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Issues and Challenges

S. Smys and Dr. G. Josemin Bala

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S.Smys[1], Dr. G.Josemin Bala [2]

[1] Assistant Professor, Department of Electronics and Communication, Karunya University, Coimbatore, India. smys@karunya.edu

[2] Professor and Head, Department of Electronics and Media Technology, Karunya University, Coimbatore, India. josemin@karunya.edu

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ABSTRACT

As there is no fixed infrastructure in mobile ad hoc networks virtual backbones are proposed in many wireless applications. Terminals in ad hoc networks are free to move anywhere at any time. Each terminals which change as position as to execute a maintenance procedure to connect the backbone. Existing research works mainly concentrate on construction of virtual backbone to avoid broadcasting storm problem with minimum dominating set. One issue in mobile ad hoc networks is constructing and reconfiguring a virtual backbone with nodes of various transmission powers and maintaining the network topology during mobility. This paper mainly concentrates on reconstruction virtual backbone during mobility and without the need for reconstructing the whole connected dominated set (CDS).

Although CDS construction approaches are able to approximately find a near optimal CDS, they do not support reconfiguration of the network and especially, node mobility. As an instance, consider a mobile node leaves its neighbors and travels until reaches a particular destination. Therefore, the CDS is required to be reconstructed twice when the mobile node leaves and also when it stops traveling. Constructing the whole CDS twice from the scratch imposes extra load on all network nodes. In addition, energy balancing approaches of virtual backbone also follow the same scheme i.e. lack of energy in one node generates a new CDS for all nodes. To the best of our knowledge, there is no work which regards reconfiguring a CDS. In this case, only neighbors of a mobile or low energy node are reconfigured in such a way that the CDS properties are preserved. In this paper we examine various strategies that have been used to support various power levels and mobility in virtual backbone environment for improved performance. The purpose of this paper is to investigate the network modeling issues in ad hoc wireless networks under a virtual backbone scheme.

Key Words: *Connected Dominating Set (CDS)*; *Virtual Backbone (VB); Reconfigurable Networks (RN); Mobile Ad-Hoc Networks (MANET).*

1. INTRODUCTION

An ad hoc network is an infrastructure less and no centralized control network that is established between groups of mobile nodes which share the same wireless communication medium. The nodes may personal computers, notebooks, PDA'S and other devices. It is mainly useful in emergency operations such as rescue and military applications. A mobile ad hoc Network (MANET) is a self-organizing to provide communication throughout the entire network; nodes are designed to serve as routers. The result is a distributed multi-hop network with a time-varying topology. Hence, the topology and capacity control are critical issues. The recent trend is implementing ad hoc features in sensor networks. The characteristic of an ad hoc network is highly dynamic topology, unreliable communication links and dynamic routing. However, the properties of frequently route breakage and unpredictable topology changes in MANETs [1] still make most of these traditional routing protocols inherently not scalable with respect to number of nodes, control overhead, and degree of mobility. In order to provide routing scalability, a hierarchical of layers is usually imposed in the network where subsets of mobile nodes are selected to form a virtual wireless backbone. The basic motivation of creating the virtual backbone is the substantial reduction of protocol overhead and the minimization of storage requirements as compared with a pure flooding mechanism in flat structure. A common source of overhead in a MANET comes from blind flooding/broadcasting, where a broadcast message is forwarded by every node exactly once. Broadcasting is used in the route discovery process in several reactive routing protocols. Due to the broadcast nature of wireless communication (i.e., when a source sends a message, all its neighbors will hear it), blind flooding/broadcasting may generate excessive redundant transmission. Redundant transmission may cause a serious problem, referred to as the broadcast storm problem [2], in which redundant messages cause communication contention and collision, and this effect is shown in figure 1.

When each node forwards the message once, node *F* will receive the same message five times. If all nodes send the same message to F, it will lead to broadcast storm problem.

