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CBRP Strategy for Two-Level Hierarchical Clustering in MANET's

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Abstract
MANET is a self-organizing, self-configuring wireless ad-hoc network where all the nodes in a network are free to move anywhere anytime and does not need any pre-existing setup for communication. This dynamic behavior of nodes makes the communication in MANET most difficult task. Mobility is one of the major issues, which causes frequent link breakages and every time a new path for routing is to be searched. Clustering is the scheme where nodes with similar behavior are virtually grouped together and make the efficient routing. Each cluster is headed by a special node called cluster-head. In this paper, a new two-level hierarchical clustering formation scheme is presented aims to control the cluster stability of nodes and can reduce the cluster change rate to avoid frequent updates in network that creates unnecessary overheads. The routing protocol which is the extension of CBRP routing protocol is also implemented on the proposed cluster formation scheme to present packet transmission procedure and controls the network traffic.

Keywords
Ad-hoc Networks, MANET, Clustering, Mobility, Routing, WCA, CBRP

I. Introduction

Mobile Ad-hoc network, sometimes also called as mobile mesh network is an infrastructure-less wireless network where nodes within the range communicate directly through radio-waves while others communicate through multi-hop routing. MANETs sponsored by DARPA in early 1970's and [8] initiated by the Department Of Defense of the United States of America was earlier called as "packet radio networks". Nodes in the network can be either fixed or movable. Mobile phones, PDA, laptops etc. Some common applications of MANETs include emergency services, education, sensor networks, disaster relief, entertainment etc.

Because of the dynamic characteristic of network MANET is facing lots of issues e.g. scalability, bandwidth constraints, energy constraints, limited security etc. Since nodes are highly mobile therefore links also keep on changing constantly and this creates lot of overhead, link failures within the network. So, to make the network more reliable these issues are to be considered. Nodes in a network can be organized into flat and hierarchical structure. In flat structure all nodes are assigned equal responsibilities. But during transmission packet is to be transmitted to all the intermediate nodes between source and destination. This increases the communication delay and introduces [9] scalability issues. Therefore a new concept of hierarchical structure was introduced where nodes are leaded by special root node.

Clustering is a technique where nodes are organized into hierarchical structure and grouped virtually to form a cluster. Nodes with similar characteristics like mobility, direction, speed, transmission range are grouped into same cluster. A cluster is headed by a root node called cluster-head used for intra-cluster communication and inter-cluster communication is performed through cluster-gateway. Other nodes in a network are called cluster-members. If in case two cluster-heads become adjacent to each other one of them resigns their responsibility. Selection of an efficient cluster-head is very essential. A cluster-head is said to be efficient if it can serve the members for longer duration without any failures. Many schemes and algorithms have been proposed for cluster-head selection one of them is Weighted Clustering Algorithm [2,3]. According to this algorithm weight of each node is calculated based on multiple parameters like mobility, serving time period, degree difference and total distance of neighbors and node with minimum weight is selected as cluster-head.

Clustering allows spatial reuse of resources. It prevents the message flooding as only selected nodes are responsible for message forwarding. Cluster structure makes the network appear smaller and stable as when a node changes the cluster only local cluster needs the updated information [2]. In a clustering architecture, when a mobile host changes its position, it is sufficient only for the hosts within its cluster to update their topology information, but not for all the hosts in this network [4]. It is important to maintain stability of the network due to the dynamic characteristics of nodes. Every time node joins or leaves the network topology information is to be updated within whole network. This can create unnecessary overhead and can lead to congestion that can reduce the performance.

Routing is an essential mechanism that is used to find the optimal route for packet transmission. As we know, in MANETs each node acts as a router and a host itself. Therefore, multi-hop routing is quite possible in MANETs. Routing protocol should be so efficient that it can adapt to changing topology of network quickly. Many routing protocols have been proposed by the researchers in past years and still work is going on to improve efficiency of such schemes in terms of reliability, security etc.

