



A Novel Distributed Topology Control Algorithm for Energy Efficiency and Minimum Delay in MANET with symmetric Links

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Abstract— *Efficient Topology control algorithms are an important consideration in mobile ad hoc networks since they can increase network capacity and lifetime of nodes. With the advance development of mobile ad hoc networks (MANETs), there is a growing requirement of quality of service (QoS) in terms of delay and energy. In order to resolve the delay problem, it is essential to consider topology control in delay constrained environment with energy efficient. The proposed Energy Efficiency and Minimum Delay distributed topology control Algorithm implemented system, study on the delay-constrained topology control problem, and take into account delay and energy efficiency. Simulation results are presented demonstrating the effectiveness of this new technique as compared to other approaches to topology control.*

Keywords— *delay; energy efficient; MANETs networks; topology control algorithm; interference.*

I. INTRODUCTION

Mobile ad hoc Network (MANET) is a special type of wireless network which represent a class of self- configuring and infrastructure-less networks with mobile nodes connected without wires. Each node in a MANET is free to move independently in any direction and also acts as a router, as well as a communication end-point

.With the increasing demand and development of MANET, there is a growing attention for application that require quality of service (QoS) provision, such as such as voice over IP (VoIP), transmission of multimedia data, real-time collaborative work. QoS routing needs not only to find a route from a source node to a destination node, but a route that satisfies the end-to-end QoS requirement, often given in terms of bandwidth, delay, packet loss rate, packet jitter, hop count, path reliability and power consumption. Quality of service is more difficult to guarantee in ad hoc networks than in most other type of networks, because the network topology changes as the nodes move and network state information is generally imprecise. This requires extensive collaboration between the nodes, both to establish the route and to secure the resources necessary to provide the QoS.

In order to provide the QoS requirement problem in terms of delay, some researchers found the delay incurred in a forwarding node or a routing path. [1] Delay depends on the speed of propagation and the number of hops a packet must travel to reach its destination that is one portion of the path between source and destination. In [2], delay is defined as the transmission delay of a packet. Then, Xie et al. [3] said that in many cases the queuing delay takes a significant portion of the total delay over a hop. Processing delay and propagation delay which change in microseconds are much shorter than transmission delay, contention delay and queuing delay which change in millisecond. Therefore, the end-to-end (E2E) delay of nodes in MANET is just transmission delay.

In Mobile ad hoc wireless networks, each node is usually powered by a battery equipped with it. Since the capacity of battery power is very much limited, energy consumption is a major concern in topology control. To increase the life time of such networks, an essential requirement of topology control algorithms is to achieve the required topology by using minimum energy consumption. The main goal of a topology control algorithm in Mobile Ad hoc Network is to reduce node power consumption in order to extend network lifetime good topology not only can provide a better service for routing layer, but also can save energy, increase network capacity and satisfy the QoS needs. The foregoing topology control algorithms [4]–[5] mainly concentrated on the interference constraint. And how to employ topology control to minimize delay is not fully researched by those works. The other way to reduce source to destination node delay is to increase the transmission power of a certain node in a path which it travel, so that the transmission range of the node is increased and thus the hops between the source and destination are reduced. Transmission delay may be decreased due to the reduction in hops and queuing delay is also decreased. But, it may cause more interference to other neighboring active receiving nodes, excessive contention to nearby potential sending nodes, which may cause more retransmissions. Retransmission causes transmission delay. Because of increasing the transmission power among the intermediate node, reduces the life time of network. Therefore, reducing delay and increase the life time of the network with minimum interference is our conflicting goals of the project.

The vast majority of researches on topology control focused only on reducing the power of each node to save energy and reducing the network interference. Some of the researches focus on reducing delay with interference. Here we developed algorithms on topology control focused on reducing delay while transmission and minimum usage of the

energy. The proposed algorithm has the two objectives. The first objective is to minimize the delay and minimum interference and the second is to reduce transmission power through increase life time of nodes.