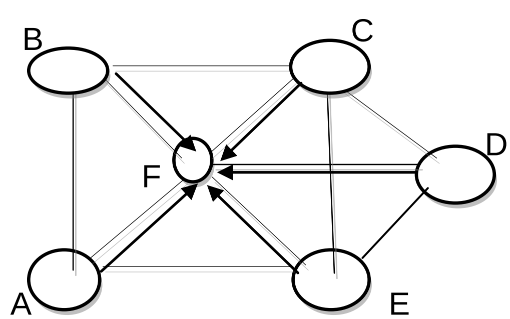

Fig.1-Broadcast storm problem

In virtual backbone concept whereby few of the network nodes are selected as dominating points to access other nodes in the network. A connected dominating set (CDS) can form an interesting virtual backbone. A dominating set (DS) of a graph is a subset of nodes such that each node in the graph is either in the subset or adjacent to at least one node in that subset. A connected DS (CDS) is a DS in which all nodes are connected to at least one other node.

This paper consists of the following sections. In section 2, we briefly give the overview of network model, in section 3 virtual backbone construction in detail, section 4 describes the reconstruction of VB, and section 5 concludes the paper.

2. OVERVIEW OF NETWORK MODEL

The following sections deals with various graphs for modeling Ad-Hoc network.

2.1 Unit Disk Graph

For same transmission range unit disk graphs (UDG) [3] are required. Note that, in this case, G is undirected. With unit-disk graph, a network consists of a set of nodes located on a flat surface, and a link between two nodes exists if and only if the distance between these two nodes is less or equal than a unit threshold. A network modeled by a unit-disk graph has the following characteristics:

All links are bi-directional: if a link from one node, u, to another node, v, denoted as (u, v) exists, the link from v to u, (v and u) should also exist. If two nodes share a common neighbor, the probability that these two nodes are neighbors of each other (noted as clustering coefficient is very high. For its simplicity and well characterization of wireless communication pattern (in an ideal scenario), unit-disk graph has been the mostly used graph model for the topology of a wireless multi-hop networks. However, for unit-disk graph to model a wireless multi-hop networks perfectly, the following assumptions must hold:

1) Omni directional antenna
2) All nodes use the same wireless technology
3) All nodes have the same transmission power and propagation Condition
4) No interference/Perfect interference cancelation
5) All nodes operate at the same channel

2.2 Random Partial Digraph model

Despite of its popularity, unit-disk graph is not the perfect topology model due to the following factors besides distance that influence the existence of links:

* Transmission power control
* Modulation and coding scheme selection
* Parameters for medium access control
* MIMO scheme selection
* Environment factors affecting the propagation condition, e.g. obstacles

Due to the lack of a comprehensive topology model in the literature, we decide to introduce a very general model, i.e. random partial digraph model [4]. With this model, the link between any ordered node pair is modeled to be on with a certain probability, which leads to a partial digraph where both bidirectional and unidirectional links may exist.

2.3 Disk Graph (DG)

A disk graph (DG) is an intersection graph of set of disks in the Euclidean plane. Recently, there has been increasing interest in studying the class of DGs. This primary motivated by its applications which can be found in radio networks, map labeling, and in sensor networks, just to name a few. From another side, DGs have a very simple geometric structure. Every node has the different transmission range so that the network topology can be modeled using disk graph (DG). Note that G is directed, consisting of both bidirectional and unidirectional links. Node locations are modeled as Euclidean points, and the area within which a signal from one node can be received by another node is modeled as a circle. If all nodes have transmitters of different power, these circles are all not equal. Random geometric graphs, formed as disk graphs with randomly generated disk centers. It is NP-hard to determine whether a graph, given without geometry, can be represented as a disk graph. However, many important and difficult graph optimization problems such as maximum independent set, graph coloring, and minimum dominating set can be approximated efficiently by using the geometric structure of these graphs, and the maximum clique problem can be solved exactly for these graphs in polynomial time, given a disk representation. When a given vertex set forms a subset of a triangular lattice, a necessary and sufficient condition for the perfectness of a unit graph is known [3]. For the perfect graphs, a number of NP-complete optimization problems (graph coloring problem, maximum clique problem, and maximum independent set problem) are polynomially solvable.

