Intellisense Cluster Management and Energy Efficient Routing in Mobile Ad Hoc Networks

K. Sangeetha, A. M. Natarajan

Abstract— Mobile ad hoc network (MANET) is a collection of distributed nodes which communicate using multi-hop wireless links with frequent node mobility. The goal for ad hoc networks is to accommodate light weight, battery powered portable devices. Because of the finite power limitation, we have to design efficient ways to use the existing power. For a networking device, significant power is consumed for communications and more specifically for transmissions. A first step towards efficient utilization of power is to maintain the topology and control the transmission range. For maintaining the topology a new clustering scheme is developed considering the cluster coefficient and degree of the nodes. The transmission ranges of the nodes are controlled for avoiding more power consumption. The proposed intellect clustering algorithm is compared with one of the distributed weighted clustering algorithm. The method of clustering is more efficient to the latter and the variable transmission range is adopted to control the utilization of power. The proposed method improves the modeling of ad hoc networks and the serves as good foundation for formation of ad hoc networks.

Index Terms—clustering, cluster coefficient, energy conservation, node degree, transmission range

I. INTRODUCTION

MANET is a special type of wireless network in which a collection of mobile network interfaces may form a temporary network without aid of any established infrastructure or centralized administration. Ad Hoc wireless network has applications in emergency search and-rescue operations, decision making in the battlefield, data acquisition operations in hostile terrain, etc. It is featured by dynamic topology, multi-hop communication, limited resources (bandwidth, CPU, battery, etc.) and limited security. These characteristics put special challenges in routing protocol design. The one of the most important objectives of MANET routing protocol is to maximize energy efficiency, since nodes in MANET depend on limited energy resources.

The primary objectives of MANET routing protocols are to maximize network throughput, to maximize network lifetime, and to maximize delay. The network throughput is usually measured by packet delivery ratio while the most significant contribution to energy consumption is measured by routing overhead which is the number or size of routing control packets. A major challenge that a routing protocol designed for ad hoc wireless networks faces is resource constraints. Devices used in the ad hoc wireless networks in most cases require portability and hence they also have size and weight constraints along with the restrictions on the power source.

It is well-known that cluster architecture enables better resource allocation and helps to improve power control. It also scales well to different network sizes and node densities under energy constraints. In a typical hierarchical architecture, individual sensor nodes forward information to their respective cluster heads (CHs). At the CH the information is aggregated and then sent to a BS by the CH. The CHs and the BS usually form a multihop network, for which energy-efficient routing protocols need to be applied.

The primary goal of topology control in mobile ad hoc networks is to maintain network connectivity optimize network lifetime and throughput and make it possible to design power – efficient routing. Restricting the size of the network has been found to be extremely important in reducing the amount of routing information. We assume that each node can adjust its transmission power according to its neighbors' positions for possible energy conservation.

The gateway is responsible for forwarding routing information and transmitting data packets. It plays the most important role in our protocol and consumes much energy. All hosts should take their turn as the gateway to prolong the lifetime of the network. The election of the gateway should take the remaining battery capacity and position into consideration. A gateway with remaining energy and nearer the center of the cluster is preferred. These two principles prevent another gateway election from being triggered soon. Routing within the clusters are localized and made easy as the size of the routing table is reduced for the individual nodes. The scalability of the network is improved a lot. Clustering avoids the frequent communication of the nodes as result of which the bandwidth utilization is conserved. The network topology is stabilized through clustering and also reduces the topology maintenance overhead.

The main aim of the work is to achieve good balanced cluster size and it serves as the best method for ensuring minimum energy topology. The proposed clustering algorithm is termed as "Intellisense Clusterithm" as it calculates each node's residual energy and based on that cluster head is chosen and it paves way to energy efficient topology. The clustering coefficient is considered for framing the clusters. Every node implements this algorithm individually. This algorithm is implemented in a distributed manner and it carried out iteratively till the resulting clusters have a hierarchical structure. Each node is either a cluster head or a child. The cluster range, cluster coefficient and the minimum energy path to the cluster head determines the number of levels of clusters in the network. All the nodes communicate within the cluster with one-hop neighbors' information and the information are sent to the cluster head. At the different levels the nodes communicate through the gateways.

