Reliable Scheme for Cluster Head Election in Mobile Ad Hoc Networks

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Abstract
Ad hoc mobile devices are set of consistent heterogeneous devices that move in an independent fashion and communicate with one another over a wireless channel. These devices are presumed to have a non-deterministic mobility pattern. Clusters are formed by clubbing together nodes and heads are elected to manage, serve as a backbone, and route packets to other cluster heads. A lot of policies used in selection of cluster heads are biased in favor of some nodes. The result of the responsibilities of cluster heads, may deplete their energy faster due to higher number of communications with nodes on the network. This situation might cause them to drop out of the network. This paper therefore, proposes a reliable scheme for election of cluster heads by giving all nodes the opportunity to serve as a cluster head and provides enhancement to existing algorithms to minimize the unbalanced distribution of nodes under cluster heads and increase the active life of a node in a network. The scheme elects right cluster head and help nodes to relinquish their headship to other nodes if their power is low.

Keywords — ad hoc network, load balancing, clustering, communications, policies

I. INTRODUCTION

Mobile ad hoc network (MANET) is a type of network where nodes communicate with one another using a shared medium. The nodes communicate with each other through multi-hop shared radio channel. Ad hoc networks are easy to setup since no infrastructure is required, and thus a cost effective implementation. The nodes communicate with each other within their transmission range [1]. All nodes in this network take part in the communication process. The nodes in this type of network move freely, and topologies can change capriciously. The free movement of nodes, and the frequent change of topology usually result in unpredictable topology as there is no heavy network infrastructure. MANETs can operate in standalone mode or connect to gateway devices to give Internet access to other nodes in remote areas. MANETs have numerous advantages as outlined in [3]. The many advantages of MANETs include law enforcement, disaster and relief, industrial and government applications, collaborative and distributed computing, sensor networks, and vehicular communications. In [4], the authors proposed two main forms of MANET; flat and hierarchical MANETs. In flat MANETs, all nodes have to store the topology of the network. This usually causes scalability problem, and only recommended for small networks. Hence robust clustering algorithms are needed to solve scalability problem and provide effective quality of service [2]. Hierarchical MANET on other hand divides the nodes into groups called clusters. The nodes are classified into three; namely cluster head, gateway and ordinary node or member. Cluster head is elected from the cluster and has responsibility of managing the routing and control messages within the cluster. The other nodes associate themselves with their neighboring cluster heads. The gateway nodes are also responsible for communication and forwarding of messages between clusters. Some of the advantages of clustering are efficient handling of mobility management, power management, shared use of applications within the cluster, spatial reuse of resources, virtual client support, better bandwidth utilization, aggregation of topology information, and minimal storage requirements for communication [5]. However, there are inherit traditional problems with wireless networks. These problems are not only limited to the dynamic nature of the network, link failure and packet loss, unpredictable topology, and energy constrained.

This paper proposes a novel clustering algorithm which solves the problems outlined above through an effective way of electing cluster heads in MANETs. This scheme also enables the formation of stable and scalable clusters and uses a technique that maintains the cluster structure thereby reducing messages in the group.

In [5, 6], Ad hoc network clustered architecture organizes nodes into clusters, each governed by cluster head. The nodes in the cluster involves in message dissemination and routing. The messages are also forwarded to other cluster heads or base stations in sensor networks. They outlined a typical sensor network where sensor nodes forward messages through a base station which are basically two hops. Cluster network is good for sensor networks because of its inherent suitability for data fusion. Since all data gathered by members of the cluster can be fused at the cluster head and later communicated to a base station or other routers. Sensor networks are self-organizing, and therefore formation and election should be conducted by themselves [27]. The election
of the cluster head should be autonomous; thus every node should be given opportunity to be elected. 

The rest of the paper is organised as follows. Related work done in the area of cluster-based routing is reviewed in Section 2. Section 3 discusses the clustering setup. Section 4 presents the proposed enhancement. Section 5 deals with performance evaluation and section 6 concludes the paper.

II. RELATED WORK

A lot of work has been done by researchers in the field on selecting cluster heads in MANETs. In [7] and [8], the authors presented on link cluster algorithm. In their work, the selection of cluster head is based on node with highest identity number among the group members in the network. The maximum connectivity algorithm proposed by the authors in [9], based their selection of cluster head on the maximum number of neighbor nodes, and the throughput. The system performance however decreases with the increase in the number of nodes that make up the network under investigation. The lowest-ID algorithm proposed in [8] is one of the popular algorithms employed in the cluster head selection; based on lowest virtual identification number. There have been several modifications on this algorithm to make selection of cluster heads and management of clusters more suitable, and power efficient. For example, in [10], [11] and [12] the authors affirmed it with the same concepts in their works. However, these schemes are not effective in electing the most suitable node as the cluster head.