2.4 Growth-Bounded Graph

The growth-bounded graph captures the intuitive notion that if many nodes are located close from each other, many of them must be within mutual transmission range. In graph theoretical terms, a graph is growth-bounded [4] if the number of independent nodes in a node's *r*-neighborhood is bounded. We have the following definition.

An undirected graph $G=(V, E)$ is called a growth-bounded if there exists a polynomial bounding function $f(r)$ such that for every $v \in V$ and $r \geq 0$, the size of any maximal independent set in the *r*-neighborhood $\Gamma_r(v)$ is at most $f(r)$. Further, we say that G has polynomially bounded growth if $f(r)$ is a polynomial $p(r)$.Note that $f(r)$ does not depend on the number of vertices in the graph, but on the radius of the neighborhoods only.

2.5 Comparison of various virtual backbone algorithms

Each graph is used to model the wireless link and network in the AdHoc domain. But compare to all unit disk graph(UDG) mainly used to model the wireless network, because it support bi-directional links, high node transmission power and transmit power in all direction equally. These same phenomena happen in real world computer communication. Based on the graph modeling we give the comparison table given below, which relates the hop limit, simulation time and message length etc. The complexity level of 2-hop based VB constructions is high compare to one hop algorithms, due to high control overhead. There exist several distributed algorithms ([5] [6][7][8]) for CDS computation in the context of ad hoc wireless networking. The one in [5] first builds a rooted tree distributedly.Then the status (inside or outside of the CDS) is assigned for each host based on the level of the host in the tree. Das and Bhargavan in [5] provide the distributed implementation of the two centralized algorithms given by Guha and Khuller [9]. Both implementations suffer from high message complexities. The one given by Wu and Li in [6] has no performance analysis. It needs at least two-hop neighborhood information. The status of each host is assigned based on the connectivity of its neighbors.

Performance comparison of various VB construction algorithms based on the graph model is shown in Table 1.

	[5]	**[6]**	**[7]**	**[8]**
Cardinality	≤(2ln□ □+3)opt	N/A	≤8opt+1	<8 opt
Message	O((n│C│+m+n*log* n)□ □)	O(n□)	O(n n*log* n)	O(n)
Time	O((n+│C│)□ □)	O(□ □ □)	O(n□)	O(n□)
Msg length	O(□)	O(□)	O(□ □	O(□ □
Information	2-hop	2-hop	1-hop	1-hop

Table 1: Performance comparison of the algorithms in [5], [6], [7], [8]. Here *opt* is the size of the given instance; D is the maximum degree; *C* is the size of the generated connected dominating set; *m* is the number of edges; *n* is the number of hosts**.**

3. VIRTUAL BACKBONE CONSTRUCTION

In this section we specify the research problem and modeling of virtual backbone in MANET.

3.1 Research problem in Virtual Backbone (VB) based wireless networks

Virtual Backbone (VB) construction approaches are able to approximately find a near optimal CDS; they do not support reconfiguration of the network and especially, node mobility. As an instance, consider a mobile node leaves its neighbors and travels until reaches a particular destination. Therefore, the CDS is required to be reconstructed twice when the mobile node leaves and also when it stops traveling. Constructing the whole CDS twice from the scratch imposes extra load on all network nodes. In addition, energy balancing approaches of virtual backbone also follow the same scheme i.e. lack of energy in one node generates a new CDS for all nodes. To the best of our knowledge, there is no work which regards reconfiguring a CDS. In this case, only neighbors of a mobile or low energy node are reconfigured in such a way that the CDS properties are preserved. In this paper we examine various strategies that have been used to support various power levels and mobility in virtual backbone environment for improved performance. To overcome twice reconstruction problem we give the localized reconstruction algorithm in section 4.1.

