A Stable and Energy Based Weighted Clustering Algorithm in MANET (SEBWCA)

P. Annadurai
Department of Computer Science, Arignar Anna Government Arts & Science College, Karaikal
pannadurai98@yahoo.com

S. Vijayalakshmi
Department of Computer Application, Hindustan University, Chennai, Tamilnadu
anvij.lakshmi@yahoo.co.in

ABSTRACT

Cluster computing in ad hoc network draws special attention among the research community as it mandates the usage of single bandwidth for many receivers associated with the group/cluster. Ad hoc network operational environment has incurred the adoption of cluster computing as it innately assists its formation. Cluster computing in ad hoc network has undergone a paradigm shift in the deployment of community centric applications like multiparty video conferencing, multiplayer online video games, online software patch update and online auction etc. In a cluster structure, the mobile nodes in a network are divided into several clusters. Every mobile node assigned a different function, such as cluster head, cluster gateway or cluster member. The cluster head works in dual power mode at high transmission range for inter-cluster communication and low transmission range for intra-cluster communication. The main idea in this paper to have group members actively participate among the group members within cluster. Therefore reducing the communication and computation load on the source. In this paper carries on by highlighting the stability and energy based weighted clustering algorithm. The stability and energy is one of the main criteria for maintaining the cluster in the MANET. Thus the stable and energy is maximum maintain the cluster in the MANET using the proposed work. Finally the detailed simulation experiments and working flow of our clustering algorithm yields the better performance as compared with the existing heuristics in terms of network division (clusters), reauthentication frequency, transmission range, energy consumption and mobility.

Keywords:- Ad hoc network; Cluster; Load balancing; Connectivity; Stability; Energy

1. INTRODUCTION

We ask that authors follow some simple guidelines. In essence, we ask you to make your paper look exactly like this document. The easiest way to do this is simply to download the template, and replace the content with your own material. A collection of wireless nodes that self-configure to form a network without the aid of any established infrastructure is called mobile Ad hoc network (MANET). They can be also defined as a collection of mobile nodes that intercommunicate on shared wireless channels. The nodes entering or leaving the network have routing capabilities which allow them to create multi-hop paths connecting node which are not within radio range [1]. Communication in such a network can be performed if nodes are agreed to exchange packets. Effective support of group communication is essential for most ad-hoc network applications. There are many applications where group communication is a crucial task. Group communication, both one-to-many and many-to-many, has become increasingly important in ad-hoc networks.

Clustering in Mobile Ad Hoc Networks (MANETs) has many advantages as routing efficiency, transmission management, information collection compared to the traditional networks. But the highly dynamic and unstable nature of MANETs makes it difficult for the cluster based routing protocols to divide a mobile network into clusters and determination of cluster heads for each cluster. The clustering technique adopts any one of the following clustering approaches like Location based, Neighbor based, Power Based, Artificial Intelligence Based, Mobility based and Weight Based [2]. Each approach advocates its own formation of clusters and cluster head selection for the smooth transit of messages across clusters. A hierarchical routing is possible by clustering in which paths are recorded between clusters instead of between nodes. It increases the routes lifetime, thus decreasing the amount of routing control overhead [3]. The cluster head coordinates the cluster activities inside the cluster. The ordinary nodes in cluster have direct access only to cluster head and gateways. Gateway nodes are those that are present in the overlapping zone of two clusters to facilitate the data transmission across clusters [4].

This paper addresses the clustering algorithm which is used for electing the cluster heads in the network. The clustering algorithm takes into consideration the parameters are neighbor node, degree-difference, battery power, sum of distance, stability. The clustering algorithm is invoked adaptively based on the mobility of the nodes, thus the cluster head election procedure is invoked. Due to this the balancing the load between the cluster heads is another desirable feature of any clustering algorithm. Ad hoc networks are dynamic in nature so that to maintain the complete stability and battery power is very difficult but our algorithm achieves the stability; maintain energy level by specifying a pre-defined threshold on the number of nodes that a cluster head can handle ideally.

1.1 Reading Roadmap

The remainder of this paper is organized as follows: **Section 2** describes the analysis of the related work. **Section 3** gives a detailed description about the proposed work and explains the various algorithms for clustering, **Section 4** lists the simulation results to
evaluate its performance, and finally, Section 5 concludes the paper.

2. RELATED WORK

They are several heuristic have been proposed to choose cluster heads in ad hoc networks. They include (I) Highest-degree heuristic, (II) Lowest-ID heuristic, (III) Node-weight heuristic (IV) Weighted clustering algorithm.

