A Load-Balancing and Weighted Clustering Algorithm in Mobile Ad-Hoc Network

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ABSTRACT

A Mobile Ad Hoc Networks (MANET) is a collection of two or more mobile devices (e.g. PDAs, laptop, cell phones, etc.), with multi-hop wireless communication. These nodes or devices can communicate with other nodes directly within or outside their transmission range. In previous research on mobile ad-hoc network indicated to use of clustering algorithm because it simplifies routing and can improve the performance of flexibility and scalability in the network. In this paper, we propose that the enhancement on weighted clustering algorithm (EWCA), leads to a high degree of stability in the network and improves the load balancing. In this simulation study, a comparison was conducted to measure the performance of our algorithm with original WCA in terms of numbers of clusters formed with satisfy load balancing , topology stability, and number of clusterhead change.

Keywords – **Mobile Ad-Hoc Networks, Weighted Clustering Algorithm, Load Balancing.**

1. INTRODUCTION

With the development of the next generation of wireless communication systems, development in personal computing devices and the widespread use of mobile and handheld devices has resulted in an increasing popularity of mobile ad hoc networks (MANET). In simply stating, a Mobile Ad Hoc Network (MANET) is a mobile, multi-hop wireless network, which does not need pre-existing infrastructure or centralized administration. Every node in the network is serving as a router, which means that every node is able to forward data to other nodes. There are many applications of ad hoc networks, for example meetings or conventions, electronic email and file transfer, and emergency disaster relief personnel coordinating efforts after a hurricane or earthquake [1,2].

Dynamic routing is the most important issue in MANET's. In flat structure exclusively based on proactive and reactive routing algorithms cannot perform well in a large dynamic MANET. That means, with the increase in size of the networks, flat routing schemes do not scale well in terms of performance. In order to cope with these problems by grouping a number of nodes into an easily manageable set known as cluster [4,3]. The previous research on mobile ad-hoc network has heavily stressed the use of clustering algorithm because clustering simplifies routing and can improve the performance of flexibility and scalability in the network. Several clustering algorithms have been proposed to increase scalability, improve bandwidth utilization, and reduce delays for route strategies.

In a clustering structure, the mobile nodes in a network are divided into several virtual zones (clusters). Every mobile node may be assigned a different status or function, such as clusterhead, clustergateway, or clustermember. The clusterhead can be used as a repository for the knowledge of the cluster and as a coordinator of the cluster operations. Clustergateway is a boarder node in communication range for more than one cluster. Summarized cluster information is sent to the neighboring clusterheads via gateways [5, 6].

If the mobile nodes are high dynamic i.e. it is connected and disconnected to and from clusters that leads to the stability of the network reduced and reconfiguration of clusterheads is unavoidable. A good clustering structure should preserve its structure as much as possible when nodes are moving and/or the topology is slowly changing. Otherwise, re-computation of clusterheads and frequent information exchange among the participating nodes will result in high computation overhead [7, 10].

In this paper, we propose enhancement on a weighted clustering algorithm (EWCA). We can show that this enhancement depends on two factors, improving the load balancing and performing the stability in the network. The load balancing is accomplished by determining a pre-defined threshold on the number of nodes that a clusterhead can cover ideally. This ensures that none of the clusterheads are overloaded at any instance of time. Moreover the stability can be accomplished by reducing the number of nodes detachment from its current cluster and connect to another existing cluster. Finally, the simulations results show that the proposed enhancement provides better performance in terms of stability of the created clustered topology, load balancing and number of clusterhead change.

The remainder of this paper is organized in five sections. In Section 2, we discuss work relevant to the scope of this study and its limitation. In Section 3, we discuss the Enhancement Weighted Clustering Algorithm (EWCA) in details. Discussion of the simulation results and analysis is presented in Section 4. Finally, the study's conclusion is provided, in Section 5.

2. PREVIOUS WORK

Several original clustering algorithms have been proposed in MANET to choose clusterheads, namely: (I) Highest-Degree heuristic, (II) Lowest-ID heuristic, (III) Node-Weight heuristic and (IV) weighted clustering algorithm, etc. We will give each of them a brief description as follows.

