Significance of Virtual Backbone In Wireless Ad-Hoc Network

Prashant Rewagad, Nisha A Lodha

Abstract:- This paper based on research related Ad hoc networks does not rely on dedicated network devices. It relay or route messages from a source to a destination. As there is no global coordinator, nodes have to organize themselves to avoid scalability issues that may arise when the size of the network is growing. Virtual backbones, by selecting a subset of network nodes and / or communication channels, are a set of techniques mimicking the infrastructure in the classical network paradigm. Ad hoc virtual backbones however are not composed of dedicated devices but from regular network nodes which were selected to help relaying messages. The connected dominating set (CDS) has been extensively used for routing and broadcast in wireless ad hoc networks. While existing CDS protocols are successful in constructing CDS of small size, they either require localized information beyond immediate neighbours, lack the mechanism to properly handle nodal mobility, or involve lengthy recovery procedure when CDS becomes corrupted.

Index Terms:- Ad-hoc Network, Virtual backbone, cds-based virtual backbone.

1 INTRODUCTION

As the importance of computers in our daily life increases it also sets new demands for connectivity. Wired solutions have been around for a long time but there is increasing demand on working wireless solutions for connecting to the Internet, reading and sending E-mail messages, social networking, changing information in a meeting and so on. There are solutions to these needs, one being wireless local area network that is based on Infrastructured Network. However, there is increasing need for connectivity in situations where there is no base station (i.e. backbone connection) available (for example two or more PDA's need to be connected). This is where ad hoc networks step in. These are infrastructureless networks which have no central point of control [1]. Mobile ad hoc network is a collection of independent mobile nodes that can communicate to each other via radio waves. The mobile nodes can directly communicate to those nodes that are in radio range of each other, whereas others nodes need the help of intermediate nodes to route their packets. These networks are fully distributed, and can work at any place without the aid of any infrastructure. This property makes these networks highly robust. Mobile ad hoc networks are characterized by dynamic topology due to node mobility, limited channel bandwidth and limited battery power of nodes. The key challenge here is to be able to route with low overheads even in dynamic conditions. Overhead here is defined in terms of the routing protocol control messages which consume both channel bandwidth as well as the battery power of nodes for communication / processing. In Latin, ad hoc means "for this," further meaning "for this purpose only. It is a good and emblematic description of the idea why ad hoc networks are needed. They can be set up anywhere without any need for external infrastructure (like wires or base stations). They are often mobile and that's why a term MANET is often used when talking about Mobile Ad hoc networks.

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MANET's are often defined as follows: A "mobile ad hoc network" (MANET) is an autonomous system of mobile routers (and associated hosts) connected by wireless links - the union of which forms an arbitrary graph. It is characterized by a dynamically changing topology and is a self configuring network of mobile nodes connected by wireless links. The nodes in a MANET are mobile. Such a network may operate in a standalone fashion, or may be connected to the larger Internet. One key feature in adhoc communication is traffic. Large amount of control traffic is generated by the routing protocols implemented for Mobile Ad Hoc Networks in which the network topology changes frequently. Resources such as bandwidth and battery power are usually severely constrained in such networks. Therefore, minimizing the control traffic to set up and maintain routing state is one of the main challenges in the design of scalable routing protocols for Mobile Ad Hoc Networks. Classification of routing protocols in mobile ad hoc network can be done in many ways, but most of these are done depending on routing strategy and network structure. The routing protocols can be categorized as flat routing, hierarchical routing and geographic position assisted routing while depending on the network structure. According to the routing strategy routing protocols can be classified as Table-driven/ Proactive and On- Demand /Reactive. Proactive MANET protocols are also called as table-driven protocols and will actively determine the layout of the network. Through a regular exchange of network topology packets between the nodes of the network, at every single node an absolute picture of the network is maintained. There is hence minimal delay in determining the route to be taken. This is especially important for time-critical traffic. Reactive protocols start to set up routes on-demand. The routing protocol will try to establish such a route, whenever any node wants to initiate communication with another node to which it has no route. This kind of protocols is usually based on flooding the network with Route Request (RREQ) and Route reply (RERP) messages .By the help of Route request message the route is discovered from source to target node; and as the target node gets a RREQ message it send RERP message for the confirmation that the route has been established. This kind of protocol is usually very effective on single-rate networks. It usually minimizes the number of hops of the selected path. However, on multi-rate networks, the number of hops is not as important as the throughput that can be obtained on a given path. Topology management techniques have been extensively studied since the late 90s as they try to leverage the encountered scalability issues in ad hoc networks. In a first time we present the main problems induced by the usage of a shared medium and an ever changing topology[2]. Then, we propose a classification of the techniques that have been developed so far to settle such issues.