2.1 Highest-degree heuristic

The highest-degree also known as connectivity-based clustering was originally proposed by Gerla and Parekh [5,6,7]. In which the degree of a node is computed based on its distance from others. Each node broadcasts its ID to the nodes that are within its transmission range. The node with the maximum number of neighbors (i.e., maximum degree) is broken by the unique node IDs. The neighbors of a cluster head become members of the cluster and can no longer participate in the election process. Since, no cluster heads are directly linked, only one cluster head is allowed per cluster. Major drawbacks of this algorithm are the number of nodes in a cluster is increased, the throughput drops and hence a gradual degradation in the system performance is observed, and another drawback is the reaffiliation counts of nodes are high due to node movements and as a results, the highest-degree node may not be re-elected to be a cluster head even if it loses one neighbor.

2.2 Lowest-ID heuristic

In this algorithm was originally proposed by Baker and Ephremides [8,9,10]. This Lowest-ID also as known as Identifier based clustering. Here each node is assigned a distinct ID and the clusters are formed, periodically a node broadcasts the list of nodes that it can hear including itself. A node, which only hears nodes with ID higher than itself, becomes a cluster head. The lowest-ID node that a node hears is its cluster head, unless the lowest-ID specifically gives up its role as a cluster head. A node, which can hear two or more cluster heads, is a gateway otherwise the node is an ordinary node. Major drawbacks of this algorithm are its bias towards nodes with smaller IDs which may lead to the battery drainage of certain nodes, and it does not attempt to balance the load uniformly across all the nodes.

2.3 Node-Weight Algorithm

Basagni proposed two algorithms, namely distributed clustering algorithm (DCA) and distributed mobility adaptive clustering algorithm (DMAC) [11,12]. In this approach, each node is assigned weights (a real number ≥ 0) based on suitability of being a cluster head if its neighbors weight; otherwise, it joins a neighboring cluster head. The smaller ID node ID is chosen in case of a tie. The DCA makes an assumption that the network topology does not change during the execution of the algorithm. Major drawbacks are the node-weight heuristic assigns node-weights based on the suitability of nodes acting as cluster head and the election of the cluster head is done on the basis of the largest weight among its neighbors. This means a node decides to become a cluster head or ordinary node depending on the weights of its one hop neighbors. Basically, the node has to wait for all the responses from its neighbor to make its own decision to be a cluster head or on ordinary node. Here a node is may need to wait to receive responses from its neighbors.

2.4 Weighted Clustering Algorithm

The weighted clustering algorithm (WCA) was originally proposed by M.Chatterjee [8]. It takes four factors into consideration and makes the selection of cluster head and maintenance of cluster more reasonable as is shown in equation (1), the four factors are node degree, distance summation to all its neighboring nodes, mobility and remaining battery power respectively.

\[
W_i = W_{i\Delta v} + W_{iDv} + W_{iMv} + W_{iPv} \quad \cdots \quad (1)
\]

Although WCA has proved better performance than the entire previous algorithm but it lacks a draw back in knowing the weights of all the nodes before starting the clustering process and in draining the cluster head rapidly by WCA is very high. The WCA and mobility based algorithms try to include the stability of nodes as a factor in the election procedure, in order to elect the most stable node as cluster head. But their methods to compute stability are based on some assumptions which are not always valid in all ad hoc networks. When a node has moved out of its cluster, it will firstly check whether it be a member of other clusters, if such a cluster exists, it will detach from current cluster and attach itself to that one. The process of joining a new cluster is known as reaffiliation. If the reaffiliation fails, the whole network will recall the cluster head election routine. Here the drawback is high reaffiliation frequency when network scenario changes very fast high frequency of reaffiliation will increase the communication overhead.

3. PROPOSED WORK – A STABLE AND ENERGY BASED WEIGHTED CLUSTERING ALGORITHM IN MANET (SEBWCA)

Clustering is a process that divides the network into interconnected substructures, called clusters. Each cluster head acts a temporary base station within its zone or cluster and communicates with other cluster heads and also act as a coordinator within the substructure. The cluster head forward packets on behalf of the members of their cluster. Cluster members forward all their traffic to their cluster head. The cluster heads act as routers for their cluster members. In this (SEBWCA) was designed with the main goal for the clustering areas are set to minimum the number of cluster and to maximize the life span of mobile nodes in the system. To achieve these goals, by utilizes factors the number of neighbor node, degree-difference, battery power, sum of distance, stability.