II. RELATED WORK

Many clustering algorithms have been proposed. Most of these algorithms are heuristic in nature and their aim is to generate the minimum number of clusters.

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X. Hong *et al* (2002) suggest improving the number of nodes in the mobile ad hoc networks.
M. Steenstrup (2001) had presented about the considerations of clustered network for MANET.
Ratish Agarwal *et al* (2009) gave about different ways of clustering and the different algorithms.
Javier Gomez *et al* (2007) had presented a paper regarding the transmission range adopted for mobile ad hoc networks.
S. Chinara *et al* (2009) survey the different method of clustering for one-hop ad hoc networks.
S. Basagni *et al* (2004) presented about the different methods of power conservation in mobile ad hoc networks.
P. Santi (2005) had made presented the issues in topology control
R. Ramanathan *et al* (2000) suggested about the topology control of multi-hop wireless networks using transmit power adjustment.
Murthy, C. S *et al* (2004) had discussed about different architecture and protocols for mobile ad hoc networks.
Zhuochaun, H *et al* (2002) had given methods for topology control using directional antennas

III. MATERIALS AND METHODS

We assume that an ad hoc network can be composed of hundreds of nodes.

- Nodes make decisions on local information.
- Nodes are location-aware, which can be defined using GPS, signal strength or direction.
- The energy consumption among nodes is not uniform.
- Nodes transmit at the different power levels, which is dependent on the transmission distance.

We do not make any assumptions about:

- the size and density of the network;
- the distribution of the nodes;
- the synchronization of the network.

We believe this model and these assumptions are appropriate for many real networks

For node A with di >= 2 , an edge (p,q) is opposite to node A if there exist edges(A,q) and (A,q).The clustering coefficient of node A is the ratio between the actual number of links between the neighbors of node A and the maximum possible number of links between these neighbors. In other words, the clustering coefficient is the ratio between the number of triangles that contain A and the number of triangles that would contain A if all neighbors of A were interlinked. The cluster radius specifies the range of the cluster and it gives how far the farthest node inside a cluster can be from the cluster head. It is a system parameter and is fixed for the entire network. The nodes which do not need relaying when a node A transmits to them are called neighbors of node A.

The rank is locally calculated for each node based on the power which is used for cluster head election. The rank is calculated based on the initial energy Ei residual energy Er, cluster radius, r distance of the node A from the neighboring node B, d.

$$R=\sum(r- d/6r) \times (Er/Ei)$$

Improving Energy efficiency and prolonging the lifetime of the network are the main goal of the work. The cluster head will consume much more energy than the rest of the nodes since it needs to forward all data from the nodes inside its cluster to the gateway nodes. If the nodes inside the cluster are more also it leads to more consumption of energy.

Each cluster is multi-level. There is no optimal number of levels. This is because we make no assumptions about the size and topology of the network. The number of levels in a cluster depends on the cluster range and the minimum energy path to the cluster head, which is represented by Min_Power path. Fig.1 shows a multi-level cluster generated by IC, where H is the cluster head, first level children are a,d,i and second level children are b,c,e,f and etc.. A parent node and its child nodes are neighbors.

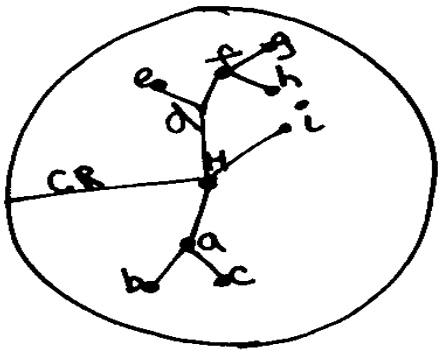

Fig. 1 Cluster node levels

The clusters are generated before the communication is begun. The time to generate the cluster is Tg. Two types of communication can take place in a clustered network as intra-cluster and inter-cluster communication. The time for these two communications is Tc. To guarantee a good performance Tc should be Tg. To avoid a cluster head from drying out the intellisense clusterithm runs periodically every Tc+Tg.During Tg, each node runs IC to generate the clusters. During the initialization phase, a node broadcasts its (x, y) coordinates and uses the neighbor discovery algorithm to find its neighbors. After running the algorithm, each node will have its own set of neighbors inside its enclosure region. These neighbors will be its first level children if it becomes a clusterhead.All the other nodes inside its cluster range will be reached through at least one relay using one of these neighbors. All nodes set their CH to -1 in the beginning, which indicates that they have not joined any cluster yet.

