A Modified Weighted Clustering Algorithm for Stable Clustering using Mobility Prediction Scheme

S. Muthuramalingam, R. Viveka, B. Steffi Diana and R. Rajaram
Department of Information Technology, Thiagarajar College of Engineering, Madurai, India

***Abstract*—This paper proposes an idea for selecting stable cluster heads using a modified Weighted Clustering Algorithm and combining it with Link Expiration Time calculation. The mobile ad hoc network consists of nodes that move freely and communicate with each other. One way to support efficient communication between nodes is to partition ad hoc networks into clusters. Many clustering schemes have been proposed to form clusters. The WCA has improved performance compared with other previous clustering algorithms. However, the high mobility of nodes will lead to high frequency of re-affiliation which will increase the network overhead. To solve this problem, we propose a time-based WCA which can enhance the stability of cluster formation followed by stable cluster head selection. Then duration of nodes that are alive is considered. Meanwhile for forthcoming nodes the duration of link between them and the Cluster head is calculated. This is the Link Expiration time and it is calculated based on the three factors, namely position, speed and direction of nodes. If the calculated link expiration time is greater than the threshold value it is allowed to join the respective cluster. This is done to form stable clusters and to reduce the re-affiliation frequency.**

***Index Terms*—Adhoc Networks, Stable clustering, Weighted clustering algorithm, re affiliation, mobility prediction, link expiration time.**

I. Introduction

In recent years, the development in wireless communication, and the widespread use of mobile and handheld devices, has resulted in the increasing popularity of mobile ad hoc networks (MANET). A mobile ad hoc network is a collection of wireless mobile nodes that dynamically form a network without the need for any pre-existing network infrastructure. Every node in the network is serving as a router, which means that every node is able to forward data to other nodes in the same transmission range. When wireless nodes are in an area that is not covered by any existing infrastructure, one of the possible solutions to achieve the ubiquitous computing is to enable wireless nodes to operate in the ad hoc mode and self-organize themselves into cluster based network architecture. Ad-hoc networks do not use specialized routers for path discovery and traffic routing develops the wireless backbone architecture. This means that certain nodes must be selected to form the backbone. One of the general approaches to build up a cluster based network architecture is to design an algorithm to self-organize themselves into cluster based network architecture. This is achieved by partitioning ad hoc networks into clusters. Certain nodes, known as *cluster-heads*, would be responsible for the formation of cluster and maintenance of the topology of the network, and also for the resource allocation to all the nodes belonging to their clusters. The clustering algorithm is usually performed in two phases: clustering formation and clustering maintenance [3]. In the clustering formation phase, the election of a cluster-head among the nodes in the network is conducted. The functions of cluster heads are the coordination of the clustering process and relaying routers in data packet delivery. After electing cluster-heads, some of nodes move out from the current cluster and are attached to another cluster. Other cluster-heads are downed. This leads to the second phase, namely, clustering maintenance. In light of this, this paper aims to avoid excessive computation in the cluster maintenance, and current cluster structure should be preserved as much as possible.

In this paper, we propose an enhancement on a *weighted clustering algorithm* [1, 5] (WCA) by maintaining stable clusters. In WCA, a node is selected to be the cluster-head when it has the minimum weighted sum of four indices: the number of potential members, the sum of the distances to other nodes is its radio distance, the node's average moving speed and the battery life of the node. However, only the individual nodes' mobility is measured in WCA, whereas the relative mobility of a node and its neighbors is more important to the cluster stability. The ignorance of the relative mobility will lead to the situation that the high mobility of nodes causes a high frequency of re-affiliations, which will increase the network overhead. To solve this problem, we propose an enhanced weight-based clustering algorithm using mobility prediction scheme (MWCAMP). This can enhance the stability of the network by taking the relative mobility of a node and its neighbors into consideration for the clustering formation [1, 2, 5] and maintenance, by predicting the mobility of a node using the link expiration time [12].

The remainder of this paper is organized as follows. In Section 2, we review the several relevant clustering algorithms proposed previously and their limitations. Section 3 presents

S. Muthuramalingam can be reached at smuthoo@gmail.com. R. Viveka can be reached at shekinviveka@gmail.com. B. Steffi Diana can be reached at dianasaturcall@gmail.com. R. Rajaram can be reached at rrit@tce.edurrit@tce.edu.

the proposed algorithm for ad hoc networks. Section 4 discusses the proposed algorithm. Section 5 discusses the simulation results and analysis. Finally, Section 6 concludes this paper.