I) Scalability problems

Mobile ad hoc networks face scalability problems due to their wireless communications and their ever-changing topology. In this problem related scalability in ad hoc network, we provide details concerning the impact of the node density on the available bandwidth[2]. The second part introduces the broadcast storm problem, a network layer issue that has to be overcome to fully benefit of the ad hoc networking possibilities

II) Two different approaches

To leverage such scalability issues, many contributions have been proposed since the end of the 90s. From our point of view, all these propositions can be classified into two main categories: topology control methods and topology management techniques, also known as virtual backbones[12].

- **Topology control**

Topology control methods aims at designing the network topology, i.e. changing the actual shape of the communication graph[5]. topology control is about tuning the range assignment in order to optimize either the energy consumption or the network capacity.

- **Virtual backbones**

Another approach to optimize ad hoc network communications is referred as virtual backbones. Its main difference with topology control techniques lies in the fact that the communication graph is not physically altered, i.e. the range assignment is not modified[12]. A *virtual* structure is instead created to support the necessary network services and optimize the resource usage. That structure or backbone is said to be virtual as it is not the direct result of the physical dedicated network components like in the classical networks realm. Virtual backbones can be apprehended as a way to mimic the hierarchical organization scheme used in the regular networks in order to leverage the intrinsic scalability issues of the ad hoc networks[5].

