Interference Minimization in Topology Control for Ad Hoc Networks

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Abstract
The topology of a wireless ad hoc network has a significant impact on its performance. Topology control tries to lower energy consumption of the nodes in the network by reducing their transmission powers. As a result of the sparseness of the resulting topology interference is assumed to be low. However this is not guaranteed. We propose a framework that will ensure minimal interference as a result of topology control.

1. Introduction

A wireless ad hoc network is a collection of autonomous nodes or terminals that communicate with each other by forming a multi-hop radio network and maintaining connectivity in a decentralized manner. Nodes are generally battery powered. Thus energy is a precious resource that has to be carefully managed by the nodes in order to extend network lifetime. Due to interference ad hoc networks are generally characterized by bandwidth-constrained and variable-capacity links that makes bandwidth allocation difficult. The application of ad hoc networks in military communications and disaster relief makes minimization of power consumption and interference even more critical.

2. Related Work

2.1 Topology Control

The network topology has a huge impact on the performance of the network. A dense topology may result in inducing high interference and low capacity, while a sparse topology may suffer from link failure and network partitioning. Generally, algorithms follow either a centralized approach or a distributed approach. The centralised algorithms (Minimum Spanning Tree, Connect, Minimum Radius Graph) are not scalable for large ad hoc networks [2] because the central entity has to collect excessive amount of information. Using distributed algorithms (Local Information No Topology, Local Information Link-State Topology, Common Power level, MobileGrid) strong connectivity cannot be guaranteed [2] because the information each node obtains is limited.

A hybrid approach has been proposed by Chien-Chung Shen et al. [1]. This achieves topology control in three phases.

(i) Clustering
(ii) Intracluster topology control
(iii) Intercluster topology control

We have used this hybrid cluster based topology control algorithm for our framework.

The clustering algorithm aims to partition the network into clusters and assign a clusterhead for each cluster. For this purpose, each node is assigned a weight. The bigger the weight, the better that node is for the role of a clusterhead. For example, weight is a value that is inversely proportional to is mobility. Therefore a node will remain the clusterhead for a longer period. The assumption made here is that each node knows its own weight and position as well as the weight and position of its one-hop neighbours that fall within its maximum transmission range.

For our proposal we have used a distributed clustering algorithm [4].

2.2 Interference

The interference of a network is defined as follows.

D(u; r) denotes a disk centered at node u with radius r.

The cover of an edge e(u,v) is defined as the union of vertices that fall within the disk centered at u with radius |u,v| and the disk centered at v with radius |u,v|.

$Cov(e) = |\{ w \in V | w \text{ is covered by } D(u; |u,v|)\} \cup \{ w \in V | w \text{ is covered by } D(v; |u,v|)\}|$, where e = (u,v)

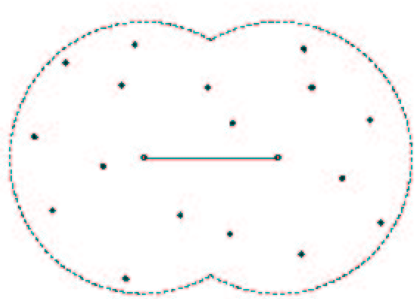

Fig. 2.1 - Cover of an edge

Interference of a graph is defined as the maximum of the cover values among all the edges in the graph.

$$I(G) := \max Cov(e): e \in E$$

In Fig.2.1 cover of the edge is 17 because the number of nodes that fall within its range is 17.

Besides energy conservation, topology control also aims at reducing interference. The interference aspect is often solved by sparseness or low node degree of the resulting topology graph. The topology control algorithms try to reduce interference implicitly but interference is not reduced in all cases. In the network shown in Fig. 2.2 the nodes have less degree. However the interference is very high. Thus there is a need to explicitly reduce interference through topology control [3].

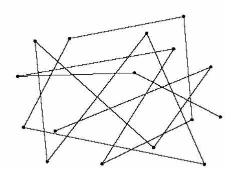

Fig 2.2

3. Proposed Solution

Topology control is achieved in three phases, as mentioned before. We have incorporated our proposal to minimize interference in the intracluster and intercluster topology control phases.

3.1 Intracluster Topology Control with Interference Minimization

The algorithm used in this phase is given below.

3.1.1 Algorithm

INPUT:

i. Multihop wireless network
ii. Least_power function
iii. Initial power assignment inducing connected network

OUTPUT:

Power levels p for each node that induces a biconnected graph and minimal interference.

ALGORITHM:

Interference is calculated for each edge of the cluster. The edges are sorted in non-increasing order of interference. For each edge, ‘e’, in the sorted order the following has to be done. The graph is checked without the edge ‘e’ for biconnectivity. If the graph is biconnected without the edge ‘e’, then the edge ‘e’ can be removed. If the graph is not biconnected, then the edge ‘e’ has to be retained. The power required to retain that edge ‘e’ is calculated using the minimum power function λ. Then that power is stored in the power array of the end vertices of that edge ‘e’. (Each vertex has a power array and it stores various powers required to maintain different edges). Finally after all the edges are considered, the final intracluster power has to be assigned to the vertices. This is done by finding the maximum power in the power array of each vertex and assigning that power to that vertex.

begin
1. sort node pairs in non_increasing order of interference
2. G = graph induced by (A, λ, p)
3. for each edge e in sorted order do
4.   if biconn_comp(G,e)
5.   remove e from G
6.   else
7.   retain e
8.   p = λ(distance(u,v))
9.   add ‘p’ to the power array of vertices ‘u’and ‘v’ of the edge e
10. for each vertex in the cluster do
11.   assign max. power in the power array to the vertex

end

3.2 Intercluster Topology Control with Interference Minimization

This phase is done in order to achieve topology control between clusters. This is established using the border nodes. A ‘border node’ refers to a node that belongs to a cluster and has a node in the neighboring cluster within its transmission range. The communication between two clusters is made by the usage of these border nodes.