3.2 VB formation

From our analysis Greedy algorithms are used to construct virtual backbone in MANET. Normally Dijsktra algorithm used to find the shortest path between nodes and kruskal algorithms used to find the minimum spanning tree (MST).The following steps are used to construct virtual backbone

i) Calculate the spanning tree of the network.
ii) Non selection of edge node, hence only 50% of the nodes act as a backbone node

In this way only half of the nodes will act as a virtual backbone node, which will give extra life time for the network (i.e. network life time increased).The virtual backbone concept is shown in figure 2. Network with few forwarding nodes (G, D), black nodes-VB nodes, and white nodes are-non VB nodes. The selection of virtual backbone is based on greedy algorithm like kruskal algorithm.

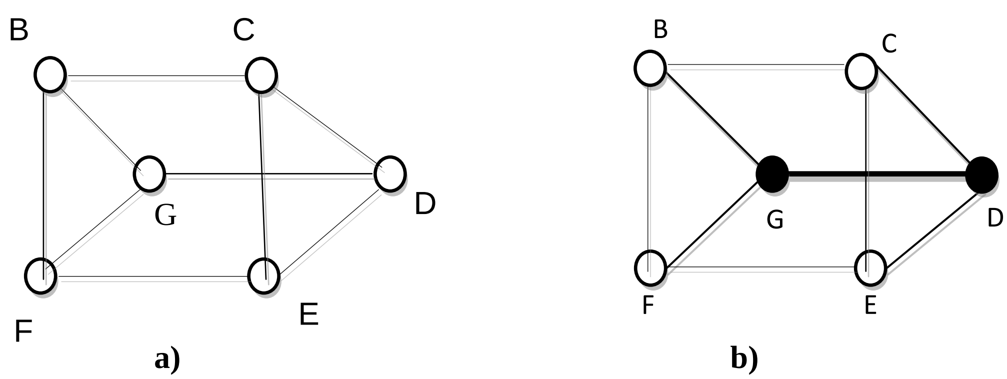

Figure.2 a) Node connectivity in ad-hoc network. b) Network with few forwarding nodes (G, D), black nodes-VB nodes, and white nodes are-non VB node.

3.3 Creation of Virtual backbone in UDG

A graph *G (V,E)*, a Dominating Set *S* of *G* is defined as a subset of *V* such that each node in *V\S* is adjacent to at least one node in *S*. A Connected Dominating Set (CDS) *C* of *G* is a dominating set of *G* which induces a connected sub graph of *G*. The nodes in *C* are called dominators, the others are called dominatees. A CDS is a set of nodes inducing a connected sub graph and having the property that every node in the network is either in the set, or has at least one directly connected neighbor in the set. Only nodes in the backbone forward (rebroadcast) messages. When all nodes use constant and identical transmission power, energy-efficient broadcasting amounts to minimize the size of the backbone, i.e., the cardinality of CDS A connected dominating set (CDS) is a good candidate of a virtual backbone for wireless networks, because any node in the network is less than 1-hop away from a CDS node. Only the backbone nodes are responsible for relaying messages for the network.

Using this virtual backbone, a sender can send messages to its neighboring dominator. Then along the CDS, the messages are sent to the dominator closest to the receiver. Finally, the messages are delivered to the receiver. Furthermore, a CDS can also be organized into a hierarchy to reduce control overhead. Computing a minimal CDS (denoted by MCDS) of a UDG graph has been proved to be NP-hard .Therefore; CDS construction approaches try to generate a CDS of small size as much as possible. They usually generate a maximal independent set (MIS) in order to heuristically find a CDS. An independent set (IS) of a graph is a subset of V that no two nodes in the subset have an edge. An MIS of a graph is an independent set that cannot include any more nodes in V. Coloring scheme used differentiate dominators (VB nodes) and dominates (other nodes in the network),where black nodes are dominators and blue nodes are dominatees. Each vertex of G is said to dominate every neighbor vertex. A subset S, $S \subset V$ is a dominating set if each node u in V is either in S or is adjacent to some node v in S. Nodes from S are also called dominators. A dominating set with minimum cardinality is called minimum dominating set.