In this paper, we present new cluster formation scheme and routing procedure over new clustering scheme is also shown. Two level hierarchical cluster formation is proposed that requires existing WCA algorithm [2,3] for primary cluster formation and new node LM for secondary cluster formation which can directly communicate to cluster-head on behalf of its members. The routing scheme is also shown that is the modification of Cluster Based Routing Protocol for ad-hoc networks. The advantage of CBRP is that only cluster heads exchange routing information, therefore the number of control overhead transmitted through the network is far less than the traditional flooding methods.

II. Cluster Formation

Cluster formation [7] is building up the cluster structure based on the parameter of mobile nodes. Cluster Formation here is divided into two phases: Primary cluster and Secondary cluster formation.

A. Primary Cluster Formation

For primary cluster formation [1] existing WCA [2-3], algorithm is used. Every node broadcasts a message to its neighboring node along with the weight information and node with the minimum weight is selected as a cluster-head. Weight of the node can be calculated as given below:

$W = aD_v + b\,M_v + cT + dD$

Were,

D_v – Degree difference to know how many more nodes can be adjusted within a cluster and can be computed as $D_v = |d_v - N|$ where dv is the number of neighbors of a mobile node v.

M_v – Mobility measure

T – Node survival time period.

D – Total distance of neighboring nodes.

a, b, c, d are the weighing factors such that

a + b + c + d = 1 in order to normalize the factors Dv, Mv , T and D .

B. Secondary Cluster Formation

1. Assumptions

A node is used as a location manager after the hop count =1 that performs location management for each cluster. Location updates and location finding is performed by LM which reduce the routing overhead [1].

2. Identifying Location Manager

For the selection of Location Manager, mobility of all the nodes is calculated along with the weight calculation during primary cluster formation. Node that is out of the range of CH and having minimum mobility measure and high power level within the area is selected as a Location Manager. The cluster-head maintains the field (zoneID, nodeID) in the table to keep the knowledge of destination address. There can be more than one LM within a primary cluster. The nodes that are within range of each LM form a group called zone. Nodes that are within direct transmission range of LM can send the request to join the respective LM and LM can grant the request to limited number of nodes that it can handle to form a cluster. Rests of the nodes are served by other neighboring LM. In case, if LM is about to change its position or if the power level decreases to some threshold "RESIGN" message is passed to the nodes within the zone and the same process is again repeated for new LM selection.

Process of sending the information of mobility and power along with the weight calculation during primary cluster formation may again reduce the traffic within the network as no extra messages are to be transmitted separately for LM selection. This clustering approach requires topology information updates only within the clusters instead of whole network. This reduces the routing overhead. Also LM helps to reduce the load of CH that increases the lifetime of CH and in turn increases the efficiency of CH.

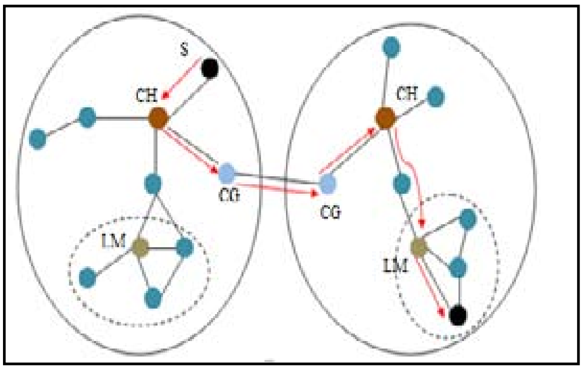

Fig. 1: Cluster Formation

3. Illustration

Now, we illustrate the proposed cluster formation procedure of MANET's. An unclustered network having ten nodes is shown in fig. 2 that are labelled from 1-10. Weight of all the ten nodes is calculated and one of the nodes is selected as a cluster-head having minimum weight. Distance between the nodes is labelled in the fig and the table1 represents the neighboring nodes and assumed mobility measure of each node. Node is said to be the neighbor if it has a direct link to other node. Assumed mobility measure is randomly assigned representing the number of times a node connects to the network.