Mobility is one of the unique features of MANETs [13, 14]. Mobility always lead to change in topology, cluster head re-election and route invalidation. The impact of mobility in MANETs is outlined in [15]. In mobility-aware clustering, nodes with same speed are grouped together under same cluster head to ensure stability and collaborative activities. In [16], the authors designed mobility-based algorithm where each member, calculates the relative mobility values with respect to the neighboring nodes which are used for cluster head election Therefore nodes with low speed relative to their neighbors are elected as cluster heads. This leads to large communication overheads and large latency during cluster formation.

Another issue with MANET is extensive power consumption by the cluster head. The cluster head consumes a lot of power since it is involved in every routing and broadcasting in the network. If the elected cluster head keeps controlling the activities on the network for long time, it will deplete all its power which will lead to partitioning of the network and consequent disruption in communication on the network. In [17] and [18], the authors proposed a distributed heuristic clustering scheme for energy conservation in two-tiered MANETs, and energy aware based on DS-Marking algorithm respectively. Usually, the maximum number of hops between two nodes in a cluster is two. With these algorithms, if the network is densely populated the degree of the cluster head and the workload become high for the creation of clusters. In [19] a proposed max-min-D-cluster algorithm, where the cluster head form part of a d-hop dominating set, nonetheless there is no limit to the maximum size of each cluster and resulted in overloaded clusters.

In Distributed Cluster Algorithm (DCA) as proposed in [20], the authors introduced a weight-based scheme for the selection of a cluster head. In their work, they assumed a unique weight for each node in the cluster however, the technique for assigning weights to the nodes was not properly addressed. They only presented a distributed cluster algorithm that partitions the nodes of a multi-hop wireless network into clusters and adapt to changes in the network topology.

III. CLUSTER SET-UP ALGORITHM

To set-up a proficient cluster, a central or distributed (k, r) dominating set finding algorithm is used for selecting the nodes that act as coordinators of the clustering process. In the process of selecting dominating nodes, redundancy is achieved by choosing the value of the parameter k greater than one and parameter r allows increased local availability. The following are concerns that need to be addressed while designing and implementing SCAM clustering algorithm as proposed in [20]:

1. Selection of the minimal number of cluster heads, which yields high throughput but with low latency as possible.
2. Efficiency and stability of the created clusters.
3. Network scalability
4. Mechanism to prevent the clusters from growing too large. If the clusters grow too large, the load on the cluster head becomes too heavy for it to handle.
5. Maintenance mechanism for the existing clusters. Most existing clustering algorithms create new clustering structures from scratch after a specified time interval.

Algorithm 1

Data: G = (V, E) and parameters r and k
Result: DS, Dominating Set
Begin
Initialization;
DS = ∅
for each u ∈ V do
Compute the suitability_value of node u, u.
Suitability_Value;
u.Required_Ch = k;
Insert_Priority_Heap(H, u);
End
While(H ≠ ∅) do
P=del_root(H);

p.Required_Ch=0;
DS=DS U p;
Find_Rhop_Neighbour(p,G,U_prd);
For (u ∈ U_prd) and (u∈H) do
    u.Required_Ch=u.Required_Ch  1;
    if u.Required_Ch ==0 then
        delete(H,u)
    end if
end find_2rhop_Neighbour(p,G,U_p2rd);
for each (u ∈ H) and (u∈U_p2nd) do
    compute u.Suitability_value;
    find_Rhop_Neighbour(u, G, V_yrd);
    for each(w ∈ V_yrd ) do
        u.Suitability_Value=u.Suitability_Value+w. Required_Ch;
    end
end makeheap(H)
end
SCAM- (k, r) -DS algorithm

IV. PROPOSED ENHANCEMENT

We based our research on the above algorithm in setting up the cluster and incorporating the use of fuzzy logic as proposed in [24] and concept of load transfer in the determination of the cluster head. We propose an enhancement to the whole process of clustering.

The Clustering is divided into three phases:
   i. Election of the Cluster Head,
   ii. Selection of the Cluster Head, and
   iii. Load Transfer from one Cluster Head to another as in [25].