A node that has the largest rank of all its neighbors will become a clusterhead.It becomes a cluster head as certain percentage of neighbors elects it as the cluster head. In the first iteration (i=0), this percentage is 100%. In subsequent iterations (i++), it is decreased to (6-i)/6. When a node becomes a cluster head, it sets CH=1. Those nodes which are not cluster head have CH= -1which could also still become cluster heads during the following iterations. The cluster heads broadcast the information including their CH, x and y coordinates of cluster head.

A node becomes a child node of the cluster head in the following three cases:
(i)When a node's CH = -1: The node receives a broadcast message from its neighbors, which includes CH of the neighbor and the x and y coordinates of a cluster head (*head_x* and *head_y*). If the distance from the cluster head to the node is less than or equal to the cluster range then the node chooses its cluster head as its cluster head and sets its CH to CH from the broadcast message plus one,

and its d to d from the broadcast message plus its distance to the neighbor.

(ii)When a node's CH ≠ 1 : If the neighbor who sends the broadcast has a different cluster head, and the distance from the node to the neighbor's cluster head is inside the cluster range, and the new calculated d1 is less than the previous d from the node to its current cluster head. This indicates that it has already chosen its cluster head.

(iii) When a nodes' CH ≠ -1: The node receives a broadcast from its neighbor. If the neighbor has the same cluster head as the node, and the d1 from the node to this neighbor is less than the previous d, then the node will choose the neighbor as its parent and reset its CH and d as in the second case.

Due to the mobility of nodes in the mobile ad hoc networks, the clusters have to be reorganized and reconfigured as and when essential. The following three important cases should be considered for maintaining the clustered topology:

- Rank of CH is lost
- Mobility of child nodes
- Mobility of CH

The rank of the cluster head is calculated continuously. When its rank value (which is based on the residual energy of the node) goes down below the threshold value, the CH sends a message CH_Release to all its nodes in its cluster. After receiving CH_Release all nodes calculate the respective rank values and inform it to the present CH. Now the CH selects the next succeeding CH with CH_Rack with NID of the new CH.

When a node moves out from one cluster to another, it sends the HELLO message to find a new cluster to join the network. After receiving the HELLO message, the new CH verifies whether it has reached the threshold value of number of the threshold value of number of nodes in the cluster. If the maximum number of nodes has not been reached it sends the new node with CH_Ack for which the new node sends back CH_Join message with its latest rank. Then again the CH replies it with CH_NewNode and updates its neighbor node information and broadcasts it within the cluster. But if the CH has reached the threshold value, it replies the new node with CH_Nack which is a negative acknowledgement.

When the CH moves away beyond the cluster radius, the farthest node waits for the HELLO message from CH which is issued every $T_{ref,}$ which is the refreshing period. If the node receives the message it can maintain the membership of the cluster. If the node does not receive it floods the neighbor nodes with HELLO message indicating its presence. After receiving the acknowledgement from any reachable CH or any other nodes in an m- hop cluster, it sends the Inform message. It triggers the election of new cluster head and the process is carried out and a new CH is elected for the deserted cluster nodes.

The proposed intellect clusterithm is actually based on energy level of the nodes. From the intellisense packets received, the cluster nodes compare their own energy level. When the energy level of the cluster head is less than that of new node entering the cluster, then also based on authentication cluster head change over occurs.

Cluster heads are elected based on the value of energy the nodes possess. As mentioned before, the role of the cluster heads is to perform routing in the network. This will conserve energy since only one node at the time in each cluster is required to constantly operate with an active radio interface. The remaining nodes can resort to sensing the environment and only activate the radio when necessary. Heads of clusters will be changed once the current head of cluster energy reaches a pre-determined threshold.