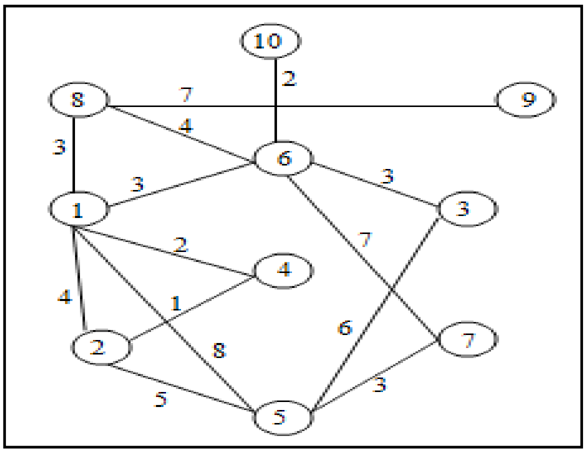

Fig. 2. Unclustered Network

Table 1: Network Information

Nodes	Neighboring Nodes	Degree Diff.	Mobility	Sum of Distances
1	2,4,5	7	2	14
2	1,4,5	7	5	10
3	5,6	8	7	9
4	1,2	8	3	3
5	1,2,3,7	6	10	22
6	1,3,7	7	1	13
7	5,6	8	9	10
8	1,6,9	7	2	14
9	8	9	5	7
10	2	9	10	2

Now, we calculate the weight of each node using WCA algorithm i.e.

$W = aD_v + b\,M_v + cT + Dd$

Were a, b, c, d are the weighing factors such that a + b + c + d = 1. Therefore, we assume a=0.5, b=0.15, c=0.2, d=0.15 in order to normalize the factors Dv, Mv , T and D and suppose number of nodes a cluster can handle be 10. We also assume that all the nodes are within the same network since 1hr. Therefore, T=1. Now, the weight calculations can be shown as:

Node1: W= 0.5*7 + 0.15*2 + 0.2*1 + 0.15*14 = 6.1

Node 2: W= 0.5*7 + 0.15*5 + 0.2 + 0.15*10 = 5.95

Node 3: W= 0.5*8 + 0.15*7 + 0.2 + 0.15*9 = 6.6

Table II: Weight Calculations

Nodes	Weight
1	6.1
2	5.95
3	6.6
4	5.1

5	8
6	5.8
7	7.05
8	6.1
9	6.6
10	6.05

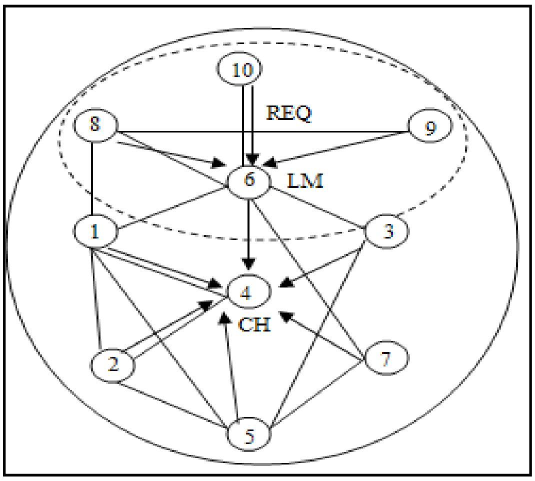

Fig. 3. Cluster Formation

From Table 2, we can see Node 4 is having minimum weight. This information is transmitted to all the nodes and Node 4 is elected as a cluster-head. For the election of LM, mobility information is transmitted and node with minimum mobility i.e. Node 6 is elected as a LM. On the selection of CH, other member nodes send the request to join the clusterhead to form a cluster. From the fig.3 we can see Nodes 8 and 10 have direct transmission link with Node 6 whereas Node 9 uses multi-hop routing to communicate to LM i.e. Node 6. LM on behalf of its members sends the request to join the CH and these nodes can communicate to CH via LM .

