An Articulation Point based Approach to Create Virtual Backbone in Mobile Ad Hoc Networks

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ABSTRACT

Connected Dominating Set is used for constructing virtual backbones in mobile ad hoc network. Virtual Backbone works as is a core group of mobile nodes. All the communication in MANET held with the help of Virtual Backbone. Mobile Ad hoc Network use undirected graph as more suitable model. In this paper we have proposed an algorithm to find Virtual Back Bone in Undirected Graph for MANET. Proposed algorithm is based on the computation of articulation point (AP) in Undirected Graph. Constructing a virtual backbone in MANET is an important issue because it reduces unnecessary message transmission or flooding in the network. It helps in to reduces channel bandwidth consumption, the Energy consumption and provide better resource management.

Keywords

Virtual Backbone, Undirected Graph, Mobile Ad hoc Networks, Adjacent Node, Articulation Point, Dominating Set

1. INTRODUCTION

A MANET is a dynamic and distributed system of wireless nodes that move independently of each other random speed and random direction. MANET routes are often multi-hope in nature because each wireless node has limited transmission range. MANET routing protocols are categorized in two types [1][2]: proactive and reactive. Proactive routing protocols determine routes between every pair of nodes in the network in advance. Reactive protocols determine routes between every pair of nodes only if data needs to be transferred, no route determine in advance between the sender and receiver. In reactive protocol route is calculated on demand basis.

The algorithms proposed for MANET is based on a connected dominating set (CDS). CDS is a suitable approach in adapting quickly to the unpredictable dynamic topology in nature of a MANET [3]. This approach is the most adaptable because whenever the topology changes it do not affect the basic structure of the CDS. In this situation CDS is not reconfigure since the routing paths based on the CDS would still be valid. A MANET is often represented as a unit disk graph (UDG) [4] built of vertices and edges, where vertices signify nodes and edges signify bi-directional links that exist between a pair of nodes if they are within a transmission range of each other's. Routing based on a CDS within a MANET means messages will be routed through only amongst the CDS nodes and not broadcast by every node in the network; this reduce the number of unnecessary transmissions of messages in routing [6].

The CDS can be formatted with multiple ways and the algorithm used to format CDS affect the lifetime, performance and efficiency of MANET as a whole. A popular approach in CDS formation is attempting to form the smallest possible CDS within a MANET, referred to as a minimum connected dominating set (MCDS). Reduction the size of the CDS mean reduction the number of unnecessary message transmission in the network. The problem of determining a MCDS in an undirected graph like that of the unit disk graph is NP-complete [7][9]. Efficient heuristics [7][8][9] have been proposed to approximate the MCDS in wireless ad hoc networks. A common thread among these heuristics is to give the preference of CDS inclusion to nodes that have high degree or neighborhood density.

2. RELATED WORK

There are lot of work done on routing protocols on MANET. Routing protocols are classified into three generations these are based on their working principles and performances. Each generation has its own characteristics and contributions.

The first generation of routing schemes for MANET primarily focuses on data collection. It mainly includes reactive and proactive routing protocols [13]14]. The proactive protocols, such as Optimized Link State Routing (OLSR) protocols [16] and Destination Sequenced Distance Vector (DSDV) [14][15], need to maintain consistent up-to-date routing information from each node to every other nodes in the network. Reactive protocols, such as Ad-hoc On-demand Distance Vector Routing (AODV) protocosl [19][20] and Dynamic Source Routing (DSR) [17][18], construct routes from source node to destinations node only when they required to transmit message. The requirement of transmission is initiated by the source node. When a source node requires a route to a destination node in the network, source node floods a route request message within the network. If any node receives a route request, it always responds with a route reply. Unfortunately, this process may lead to significant flooding in the network in order to discover the desired route. The first generation wireless network requires large bandwidth and energy due to the flooding traffic involved. Also it is quite difficult to be implemented in a large wireless network.

The second generation of routing protocol for MANET is the coordinator-based routing protocol which uses coordinator-based identifier [10][11][12] to locate nodes and perform the searching and routing process. Beacon Vector Routing protocol (BVR) [11] and Greedy Perimeter Stateless Routing (GPSR) [10] belong to this category. These schemes need the global or local coordinators to direct the routing process. The coordinator-based routing protocols are efficient and smart, since they utilize the geographic information to get the accurate address of the destination and use this information to forward packets.

However, in order to implement the coordinator-based searching and routing functions, we need to set up the fixed infrastructures for the servers [10] or beacons [11] and maintain them as well. Initially, it allows a group of distributed nodes to collectively manage a mapping from keys to data values, without any fixed hierarchy, and with a very little human assistance.

The third generation of wireless network with virtual backbone is more useful due to less involvement of routing nodes. Recently, the development of virtual backbone routing scheme belongs to the CDS routing category. With the associated backbone nodes, normal nodes in this structure can maintain their natural connection relationship and find other nodes' relationships, which can efficiently mitigate the dead-end problem. With the virtual backbone structure, packets do not need to go through every node in the network to a destination node. Instead, lots of packets can be forwarded directly to their destination with the support of backbone node's directly.

