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Procedia Computer Science 63 (2015) 482 – 487

Procedia Computer Science

Seventh International Symposium on Applications of Ad hoc and Sensor Networks (AASNET'15)

Distributed Computation of Connected Dominating Set for Multi-hop Wireless Networks

Simi Surendran, Sreelakshmy Vijayan

AMRITA University,Kollam-690525,India

Abstract

In large wireless multi-hop networks, routing is a main issue as they include many nodes that span over relatively a large area. In such a scenario, finding smallest set of dominant nodes for forwarding packets would be a good approach for better communication. Connected dominating set (CDS) computation is one of the method to find important nodes in the network. As CDS computation is an NP problem, several approximation algorithms are available but these algorithms have high message complexity. This paper discusses the design and implementation of a distributed algorithm to compute connected dominating sets in a wireless network with the help of network spectral properties. Based on local neighborhood, each node in the network finds its ego centric network. To identify dominant nodes, it uses bridge centrality value of ego centric network. A distributed algorithm is proposed to find nodes to connect dominant nodes which approximates CDS. The algorithm has been applied on networks with different network sizes and varying edge probability distributions. The algorithm outputs 40 % important nodes in the network to form back haul communication links with an approximation ratio $\leq 0.04 * \partial + 1$, where ∂ is the maximum node degree. The results confirm that the algorithm contributes to a better performance with reduced message complexity.

Peer-review under responsibility of the Program Chairs

*Keywords:*Connected Dominating Set; Distributed Algorithm

1. Introduction

In large wireless multi hop networks, efficient mode of message transmission is always an overhead. To solve this overhead of passing messages, topology control mechanisms such as finding connected dominating set (CDS) can be devised. Selecting a set of cluster heads helps in sending messages easily, hierarchically from one cluster to the other and the cluster heads will oversee the routing inside the corresponding clusters and also among the different clusters. A connected dominating set[1] is a set D of vertices with the properties that any node in D can reach any other node in D by a path that stays entirely within D and every vertex in graph either belongs to D or is adjacent to a vertex in

Peer-review under responsibility of the Program Chairs
doi:10.1016/j.procs.2015.08.372

D. A Dominating Set is called a CDS if the sub-graph induced by the vertices in the DS is connected. As the nodes in the network are not with the capability to undertake such complex algorithms as for finding the CDS, it is an NP-complete problem and there by cannot compute an optimal solution in polynomial time. Thus, the possible way is to approximate the CDS.

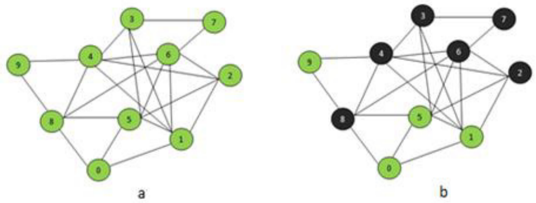

Fig. 1 (a) Initial graph; (b) CDS.

This paper proposes a method to approximate connected dominating set in a large network graphs using the spectral properties of graphs. It computes an ego centric network and uses the partial adjacency matrix for computing the importance factor. Node importance factor is computed using ego network bridge centrality and used a distributed algorithm to form the connection between important nodes. The nodes are considered to be placed arbitrarily according to some probability distribution and are considered to move frequently. The method of finding the CDS is such that it does not transfer much messages for finding CDS and here random geometric graphs are taken. The cluster heads are found which are distributed and such that they form a connection among them, thus forming the connected dominating set. In the proposed work 40% of the total network nodes were found to be selected as members of CDS with reduced message complexity and with a bound $|CDS| = 0.8 * |OPT| + 0.5 * \partial - 2.91$ where, OPT is the minimum connected dominating set and '∂', the maximum degree.

The remainder of the paper is organized as follows: Section 2 deals with the works related to the area. Section 3 describes the algorithms for computation of CDS and the analysis of the results. The performance analysis is presented in Section 4 followed by conclusion.

2. Related Works

The idea of using a CDS as a virtual backbone [7] was first proposed by Ephremides et al. in 1987. There have been many other works which were done based on this backbone formation (CDS). In the earliest works the authors proposes the polynomial self-stabilizing distributed algorithm for the minimal total dominating set problem in an arbitrary graph. In those works there were no connections that were formed among the nodes inside the dominating set. Some of the self-stabilizing algorithms for well known graph problems and some more recent algorithms are given in [17-18]. In the work [4] the authors have presented a polynomial self stabilizing algorithm to construct a minimal total dominating set in an arbitrary graph. This paper also provides polynomial self stabilizing algorithms for the minimal total k-dominating set. It is proved that these algorithms converge in O(mn) moves and the storage required per node was required about O(log n) storage per node. The paper finds the minimal total dominating set by assigning each node with a variable state showing whether the corresponding node is inside or outside the dominating set. It has been found that once a node gets dominated, it remains dominated and also if a node leaves the dominating set, it will never move again.

In the case of [5] the authors present a greedy approximation algorithm for computing a Minimum CDS in multi hop wireless networks with disparate communication ranges and prove that its approximation ratio is better than the best one known in the literature. In the real scenario the situation is different that the communication ranges may differ from nodes to nodes. This work looks for a tighter relation between the independence number and the connected domination number. These numbers are important in the cases of two phase approximation algorithm for CDS where the first phase constructs a dominating set, and the second phase selects additional nodes to interconnect the nodes in the dominating set. In the paper they have found a good approximation bound. size. But, on considering such a situation the routing paths also should be given due consideration and thereby reducing the routing cost. In the method given in [7] there are two steps for finding the backbone network, first is to find MIS(maximal