3.1 Overview

The nodes in the network are starting to exchange neighborhood information and then form cluster. Each node calculates its own weight based on the following parameter such as degree difference, sum of distance, cumulative time and stability. The maximum weight value is elected as the cluster head. The cluster heads broadcast neighborhood messages which are transmitted to the neighboring cluster by the member nodes. A global knowledge about neighboring clusters in the network is obtained. The main ideas are set to minimum the cluster, minimum the life span of mobile nodes in the system and also to reduce the routing overhead during the communication process. The parameter considered
neighbor node, degree-difference, battery power, sum of distance, stability. The stability and energy based weighted clustering algorithm effectively combines the above system parameter with certain weighting factors chosen according to the system nodes. The phases of proposed clustering algorithm are

- Cluster set up phase: describes the cluster formation, cluster head selection and connectivity.
- Cluster maintenance phase: it is about how to update and maintain the cluster structure according to the network topology change during the operation such as node joining, node leaving, and cluster resign its role.

3.2 Cluster set up Phase

a) Cluster formation:

The proposed clustering technique (SEBWCA) employed here is a modified version of weighted clustering algorithm. The process of cluster formation refers to how to build a stable cluster structure for at the very beginning. The network is formed by the nodes and links can be represented by an undirected graph \( G = (V, E) \) where \( V \) represents the set of links. Initially each node is assigned a node ID value. It broadcasts its ID value to its neighbors and builds its neighborhood list. Each node computes its degree with the neighbors list. Each node calculates its own weight based on the following factors:

- **Node degree**: The node degree to find the degree of node that is single node will connect to how many neighbor nodes.
- **Degree difference**: Difference between the nodes within its transmission range and ideal degree of a node.
- **Sum of distance**: Sum of distance of the node from all its neighbors.
- **Battery power**: Initially every node must have some amount of energy. The energy gets low when it sends the data or receives the data. To increase the life span of cluster head by avoiding frequent topology changes. Therefore, it is important to choose the node with a high amount of energy.
- **Stability of node**: It is used to find the average of link expiration times between specific nodes with all its neighbors.

Election is based on weight value of the nodes and the node having the highest weight is chosen as cluster head (CH). Cluster head selection based on parameter and formulas are list is shown in TABLE 1. Each node calculates its weight by using a formula that considers all the above parameters. The weight of node \( N \) is defined as equation (2).

\[
\text{Weight } W(v) = W_d \ast \Delta_v + W_s \ast D_v + W_\theta \ast \theta_v + W_b \ast P_v -- (2)
\]

![Fig. 1 Example of cluster formation](image)

Where \( W_d, W_s, W_\theta, W_b \) are the score factors for the corresponding system parameters. In proposed algorithm there are three types of nodes are defined as shown in Fig. 1. Ordinary node are members of existing cluster, Cluster head (CH) is the node which is responsible for formation of cluster and its members and has information of all its members nodes within its cluster, and Border node: the nodes which receive messages from than one cluster head which are located in its neighborhood region are border node.

<table>
<thead>
<tr>
<th>Parameter and Terms</th>
<th>Formula and meanings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of each node</td>
<td>( d_v ) -</td>
</tr>
<tr>
<td>Degree difference</td>
<td>( \Delta_v = \mid d_v - \delta \mid )</td>
</tr>
<tr>
<td>Sum of distance</td>
<td>( D_v )</td>
</tr>
<tr>
<td>Battery power</td>
<td>( P_v = P_{av} - P_{cons} )</td>
</tr>
<tr>
<td>Stability of node</td>
<td>( S_v(i,j) = \sum_{i=j}^{l} \text{let}(i,j) ) where ( \text{let}(i,j) = \frac{av(i,j)}{\sum} )</td>
</tr>
<tr>
<td>Connectivity</td>
<td>( V ) Set of nodes</td>
</tr>
<tr>
<td>( N(v) )</td>
<td>Number of neighbor nodes</td>
</tr>
<tr>
<td>( P_{av} )</td>
<td>Energy level</td>
</tr>
<tr>
<td>( D_v )</td>
<td>Degree of each node</td>
</tr>
<tr>
<td>( \delta )</td>
<td>Ideal node degree</td>
</tr>
<tr>
<td>( N )</td>
<td>Total number of neighbor in the current node</td>
</tr>
<tr>
<td>( \text{dist}(i,j) )</td>
<td>Distance value between node i and j</td>
</tr>
<tr>
<td>( P_{av} )</td>
<td>Available Battery power of the node(Initially it is maximum battery power)</td>
</tr>
<tr>
<td>( P_{cons} )</td>
<td>Battery power consumed by the node</td>
</tr>
<tr>
<td>( r ) or ( x _range )</td>
<td>Transmission range</td>
</tr>
<tr>
<td>( v_i, v_j )</td>
<td>Speed of the node</td>
</tr>
<tr>
<td>( \theta_i, \theta_j )</td>
<td>Direction of the node</td>
</tr>
<tr>
<td>Let ( (i,j) )</td>
<td>Link expiration time between two node</td>
</tr>
</tbody>
</table>