TERMS:

- BIMAXMATCHING is used for calculating the matching cardinality.
- FINDKLINKS is used for finding ‘k’ links between the given cluster and the neighbouring clusters such that the resulting interference is minimal.

This algorithm computes the powers for the nodes in the cluster at which it is executing. Initially a graph is formed including the border nodes of the neighboring cluster. Then bimaxmatching is called. This returns the maximum matching cardinality (i.e) the number of links between the nodes of the cluster and the border nodes of the neighboring cluster. If this is less than the required connectivity then the power is assigned as the maximum power else find2links is called since the required connectivity is two. In this function two links are selected between the clusters such that power consumption and interference is minimized. This is done for all neighbouring clusters. Then the maximum of all the powers are assigned to the border nodes as the intercluster power.

After the intercluster phase, the intracluster power and intercluster power are compared for each node. The higher of the two powers is assigned as the final power of the node.

4. Implementation and Results

4.1 Assumptions

For implementing our proposed solution the following assumptions were made.
1) Each node has a weight.
2) Each node knows its own weight and position as well as the weight and position of its one-hop neighbours that fall within its maximum transmission range.
3) The ad hoc network considered is static.

4.2 Implementation

For measuring the performance of our topology control framework we implemented the framework and simulated it in the network simulator, ns2. We considered static ad hoc networks. The maximum powers of all nodes were set to 50 units. The simulation was carried out with the following scenarios.
a) Networks with densities 10, 12, 14, 16, 18 and 20.
b) For the network with 10 nodes, we considered two cases.

Case 1 - Nodes were placed in close proximity to each other.

Case 2 - Nodes were placed far away from each other.

The maximum values of interference were calculated before and after the application of our algorithm. The results are shown below in Fig. 4.1 and 4.2.

Interference Minimization

Network Density	Interference (Original)	Interference (Improved)
12	4	3
14	4	3
16	4	3
18	4	3
20	6	5

Table 4.1

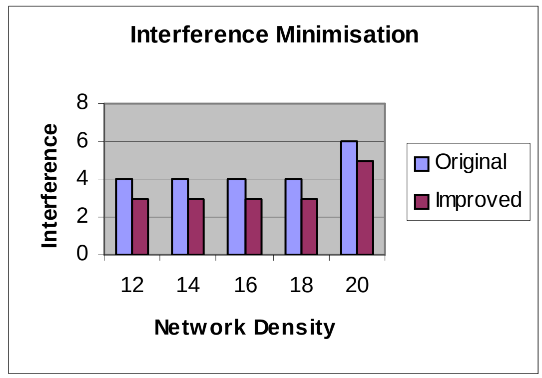

Fig 4.1

Interference Minimization for Topology with 10 Nodes

Topology	Interference (Original)	Interference (Improved)
Case 1	7	4
Case 2	1	1

Table 4.2

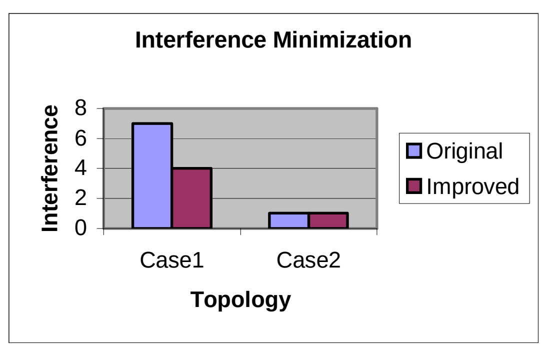

Fig.4.2

In Fig 4.2 a notable decrease in interference can be seen when the nodes are in proximity with each other. When they are sparsely distributed interference could not be reduced because the connectivity would be lost.

5. Future Work

1. The efficiency of our framework can be reduced by neighbouring nodes that are at the end of a node's transmission range. If the node is a clusterhead and the neighbour has to belong to its cluster then significant interference minimization cannot be achieved. Such a situation can be faced by initially considering nodes that fall within half of the clusterhead's maximum transmission range. The other neighbouring nodes can be considered after a certain time if they do not join any other cluster.

2. When all nodes are very close to each other the number of clusters will be very less. Thus the responsibility of the clusterheads will be very high because of the number of members that belong to them. This problem can be handled by keeping a limit on the number of members that can join a clusterhead.

6. Conclusion

In this work we have proposed a method of interference minimization while performing topology control in wireless ad hoc networks. The simulation results clearly indicate the effectiveness of the proposed algorithm.

7. References

[1] Chien-Chung Shen, Chavalit Srisathapornphat, Rui Liu, Zhuocuan Huang, Chaiporn Jaikaeo, Errol L.Lloyd, "CLTC: A Cluster-Based Topology Control Framework for Ad Hoc Networks", IEEE Trans. on Mobile Computing, vol. 3, no. 1,pp. 18 – 31, Jan-Mar 2004.

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[4] Stefano Basagni, "Distributed Clustering for Ad Hoc Networks", International Symposium on Parallel Architectures, Algorithms and Networks (I-SPAN'99), Fremantle, Australia, June 23-25, 1999, pp. 310-326.