II. TOPOLOGY CONTROL

Taxonomy

There are several different approaches to topology control and it is possible to organize them into a coherent taxonomy. The first distinction is between approaches that control transmitter power and those that impose a hierarchy in the network. Hierarchical approaches change the logical structure of the network in terms of node adjacencies and may be broken down into approaches that use clustering and those that use dominating sets.

The power control approaches act on the transmission power of nodes using several different techniques. The first distinction to make of power control approaches is between homogeneous and non-homogeneous approaches. Homogeneous topology control is the easier of the two in which nodes are assumed to use the same transmitting power and the problem of topology control becomes in essence one of finding the value of the transmitter range that satisfies a certain network wide property.

In non-homogenous topology control nodes are allowed to select different individual transmitting powers up to a certain maximum that they can support which means that they will have different transmitting ranges. This form of topology control can be split into three different categories according to the type of information that is used to generate the topology. These three categories are location based, direction based, and neighbor based.

In location-based approaches exact node locations are known and are either used by a centralized authority to calculate a set of transmitting range assignments which optimize a certain measure or are exchanged between nodes to create an approximately optimal topology in a distributed fashion. In direction-based approaches, nodes are assumed to not know their positions but can estimate the relative direction to each of their neighbors. Finally, in neighbor-based approaches the only knowledge nodes have of their neighbors is the neighbor IDs and the IDs are ordered according to some criterion when performing topology control.

Quality Measures

Different approaches to topology control will produce different results. For a collection of nodes, let denote the graph on for which there is an edge from node to node only if can directly reach. It is desirable to judge the usefulness of a topology returned by a topology control algorithm and compare it with results from other algorithms. In order to do this, some metrics and measures are required which include connectivity, energy efficiency, throughput, and robustness to mobility.

Connectivity: If there is a multihop path between and in, then there should also be a path in. This is a basic requirement for a topology control algorithm, that it should not disconnect a connected graph.

Energy Efficiency: The energy consumed for a transmission between and is a polynomial function of the distance between and. Two common notions of energy efficiency are the energy stretch factor and the hop stretch factor. The energy stretch factor is the worst increase in energy used to deliver a packet between any pair of nodes and along a minimum energy path between the original graph and the topology controlled graph. The hop stretch is similar except that the focus is on path length as opposed to energy consumption. Formally (1) where is the energy consumed along the most energy efficient path in graph Likewise (2) where is the shortest path in graph and is its length.

Node Degree: In order to better evaluate the performance of the topology control technique in terms of interference, a distinction is made between the physical and the logical node degree. The physical node degree refers to the number of neighbor nodes that are within the transmitter range of a given node. The logical node degree refers to the number of neighbor nodes that a given node is linked to.

Simplicity and Maintainability: It is desirable for a topology to be simple and easy to maintain and objective measures that can be used to evaluate these subjective goals are the number of edges in and the maximum node degree (number of neighbors) of any node in. It is desirable also for the algorithm used to have little overhead in terms of computation and communication requirements.

Throughput: It is desirable for the network topology to have a high throughput, where it is possible to sustain a comparable amount of traffic as the original network topology. Several throughput measures can be used [15] one of which is the bit-meter which is defined in terms of the bit-distance product. A network transports one bit-meter when it one bit is transported a distance of one meter. The throughput of the network is then the number of bit-meters transported per second.

Robustness to Mobility: The mobility of nodes causes neighborhood relationships to change in the original graph and some other nodes will have to change their topology information. A robust topology should only require a small number of these adaptations and avoid the effects of reorganization due to local node movement affecting the entire network. A measure of robustness is the adaptability which is the maximum.

