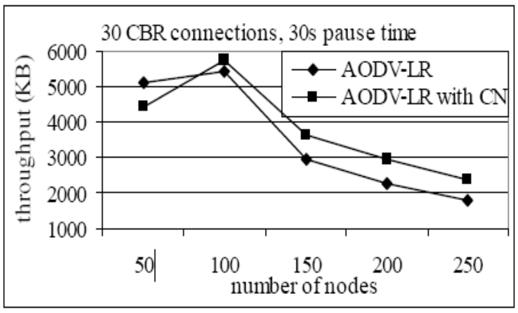
Figure 3: Pseudo code for CN scheme

V. Simulation Results & Analysis

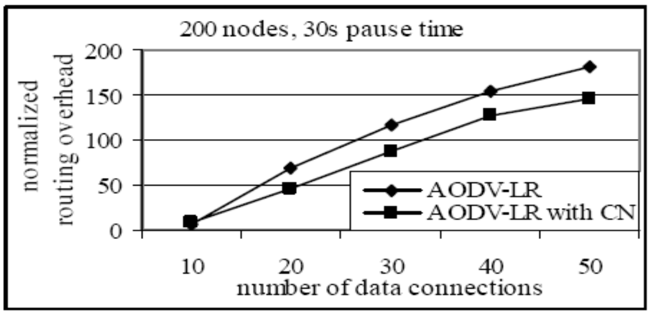
We implemented our CN scheme on AODV-LR, which is an enhanced version of AODV with Local Repair and run simulations on GloMo Sim , which provides a scalable simulation platform for wireless networks. The Random Waypoint mobility model is used with minimum and maximum speeds of 10 ms-1 and 20 ms-1 respectively and the pause time is set to 30s. Nodes are uniformly distributed and CBR (Constant Bit Rate) traffic with data packets of size 512 bytes are transmitted at an arrival rate of 10packets per second. Our simulations are evaluated according to the following performance measures:

- Throughput – total number of successfully delivered data (in kilobytes);
- Packet delivery ratio – total number of data packets received as a fraction of the total number of data packets originated from all the nodes in the network;

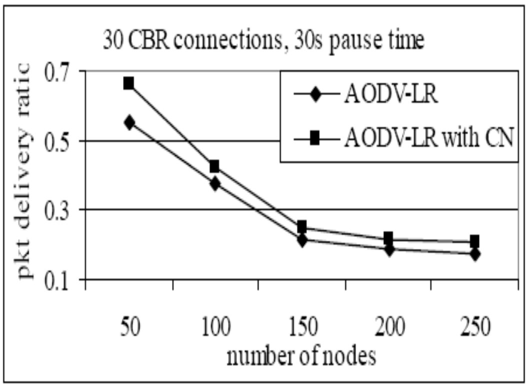
- End to end delay – average time taken to transmit a packet from source to destination; and
- Normalized routing overhead – total number of control packets as a fraction of the total throughput.



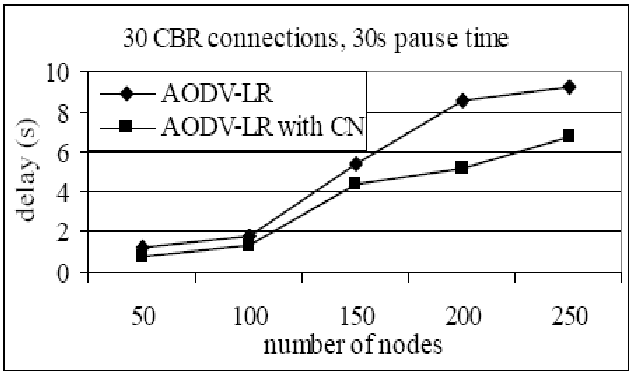
Throughput Vs Network Size



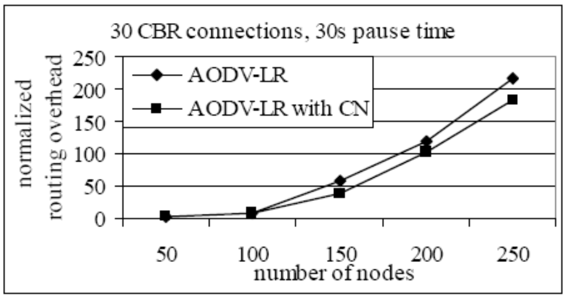
Normalized routing overhead vs data load



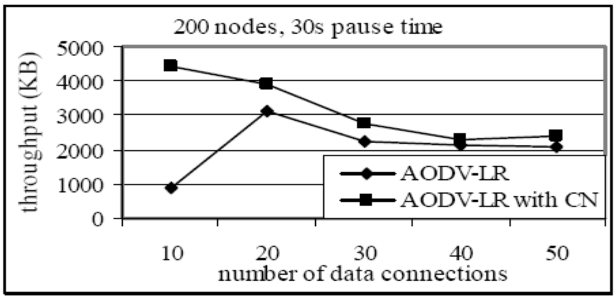
Packet delivery ratio vs network size



End to end delay vs network size



Normalized routing overhead vs network size



Throughput vs data load

VI. Conclusion and future work

In this paper we adaptively reduce the transmission range of nodes such that there is less overlapping, interferences. This helps to increase the spatial reuse of the channel bandwidth. As a result, there is higher throughput in the network, which leads to higher packet delivery ratio. By using CN scheme results in lesser normalized routing overhead because each node has a smaller node degree. As such, during propagation of control packets, there are lesser nodes within the transmission range of the broadcasting node, resulting in less control overhead. The CN Scheme, the transmission range of nodes is typically smaller. As such, more nodes are able to transmit data at the same time and thus increase the throughput of the network. The results are obtained for sparse network. Therefore fewer packets are lost or corrupted, resulting in higher packet delivery.

As part of future work, we will study the effects of the CN scheme in larger network sizes. Our continued research efforts include the investigation of other adaptive mechanisms to improve the scalability and performance of typical reactive routing protocols.

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AUTHOR(S) PROFILE

v.veda sahithi, working as a Asst. Prof in the department of Computer Science and Enginnering , Annamacharya Institute of Technology and Sciences, Hyderabad.

B.RATNAKANTH, working as a Professor and H.O.D, Computer Science &Engineering, Annamacharya Institute of Technology, and Sciences, Hyderabad.