III. Routing

A. CBRP: Routing Process

Cluster Based Routing protocol is used for routing in hierarchical network architecture. [5-6] in which nodes are organized into hierarchy and are grouped into clusters. Each cluster has a cluster-head that coordinates the data transmission within the cluster, cluster gateway performs the inter-cluster routing and other non cluster head nodes join the cluster as cluster member. The advantage of CBRP is that only cluster heads exchange routing information, therefore the number of control overhead transmitted through the network is far less than the traditional flooding methods.

B. Proposed Extension to CBRP Routing for Two Level Hierarchy

Each node in network maintains routing table that consists of the fields like (Node Id, Node Status) but cluster head maintains the cluster adjacency table having fields (ch_id, ch_status, cm_id, neighbour_ch, zone_id) where ch_id denotes the unique id of cluster head, ch_status shows whether it is a cluster member / cluster head / cluster gateway, cm_id is the id's of all the cluster member that are under specific clusterhead, neighbour_ch used to denote the neighbouring cluster heads for inter-cluster transmission and zone_id is used to send the packet to LM if the node is out of reach of CH. Routing can be divided into two phases: Route Discovery and Route Maintenance. Route discovery is initiated if the source node does not have valid route to destination, so it will requests CH to get the route and Route maintenance is initiated to sense any link breakages so that there is reliable communication. Both the phases have been described below in detail.

1. Route Discovery

If the source node does not contain valid route to the destination Route Discovery process is initiated. To transmit the packet from source to destination a session is initiated for specific time period T. Now there exist different cases for routing the packet to destination:

Case1: Packet is to be sent to node within same cluster.

In this case, when a packet is to be transmitted to unknown destination D from source S, RREQ message is first sent to cluster-head. Cluster-head checks the Sequence number of packet to confirm packet with same sequence number has not been sent earlier otherwise it discards the packet. Then it checks if the node is in the same cluster or any neighbouring cluster using the cm_id field and sends the RREP message with same sequence number and current route information to S to indicate the member resides within the same cluster. Then source S sends the packet directly to the destination D up to k hops. But if the D is out of the transmission range of cluster head, it becomes the responsibility of cluster head to transmit the packet to appropriate Location Manager and location manager further transmits the packet to destination address using the zone ID. On receiving the packet successfully destination node sends the ACK message to source directly.

Sequence Number	Source Address	Destination Address	Message

Intra-cluster communication message format

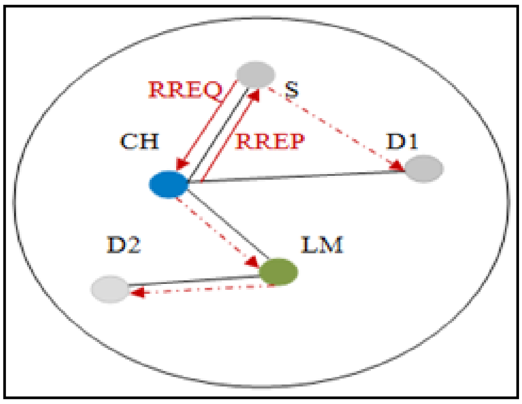

Fig. 4: Inter-Cluster Communication

For example, in the fig above two cases are represented. In first case destination D1 is in direct transmission range. Therefore, Source S asks for the route to D1 from CH and then transmits the packet directly to destination. In second case, destination D2 is out of the reach of CH, therefore it asks

Case2: If the destination address is present in any other adjacent cluster

Now in second case, the source has to transmit the packet to destination that is in any other cluster and sends the packet to nearby cluster-head i.e. adj_ch via cluster gateway. CH further checks if it is within range. If packet is to be sent to destination that is in range of cluster-head, packet is directly transmitted to destination address otherwise it is sent to the LM for further transmission. And on successful reception of packet ACK message is sent to S.