III. RELATED WORK

Itcd Algorithm

ITCD Algorithm [6] describes a cross-layer distributed algorithm called interference-based topology control algorithm for delay-constrained (ITCD) MANETs with considering both the interference constraint and the delay constraint. The transmission delay, contention delay and the queuing delay are taken into account in the ITCD algorithm. This algorithm decreases source to destination delay by decreasing the intermediate node between the source and destination. The

intermediate node is decreased due to increasing the transmission power of the intermediate node. But it causes to spend the maximum amount of energy for transmission of node. It reduces the life time of the node in the network.

Smart Boundary Yao Gabriel Graph (Sbyaogg)

The SBYaoGG [7] topology aims to control the graph representing communication links between nodes, with the purpose of meeting a global property of the graph such as connectivity, while reducing energy consumption and radio interference. Each node in the network makes local decisions about its transmission power and the culmination of these local decisions produces a network topology that preserves global connectivity. This algorithm increases the level of interference in the network as measured by the maximum and average node degree of the generated topology. It uses itself to the mechanisms of multihop communication and energy-efficient operation. However, it did not provide any solution to the transmission delay problem occurs while increasing intermediate node between source and destination.

IV. ENERGY EFFICIENCY AND MINIMUM DELAY ALGORITHMS :EEMDA

The proposed Energy Efficiency and Minimum Delay distributed topology control Algorithm implemented system, we study on the delay-constrained topology control problem, and take into account delay and energy efficiency.

Delay model of a path:

The source to destination delay contains transmission delay over intermediate links, contention delay caused by nodes' contention for the shared channel and queuing delay induced at each intermediate node due to queuing policy/or severe channel conditions.

For a path $P : n_1, n_2, \dots, n_i, \dots, n_N (N \geq 1)$, a packet is sent from node n_1 to n_N according to path P . $L(i)(i+1)$ is the transmission delay of link between node i and node $i+1$. Let C_i and Q_i denote the contention delay and queuing delay at node i , respectively. The total delay DP contains the contention delay and the queuing delay at each node and the transmission delay of links on the path P .

$$D_p = \sum_{i=1}^{N-1} (L(i)(i+1) + C_i + Q_i) \quad (1)$$

Delay model of an intermediate node:

If the data is transmitted successfully in the first attempt, transmission delay of link between node i and node $i+1$ is

$$L(i)(i+1) = \frac{L}{B} + DIFS + T_{TACK} + SIFS \quad (2)$$

where L denotes the packet length and B is transmission data rate, DIFS stands for the Distributed Inter-Frame Spacing, SIFS stands for the Short Inter-Frame Spacing and TACK represents the transmission delay of acknowledge frame.

Based on the expected number of transmission above, the expected transmission time can be estimated by

$$E(L(i)(i+1)) = ETX * L_{(i)(i+1)} \quad (3)$$

The delay incurred by contending channel should take the retransmission times into account. However, the backoff times a sending node has to wait in retransmissions are correlated and not independent. With the channel access occurring to conflict continuously for $k-1$ times, the probability for k th channel access is P_k . Thus, the expected delay for node i to access channel is represented by

$$E(C(i)(i+1)) = \frac{\sum_{k=1}^{\log_2 m} Q A k * P_k}{\sum_{k=1}^{\log_2 m} P_k} \quad (4)$$

Delay constraint at an intermediate node:

From the above equations, the delay constraint for a path is transformed into delay constraints at intermediate nodes. However, it is an extremely hard problem to partition the end-to-end delay constraint into each node accurately. We define a max delay D_{max} at intermediate nodes, which is similar to the max transmit power. It is determined by the information of the real-time requirement T_{real} and the number of hops n . T_{real} is given by the requirement of applications. As to n , we use a prediction method to estimate the number of hops. According to the AR(p) model, we can obtain the estimation of the i th hop count by the last p hop counts as below:

$$h_i = k_o^h + k_1^h h_{i-1} + k_2^h h_{i-2} + \dots + k_p^h h_{i-p} + \sigma_i^h \quad (5)$$

where h_i is the estimated i -th routing hops, and $h_{i-1} \dots h_{i-p}$ are the last p -th measured historic routing hops respectively. k_i is the i -th parameter of the AR(p) about hops. Σh_i is the white noise in the prediction. With Yule-Walker equation, we can solve the value of h_i .

