A Pure Localized Algorithm for Finding Connected Dominating Set in MANETs by Classification of Neighbors

Hui Liu[1], Yi Pan[2], and Ivan Stojmenovic[3]

[1] Computer Science Department, Missouri State University, Springfield, MO 65897, USA
huiliu@missouristate.edu
[2] Computer Science Department, Georgia State University, Atlanta, GA 30303, USA
pan@cs.gsu.edu
[3] SITE, University of Ottawa, Ottawa, Ontario KIN 6N5, Canada
ivan@site.uottawa.ca

Abstract. An important problem in wireless ad hoc networks is to select a few nodes to form a virtual backbone that supports routing and other tasks such as area monitoring. Connected dominating set (CDS) has been proposed to approximate the virtual backbone. Although computing minimum CDS is known to be NP-hard, many distributed protocols have been presented to construct small CDS. However, these protocols are either too complicated, need non-local information or have slow convergence speed, are not adaptive to topology changes. In this paper, we propose a new pure localized algorithm for computing the approximate solution to the minimum CDS problem. The algorithm starts with a feasible and near-optimal CDS solution via marking process based on classification of neighbors, and removes vertices from this solution by redundancy elimination, until an approximate CDS is found. Both analytical and experimental results demonstrate that our algorithm has better performance than other distributed algorithms.

Keywords: connected dominating set, distributed algorithm, pure localized algorithm, routing, wireless ad hoc networks.

1 Introduction

The simplest way of updating routing information in wireless ad hoc and sensor networks is to send data about the neighborhood of nodes through all available links. The simple technique is called "global flooding". The main drawback of "global flooding" is the excessive amount of redundant rebroadcasts through the network, thus, degrading its available bandwidth, causing contention and collision easily, the lack of packet delivery successfully guaranteed, etc.

In order to avoid the "global flooding" problem, many researchers propose the promising idea of virtual backbones such as cluster-based routing, backbone-based routing and spine-based routing [1-4], even a mobile ad hoc network has no fixed backbone infrastructure. The basic idea behind this is to divide a mobile ad-hoc network into several small overlapping subnetworks, where each subnetwork is a clique (a complete subgraph). Each subnetwork has one or more virtual backbone

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hosts to connect to other parts in the network. These virtual backbone hosts form the core infrastructure of the ad-hoc mobile network. The routing process is operated over the core. As a result, any broadcasting of control packets only happens in the core, and communications between core nodes and non-core nodes are all through unicast communications. Therefore, this can substantially reduce the protocol overhead caused by global flooding. The number of hosts forming the virtual backbone must be as small as possible in order to reduce the protocol overhead, to increase the convergence speed, and to simplify the connectivity management. In this case, defining the structure of a suitable backbone is one of the subproblems that must be solved with the objective of providing optimal routing between clients.

We refer to nodes that are not selected for particular dominating set as being *covered* nodes. In case of routing, route through a covered node *A* may instead bypass it and traverse a connected set of its neighbors that cover it. More formally, a subset of nodes which is connected and which has the property that any node not in it is neighbor of at least one node from the subset is known as *connected dominating set (CDS).* Currently, Minimum Connected Dominating Set (MCDS) is the main method utilized to approximate the virtual backbone in a mobile ad-hoc network.

Various algorithms that construct a CDS in ad hoc networks have been proposed in recent years. They can be divided into two categories: centralized algorithms that depend on network-wide information or coordination and decentralized that depend on local information only. Centralized algorithms usually yield a smaller CDS than decentralized algorithms, but their application is limited due to the high maintenance cost and is not practical in wireless ad hoc networks. Decentralized algorithms can be further divided into cluster-based algorithms and pure localized algorithms. Cluster-based algorithms have a constant approximation ratio in unit disk graphs, however it has relatively slow convergence ($O(N)$ in the worst case). Pure localized algorithms take constant steps to converge, produce a small CDS on average, but have no constant approximation ratio.

Wu and Li [5] introduced first fully localized dominating set definitions. Each node is marked as white initially. Let $N(v)$ be the open neighbor set of vertex v, which means $N(v)$ includes all the neighbors of vertex v. And let $N[v]$ be the closed neighbor set of vertex v, the set of all neighbors and itself. By assumption, each node has a unique ID number. This algorithm runs in two phases. In the first phase, each node broadcasts its neighbor set $N(v)$ to all its neighbors, and after collecting all adjacency information from all neighbors every node marks itself as black if there exist two unconnected neighbors. All black nodes form the initial CDS. However, considering only the first phase, there are too many nodes in the dominating set. So in the second phase, the algorithm executes extensional rules to eliminate local redundancy. Wu and Li [6] proposed several dominant pruning rules, which are rule 1, rule 2 and a generalized rule K. Thus, the second phase removes some nodes from the original dominating set and the size of a dominating set is further reduced.

Finding minimum CDS on graphs is a NP-complete problem. Authors in [7] explore the local structure of the neighborhood of a single vertex and the union of the neighborhoods of a pair of vertices, and propose a polynomial-time data reduction for dominating set. Their target is to deal with the NP-complete dominating set problem in graph theory and combinatorial optimization. However, the local structure analysis