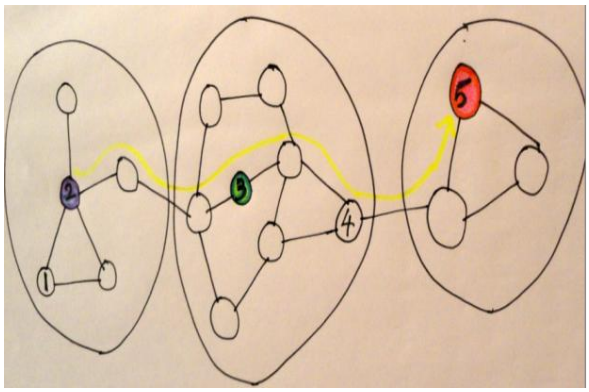

Fig.2 Cluster Communication

Intra-cluster communication is performed within the cluster as contention-less communication. Each node communicates with its one hop neighbors and forwards the data to the neighboring nodes until the data reaches the cluster head.

The format of the Hello message is as follows:

Hello Message: (CID, NID, N, n (N), B, BN, AVG, NG)

Where
CID - Cluster identity
NID - The identifier of the node
L - List of neighbor nodes
n (N) - The number of neighbors
C - The carry parameter of a node: the number of nodes which can be used to reach the destination in two–hop neighbors.
CN - Carry node: the preferred node (having the maximum value of C) for the distribution to two jumps.
AVG - The choice average of a CN
NG - Neighbor gateway: to indicate the nodes which are . gateways.

To find the destination, the source sends a request "route_req", which forms a structure of a list:

route_req = (S, Inter, Dest, d)

Where
S - contains the identity of the source node.
Inter - indicates the identities of intermediate nodes.
Dest - contains the identity of the destination node
d - indicates the distance between each intermediate node and the source.

Once the destination receives the 'route_req' request, it sends a route_rep response which has almost the same structure as the 'route_req' except it doesn't use the last field d**.** Reverse path can be adopted for 'route_rep'.

Inter-cluster communication is achieved through the gateway.

The cluster heads poll their first level children, include their own data and transmit to the gateway. The cluster heads consolidate several data packets into one data packet thus reducing overhead. Routes between clusters are achieved by using any reactive protocol throughout the network. When node wants to send a packet to its destination which is not within its cluster, the following scenario may occur:

- When there is a route to the destination already stored source node's routing table then it carries out the inter cluster routing to reach the destination.
- When the destination is unknown the source initiates a 'route_req' to its neighbors' clusters head or carry nodes (ordinary nodes are no longer part of this phase).

If the source is a simply a node, it sends the 'route_req' directly to the carry node which generates a route discovery. The clusters Head or the carry nodes which receive a 'route_req' save their identities in the field intermediate and their distances in the field d;then they test if the destination is present nearby; otherwise, they send the new request to Cluster Head "CH" or carry nodes"CN" consulting their inter cluster routing table. Once the 'route_req ' requests arrive at the destination, it chooses the shortest route and sends a 'route_rep' response. To avoid the problem of loops, each gateway node sends a single packet that came from the same node.

The nodes can alter their transmit power level to maintain the connectivity of the network topology, while increasing the network capacity, and reducing the interference and energy consumption. Here, Signal to Interference Ratio (SIR) threshold, transmit power and received signal strength are generally used to end the minimum transmission power required between any two nodes in the network.

We start by calculating the required transmission power for the highest data rate using the lowest transmission power. If the calculated transmission power is feasible (that is, if we send a packet using a transmission power supported by the radio and the reception power provides an acceptable signal to noise ratio), then the process stops. If not, we increase the transmission power up to the maximum transmission power of the radio. Next, if the highest data rate is not achievable, we reduce the tentative data rate and reapply the equation with its associated SINR. The process repeats until a valid transmission power is found or all the data rates and transmission powers are tried. This algorithm is fast, as the number of transmission power and data rate combinations is usually lower than fifty.

IV. RESULTS

The simulation results are implemented by using ns. The below table shows the parameters used in simulations. We have implemented two sets of simulations, one with 100 nodes in half square kilometer, and the other with 400 nodes in a two square kilometer area. The sink node (i.e., the data center) is placed in the middle.