Computing average direction vector in intermediate node:

Computing average direction vector in intermediate node is generated by first computing the Gabriel graph from the Unit Disk Graph (UDG) at maximum transmitter power and then computing the Yao graph on the reduced topology to produce the final topology.

Pruning the Edges of the Gabriel Graph:

The Gabriel graph computed on the UDG has its edges pruned by computing the Yao graph on the reduced topology. This, in effect, generates the previously developed Yao Gabriel graph. In order to achieve low interference, it is desirable to reduce the node degree as much as possible, while maintaining the power spanner properties of the Gabriel graph. The Yao Gabriel graph can achieve this. However, further reduction in interference levels can be obtained by variable selection of the axes of the cones for each region of the Yao graph. The procedure employed to reduce interference was as follows.

- Prune the edges of the Gabriel graph using the Yao graph.
- Use large regions in computing the Yao graph.
- Select the axes of cones for each region of the Yao graph using heuristics.
- Reduce the transmitter power of each node to the lowest level so that it allows it to reach its furthest neighbor in the final topology.

Determining the Region Boundaries of the Yao Graph:

A heuristic that was used whilst forming the reduced topology graph was to align the axis of the first cone used in the Yao graph computation to the region where nodes are most densely deployed. This can be accomplished by obtaining the unit direction vectors of all the neighboring nodes and then calculating the average direction vector. The average direction vector is then used as the axis of the cone for the first Yao graph region.

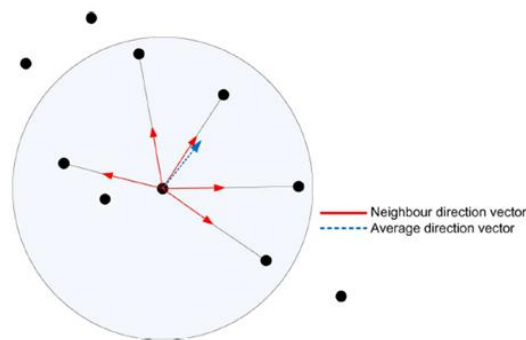


Figure1. Neighbor direction vectors and the average direction vector.

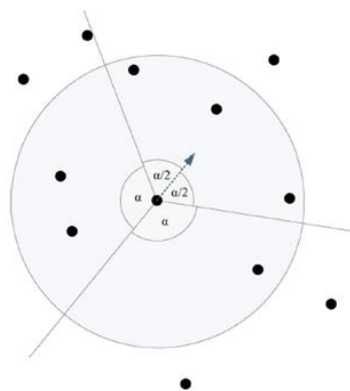


Figure2. Yao graph boundaries using an average direction vector.

Algorithms :EEMDA

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Path P: S, ..., i - 1, i, i + 1, ..., D;
Dpre= Dmax;
1: Forwarder i selects stable links which satisfy
PTd<PMd;
2: while (Dsd≤ Dmax) and (PTsd≤ Pmax) do
3: { minimizing the power consumption while satisfying
the interference constraint }
4: SINRd= Dsd• αsd2/((DIId+ σ2d )psd_);
5: Dsd= Dsd• ξd/SINRd;
6: { adjusting Pmax with the balancing factor tr }
7: if (Pi < Pmax) then
8: tr+ = Pmax- Pi;
9: Pmax+ = tr;
10: end if
11: { Find Average Transmission Range Node

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And swapping Source Node to Another}
12:while(Dpre<=PTd) do
14:  while(PTsd<PRsd) do
16:      Sum = Sum+PTi;
17:      count++;
18:  end while
18:  PTave = Sum/count;
19:  PTs = Node(PTave);
20:Dpre=PTs;
21: end while
22: end while

