Backbone Based Routing Protocol with Adaptive MAC for Heterogeneous Ad Hoc Networks

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***Abstract* -** Ad hoc networks are usually modeled as a collection of homogenous nodes, i.e., nodes having the same communication capabilities and characteristics. Most existing routing protocols mainly consider homogeneous ad hoc networks in which all nodes are treated as identical. It does not mirror the real situation. The homogeneous ad hoc network limits scalability and also under utilizes the resources available in the network. But in real world many type of nodes coexist in the ad hoc network, i.e., some nodes have better processing capability, large transmission power and higher data transmission rate and some others have less capabilities and characteristics. It is more realistic and it has many advantages. The existing protocols are not optimized for heterogeneous network. In this paper, we propose a new routing protocol called Backbone Based Routing protocol designed specifically for heterogeneous ad hoc networks. We also modify the (Medium Access Control) MAC that supports heterogeneity and to minimize the loss due to interference, as nodes of several transmission ranges are communicating within the network.

1. Introduction

Mobile ad hoc networks (MANETs) are collection of communication devices which are capable of operating without any infrastructure. Nodes within transmission range can communicate directly with one another. Nodes outside the transmission range must communicate indirectly using a multihop route through other nodes. Individual nodes are responsible for dynamically discovering the route. In most of the ad hoc network nodes are considered to be homogeneous, in which all nodes are treated as identical, i.e., they have the same capabilities and characteristics. Homogeneous network is simple and easy to analyze, but in realistic homogeneous network leads to under utilization of resources and limits scalability. Ramanathan et al [3] provide an overview of the open problems in ad hoc networks.

In realistic environment, ad hoc network contains different types of nodes i.e., some nodes have better processing capability, high transmission power, high data transmission rate and some other nodes have less transmission power, less processing capability and less data transmission rate. In heterogeneous network if resources are properly utilized and it will improve the performance of the network. The general assumption in heterogeneous network is it works as a bidirectional and also varies the transmission range on the fly depending upon the need. But in heterogeneous network since nodes have different transmission range communication link among these nodes are unidirectional. Next problem is interference, which is caused due to the nodes with higher transmission power, i.e., the high capable node's communication range interferes with the low capable node's communication range.

Heterogeneous network achieves scalability by making use of hierarchical network structure, by dividing the entire network in to cluster. By using cluster we can increase the size of the network without loss of performance. We can utilize the higher capable nodes effectively by using cluster. It also increases the reliability of the network.

Most routing protocol has only been designed for homogeneous ad hoc network, i.e., they treat all the nodes as same capable nodes. If two nodes, are within the same transmission they can easily communicate no real routing protocol or routing decisions are necessary. But ad hoc network is a multi hop network it needs a routing scheme to establish a connection between two nodes. Some of the routing protocols used in ad hoc networks are Dynamic Source Routing (DSR) [2], Ad hoc On demand Distance Vector (AODV) routing protocol, Zone Routing Protocol (ZRP), Loop Based Source Routing (LBSR) protocol etc., Even though most of the routing protocols support homogenous network, recently routing protocols like Multi Class (MC) [1] routing has been developed for heterogeneous ad hoc network. For heterogeneous ad hoc network modification at the network layer alone is not sufficient, we have to consider the protocol at the MAC layer that is mainly affected by the transmission power.

Generally IEEE 802.11b is suitable for homogeneous nodes, because all the nodes have the same transmission power. In the heterogeneous network all nodes have different transmission power that leads to interference. IEEE 802.11b has no functionalities to avoid the interference due to heterogeneity.

In this paper, we propose a new routing protocol for heterogeneous ad hoc networks called Backbone Based Routing (BBR) protocol. This protocol effectively utilizes the resources available in the network and provides a hierarchical structure (Cluster) for improving scalability. We also modify the medium access control (MAC) protocol that supports functionalities for heterogeneous network.

This paper is organized as follows. Section 2 discusses the background and related work. Section 3 deals with the proposed scheme. Section 4 deals with the adaptable MAC scheme for backbone based routing protocol. Section 5 concludes the paper.

2. Related Work

Most of the research works in an ad hoc network focuses on the homogenous characteristic of the nodes present in a network. Now people have started looking at the heterogeneity among the nodes and they have provided some solutions for it.

Kulkarni et al [5] discuss different classes of routing protocols that can be used to optimize the performance of heterogeneous ad hoc networks.