2.1 Lowest-ID Algorithm:

In this algorithm was originally proposed by [11, 13] each node is assigned a distinct ID and the clusters are formed following the steps given below:

1. Periodically a node broadcasts the list of nodes that it can hear (including itself).
2. A node, which only hears nodes with ID higher than itself, becomes a Clusterhead (CH).
3. The lowest-ID node that a node hears is its clusterhead, unless the lowest-ID specifically gives up its role as a clusterhead.
4. A node, which can hear two or more clusterheads, is a Gateway.
5. 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.

2.2. Highest-Degree Algorithm:

The Highest-Degree Algorithm, also known as connectivity-based clustering algorithm, was originally proposed by Gerla and Parekh [12, 14], in which the degree of a node is computed based on its distance from others. A node x is considered to be a neighbor of another node y if x lies within the transmission range of y. The node with maximum number of neighbors (i.e., maximum degree) is chosen as a clusterhead. The neighbors of a clusterhead become members of that cluster and can no longer participate in the election process. Any two nodes in a cluster are at most two-hops away since the clusterhead is directly linked to each of its neighbors in the cluster. Basically, each node either becomes a clusterhead or remains an ordinary node (neighbor of a clusterhead).

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 limitation is the reaffiliation counts of nodes are high due to node movements and as a result, the highest-degree node (the current clusterhead) may not be re-elected to be a clusterhead even if it loses one neighbor. All these drawbacks occur because this approach does not have any restriction on the upper bound on the number of nodes in a cluster.

2.3 Node-Weight Algorithm

Basagni et al. [15, 16] proposed two algorithms, namely distributed clustering algorithm (DCA) and distributed mobility adaptive clustering algorithm (DMAC). In this approach, each node is assigned weights (a real number above zero) based on its suitability of being a clusterhead. A node is chosen to be a clusterhead if its weight is higher than any of its neighbor’s weight; otherwise, it joins a neighboring clusterhead. 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. To verify the performance of the system, the nodes were assigned weights which varied linearly with their speeds but with negative slope. Results proved that the number of updates required is smaller than the Highest-Degree and Lowest-ID heuristics. Since node weights were varied in each simulation cycle, computing the clusterheads becomes very expensive and there are no optimizations on the system parameters such as throughput and power control.

2.4 Weighted Clustering Algorithm

The Weighted Clustering Algorithm (WCA) was originally proposed by M. Chatterjee et al. [7, 5,9]. It takes four factors into consideration and makes the selection of clusterhead 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. And their corresponding weights are w1 to w4. Besides, it converts the clustering problem into an optimization problem since an objective function is formed.

$$W_v = w_1 \Delta_v + w D_v + w M_v + w P_v \quad (1)$$

Although WCA has proved better performance than all the previous algorithms, it lacks a drawback in knowing the weights of all the nodes before starting the clustering process and in draining the CHs rapidly. As a result, the overhead induced by WCA is very high.

3. PROPOSED ENHANCEMENT WEIGHTED CLUSTERING ALGORITHM (EWCA)

3.1 Principles of Our Algorithm:

- In our algorithm election, clusterhead is adaptive invoked based on moving of nodes or changing the relative distance between the nodes and clusterhead. Election is repeated until all of node must be as a member of any cluster or as a clusterhead.
- In Load-balancing, assume that there are a predefined threshold number of mobile nodes that a cluster can cover. When the number of cluster's members is too large, that may produce a small number of clusters which make bottleneck of a MANET and reduce system throughput. Moreover, too-small cluster's member may produce a large number of clusters and thus resulting in extra number of hops for sending a packet from source to destination, and longer end-to-end delay. When a cluster size exceeds its predefined limit, election

procedure is repeated to adjust the number of mobile nodes in that cluster.