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V. PERFORMANCE EVALUATION

Simulation Environment

In order to evaluate the performance of the proposed EEMDA protocol, we compare EEMDA with the conventional ITCD [1] protocol and the energy-efficient and delay-constrained routing protocol [33] (for convenience, we rename the protocol as EEDCR which is to find an energy-efficient path with explicit delay constraint. Adjusting the transmission power in data and set the pause-time to 0. The simulation time for each simulation scenario is set to 50 seconds. In the results, each data point represents the average of 20 trials of experiments. The confidence level is 95%, and the confidence interval is shown as a vertical bar in the figures. The detailed simulation parameters are shown in Table I.

Table 1. Simulation parameters

SIMULATION PARAMETERS	
Simulation Parameter	NS-2(v2.34)
Simulation Time	50 s
Topology Size	1000 m * 1000 m
Min speed	0 m/s
Max speed	2 m/s
Max nodes	100
Pause time	0 s
Traffic Type	CBR
Packet size	512 bytes
Mobility mode	Random way point

The experiments are divided to three parts, and in each part we research the impact of one of the following parameters on the performance of routing protocols:

Number of nodes: We vary the number of nodes from 50 to 100 in a fixed field to research the impact of different network density. In this part, we set the number of CBR connections to 10.

Number of CBR connections: We vary the number of randomly chosen CBR connections from 2 to 10 with a fixed packet rate to research the impact of different traffic load. In this part, we set the number of nodes to 100.

Delay constraint: We vary the delay constraint from 40ms to 140ms in a fixed field to research the impact of delay constraint. In this part, we set the number of nodes to 100, the number of CBR connections to 15.

Performance with Varied Number of Nodes

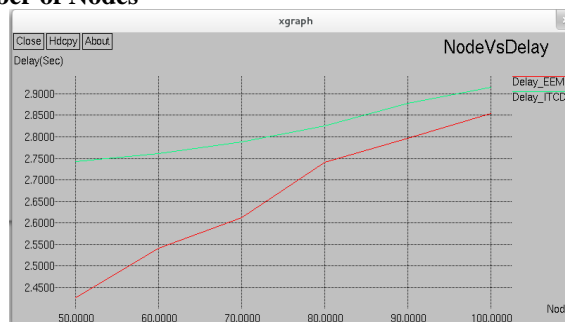


Figure3. Performance of delay with varied Number of Nodes

Fig. 3 measures the average end-to-end delay of CBR packets received at the destinations with increasing network density. Average delay is defined as the average delay of a successfully delivered CBR packet from the source node to the destination node. In MANETs, inappropriate transmission power will increase the delay. If transmission power is too large, it will incur too many channel contentions, which increases the backoff timer in MAC layer, so as to increase the delay. EEMDA protocol shows minimum delay while comparing with ITCD.

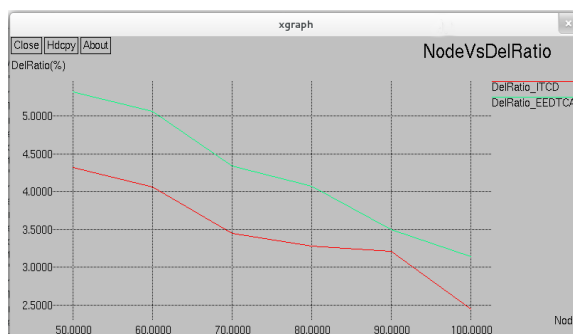


Figure4. Packet delivery ratio with varied number of Nodes.

Fig. 4 shows the packet delivery ratio with increasing network density. Hence, the EEMDA protocol can increase the packet delivery ratio. On average, the packet delivery ratio is improved in the EEMDA protocol when compared with the conventional ITCD protocol.

