Cluster Based Mobility Considered Routing Protocol for Mobile Ad Hoc Network

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Abstract. Mobile ad hoc networks consist of wireless hosts that communicate with each other without the support of fixed infrastructure. In case of large network, a flat structure may not be the most efficient organization for routing. For this purpose many clustering schemes have been proposed that organize the MANET into a hierarchy, with a view to improve the efficiency of routing. In this paper, we have presented a brief review of the state of the art scenario of routing topologies for mobile ad hoc networks and try to present a scheme that leads to cluster formation which efficiently uses the resources of the MANET. The proposed Cluster Based Mobility Considered Routing Protocol obtains efficient communications among MANET and achieves scalability in large networks by using the clustering technique. The new algorithm takes into consideration the mobility factor during routing and as well as computational overhead is also diminished.

Keywords: Mobile ad hoc networks, routing, clustering, mobility, MANET.

1 Introduction

Mobile ad hoc network is an autonomous system of mobile nodes connected by wireless links; each node operates as an end system for all other nodes in the network. But there are some constraints such as low bandwidth, limited energy, mobility, non-deterministic topology and the broadcast nature of wireless communication make the task complex. Wireless nodes that communicate with each other, forms a multi hop packet radio network and maintains connectivity in a decentralized manner.

Existing research work in ad hoc network's protocols mostly aims at improving stability of routes and creating a collaborative environment between nodes. In the absence of prior knowledge, as in the case of mobile ad hoc network, the work becomes more difficult. Jie Wu and Fei Dai [9] say that mobility of nodes adds another dimension of complexity in the mutual interference. T.Camp, J.Boleng and V.Davies gave an excellent survey on mobility models for MANETs [12]. The popular mobility models include (1) random walk, which is a simple mobility model based on random directions and speeds; (2) random waypoint, which includes pause time between

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changes in destination and speed; (3) random direction mobility, which forces hosts to travel to the edge of the simulation area before changing direction & speed.

Clustering has evolved as an important research topic in Mobile ad hoc networks, and it improves the system performance of large MANETs. Clustered based ad hoc networks can distribute resources in a balanced way and are with special advantages related to scalability, efficient energy consumption, and simple data aggregation. To adopt clustering scheme, a mobile ad hoc network is usually organized into a hierarchical structure of multiple virtual subnets, which form a high-level and relatively stable backbone network. Clustering is a technique to dynamically group nodes in a network into logically separating or overlapping entities called clusters. The clustering structure divides a network into one or several clusters, one of which consists of one cluster head and some cluster members. However, in a clustering network the cluster head serves as a local coordinator for its cluster, performing inter-cluster routing, data forwarding and has to undertake heavier tasks so that it might be the key point of the network. Thus reasonable, cluster head election is important to the performance of the mobile ad hoc network. A cluster gateway is a non cluster-head node with inter-cluster links, so it can access neighboring clusters and forward information between clusters.

The rest of the paper is organized in the following way. In section 2, a comparative study of some of the existing routing topologies has been carried out. We have design and describe the new routing protocol to reduce the overhead for maintaining all routing information for each mobile node, in the section no 3. This will eventually reduce the overhead of maintaining a large database and also save large amount of network capacity, which is required for maintaining current information. Intensive performance evaluations are presented in section 4. Finally in section 5, a conclusion has been summarized.

2 Related Works

In recent years clustering is a very well known routing technique for mobile ad hoc networks. Different clustering algorithms have different optimizations, such as minimum cluster head election and maintenance overhead, maximum cluster stability, maximum node lifespan, etc. In this section we have studied many routing protocols which have been proposed for mobile ad hoc networks.

The Cluster-based Inter-domain Routing [4] protocol obtains efficient communications among MANETs. CIDR [4] protocol has ability to control the overhead reduction. The Cluster-based Inter-domain Routing [4] protocol achieves scalability in large networks by using the clustering technique. This approach exploits the clustering by group affinity. In each domain, the distributed clustering algorithm discovers the set of "traveling companions" and elects within each set a Cluster Head for each affinity group. In CIDR [4], packets to remote nodes are routed via cluster-head advertised routes and packets to local destinations are routed using the local routing algorithm. In this CIDR [4] protocol the cluster head in the subnet acts as local DNS for own cluster and also for neighbor clusters. The cluster head advertises to neighbors and the rest of the network its cluster information. This algorithm has an ability of dynamic discovery of route and dynamic split/merge of route. It uses FSR

[11] like technique for controlling overhead reduction. For enhancing its scalability it implements member digest with Bloom Filter. For evolving membership in time, CIDR [4] preserves its legacy routing scheme in each MANET. So, it is scalable in size and robust to mobility.