- If the distance between clusterhead and cluster member is within the transmission range, that with result a better communication.
- The relative distance between nodes affects the consumption of the battery power. It is known that more power is required to communicate through a larger distance. Since clusterheads have the extra responsibility to send packets to other nodes, they consume battery power more than ordinary nodes.
- Mobility is one of the most important challenges of MANETs, and it is the main factor that would change network topology. A good electing clusterhead does not move very quickly, because when the clusterhead changes fast, the nodes may be moved out of a cluster and are joined to another existing cluster and thus resulting in reducing the stability of network .There are many mobility models known such as Random Way Point Model (RWP), Random Way Point on Border Model (RWBP), Random Gauss Markov (RGM) model, and Reference Point Group Mobility model (RPGM). In our algorithm we used Random Way Point Model [8,10].

3.2 Our Procedure Algorithm:

The procedure consists of six steps as described below:

<u>Step 1</u>: Initialize scenario: **we defined some parameters such as:**

- x_range and y_range // x-axis and y-axis boundary.
- max_distance= x_range * y_range // the maximum distance between two nodes.
- The number of nodes (N).
- max_disp // maximum displacement of one node.
- Delta (cluster size).
- Weights (w1, w2, w3, w4).
- RUN_TIME //the time of simulation.
- tx_range // transmission range.
- Connection //the weighted connection matrix between all nodes.
- Linkage //the linkage matrix, if linkage==1 then exist link between two nodes.
- node_property//node property, 2=cluster head, 1=head neighbor, 0=homeless node
- dv //the degree of every node.
- Dv // the total distance from all its neighbors.
- Mv // mobility.
- Pv // power battery.

<u>Step 2</u>: Determine specific location for each node in the network by using uniform generation random.

- grand ('unf' , 0 , x_range); // generating node location x.
- grand ('unf' , 0 , y_range); // generating node location y.

<u>Step 3</u>: compute the distance between any node and others lying in the same transmission range.

<u>Step4</u>: clusterhead election procedure:

4.1. Calculating degree of every node // dv=sum(linkage) -1;
4.2. Compute the degree difference for each node

// delta_v=abs (dv-delta); , where delta is a threshold for the cluster's size

4.3. Compute the distance summation DV to its neighboring nodes

```
Dv=sum (connection);
for n=1:N
      if (dv ==0) then  Dv = max_distance ; end;
end;
```

4.4. Compute the running average of the speed for every node till current time *T*, This gives a measure of mobility and is denoted by M_v, as

$$M_v = \frac{1}{T}\sum_{t=1}^{T}\sqrt{(X_t - X_{t-1})^2 + (Y_t - Y_{t-1})^2},$$

Where (X_t, Y_t) and (X_{t-1}, Y_{t-1}) are the coordinates of the node *v* at time *t* and $(t - 1)$, respectively.

4.5. Compute the remaining battery power PV for every node.

4.6. Calculate the *combined weight* W_v for each node *v*,

$$Wv=w1*delta\_v+w2*Dv+w3*Mv+w4*Pv$$

Where w_1, *w2*, *w3* and w_4 are the *weighing factors and w1+w2+w3+w4=1*

4.7. Taking the node with the smallest Wv as the clusterhead. All the neighbors of the chosen clusterhead are no longer allowed to participate in the election procedure. If the number of neighbors is larger than a predefined threshold we will take a Predefined threshold only.

4.8. Repeat steps 4.2 – 4.7 until there is no any node not selected yet as a member of any cluster or as a clusterhead

step5: ***Update node position: all the nodes move randomly after some unit time. Using this formula to compute the velocity for each node.***

```
velocity =grand(N,1,'unf',0,max_disp);  // determine the position
velocity =grand(N,1,'unf',0,2*pi);         // determine the direction
```

step6: ***Repeat steps 3 – 5 until reach the maximum number of time.***

4. SIMULATION STUDY:

4.1 Simulation Parameters:

In our simulation experiments, N was varied between 30 and 300, and the transmission range was varied between 0 and 200. At every time unit, the nodes are moved randomly according to the random waypoint model in all possible directions in 250 X 250 meters square space with velocity distributed uniformly between 0 and maximum displacement along each of the coordinates. This behavior is repeated for the duration of the simulation. We assumed a predefined threshold for each clusterhead which can handle (i.e. cluster size) at most 5 nodes (ideal degree). Due to the importance of keeping the node degree approximate to the ideal as possible and to satisfy load balancing for each cluster, and due to the stability of the topology network, we must select the weight w1 and w3 a high in equation 1. Distance and battery power were given low weights.