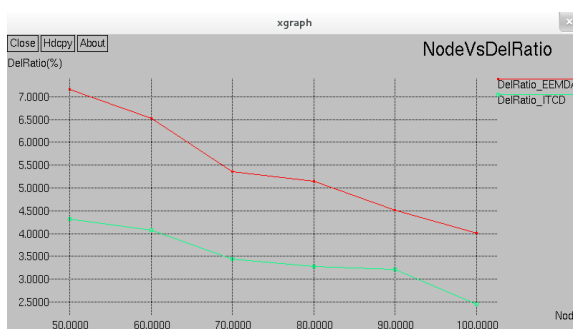


Figure5. Performance with Varied Energy with Node

Fig. 5 describes the energy consumption in the network with increasing the node density. The energy consumption of EEMDA protocol is lower while comparing with the existing ITCD routing protocol.

Performance with Varied Number of CBR Connections

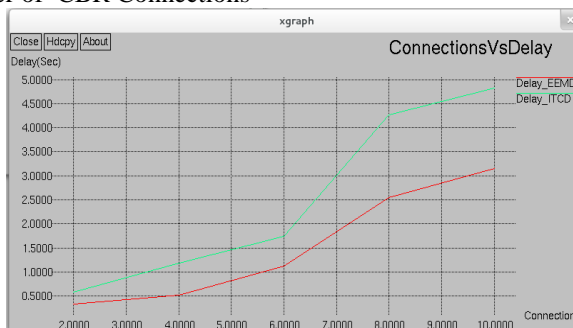


Figure6. Performance of Delay with varied network traffic (ms)

Fig. 6 measures the average end-to-end delay of CBR packets received at the destinations with increasing traffic load. On average, the end to-end delay is reduced in the EEMDA protocol when compared with the conventional ITCD protocol while increasing the traffic load.

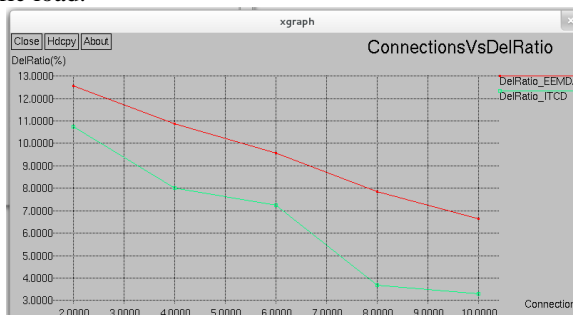


Figure 7. Performance of Packet Delivery Ratio with varied network traffic (ms)

Fig. 7 shows the packet delivery ratio with increasing network traffic. The EEMDA protocol can increase the packet delivery ratio. The packet delivery ratio is improved in the EEMDA protocol when compared with the conventional ITCD protocol.

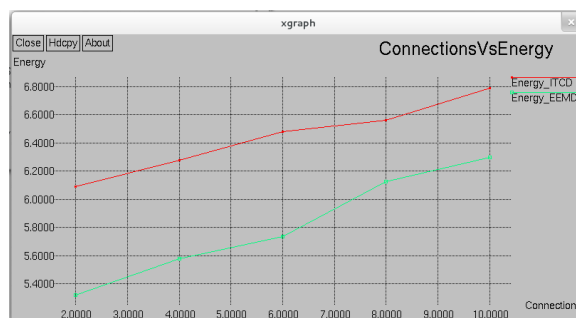


Figure 8. Performance with Varied Node Connection with energy

Fig. 8 describes the energy consumption of EEMDA protocol. The energy consumption of EEMDA protocol is low while comparing with the existing ITCD routing protocol.

VI. CONCLUSION

In this paper, we propose energy efficient, reduced delay and minimum distributed topology control algorithm for mobile ad hoc networks. The simulation results show that EEMDA can reduce the delay and improve the packet delivery performance effectively with efficient energy in mobile ad hoc networks. In future we can study behavior of this algorithm for sensor networking environment.

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