Cluster-head Gateway Switch Routing [17] is a hierarchical routing protocol where the nodes are grouped into cluster. In CGSR [17], there is no need to maintain a cluster hierarchy. Instead, each cluster is maintained with a cluster-head, which is a mobile node elected to manage all the other nodes within the cluster. This node controls the transmission medium and all inter-cluster communications occur through this node. The advantage of CGSR [17] protocol is that each node maintains routes to its cluster-head which means that routing overheads are lower compared to flooding routing information through the entire network. However, there are significant overhead with maintaining clusters. This is because each node needs to periodically broadcast its cluster member table and updates its table based on the received updates.

Cluster Based Routing Protocol [14] is a cluster on-demand source routing protocol. It has many similarities with the Dynamic Source Routing Protocol [10]. In CBRP [14], cluster head manages all cluster numbers all the information and behavior in each cluster, and finds the adjacent clusters for routing through the gateway node. By clustering nodes into groups, the protocol efficiently minimizes the flooding traffic during route discovery and speeds up this process as well. Its route shortening and local repair features make use of the 2-hop-topology information maintained by each node through the broadcasting of HELLO messages. CBRP [14] has small routing control overhead, less network congestion and search time during routing.

The Border Gateway [7], [18] protocol is the de-facto inter-domain routing protocol for the Internet. BGP [7], [18] provides a standard mechanism for inter-domain routing among heterogeneous domains. The principle of BGP [7], [18] is to enable opaque interoperation, where each domain has the administrative control over its intra-domain routing protocol and inter-domain routing policy. In Border Gateway Protocol [7], [18] the routes to an internal destination within the same domain are determined by an intra-domain routing protocol, where as the routes to an external destination are determined by the inter domain routing policies among domains. BGP [7], [18] relies on a path vector protocol for exchanging inter-domain level reach ability information.

In Hybrid Cluster Routing [8], nodes are organized into a hierarchical structure of multi-hop clusters using a stable distributed clustering algorithm. Each cluster is composed of a cluster head, several gateway nodes, and other ordinary nodes. The cluster head is responsible for maintaining local membership and global topology information. In HCR [8], the acquisition of intra-cluster routing information operates in an on demand fashion and the maintenance of inter-cluster routing information acts in a proactive way. The aim of HCR [8] is to acquire a better balance between routing overhead and latency delay than previous protocols. In HCR [8], the high-level routing information is maintained via a proactive method while the low-level routing information is acquired via an on-demand method.

K-Hop Cluster Based Routing Protocol [5] enlarges the range of electing cluster head to K-hops and introduces the concept of metric of constraint degree to restrain the cluster head election. KHCBRP [5] also improves the routing discovery by integrating the inter-cluster on-demand routing and the intra-cluster table-driven routing.

In KHCBRP [5], the neighbor list is amended to introduce a new data structure, k-hop neighbor table. The benefit is that nodes can directly get information of K-hop neighbors from there k-hop neighbor table in the cluster head election.

Low-Energy Adaptive Clustering Hierarchy [13] algorithm is one of the most popular cluster-based routing protocols for sensor network. LEACH [13] organizes all sensor nodes in the network into several clusters and elects one cluster head for each cluster. The cluster head collects data from the member nodes in the cluster and aggregates the data before forwarding them to the distant base station. The performance of clustering algorithm is influenced by the cluster head election method. The operation of LEACH [13] is separated into two phases, the setup phase and the steady state phase. In the setup phase, the clusters are organized and cluster heads are elected. In the steady state phase, the actual data will be transmitted to the base station. LEACH [13] randomly selects a few sensor nodes as cluster heads and rotates this role to evenly distribute the energy load among sensors in the network. LEACH [13] is able to increase the network lifetime, the nodes far from BS will die fast because cluster heads located away from the BS consume more energy under the single hop communication mode.