Guha and Khuller [25] studied the MCDS problem and showed that this problem is NP hard in an arbitrary undirected graph. Later it was shown in [21] that computing an MCDS for a Unit Disk (UD) Graph is also a NP hard problem. Alzoutri et al. [23] proposed the first distributed algorithm guaranteeing a constant approximation factor for CDS construction based on MIS in UD Graph. A minimum size CDS for UD Graph can be constructed with distributed algorithm was provided in [24]. It also provide an analysis of the size of MCDS and the size of the MIS. This algorithm also produces an optimal CDS if the graph is a tree. An algorithm is proposed to find MCDS using dominating set in UD Graphs in [22]. This algorithm works in Phasess. First Phase, found dominating sets. Second Phase, identify connectors, connected through Steiner tree. Third Phase, the CDS obtained a MCDS. Network needs to adapt to the continuous topological changes due to deactivation of a node due to exhaustion of battery. These changes are taken care by a local repair algorithm that reconstructs the MCDS if nacessary. i.e. power aware MCDS using only neighborhood information.

3. ARTICULATION POINT CALCULATION

Articulation point can easily be find by using Depth-First Search (DFS). In a DFS tree should be an undirected graph, a node u is an articulation point, for every child v of u, if there is no back edge from v to a node higher in the DFS tree than u. That is, every node in the decedent tree of u have no way to visit other nodes in the graph without passing through the node u, which is the articulation point. Thus, for each node in DFS traversal, we calculate dfsn(v) and LOW(v). The definition of LOW(v) is the lowest dfsn of any vertex that is either in the DFS sub-tree rooted at v or connected to a vertex in that sub-tree by a back edge. Then, in DFS, if there is no more nodes to visit, we back up and update the values of LOW as we return from each recursive call.

DFS is a recursive algorithm and stack is used to trace back the recursive calls. When we process an edge (u, x) - either by a recursive call on vertex x from vertex u, or (u, x) is back edge, we push that edge to a stack. Later, if we identify u as an articulation point, then all edges from the top of the stack down to (u, x) are the edges of one bi-connected component. So, we pop edges out of the stack until the top of the stack is (u, x). Those edges belong to a bi-connected component.

4. PROPOSED ALGORITHMS

This algorithm utilize the Articulation Points have been proposed in this section. This algorithm is variation of [26].

4.1 Algorithm

This Algorithm is an improvement on Guha and Khuller's algorithm with addition of Articulation Point concept. This algorithm works in two part. In Part One, it finds Articulation Points and connect them. In Part Two, it generates Minimum Dominating Set Nodes in Connected manner.

4.1.1 First part

Initially all articulation points are computed and if articulation points are not connected then connect them by using shortest path algorithms. Series of nodes are generated this way. Further, Generated Nodes (including Articulation Points) are colored Black and all adjacent nodes are colored Gray.

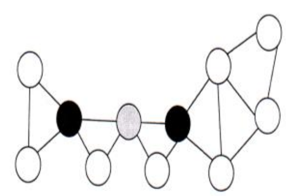

Figure 3 : DS induced by algorithm

In the above figure 3, black nodes are the articulation points. Since articulation points are not connected using shortest path algorithms a gray node is discovered to connect articulation points. This gray node is declared as part of DS and colored black as shown in figure 4. Gray nodes shown in figure 4 represent the covered nodes (CN) of Dominating Set (DS) like in proposed algorithm.

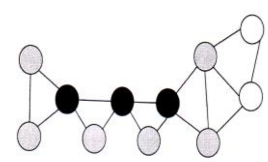

Figure 4 : CDS induced by algorithm

4.1.2 Second part

A gray node which is connected with maximum number of white adjacent nodes is selected and colored black. Second Part is repeated till no white nodes left in the graph. Finally a series of black nodes are generated as CDS. This part of algorithms is also completely dependent on existence of articulation points.

4.2 Characteristics of the proposed approaches

- To select articulation point heuristic used in this approach is an optimal choice for selection of Starting Node.
- Proposed approach gives lesser CDS size as compared to algorithm discussed in [26] and [27].
- Proposed approach is more suitable for large network.
- As the number of articulation points goes high in the network, this approach gives more optimal solution.
- Proposed approach increases the Bandwidth Efficiency.

- Proposed approach reduces Channel Bandwidth and Energy consumption.

5. ANALYSIS OF PROPOSED ALGORITHM

The proposed Algorithm is use Articulation Points to form MCDS. Articulation Point acts as a connecting link between two Graphs or Networks.

5.1 Part One

i) All Articulation Points of Graph are computed. In the above Graph, Articulation Points are Nodes { 1, 3, 4, 6}.

ii) If Articulation Points are not connected, then connect them by means of Shortest Path Algorithms.

iii) Further, Generated Nodes are colored Black and all adjacent nodes are colored Gray.