3.4 Two widely used applications of VB constructions

Determining a connected dominating set (CDS) for efficient routing, Selecting an appropriate transmission range of each node for topology control algorithms proposed in [5-8].A CDS is a subset such that each node in the system is either in the set or the neighbor of a node in the set. The CDS has been used widely to support the notion of a *virtual backbone* in MANETs. A number of algorithms have been proposed for the problem of finding a CDS of minimum size. We refer to [7], [8], and for surveys of these algorithms. The algorithms can be classified into two categories. The first category consists of algorithms that construct a CDS from scratch by successively adding nodes to the backbone. Algorithms in the second category prune nodes from a backbone that contains redundant nodes.

Wu and Li [6] proposed a self-pruning process, called marking process, to construct a CDS. Marking process: Each node is marked if it has two unconnected neighbors; otherwise, it is unmarked. The marked nodes form a CDS, which can be further reduced by applying Dai and Wu's pruning rule k [10] (i.e., changing a marked node back to an unmarked node).Pruning Rule k: A marked node can unmark itself if its neighbor set is covered by a set of connected nodes with higher priorities. The following MANET routing algorithm based on the concept of Virtual Backbone Routing (VBR).Area of operation divided into square hexagonal cells (like cells in cellular network).In each cell one node is a dominator and it performs the inter-cell communication is through the dominators of other cells in the network. Nodes communicate through their cell dominators. A node initiates the Hello message to its neighbor and waits for the reply. If it not receives any response from other nodes, it declared itself as a router. The new router sends a RH (Router Here) message. This is used to prevent multiple routers in a cell. Before moving cells a router hands off routing information. In this way multiple routers in various cells are created. The newly created routers are forming the virtual backbone using any one of the previous algorithms**.** For construction of the VB Greedy algorithms mainly used. Normally Dijsktra algorithm is used to find the shortest path between nodes and kruskal algorithms are used to find the minimum spanning tree (MST).

4. RECONSTRUCTION OF VB

In order to reconstruct virtual backbone hello packets are exchanged periodically between nodes. The details of modified hello packet with various fields are given in figure 3.

<table>
<tr><td colspan="2">Source(32 bit)</td></tr>
<tr><td colspan="2">Destination(32bit)</td></tr>
<tr><td colspan="2">Dominator(32bit)</td></tr>
<tr><td>State(2 bit)</td><td>Power(8 bit)</td></tr>
<tr><td colspan="2">Dominatee(32bit)</td></tr>
</table>

Fig.3-Modified hello packet

During the reconstruction a terminal can be one of the following states

- Dominator-a CDS node
- Dominatee-non CDS node, neighbor of dominator
- Leaving node-node in active condition (i.e. node in movement)
- Stable state-node enter to a new set

Power indicates the life time of the VB/Non-VB node.

4.1 Algorithm for R-VB

The following algorithm which is able to reconstruct a CDS without the need for whole reconstruction of the CDS. Whenever a change occurs and locally finds a new configuration for 1-hop neighbors of the node which experiences mobility or low energy, based on 2-hop neighborhood information in such a way that the new configuration is also a CDS.