Two Step Cluster Head Selection [6] routing protocol, is used to solve the cluster head number variability problem of LEACH [13]. Two Step Cluster Head Selection [6] routing is to prolong the lifetime of a sensor network. In TSCHS [6], cluster head selection is divided into two stages. Firstly, temporary cluster heads are selected in initial selection stage with the number larger than the optimal value and then cluster heads of optimal number are chosen out of the temporary cluster heads according to both residual energy and distances from them to the base station. TSCHS [6] can balance the energy load significantly and increase the lifetime of the network.

Cluster Head Load Balanced Clustering [3] routing protocol is used to load balanced among cluster heads for wireless sensor networks. CHLBC [3] builds backbone network's inter-cluster transit route which is composed of cluster heads and calculates relay traffic of cluster heads. CHLBC [3] elects uneven distributed cluster heads according to the distance from sensors to the base station. CHLBC [3] builds up the hop number field from cluster heads to the base station and constructs inter-cluster transit routes in the backbone network which is composed of cluster heads. Cluster heads calculate relay traffic and sensors select corresponding cluster head according to not only the distance with cluster heads but also the relay traffic of cluster heads. The cluster head with heavy relay traffic has less cluster members, so the load of cluster heads will be balanced.

In the above discussion we have discussed about various existing cluster based routing protocols. In our proposed routing protocol we have considered two important issues of MANETs. One is the clustering technique and other is the node mobility. For consider this purpose, some mobility related algorithms have been also discussed.

In DREAM [16] each mobile node (MN) maintains a location table for all other nodes in the ad hoc network. A location packet from each MN to a nearby MN is transmitted in the ad hoc network at a given frequency and too far away MNs at another lower frequency. In this way by making a difference between far away and nearby nodes, A Distance Effect Algorithm for Mobility [16] attempts to reduce the overhead of location packets. Each location packet contains the coordinate of the source node, the source node’s speed, and the time of transmission of that LP. DREAM [16] defines a timeout value on location information, i.e. when the limit specified for location information exceeds then source resorts to the recovery procedure.

An Advanced Mobility Based Ad Hoc Routing Protocol for Mobile Ad Hoc Networks [1] is based on mobility control to address connectivity, link availability and consistency issues. According to this algorithm mobility of node k is defined as,

$$\gamma k = \sum_{1}^{N} (loctj - locti) / (tj - ti) \quad (1)$$

Where, loctj and locti gives the position of the node at time tj and ti respectively. Here every node maintains only its neighbor's information. After the calculation of node mobility, it only considers least mobile nodes. For next hop selection it also takes less mobility as a criterion, i.e., it selects least mobile node as next hop. The main objective of AMOBIROUTE [1] is reduce overhead of maintaining routing information. For this purpose this algorithm maintains information only next neighbor and maintains information about lesser mobile nodes.

In Mobile Ad hoc Network Routing Protocol [2] we can calculate the displacement of mobile nodes with respect to time, by using beacon messages. In MOADRP [2], we have also considered the angle of displacement. The main objective of MOADRP [2] is to reduce the overhead of maintaining routing information and as well as to reduce the time delay for finding the route.

In the next section we are going to propose a new routing protocol and try to reduce the problems of previously discussed routing protocols.

3 Proposed New Routing Protocol

The basic advantage of hierarchical cluster routing is that it generally produces less routing overhead than flat routing protocol in mobile ad hoc networks. The hierarchical structures are more flexible routing schemes, which may in turn help well in large scale MANETs. In mobile ad hoc network, one of the important challenges of routing is its node mobility. High mobile nodes very frequently change their position. For maintaining information about those highly mobile nodes, we have to update routing table very frequently. For this reason, in the proposed routing protocol, i.e. in Cluster Based Mobility Controlled Routing Protocol or CBMCRP, we have characterized mobile nodes according to their mobility.

In this paper, we use the self-organizing principles for binding a node to a cluster and as well as to minimize the explicit message passing in cluster formation. We also used the beacon message for keeping track of nodes in cluster. Thus, there is no need for explicit message passing during cluster maintenance.