The values used for simulation were w1 = 0.45, w2 = 0.05, w3 = 0.45 and w4 = 0.05. Note that all weights are kept fixed for a given system and the sum of these weighting factors equal 1. The simulation parameter is summarized in table 1 and shows in figure 1.

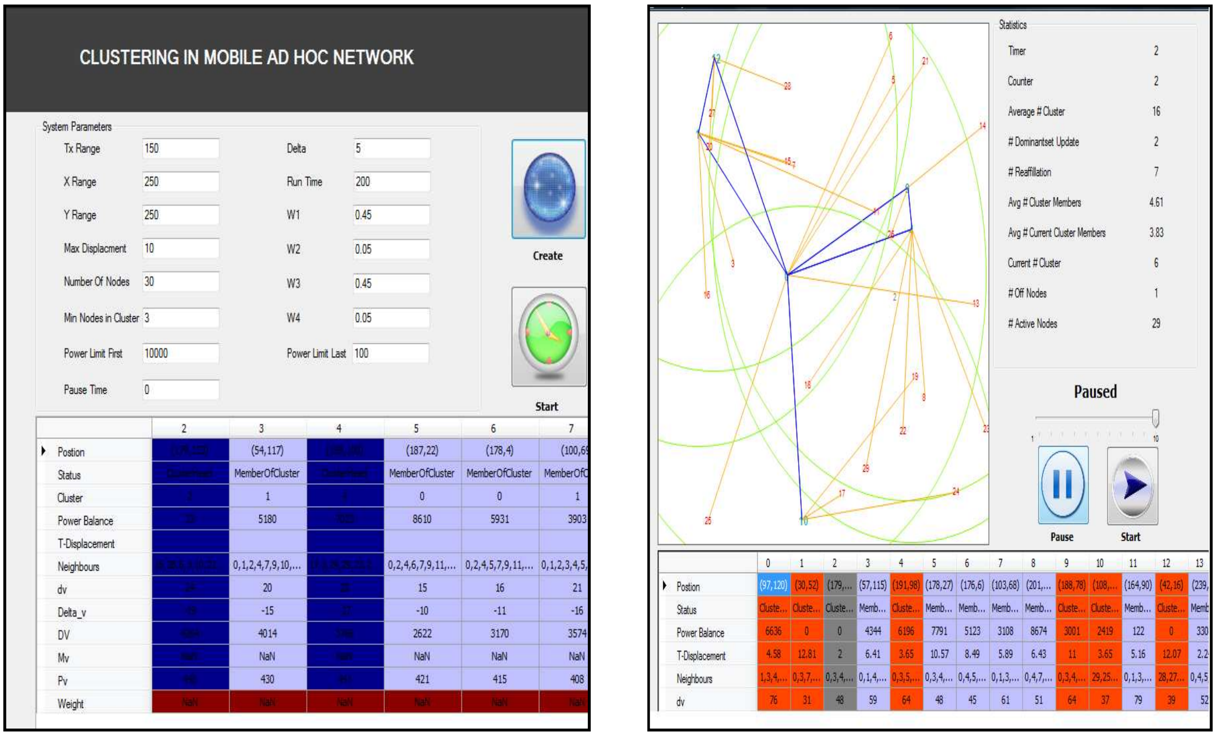

Figure 1. Snapshot from simulator

Parameter	Meaning	value
N	Number of mobile hosts	30 - 300
X * Y	Simulation Area	250 * 250 m
Max_Disp	Maximum Displacement of one nodes	0-10 m
TX_ Range	Transmission Range	0 – 200 m
Cluster Member	Number of member for each cluster	5
Run Time	Simulation Time	200 sec
Mobility Model	Random Waypoint with pause time 0 sec	-----
w1,w2,w3,w4	Weights	0.45,0.05,0.45,0.05

Table 1. Simulation Parameters

4.2 Performance Metrics:

In our algorithm, we are concerned in studying the performance of the following metrics:

- Average number of cluster formation: That means the total number of clusters that are formed in network space. Every cluster is headed by a single clusterhead. This is defines the number of the dominated set and it ranges between 1 and N, where N is the number of node in the network.
- Stability: that means the number of nodes which will be remaining in the cluster during the simulation time. The stability is decremented when a node is moved out from the current cluster and attached to another cluster.
- Load Balancing: that means for each clusterhead can handle the same number of nodes at the same time.