Du et al [1] have proposed a routing protocol for heterogeneous ad hoc network based on location dissemination scheme. In this, entire network is divided in to fixed size area called cells and routing is carried based on the location information of the node. This scheme is to minimize the overhead due to broadcast within the cell. The main shortcoming of this paper is the presence of a location server that is assumed to contain the location information of all the nodes, which then becomes like a centralized approach. Another assumption is that the location server has very low mobility. The drawback with the routing protocol is that it does not provide solution for unidirectional communication.

Chi-Hsiang et al [4] proposes an interference aware MAC scheme Interference Aware Multiple Access (IAMA), for heterogeneous ad hoc networks. It addresses the problem of increased interference in heterogeneous ad hoc networks using spread spectrum and collision prevention techniques.

We propose solution to solve the unidirectional problem and introduce a clustering scheme to increase the scalability as well as remove the location dissemination scheme. We propose a scheme, in this we divide the time frame into sub frames of fixed size to adaptively adjust the sub frame length based on the traffic available.

3. Backbone Based Routing

In a heterogeneous ad hoc network nodes are of different capability. We can use the resource of higher capable nodes for routing purpose. Reliability can be achieved by routing through the higher capable nodes. To achieve scalability we use clustering mechanism. Clusters in ad hoc network are formed using higher capable nodes. In heterogeneous ad hoc network different types of nodes coexist. We classify the nodes in to two categories. They are Backbone Node (B-node) and General Node (G-node).

Backbone Node (B-node): Backbone nodes have larger transmission range, higher data rate and better processing capability and are more reliable than other type i.e., we consider more powerful nodes as Backbone nodes.

General Node (G-node): General nodes have less transmission range, less data rate and less processing capability.

In our network we consider all nodes are location aware using GPS and each node knows its own stability time i.e., how stable it going to be in a position. The stability of a node is obtained when a node follows some regular movement. This regular movement is obtained as a trace and the nodes follow a trace based mobility model [6]. Hence a node can predict its own stability time when it follows trace based mobility model.

3.1 Cluster Formation

The formation of cluster brings a sort of hierarchy that divides the entire network into clusters, with each cluster under a B-node. The B-node is made to act in two different transmission power min power and max power, in order facilitate the G-node to communicate with B-node. During the cluster formation the B-node uses the min power to broadcast the hello message and routing purpose the B-node uses max power. The broadcast message is limited by hops; the hop count depends on the max power of B-node.

$$\text{Max power} \cong N * \text{min power}$$
$$\text{Hop Count} = N$$
$$(N = 1, 2, 3 \ldots n)$$

While sending the hello message the B-node changes its transmission power to min power that is equivalent to G-node's transmission power. This is done in order to form route between the G-node to B-node and to facilitate proactive routing. The hello message includes the node id, position and stability time of the cluster head and it contains a route field which is filled by every node that receives the hello packet as shown in figure 1.

Node ID	Stability	Position	Route

Figure 1 Hello Message

Stability time of the cluster head gives the stability of the cluster and the route field is used to obtain the route to the cluster head from the hello message. When a G-node receives the hello message it first caches the route, then appends its own node id in the route field and then forwards it to the next node. After this, it sends a cluster_join message to the cluster head which includes the node id and stability time of the node. The cluster head caches this information in a cluster table as shown in figure 2. The node ID indicates the members of the cluster and stability is the stability time of the node.

Node ID	Stability

Figure 2 Cluster Table Format

An entry in cluster table is flushed after the stability time of the node expires. Each node maintains a route until the stability time (advertised in hello message) of the cluster head expires. It implements the proactive routing within the cluster. The cluster head send a beacon message periodically to indicate its presence. Based on the beacon it receives, it updates the cluster head information and the route to the head. Due to random movement if the cluster head moves away, it is identified by a route error message and cluster head election mechanism is followed.

3.2 Cluster Head Election

The cluster head election mechanism must be such that it takes the dynamic nature of the ad hoc networks into consideration. It may be the case that either the cluster head or the G-nodes in the cluster migrate to another cluster. The election mechanism must be designed such that it factors all these criteria.