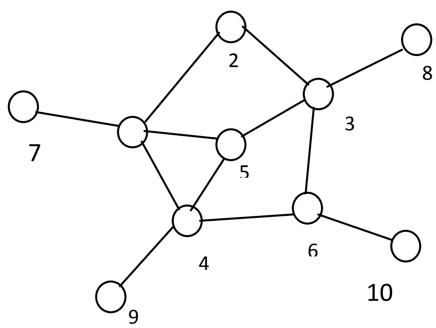

Figure 5 : Network of 10 Nodes

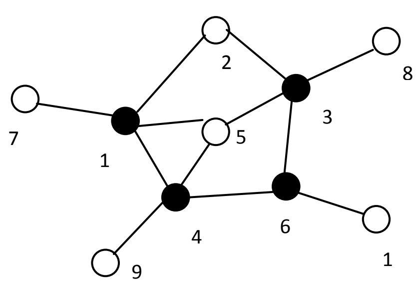

Figure 6(a) : APs { 1, 3, 4, 6 }

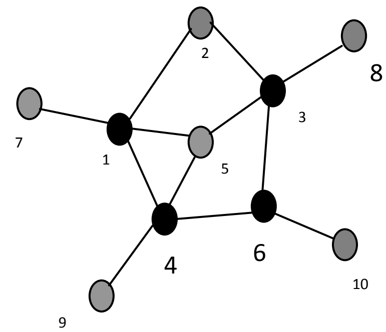

Figure 6(b) : Adjacent Nodes of APs are colored Gray

Since in the above Graph, all the Nodes of Graph have been covered i.e. no node left in the Graph to be unreachable by DS. Hence, there is no need to move onto 2nd Part. Therefore, the above Graph has generated the Final Output.

5.2 Part Two

This Part encompasses of Discovery of Gray Nodes in terms of Iteration. A Gray Node with Maximum number of White Adjacent Nodes is selected and colored gray. Finally, a Series of Black Nodes is generated as CDS. This Part proceeds as follows:

i) Else, a Gray Node with Largest number of White Adjacent Nodes is selected and color it Black.

ii) Now, the nodes which are adjacent to Black Node are colored as Gray.

iii) Repeat Steps (1 & 2) till no Node is left in the Graph and complete CDS is found.

5.3 Comparison in virtual backbone generated by Guha Khullers & Proposed Algorithm

This section depicts the variations in MCDS Nodes obtained by performing the calculations by applying proposed Algorithm which shows the modifications on existing Algorithm.

5.4 Virtual backbone generated by Guha and Khuller (CDS based) Algorithm [26]

MCDS nodes generated by algorithm are {1 2 3 4 5 6} and represented by Black nodes in Figure 5.5. Total number of nodes in MCDS is ten.

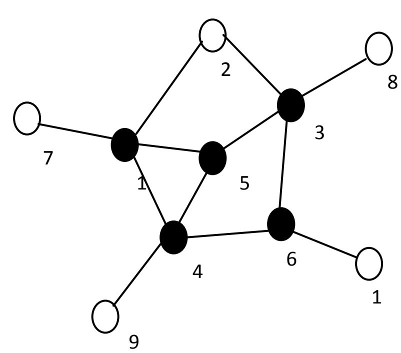

Figure 7(a) : Output generated from Guha & Khuller Algorithm (for Network of 10 Nodes).

5.5 Virtual backbone generated by Proposed Algorithm

MCDS nodes generated by Algorithms are {1 3 4 6} and represented by Black nodes in Figure 5.6(b). Total number of nodes in MCDS is four.

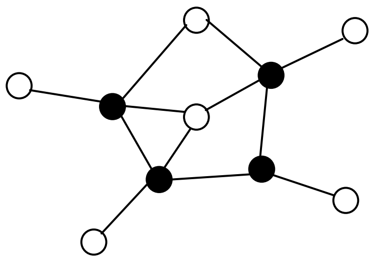

Figure 7(b) : Virtual Backbone generated by Proposed Algorithm

6. RESULT

In this section, we compares the size of the Dominating Set generated from proposed approaches with Guha and Khuller approach (CDS-based). Graph has only considered nodes which have Non-Null Degree and consist of Articulations Points. Analysis shows that proposed approaches generate lower size of MCDS as compared to Guha and Khuller (CDS based) approach. The result can be justified by the fact that proposed approach chooses the node which are Articulation Points. Every articulation points are member of MCDS.

Analysis shown in section 5 the performance of proposed algorithm is best as compared to Guha Khullers approaches. For example network of 10 Nodes, in which the size of MCDS generated by Guha Khullers algorithm is 5 where as by Proposed Algorithm is 4. The performance of proposed algorithm is best. Finally, performance of proposed algorithm is better than Guha Khullars.

7. CONCLUSION

Virtual backbone in a MANET is a subset of mobile nodes which can transmit and receive the messages through out the network. Construction of a CDS in undirected graph is a common way to generate virtual backbone in MANET. We introduce an algorithm to find Virtual Backbone for undirected graph based on computation of articulation point. This is an important issue due to many causes such as it precludes unnecessary message transmission of flooding in the network. In this paper we have proposed an algorithm for calculating Minimum Connected Dominating Set in the MANETs. We have also introduced an Articulation Point concept to generating virtual backbone and discussed how to find the better result. Analysis shows that inclusion of articulation point concept gives a better solution compared to approach given by Guha and Khullers.

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