4.3 Experimental Result and Discussion:

4.3.1 Analysis of Average Cluster Number Formation:

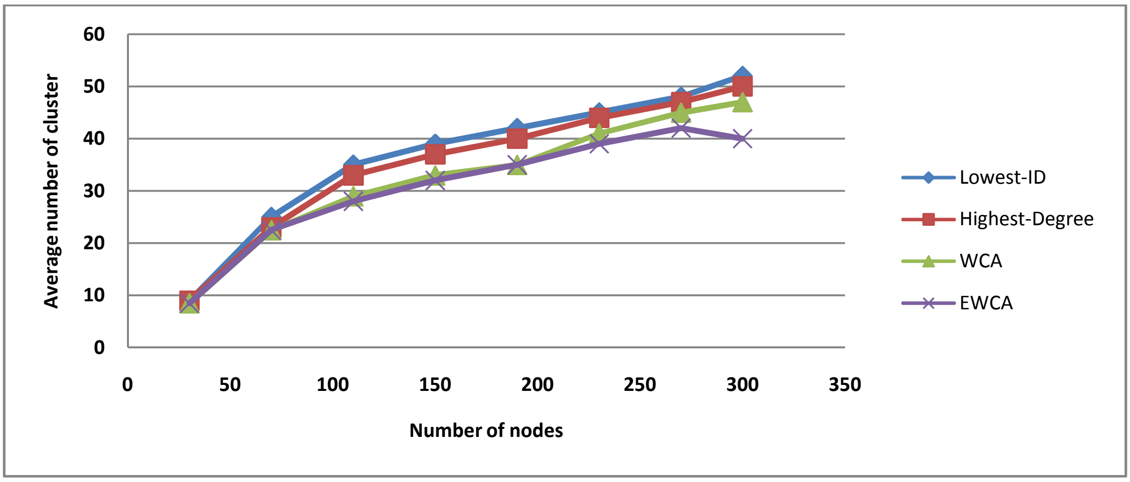

Figure 2. Number of nodes Vs. Average No. of clusters, Max_disp=10, Tx_Range= 150

Figure 2 shows the mutation of the average number of clusters with respect to the number of nodes where the transmission range=150 and Max_disp =10. We conclude that our algorithm obtains fewer clusters than the others. Also, when the transmission range increases; the average number of clusters is decreased. The possible reason for this kind of behavior is that a clusterhead with a large transmission range will cover a larger 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.

4.3.2 Analysis of Topology Stability

Figure 3 and 4 shows the variation of the stability of clusters per unit time with respect to the transmission range, where Max_disp =10. We can conclude that:

1. Figure 3 shows that, as the transmission range and number of nodes become larger, the nodes tend to move further from their clusterhead, detaching themselves from the clusterhead and causing low stability per unit time.
2. Figure 4 shows the stability decrease, as the transmission range increases, until it reaches a peak when transmission range is between 30 and 40. Further increase in the transmission range results in increasing the stability of clusters.

As shown in Figure 3 and 4, with the number of nodes between 30 and 120 in the ad hoc network and the transmission range between 40 and 100, the proposed algorithm produced about 20% - 70% more stability than original WCA