A B-node is selected from the contending backbone capable nodes based on stability time, because stability time of the cluster head is the important parameter as it implies stability of the cluster. In case of ties, node ID is used to resolve, i.e., selecting the node that has the smallest node ID. Initially all backbone capable nodes are contending for the cluster head. But if a backbone capable node receives a hello message from other backbone capable nodes that has more stability time, then the node switches from the contending node to the participating node. Similarly other nodes in the cluster also update their knowledge of cluster head based on stability time of the received hello message. Every node in the cluster sends a cluster join message to the elected cluster head. When a cluster head moves away it may be after the stability expires or before the stability expires, in such situation, if a B-node or G-node within the cluster detects the absence of the cluster head, then the above election mechanism is carried again to elect the new cluster head. The formation of cluster will increase the scalability of the routing protocol.

3.3 Backbone Based Routing Protocol

Initially the entire network is divided into hierarchical structure called cluster based on the backbone capable nodes available in the network. Assume that every node in the network will be a part of the cluster. Each node has its own id, position, stability and also the information about the cluster head such as head id and route to the head from the hello packet. This hierarchical structure routing is generally divided into two categories. They are intra cluster routing, which is proactive or table driven, i.e., the source and destination node belongs to the same cluster or routing within the cluster. The other one is inter-cluster routing which is reactive or on-demand, i.e., the source and destination node belongs to different cluster or routing across the cluster. Depending upon the node capabilities there are four different type of communication involved. They are G-to-G node, B-to-B node, G-to-B node and B-to-G. The G-to-G node means communication between two general nodes; similarly B-to-B means communication between B-Nodes, and so on.

3.4 Route Discovery

Consider, node S and D wants to communicate then, it will first initiate a route discovery process. The source node S sends the route request (RREQ) packet to the cluster head Cs. It may be the case node D may be available within the cluster or across the cluster. The cluster head check whether D is available in the cluster by using cluster table. If node D falls within the cluster then the cluster head sends the route (S-Cs-D) back to the node S through the route reply (RREP) packet. In the other case, node D lies in another cluster Cd then the cluster head Cs after receiving the route request packet from the source S it uses the reactive protocol to find the route through cluster heads. At that time, the cluster head (B-node) varies its transmission range to max power to find the route among cluster head. The intermediate cluster head receives the route request packet it searches for the node D within the cluster from the cluster table. If the node D is available then it sends a route reply packet back to the cluster head Cs with the available route (S-Cs-Cx-…-Cd-D). If node D is not available in the cluster then it either relay the route request to the neighboring cluster or drops the packet.

3.5 Routing between G-to-B node

In heterogeneous ad hoc network the routing between B-to-G nodes is simple, because B-node has higher capability it reach the G-node either one hop or more than one hop. But it is not necessary that G-to-B have the same route because of variation in transmission power. This is the one of the major problem in heterogeneous ad hoc network i.e., unidirectional problem. To overcome the unidirectional problem the B-node uses two different powers. At the time of cluster formation the B-node uses min power. Each node within the cluster maintains a route to the cluster head which is obtained, when a cluster hello message is received. The update of route is done when head send a periodic hello message. The route information is valid until the stability time of the cluster head expires. After the time expires or any one of the node detects the absence of the cluster head then cluster head election mechanism is triggered again.

4. Adaptive Medium Access Control

For heterogeneous ad hoc network IEEE 802.11b is not an efficient MAC protocol, because it is not capable to manage the nodes that have variation in transmission power. Changes are made in MAC protocol to adapt to the backbone based routing protocol. The main theme is the combination of a time slotted mechanism and a contention-based mechanism. A large time frame is divided into different sub frames. An important parameter is the length of the sub frame. The length of the subframe is dynamic, i.e., the length of the subframe is adaptively adjusted depending upon the length of each type of communication or traffic. The entire time frame is divided into three subframes, which include G-to-G, B-to-B and B-to-G. The traffic between two general nodes is carried through the G-to-G subframe. Similarly, B-to-B and B-to-G have same meaning. The other type of communication G-to-B is carried within the G-to-G subframe. Within the subframe every node gets the channel through contention-based mechanism. The problem of increased interference which may occur due to greater transmission and interference range of B-node and hence which can potentially interfere with the communication of the entire cluster is avoided by bringing in subframes for each type of node. It minimizes the interference and also increases the throughput.

5. *Conclusion*

Backbone Based Routing protocol along with Adaptive MAC which has been designed taking into consideration the heterogeneity of the nodes and their capabilities can provide better optimization.

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