In this routing protocol, we have designed three clusters of nodes. At first we have to know all nodes' mobility. To find out the mobility of each mobile node we follow the method described in MOADRP [2]. Then according to node mobility, nodes are placed in the appropriate cluster. Each cluster must have a predefined cluster head. The algorithm is basically divided in three parts. The first part involves in the cluster formation. In addition, we choose the cluster gateway during cluster formation avoiding the need to explicitly discover the gateways, thus reducing further the transmission overhead. Every cluster head maintains information of all the nodes within that cluster. For doing this, cluster head maintains a $node_{infolist}$. The $node_{infolist}$ maintains the current position of the cluster nodes and its recent mobility.

Table 1. Node Information: $Node_{infolist}$

$node_{id}$	**$node_{posn}$**	**$node_{mob}$**	**time**

The second part is used to cluster head selection. In this algorithm a cluster head acts only as an identifying label for cluster entity. And the last part is designed of finding a path to the desired destination.

Table 2. Data Dictionary

Variable	**Description**
mob_{mid}	A middle range of mobility.
mob_{high}	A high range of mobility.
clr_{low}	Cluster designed for low mobility range.
clr_{mid}	Cluster designed for mid mobility range.
clr_{high}	Cluster designed for high mobility range.
$node_{infolist}$	Current position of the cluster nodes & its recent mobility.
$node_{id}$	Id of a mobile node.
$node_{posn}$	Position of mobile nodes.
$node_{mob}$	Mobility of mobile nodes.
S_n	Source Node.

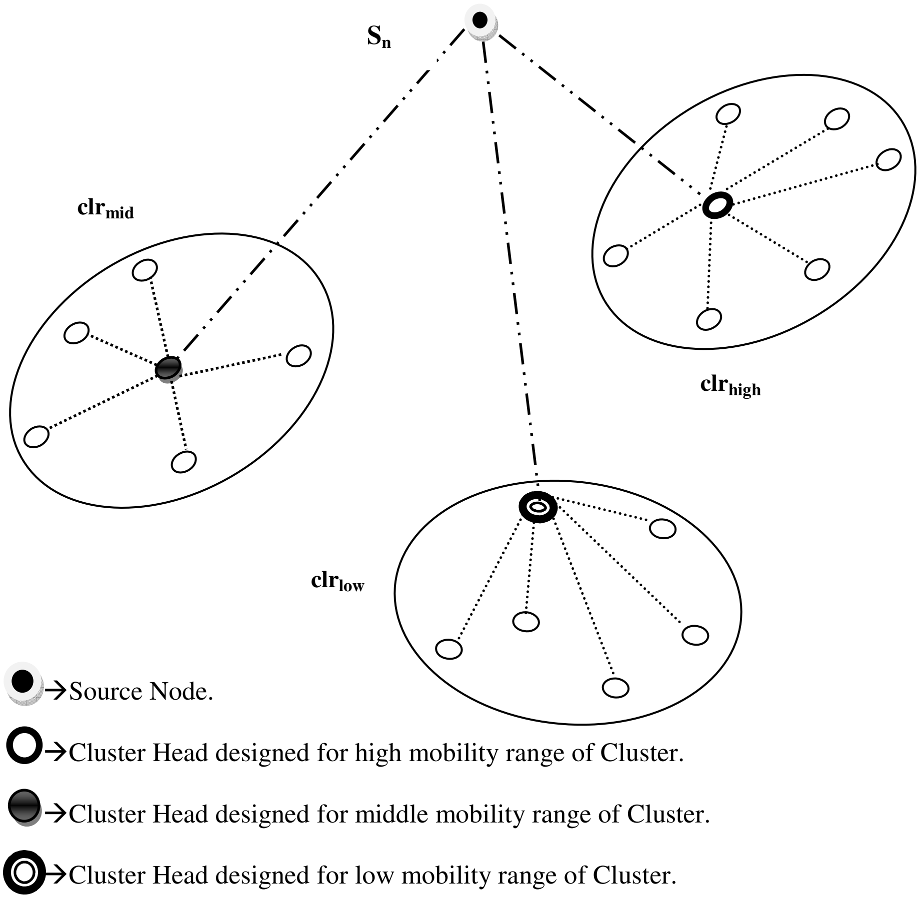

Fig. 1. Formation of Clusters According to CBMCRP

- **Cluster Formation:**

Step1: START.
Step2: Source node first calculates mobility of each node.
Step3: If the mobility is less than Mob_{mid}
Then it placed in Clr_{low} cluster.
Else if the mobility is greater than Mob_{mid} and less than Mob_{high}
Then it placed in Clr_{mid} cluster
Else it is placed in Clr_{high} cluster.
Step4: END.