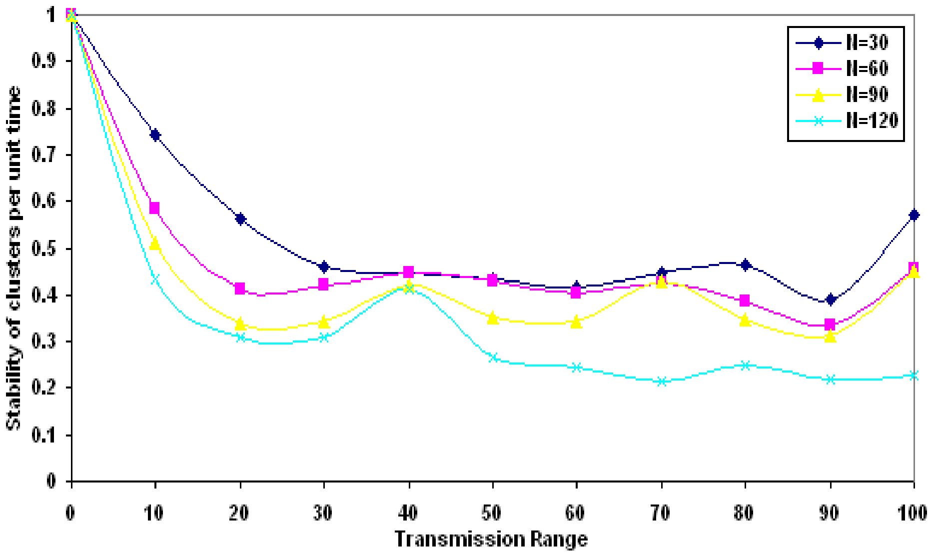

Figure 3. original WCA- stability of clusters per unit time, Max_disp=10.

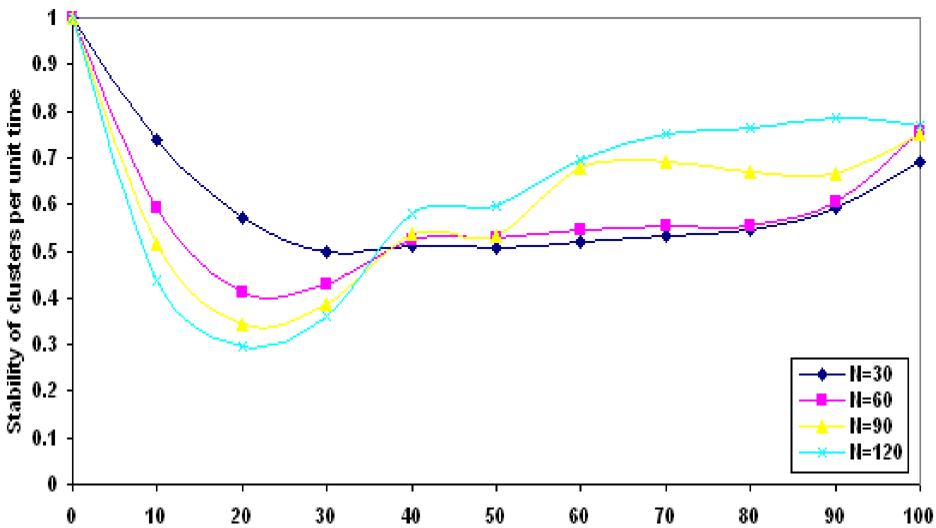

Figure 4. Enhancement WCA- stability of clusters per unit time, Max_disp=10.

4.3.3 Analysis of Load Balancing:

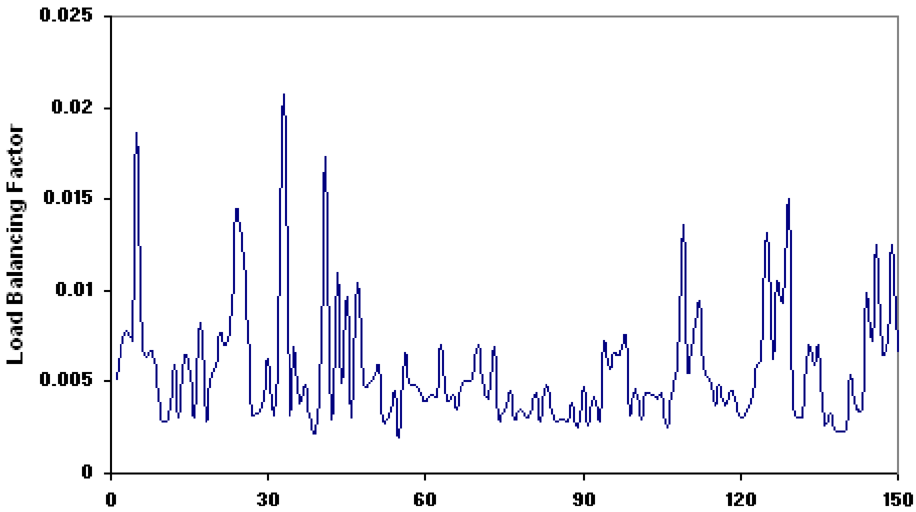

Figure 5: Original WCA – Load distribution, N=80, Tx_range=80.