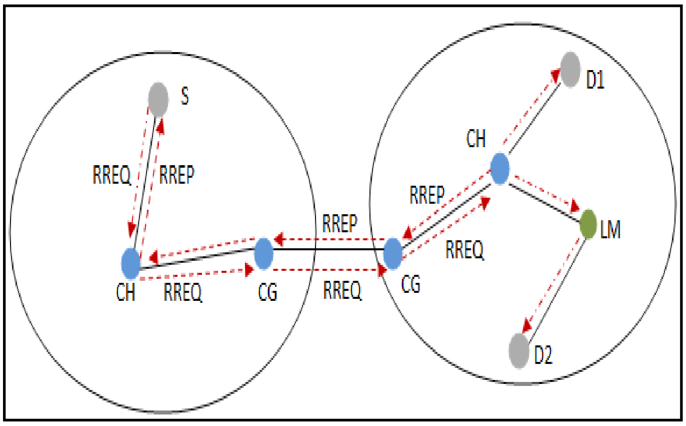

Fig. 5: Inter-Cluster Communication

Seq.No.	Source Add	adj_ch	Dest. Add	Message

Fig. 6: Message Format for Intra-Cluster Communication

2. Route Maintenance

Due to the high mobility of nodes routes of the network are more prone to failures. Routing table explained in the previous topic is used to keep the updated information of the topology. But as nodes can join or leave the network any time therefore the link breakage can also occur anytime. Therefore, we propose the time period i.e. a fixed session within which D sends the ACK message after successful reception of packet. But, if the packet is not received within specific time period T, RError message is generated by the CH since it does not get any acknowledgement from destination D and message is forwarded to destination node through CH.

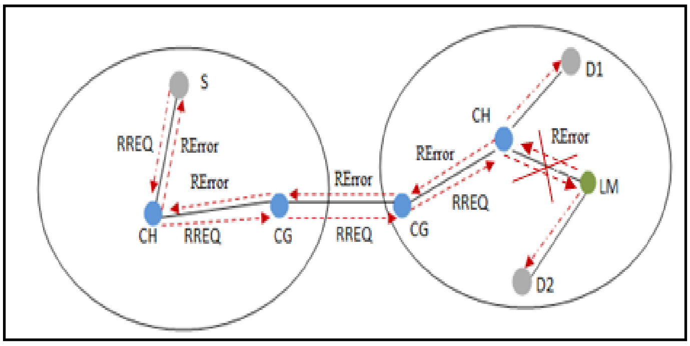

Fig. 7: Route Maintenance

IV. Conclusion and Future Perspectives

Wireless Ad-hoc networks have gained lot of importance from past few years for wireless communication. Communication in ad-hoc networks is the challenging task because of the moving nodes within the network. Links keep on changing and every time a new path is to be searched. This can introduce lot of routing overhead and congestion in the network that degrades the performance. The proposed cluster formation can have some drawbacks like the network design can become complex by using number of LM's. High mobility rate of the nodes can also create the mess in the network. But this strategy can reduce the network traffic within the network as minimum amount of messages are being exchanged between the nodes that can further make the proper bandwidth utilization. Transmission overhead within the network is also reduced by dividing the primary clusters into zones as there is no need to update topology information within whole network and only selected zones are to be updated on the node movement. This also reduces the power consumption of nodes specially of the clusterhead. Hence clusterhead lifetime can increase, hence increasing the cluster stability.

The research findings made out of this paper has opened several auxiliary directions, which can be further investigated. The proposed strategy basically deals with the cluster formation, cluster maintenance and routing. In this dissertation we try to handle the cluster stability and this can be further extended to some other areas of clustering like load balancing and security MANET. For the routing purpose, CBRP protocol has been considered other hierarchical routing protocols can also be applied over the proposed cluster formation and comparative analysis can be performed. Implementation of proposed routing protocol and cluster formation can be simulated and results can be analyzed.

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