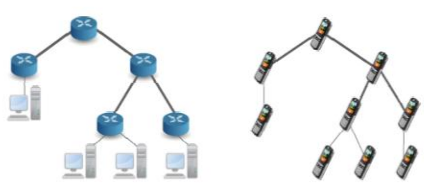


Fig.(1)-classical networks backbone and ad hoc network virtual backbone

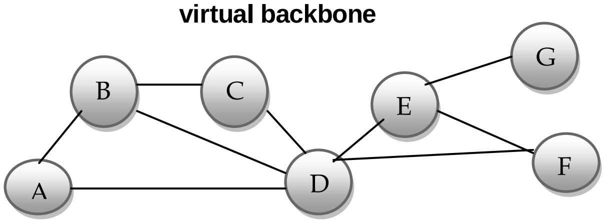


Fig.-2.(A) Original communication graph

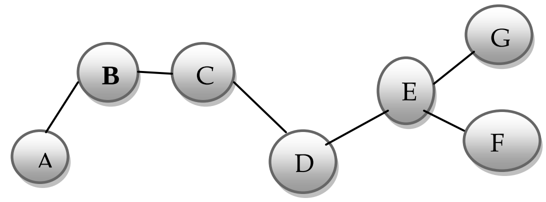


Fig-2(B) Topology Control Solution

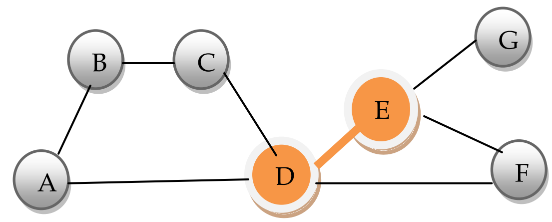


Fig-2(C) Virtual Backbone Solution

Figure 2.(A,B,C) shows the virtual backbone approach as a direct transposition of the classical network hierarchical structure. On the left, a classical network organized thanks to an infrastructure composed of dedicated relays. On the right, an ad hoc network composed of cell phones. Thick lines represent the communication backbone for both illustrations. The general purpose of virtual backbone methods is to select a subset of nodes and communication channels that will support some network services. The structure may evolve in order to adapt itself to the topology changes of the communication graph.A comparison between a topology control and a virtual backbone method. We can observe that if node A send a packet to node G, the path is longer with the TC method that the VB technique[12]. Virtual backbone can be for example clusters, spanning trees or connected dominating sets. The two bold nodes of the VB method form here a minimum connected dominating set in charge of relaying packets for all the nodes of the network.

VIRTUAL BACKBONES

There are different classification of virtual backbone techniques. In a first time we define what are virtual backbones and what are their main characteristics[11]. A classification of the most widely used techniques, i.e. trees, clusters and connected dominating sets.

Let us discuss these three criteria:

- The set of nodes in the backbone should be the smallest possible for two main reasons. First, backbone nodes are in charge of relaying packets and thus are more likely to drain their battery. In that case, less backbone nodes means that less nodes are intensively used. The second reason is related to the purpose of creating such a structure. As virtual backbone are likely to be used by routing protocols, having less backbone nodes induce less protocol-related messages, such as routing table updates, and thus increase the available bandwidth for real communications.

- The backbone should be node-failure tolerant. This characteristic is important as loosing one node may result in a useless backbone. Many propositions have been made to increase the robustness of the structure: k-connectivity, i.e. having k independent paths between any pair of nodes, empirical criteria (and their combination) such as remaining battery level, low relative speed (stable surroundings), etc...

- A backbone should be characterized by a small stretch, otherwise using it would induce a substantial decrease in some quality of service (QoS) measures (round-trip time, percentage of successful delivery).

TAXONOMY

The virtual backbone realm by detailing three different techniques: spanning trees, clusters and connected dominating set.

I) Tree-based virtual backbone

A short state-of-the-art about this type of structure is then developed and equivalencies with the other methods are tackled in the last part[11].

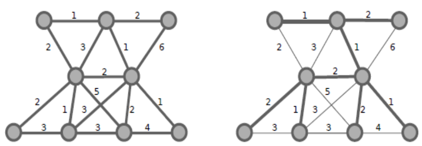


Fig (3)-On the left the communication graph with edges values

By looking at a communication graph, we can notice that only a subset of edges are required to cover all the nodes, i.e. some edges could be suppressed and the graph would still remain connected. Based on this idea, trees and more precisely spanning trees have been studied for ad hoc networks to support network services such as routing, multicast, broadcast or even security issues. Definition states that in graph theory, a tree is a connected structure without cycles. The definition of spanning trees provides an additional characteristic to the structure: the coverage, i.e. the spanning tree TG of a connected graph G is a connected cycle-free structure covering the whole vertex set of G. If G is not connected, i.e. G is composed of a set of connected components, then the cycle-free connected and covering structure is called spanning forest, i.e. one spanning tree per connected component of G. The most common distributed algorithm is the Spanning Tree Protocol (RFC 1493), used by OSI link layer devices to create a spanning tree using the existing links as the source graph in order to avoid broadcast storms in classical networks. The maximum leaf spanning tree problem is equivalent to finding the minimum connected dominating set. Moreover, this problem has been proved to be NP-complete by a reduction from the dominating set problem . Figure (4) shows this equivalence: to obtain the minimum dominating set of a graph, put all non-leaf nodes in the dominating set

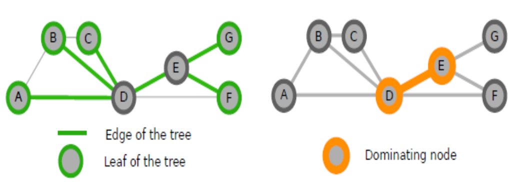
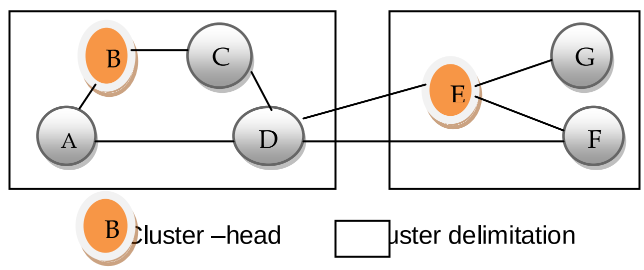


Fig. (4) On the left, the maximum leaf spanning tree of a graph example. On the right the corresponding minimum connected dominating set.