A. Election of the Cluster Head

The cluster head plays a major role by coordinating all activities on the network as explained earlier. The elected cluster head acts as a base station by forwarding packets and communicating with other cluster heads. It communicates with other clusters through respective cluster heads or through gateways by sending and receiving data, managing and controlling messages on the network. There have been several algorithms for cluster head selection as discussed in the related works section of this paper. The factors that influence an algorithm in cluster head selection as outlined in [22, 26] include geographical location of the node, stability, mobility of the node, energy, capacity and throughput of the node. The election of the cluster head is done using the Lower Identify (LID) algorithm.

Parameters for cluster head selection

- SOCH: set of all the cluster heads
- CHN: Cluster Head Node
- NT: Total number of nodes in the sample area
- CR: The nodes covered under a cluster head
- NR: Node Range (25 Units)

- Ni : Node under consideration
- NC: Set of respective Cluster Head that can take the current node under its own cluster

Implementation: Algorithm II

Begin NodeCHK
    for(x=0;x<=NT;x++)
        for(y=0;y<=NT;y++)
            if(Nx < NR && Nx != CR)
                Nx = CR for Cx
            end if
        end for
    end for
end NodeCHK

Begin LIDelect
    for(i=0;i<=N;i++)
        if(NPID = lowest && Ni != CR)
            Ni = SOCH
            Ni = present Cluster Head
        end if
    end for
end LIDelect

B. Selection of the Cluster Head

The selection of the cluster head is based on a Fuzzy decision [21] made by the nodes that come under different cluster heads. For this fuzzy selection we use a few more parameters, namely work budget left and number of nodes under the cluster head. The nodes will decide their cluster heads based on the values of these two parameters.

Parameters

- SOCH: set of all the cluster heads
- CHN: Cluster Head Node
- NT: Total number of nodes in the sample area
- CVR: The nodes covered under a cluster head
- NR: Node Range (25 Units)
- Ni: Node under consideration
- NC: Set of respective Cluster Head that can take the current node under its own cluster
- NUN: Number of Nodes Under the cluster head
- WB: Work Budget left

Implementation: Algorithm III

Begin FuzzyCHK
    for(i=0;i<=SOCH;i++)
        A1 = AVG(WB)
        A2 = AVG(NN)
        end for
    for(i=0;i<=SOCH;i++)
        if(Ni belong to NC)
            T1= MAX(WBi from SOCH)
            T2 = MIN(NNi from SOCH)
            M1 = MOD(AVG(WB)-T1)
            M2 = MOD(AVG(NN)-T2)
        end if
    end for
In the above algorithm, the average work budget left is calculated first and the average number of nodes under each cluster head. The maximum work budget left if the cluster heads are retrieved; thus, the maximum battery life span left. We store this value in T1. Similarly, we choose the cluster head with the least number of nodes under it and store it in variable T2. We then calculate the difference between the maximum WB left and NN. Here we used the MOD function since we want the difference between the values and not the actual value. We then multiply these values and store in an array M3. Now choosing the minimum value from this array will give us the desired cluster head for the current node. We multiply because if the WB is high but the difference between NN and AVG (NN) is low, we will get a lower value as compared to the rest of the combinations. The cluster head, having the lowest value will have a relatively higher work budget left and a lower number of nodes under it is selected.

C. Load Transfer

This part of the enhancements is done to reduce the effect of increased load when a new node gets admitted into the cluster. The above algorithm works well, but if the node tries to join at a later stage, the cluster heads tend to transfer this node to another cluster head which is relatively under loaded.

Parameters

- SOCH: set of all the cluster heads
- HN: Cluster Head Node
- NT: Total number of nodes in the sample are
- CVR: The nodes covered under a cluster head
- NR: Node Range (25 Units)
- Ni: Node under consideration
- NC: Set of respective cluster head that can take the current node under its own cluster
- NUN: Number of Nodes Under the cluster head
- WB: Work Budget left

Implementation: Algorithm IV

Begin TransferCHK
for(i=0;i<NC;i++)
if(Ni belongs to NC)
    T1 = ( WBi from SC)
    T2 = ( NUNi from SC)
    M1 = MOD(AVG(T1-Ti))
    M2 = MOD(AVG(T2-Ti))
    M3= M1*M2
    if(MIN(M3))
        Transfer Ni to CHNi
end if
end for
end TransferCHK

When a new request comes to a cluster head, it looks for all the cluster heads which can take this node under its own cluster. The cluster head compares its existing work budget left and number of nodes under it. So, the cluster head with relatively lower number of nodes under it will accept this incoming node.