Algorithm

On receiving control message, VB functions

Dominator

Step 1 : Send Non VB in movement nearby VB
VB update, its one hop neighbor

Dominatee

Step 2 : State change process indication to VB
Handover routing information to one hop VB

New Dominator

Step 3 : Exchange the power information to new VB (if VB move to other place named as New-VB)

Dominatee – Enter New State

Step 4 : Change to Non VB and Attach to New VB

Let *v* is a node which is experiencing a change in state. This node executes the above method. If *v* is a node, it only reacts to loosing a link. In this situation, *v* sends a leave dominatee message to its neighbors to inform them that it is leaving the neighborhood and also updates its local information. The dominator informs the new states using an update message. If the dominator node change their position, it inform to its one hop neighbor. Similarly non CDS node perform the same function to its one hop non-CDS or to a dominator node.P.Teymoori and N.Yaqdani [11] proposed a reconfiguration algorithm that reconstructs a CDS locally which has $O\ (\Delta \log \Delta)$ time complexity and $O(\Delta)$ message complexity. Our algorithm also achieves the same time and message complexities, because of each packet process a small control packet. During the movement of mobile nodes topology and backbone maintenance are the important issues. When the VB node in movement, CDS maintained by send the control information to the nearby one hop neighbor.

5. CONCLUSION

In this paper, we discussed the problem of maintaining a CDS-based virtual backbone and in-depth study of the construction of the virtual backbone with the fewest forwarding nodes in ad hoc networks. Since there is no fixed infrastructure most of the routing protocols mainly suffered from broadcast storm problem, to overcome this problem, we proposed a reconfiguration algorithm that reconstructs a CDS locally which has $O(\Delta \log \Delta)$ time complexity and $O(\Delta)$ message complexity. To achieve this maintenance procedure, changes required in state transit terminals only, no modification required in the rest of the network. We summaries many information's for construction and reconfiguration of virtual backbone that is useful for researchers in wireless networks. We also conclude that localized reconstructions perform better results in multihop wireless networks.

REFERENCES

[1] D. Johnson and D. Maltz, *Dynamic Source Routing in Ad Hoc Wireless Networks.* Kluwer Academic, 2001.

[2] Y.C. Tseng, S.Y. Ni, Y.S. Chen, and J.P. Sheu," The Broadcast Storm Problem in a Mobile Hoc Network," *Wireless Networks,vol.8,nos.2-3,pp.153-167,Mar.-May 2002.*

[3] B. Clack, C. Colbourn, and D. Johnson, "Unit Disk Graphs," *Discrete Math., vol.86, pp.165-177, 1990.*

[4] Fabian Kuhn, Thomas Moscibroda, Tim Nieberg, A.R.W. Fast Deterministic Distributed Maximal Independent Set Computation on Growth-Bound Graphs. *International Symposium on Distributed Computing*, Cracow, Poland, September 2005.

[5] B. Das and V. Bhargavan, Routing in ad hoc networks using minimum connected dominating sets, *Communications, 1997.ICC '97 Montreal, Towards the Knowledge Millennium. 1997 IEEE International Conference on,* Vol. 1, 1997,pp. 376-380.

[6] J.Wu and H.Li, On calculating connected dominating set for efficient routing in ad hoc wireless networks, *Proc. of the 3rd International Workshop on Discrete Algorithms and Methods for MOBILE Computing and Communications, 1999,* Seattle, WA usa, pp.7-14.

[7] K.M.Alzoubi, P.J.Wan and O.Freider, Message-efficient distributed algorithms for connected dominating set in wireless ad hoc networks, *manuscript, 2001.*

[8] Sergiy Butenko, Xiuzhen Cheng, Ding-Zhu Du, and Panos M. Pardalos,"On the construction of virtual backbone for ad hoc wireless network" Conference on Cooperative Control and Optimization,Feb,2002.

[9] S. Guha and S. Khuller, Approximation algorithms for connected dominating sets, Algorithmic, Vol. 20(4), April 1998, pp. 374-387.

[10] F.Dai and J.Wu,"Distributed Dominant Pruning in Ad Hoc Wireless Networks,"*Proc.IEEE Int'l Conf. Comm.,* vol.1, pp.353-357, May 2003.

[11] Peyman Teymoori and Nasser Yazdani,"Local Reconstruction of Virtual Backbone to Support Mobility in Wireless Ad Hoc Networks", IEEE Int'l Symposium on Telecommunication, 2008.