I) Cluster-based virtual backbone

Clustering techniques for ad hoc network are inspired by their data-mining counterpart. Definition gives a general template for all clustering methods. Some methods, such as *k-mean* or the *agglomerative hierarchical cluster* are well-known techniques of this domain. The ad hoc clustering techniques aims at regrouping nodes into clusters. A cluster is represented by one specific node of the cluster, the cluster-head, that is generally chosen as the most suited to help the other members of the cluster, the cluster-slaves. The objective of such a process is to create a partition of the whole communication graphs such that all the node are participating to one cluster. In statistics and machine learning, k-means clustering is a method of cluster analysis which aims at partitioning n observations into k clusters in which each observation belongs to the cluster with the nearest mean. This method requires a preset value for the number of clusters k, and thus the number of clusters has to be known a priori. This constraint is not well-adapted to the ever changing ad hoc networks as the global topology is rarely known by a global coordinator.



Fig(5)-On the same graph ,a clustering solution and a domination set

One-hop clustering algorithms creates structures in which cluster-slave have at least one cluster-head in their direct neighborhood (one-hop). Such characteristic correspond exactly to the coverage property of a dominating set. If no weight values are considered, finding the minimum number of clusters (and cluster-heads) is equivalent to finding the minimum dominating set of the communication graph. Figure provides an illustration of this equivalence[11].

II) Dominating Set-based virtual backbone

The last category of approaches to create virtual backbone aims at creating a structure with the characteristics of a connected dominating set. This notion is a connected variation of the dominating set, i.e. a set of nodes covering a whole graph. Creating such a backbone is suitable as all devices may either be in the backbone or have at least a one-hop neighbor in the backbone. Moreover, the sub-graph induced by the components of the backbone is connected, i.e. a path only composed of backbone nodes exists between any pair of backbone nodes [10].

TAXONOMY FOR CDS-BASED VIRTUAL BACKBONE

The algorithms to create connected dominating set based virtual backbones are numerous. This profusion of solutions is partly, if not mainly, due to the direct application to the ad hoc networks realm. In order to provide a clear overview of all these contributions, we start by presenting the main characteristics of these algorithms[4].

CHARACTERISTICS
The some salient characteristics concerning the algorithms in general (type of result, computation type, available data or randomization) and some others which are specific to the virtual backbones for ad hoc networks (robustness consideration and synchronization requirements).

COMPUTATION TYPE
All the contribution we are reviewing can be partitioned into two main classes: centralized and distributed algorithms.

AVAILABLE DATA
Another important criterion to classify the algorithm is related to the amount of information to which the algorithm has access to compute its solution. Two main categories can be roughly defined: global and localized.

RANDOMIZATION
Whether an algorithm always provides the same solution for the same input or not, it can be classified in two different categories[10]: deterministic or stochastic.

ROBUSTNESS CONSIDERATIONS
Many contributions have been focusing on creating connected dominating sets in ad hoc networks. However, these networks are characterized by node failure and / or mobility. As a consequence, resilient solution have been proposed: increasing the domination (or vertex domination) and the connectivity.

Conclusion
In this paper the concept of routing scheme based on the virtual backbone in wireless ad-hoc network is analysed. The reliable virtual backbone schema & study of various mobility model can be integrated in our future work to improve mobility management in wireless ad hoc network. This idea mainly used in distribute and centralize based algorithms related available data to optimization global & localization.

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