II. Related Works and Current Motivation

Recently a number of clustering algorithms have been proposed to choose cluster-heads based on the speed and direction, mobility, energy, position, and the number of neighbors of a given node. These efforts present advantages but also have some drawbacks, such as the high computational overhead for both clustering algorithm execution and update operations.

The *Highest Degree Algorithm* is also known as connectivity-based algorithm [3]. This algorithm is based on the degree of nodes assumed to be the number of neighbors of a given node. Whenever the election procedure is needed, nodes broadcast their Identifier (ID) which is assumed to be unique in the same network. According to the number of received IDs every node computes its degree and the one having the maximum degree (no of adjacent nodes) becomes cluster-head (CH). Major drawbacks of this algorithm include the situation where the degree of a node changes very frequently, and thus the CHs are not likely to play their role as cluster-heads for very long. In addition, as the number of ordinary nodes in a cluster is increased, the throughput drops and system performance degrades. All these drawbacks occur because this approach does not have any restrictions on the upper bound on the number of nodes in a cluster.

The *Lowest-Identifier* (LID) is also known as identifier-based clustering algorithm [4]. This approach chooses the node with the lowest ID as a cluster-head. The system performance is better than Highest-Degree in terms of throughput. 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.

The Distributed Clustering Algorithm (DCA) [6, 7] 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 cluster-head. A node is chosen to be a cluster-head if its weight is higher than any of its neighbor's weight; otherwise, it joins a neighboring cluster-head. The smaller weighted 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 cluster-heads becomes very expensive and there are no optimizations on the system parameters such as throughput and power control.

The *Weighted Clustering Algorithm* (WCA) [5] obtains 1-hop clusters with one cluster-head. The election of the cluster-head is based on the weight of each node. It takes four factors into consideration and makes the selection of cluster-head and maintenance of cluster more reasonable. The four factors are node degree (number of neighbors), distance summation to all its neighboring nodes, mobility and remaining battery power. Although WCA has proved better performance than all the previous algorithms, it has a drawback in needing to know 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.

III. Proposed Work

In this section, we present the proposed Enhanced Weighted Clustering Algorithm using mobility prediction scheme (MWCAMP). MWCAMP consists of the clustering formation and clustering maintenance phases. Before describing our clustering algorithm in detail, we make the following assumptions:

I. The network topology is static during the execution of the clustering algorithm.

II. Each mobile node joins exactly one cluster-head.

A. Phase-I: Clustering Formation

In WCA, the goal is to minimize the value of the sum of all the cluster heads' weighted costs. Here a node is selected as cluster head when it minimize a function of four criteria such as degree (the number of direct link to its neighbors), sum of distance between cluster head and other nodes, mobility of nodes and battery power of the nodes. WCA has high re-affiliation frequency [7, 8] which will increase the communication overhead. Thus, we present an enhanced algorithm to reduce the amount of re-affiliation frequency corresponding to the number of nodes that is not ''proper'' in current cluster. It corresponds to nodes that detach from current cluster and move to another cluster. In order to reduce the re-affiliation frequency, we should decrease the number of improper nodes. When the idea reflects on the cluster head election, the key is to choose ''stable'' nodes as cluster heads as possible. The stability of a node is relative to its neighbors.

In WCA, M_i the running average speed for every node till current time *T*, it is computed [9, 10] as

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

where (X_t, Y_t) and (X_{t-1}, Y_{t-1}) are the coordinates of the node i at time t and (t -1), respectively. It is shown that M_i is the absolute mobility of node and cannot indicate information of stability between node and its neighbors. Therefore we present an improved parameter $\overline{M}_i$ (relative mobility parameter) to substitute M_i (absolute mobility parameter). Here $\overline{M}_i$ is inversely proportional to stability factor S_i which is measured in sense of relative mobility.

The stability [13] of node "i" is computed from two aspects:

I. δ_i : The relative average speed of *i* and its neighbors. The larger δ_i is, the more unstable the node is, comparing to its neighbors.