- **Cluster Head Selection:**

Step1: START.
Step2: Sort all mobile nodes in each cluster with respect of their mobility.

Step3: The least mobile node selected as cluster head.
Step4: END.

- **Routing Algorithm:**

Step1: START.
Step2: Search destination node in Clrlow's cluster head's $node_{infolist}$
  Step i: If destination node is available
    Then go to Step 5.
   Else go to step 3.
Step3: Search destination node in Clusmid's cluster head's $node_{infolist}$
  Step j: If destination node is available
    Then go to Step 5.
   Else go to step 4.
Step4: Take information of destination node from Clushigh's cluster head's $node_{infolist.}$
Step5: Send destination node information to source node.
Step6: END.

By using the above discussed algorithm a node can communicate with any another nodes within that network.

4 Performance Analysis

The simulation model consists of a network model that has a number of mobile wireless node models, which represents the entire network to be simulated. The number of the nodes ranges from (3-25) nodes depending on the simulation scenario.

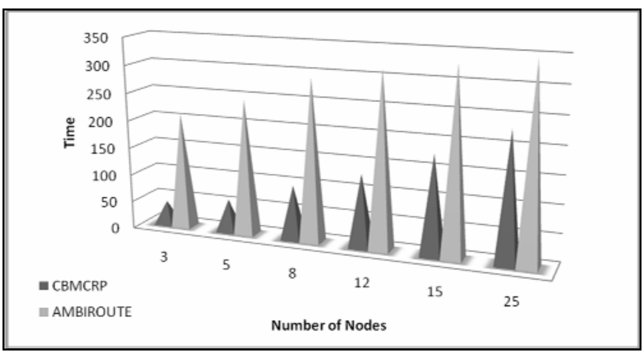

Fig. 2. Number of Nodes vs. Time Graph

The graph in fig 2, shows the time required for finding route from source to destination for a different number of mobile nodes. From that it is clearly seen that when the number of nodes in the network are increased then the required time for route finding also increased.

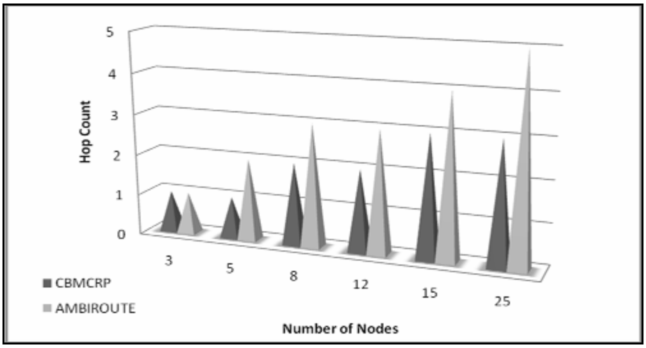

Fig. 3. Number of Node vs. Hop Count Graph

In fig. 3, there is a comparison between number of nodes and hop-count for finding route from source to destination. Here we have also observed that if the number of nodes increase, initially hop count also increase. But after a certain value, hop count fixed in a certain range.

From the above two figures, we have observed that our new proposed and implemented routing algorithm CBMCRP performs better and its time complexity is also less than other routing protocol named AMOBIROUTE [1].

5 Conclusions

In this paper, we have summarized the generic characteristics of well known cluster based routing protocols and present a new routing protocol named Cluster Based Mobility Considered Routing Protocol. This newly proposed algorithm, CBMCRP is based on load balancing approach among cluster heads for mobile ad hoc networks. Mobility is the basic characteristics of mobile node and as well as it is the main challenge for routing in MANETs. For this reason, node mobility is taken one of the important characteristics of this clustering algorithm. To design the different cluster, we have considered different node mobility and according to node mobility, nodes are placed in the appropriate cluster. The cluster head of each cluster acts as a local co-coordinator for its cluster, performing inter-cluster routing, data forwarding and has to undertake heavier tasks so that it might be the key point of the network. Some result analysis are also incorporated to show, in which way the proposed algorithm work to achieve the scalability, the robustness to mobility in large network and some performance analysis have been done with the existing routing algorithm for MANET.

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