V. PERFORMANCE EVALUATION

Simulation Bed

The test bench that we have used are:

- Mobility pattern is non-deterministic.
- Movement not more than 1 the range of a node per unit time.
- 200 x 200 Sq. Unit Areas.
- Size of the cluster is not known.
- Total number of nodes = {25, 50, 75,100}.
- Sample time = 100ms.
- Node Range = 25 Units (fixed).
- Work Budget = 5000 Units.
- Random Work deducted with a max work done of 10.

The NS2 software simulator tool is used to test the performance against other existing protocols. The simulated ad hoc network is composed of slowly changing network topology. The topology has a square area with length 200 and width 200. The network nodes are randomly distributed.

![Fig 1. Clustering formation](http://www.ijcttjournal.org)
time seconds, selects another destination, and proceeds as previously described. This movement pattern is repeated for the duration of the simulation. One of the major parameters where we can easily assess the quality of the algorithm is the average cluster head time. This gives us a fair idea of the network lifetime. Hence, we compare our proposed algorithm with the existing algorithm.

But the rate of reduction in the number of clusters created gets reduced on further increase in the transmission range. The power consumption is high for higher transmission range. Hence, the recommended value of transmission range is between 30 and 40 m.

The network shows low network lifetime in HC initially because the number of nodes are less. Less nodes amount to lower network lifetime. With the enhancement incorporated we see that the initial network lifetime i.e. with less number of nodes has improved because there was a better distribution of nodes under each cluster head.

The results shown are for varying values of total number of nodes. When the transmission range increases, more and more nodes are connected to the same cluster head resulting in reduced number of clusters created. A smaller backbone is desirable for minimising the routing overhead. Hence, transmission power of a node is also a deciding factor for finding the quality of dominating nodes. When the transmission range is increased from 20 to 40 m, the number of clusters created is reduced considerably.

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Fig. 2 High connectivity vs our scheme

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Fig. 3 Transmission range against number of clusters

Fig. 3 shows that the average number of clusters is relatively high when the transmission range is small. The results shown are for varying values of total number of nodes. When the transmission range increases, more and more nodes are connected to the same cluster head resulting in reduced number of clusters created. A smaller backbone is desirable for minimising the routing overhead. Hence, transmission power of a node is also a deciding factor for finding the quality of dominating nodes. When the transmission range is increased from 20 to 40 m, the number of clusters created is reduced considerably.

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Fig. 4 number of clusters in our scheme, SCAM WCA, and H-degree

Fig. 4 compares the number of clusters formed for Our scheme, SCAM, WCA and H-degree as a function of the transmission range. The results show that the average number of cluster heads selected using our scheme is less compared with SCAM, WCA, and H-degree. This is because they create less number of clusters when the cluster radius increases and make use of the cluster merging process. But increased radius leads to increased cluster size, which adversely affects the performance. So the selection of radius is critical over here.

Fig. 5 number of clusters in our scheme, DSCAM, Wu and Li , and H-degree

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Fig. 5 shows the number of clusters formed for our scheme, DSCAM, Wu and Li, and H-degree as a function of the transmission range. Our scheme creates less number of clusters compared with the other protocols. This is because our scheme forms less number of clusters with larger values of radius and uses pruning techniques to reduce the number of cluster heads.
As shown in Fig. 6, our algorithm clearly outperforms H-degree and WCA protocols in terms of Load Balancing Factor because it is a multi-cluster head and bounded distance clustering algorithm.

Fig. 7 compares the LBF of our scheme, DSCAM, Wu and Li, H-degree and WCA. One can observe that there is a reduction in LBF with increase in the value of radius. This is because when the value of radius increases more and more nodes are added to the same cluster head and it load gets increased.

VI. CONCLUSION

With the base algorithms being a bit inefficient in clustering in terms of the average cluster head time, we proposed an enhancement. The proposed enhancement helps the existing algorithm: LID to maintain a better network as compared to LID alone by distributing the load over to a relatively under loaded cluster heads and helps in the selection of a cluster head by monitoring two major parameters of the ad hoc network; the work budget left, and the number of nodes serviced by the cluster head. This improvement in the network lifetime is due to the change in the selection and election algorithm, and also to the transfer of node when there is a new admission to the system after it starts running. As the number of nodes in the sample area increases, the network lifetime decreases because, all the cluster heads have to handle greater responsibilities. But this fall in the network lifetime is stabilized as the nodes increase.

REFERENCES