b) Cluster head selection: In (SBWCA) various important parameters for cluster heads selection is considered as shown in table 1. The Cluster head choosing each parameter, formula and the notation details are listed in Table 1. Each node calculates its weight value with attaining the values of parameter and putting them into equation (1). And then each node broadcasts its weight to all the nodes which are in its neighborhood region. Finally the node with highest weight is chosen as the cluster head. Algorithm 1 shown the proposed Cluster formation algorithm for selecting cluster head.


**c) Connectivity:** Clustering ensures that the nodes within a cluster are able to communicate among themselves through the cluster heads, each of acts as a central node of a star. But, inter-cluster communication is not possible if the clusters are not connected. A cluster head uses low power to communicate with the members in its transmission range, and high power to communicate with the neighboring cluster heads because of greater range.

\[
\text{Let}(i,j) = \frac{d_{j} \in i N(i)}{d_{v} \in N} - \Delta
\]

When a new node arrives, it checks with the neighborhood list by broadcasting its ID to all neighbors. New node calculates its weight values and check whether the cluster head already exists or not if the cluster head already exist means it join as a cluster member to the existing cluster otherwise it form a new cluster and declare it as cluster head and inform to all the members in the cluster are shown in algorithm 2.

**Step 1:** Initially configure the node in the network.
**Step 2:** Each node in the network is assigned the unique node ID value.
**Step 3:** Each node broadcast its ID value and identifies its neighborhood list.
**Step 4:** Find the degree of each node, \( d_v \) as, \( d_v = |N(v)| \) Where N is the number of neighbor node v.
**Step 5:** Compute the degree-difference, \( \Delta_v = |dv - \delta| \) for each node.
**Step 6:** For each node, compute the sum of the distance \( D_v \) with all its neighbors.
**Step 7:** Compute the remaining battery power of each node \( P_v \) (cumulative time) for each node.
**Step 8:** Compute the average of link expiration times (Let) between a specific node with all its neighbors.
**Step 9:** Calculate the combined weight,
\[
\text{Weight}(v) = W_1 * d_v + W_2 * D_v + W_3 * P_v + W_4 * St
\]
where, \( W_1, W_2, W_3, W_4 \) are weighting factors for corresponding system Parameter
**Step 10:** Choose the node with highest \( W_v \) as cluster head.
**Step 11:** Repeat steps (3 – 10) for the remaining nodes not yet selected as Cluster head (CH) or to cluster.

### Algorithm 1: Cluster Formation Algorithm

The links between the cluster heads are shown as solid lines in Fig. 1. Define Connectivity as the probability that a node is reachable from any other node [6]. For a single component graph, any node is reachable from any other node and the connectivity is 1. If the network does not result in a single component graph, then the largest component can communicate with each other and the connectivity can be ratio of the cardinality of the largest component to the cardinality of the graph. Thus,

\[
\text{Connectivity} = \frac{\text{cardinality of the largest component}}{\text{cardinality of the graph}}
\]
### 4. EXPERIMENTAL RESULTS AND DISCUSSION

In this work, stable and energy-based weighted clustering algorithm can be implemented and analyzed the performance of the metrics like average number of cluster, the number of reaffiliation, average energy consumption, packet delivery ratio, and end-to-end throughput. Discuss the performance of the metrics from the experimental result of comparing the proposed scheme with the existing work.

#### 4.1 Experimental Set up

The simulation set up is as follows, nodes move with a fixed rectangular area, initially they are positioned randomly. Node mobility is simulated based on the random waypoint model, where each node move toward a randomly selected location at a speed uniformly distributed between 0 to maximum speed, and then pauses for a configured time, before selecting another random location and repeating the process. Table 2 shows that the simulated parameters.