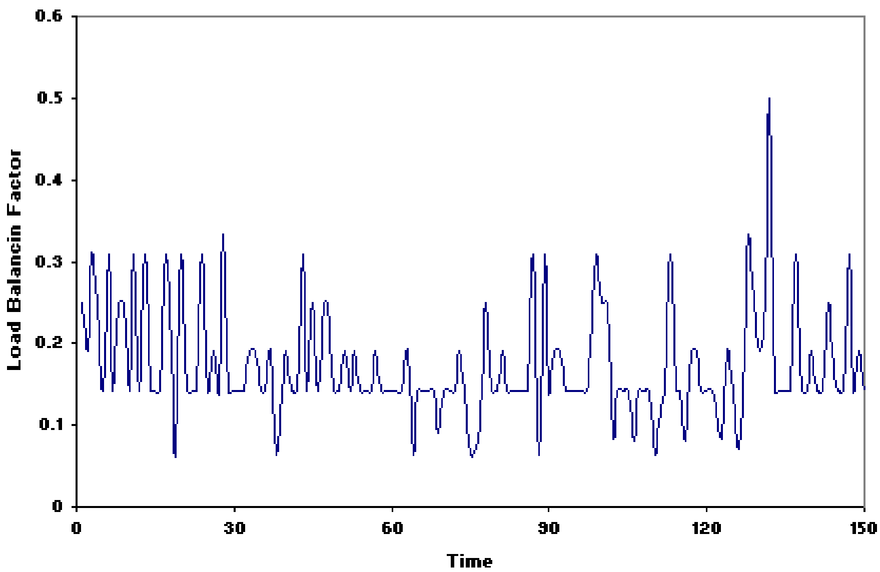

Figure 6: Enhancement WCA – Load distribution, N=80, Tx_range=80.

We use a parameter called load balancing factor (LBF) to measure how well balanced the clusterheads. We defined the load balancing factor as the same definition in [7, 9]

$$\text{LBF}=\frac{n_c}{\sum_i (x_i-\mu)^2} \qquad \text{where} \qquad \mu=\frac{(N-n_c)}{n_c}.$$

Where n_c is the number of clusterheads, x_i is the cardinality of cluster i, and μ (N being the total number of nodes in the system) is the average number of neighbors of a clusterhead. Clearly, a higher value of LBF signifies a better load distribution and it tends to infinity for a perfectly balanced system. In the previous research it is difficult to keep a perfectly load balanced system at all time due to frequent association and dissociation of the nodes from and to cluster. In our algorithm we improve the load balance. From Figure 5 we can see that the LBF has varied between 0 and 0.02 , it went up to 0.5 in Figure 6 indicating that the our algorithm is 25 times more balanced. Moreover, we found the average of LBF in our algorithm is better than original WCA. Their average values are 0.177 and 0.005 respectively.

5. CONCLUSION

In this paper, we proposed an enhancement on weighted clustering algorithm. The algorithm is executed only when there is a demand, i.e. when a node moving and changing the relative distance between nodes and clusterhead. A number of parameters of nodes were taken into consideration for assigning weight to a node. In our algorithm, we considered load balancing and stability factors to improve the original WCA. We assumed a predefined threshold for the number of nodes to be created by a clusterhead, so that it does not degrade the MAC function and to improve the load balancing. We conducted simulation that shows the performance of the proposed enhancement clustering in terms of the average number of clusters formation, stability of clusters, and load distribution. We also compared our results with the original WCA. The simulation results show that our enhancement clustering algorithms have a better performance on average.

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