Table 1: Parameters for Simulation

Parameter	Simulation 1	Simulation 2
Number of Nodes	100	400
Network grid	(0,0) , (500,500)	(0,0) (2000,2000)
Sink (data center)	(250,250)	(1000,1000)
Threshold distance	50 m	50m
Cluster Range	50,100,150,…400	100,200,300….1500
Data Packet Size	100 bytes	100 bytes
Broadcast Packet Size	25 bytes	25 bytes
Packet Header Size	25 bytes	25 bytes
Initial Energy	50 J/batt	50 J/bat

V. DISCUSSION

To measure the performance of our algorithm, we identify two metrics: (i) the number of cluster heads (iii) the transmission range of nodes. Every time a cluster head is identified, its transmission range gives the number of nodes in each cluster head. We also study how the transmission range factor changes as the system evolves and how well connected the nodes are in a cluster. Due to the importance of keeping the node degree as close to the ideal as possible, the importance is given to transmission range.

Fig. 3 depicts the average number of clusters formed with respect to the transmission range in the Ad-hoc networks. If the node density increased, intelligent clusterithm produced clusters with high mobility in comparison with HEED regardless of node speed. As a result, our algorithm Intelligent Clusterithm IC gave better performance in terms of the number of clusters when the node density and node mobility in the network is high.

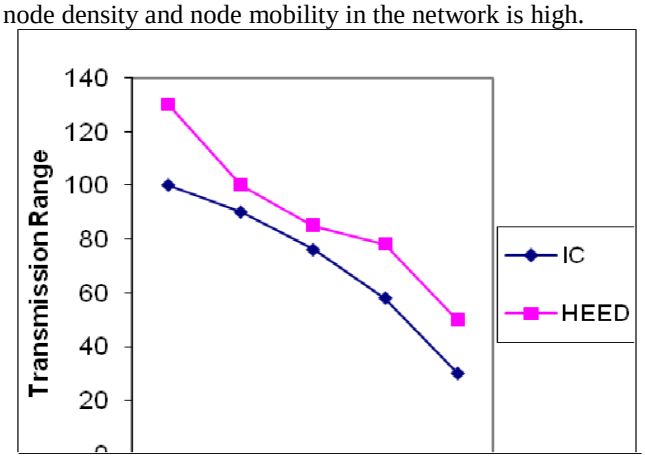

Fig. 3 Transmission Range Vs No. of clusters

Fig. 4 shows the results of end-to-end throughput of the average number of nodes formed with respect to the transmission range in the Ad-hoc networks. HEED gave lower throughput as the node density and mobility increased. Regardless of the number of nodes and the node speed, IC gives consistently better end-to-end throughput in comparison with HEED.

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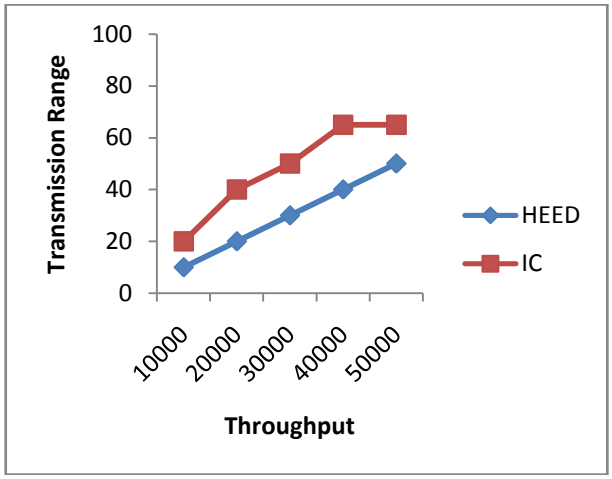

Fig. 4 Transmission Range Vs Throughput

VI. CONCLUSION

In this paper, we proposed a distributed, energy efficient hierarchical clustering Algorithm called intellisense clusterithm. It operates with only realistic assumptions. The algorithm constructs multilevel clusters and the nodes in each cluster reach the cluster head by relaying through other nodes. IC is well-distributed, and runs in optimum time which is a major advantage in a power-constrained sensor network. Our simulations demonstrated that IC generates well balanced clusters. Both intra-cluster and inter-cluster energy consumption is greatly improved over clusters generated by the HEED algorithm.

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