**Table 2. Simulation parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meaning</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Number of nodes</td>
<td>20 - 60</td>
</tr>
<tr>
<td>X * Y</td>
<td>Size of network</td>
<td>250 * 250 m</td>
</tr>
<tr>
<td>Max Disp</td>
<td>Maximum displacement of one node</td>
<td>0 – 10 m</td>
</tr>
<tr>
<td>Tx.Range</td>
<td>Transmission range</td>
<td>0 – 200 m</td>
</tr>
<tr>
<td>Cluster member</td>
<td>Number of member for each cluster</td>
<td>5</td>
</tr>
<tr>
<td>Run time</td>
<td>Simulation time</td>
<td>200 sec</td>
</tr>
</tbody>
</table>

#### 4.2 Experimental Results

##### 4.2.1 Average number of cluster vs. number of nodes

Fig. 2 shows the average number of clusters with respect to the number of nodes where the transmission range = 150 and Max_disp = 10. The SEBWCA algorithm obtains fewer clusters than the others is decreased. The possible reason for this kind of behavior is that a cluster head with a large transmission range will cover a large area. For small ranges, most nodes tend to be out of each other’s transmission range and the network may be disconnected. Therefore, most nodes form one cluster, which only consists of itself.

##### 4.2.2 Number of reaffiliation vs. Speed

Fig. 3 shows a comparison of reaffiliation per unit time of WCA and SEBWCA for varying speed. In the observation both algorithm give low reaffiliation rate. For low mobility WCA and SEBWCA similar results. However, while varying node speed between 2 and 10, SEBWCA gives more stable clusters when the speed increased (2 – 10), the proposed algorithm produced 27.53% and 38.53% less reaffiliation than WCA.

#### 4.2.3 Number of reaffiliation vs. Transmission range

Fig. 4 shows the reaffiliation per unit time. For low transmission range, the nodes in a cluster are relatively close to the cluster head, and a detachment is unlikely. The number of reaffiliations increases as the transmission range increases, and reaches a peak when transmission range is between 25 and 30. Further increase in the transmission range results in a decrease in the reaffiliations since the nodes, inspite of their random motion, tend to stay inside the large area covered by
the cluster head. When the transmission range increased (30 – 70) the SEBWCA produced 57.15% and 63.68% less re-affiliation than WCA.

4.2.4 Average consumed energy vs. Number of nodes

Fig. 5 shows the average energy consumption per node during simulation time period. As the number of nodes increased, the nodes consumed more battery power. The cluster head have to be maintained maximum battery power for communication. That is the cluster head needs high power for longer transmission range and less power for smaller transmission range. The SEBWCA maintain minimum energy consumption for every node compare to WCA.

4.2.5 Packet delivery ratio vs. Pause time

Fig. 6 shows with different pause time values which influence the node mobility in the random waypoint model. The lower the pauses time higher the mobility. The packet delivery ratio is based on the number of packets delivered and number of packets sent. Higher the packet delivery ratio (PDR) better is the performance of the cluster. The SEBWCA approaches a ratio of one or 100% delivery as the network becomes more static. Only dynamic conditions the packets collide or the packets are lost. As the pause time increases the static nature is enhanced. For WCA algorithm even as the nodes become static all the packets are not delivered so, compare to WCA, SEBWCA produced better performance.

5. CONCLUSION AND FUTURE DIRECTION

In this paper, a stable and energy based weighted clustering algorithm in MANET has been proposed. In SEBWCA each node calculates its weight based on its four important parameters: degree difference, sum of distance, stability, battery power. Each node independently choose one if its neighbors with the highest weight to be elected as cluster head. And also it maintain the cluster size when the node join, cluster head resign its role and node leave.

The proposed SEBWCA algorithm maintains the stability and energy as much as possible. Simulation demonstrated that the suggested algorithm provides less number of clusters, less re-affiliation time, less consumed energy, more packet delivery ratio and end-to-end throughput when comparing to the existing work highest connectivity, Lowest-Id, and WCA. In the future, SEBWCA will be enhancing by the security techniques and implement in different routing protocols in the MANET. Further analyze the performance with different simulation metrics and compare performance with the other existing clustering algorithm in the MANET.

6. REFERENCES


Distributed Clustering for Ad Hoc Wireless Networks


5. Mainak Chatterjee, Sajal K. Das and Damla Turgut, “An On-Demand Weighted Clustering Algorithm (WCA) for Ad hoc Networks” Center for Research in Wireless Mobility and Networking (CReWMaN).


8. Stefano Basagni, “Distributed Clustering for Ad Hoc Networks” Center for Advanced Telecommunications Systems and Services (CATSS).