II. NC_i : The change of node's neighbors. The value of NC_i can indicate the change of topology surrounding node *i*.

We also use a combined function of δ_i and NC_i to compute S_i. Another improvement of our algorithm is that we compute the average relative distances instead of the sum of distances.

The proposed MWCAMP described as follows

$$w_i = w_1\Omega_i + w_2\bar{D}_i + w_3\bar{M}_i + w_4P_i$$

where

I. Ω_i *is* the degree of each node i (i.e., nodes within its transmission range)

II. $\bar{D}_i$ *is* the average relative distances each node i with all its neighbors.

III. $\bar{M}_i$ is the relative mobility of node i

IV. P_i *is* the battery power of node i.

where w_1, w_2 , w_3 and w_4 are the weighting factors for the corresponding system parameters.

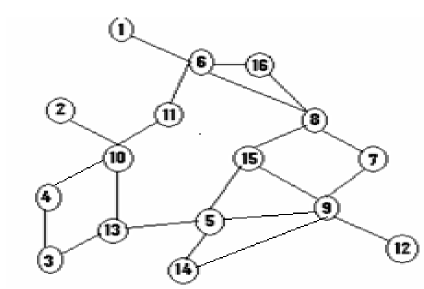

Figure 1

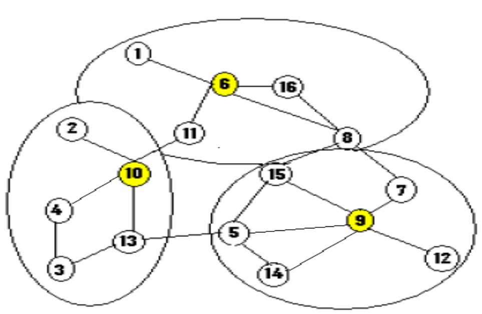

Figure 2

B. Phase-II: Clustering Maintenance Using Mobility prediction

The mobility of nodes coupled with the transient nature of wireless media often results in a highly dynamic network topology. Due to mobility some nodes will detach from the current cluster and attach itself to some other cluster. The process of joining a new cluster is known as re-affiliation. If the re-affiliation fails, the whole network will recall the cluster head election routine. One disadvantage of WCA is high re-affiliation frequency. High frequency of re-affiliation will increase the communication overhead. Thus, reducing the amount of re-affiliation is necessary in ad hoc networks. To prevent this we go for mobility prediction schemes. The impact of mobility prediction schemes on the temporal stability of the clusters obtained using a mobility-aware clustering framework. We propose a simple framework for a mobility prediction-based clustering to enhance the cluster stability.

One way to predict the mobility of nodes is using the *Link Expiration Time* [13]. The impact of mobility prediction schemes on the stability of the clusters obtained using a mobility-aware clustering framework. Compute the Link Expiration Time (LET) to predict the duration of a wireless link between two nodes in the network. The approach assumes that the direction and speed of motion of the mobile nodes does not change during the prediction interval.

C. Link Expiration Time (LET)

The *Link Expiration Time* (LET) is a simple prediction scheme that determines the duration of a wireless link between two mobile nodes. Dynamic clustering in ad hoc networks has also been extensively studied in the literature. Several distributed clustering algorithms for MANETs have been proposed. While some schemes try to balance the energy consumption for mobile nodes, others aim to minimize the clustering-related maintenance costs. Combined metrics based clustering schemes take a number of metrics into account for cluster configuration. The Weighted Clustering Algorithm (WCA) [5] is one such scheme, where four parameters are considered for the cluster head election procedure, which are representative of the degree, the sum of the distances to other nodes in its radio distance, mobility, and battery power of the mobile nodes. Here we propose an enhanced WCA which can enhance the stability of the network. Such a scheme can be tuned flexibly the parameters to suit to different scenarios. To calculate the duration of link between two mobile nodes, we assume that their location, speed and direction of movement remain constant.

Here let:

- Location of node *i* and node *j* at time *t* be given by (x_i, y_i) and (x_j, y_j).
- V_i and V_j be the speeds,
- θ_i and θ_j be the directions of the nodes i and j respectively.

- If the transmission range of the nodes is r, then the link expiration time D_t is given by the formula given below

$$D_t = \frac{-(ab+cd)+(a^2+c^2)r^2-(ad-bc)^2}{(a^2+c^2)}$$

where

$$a = v_i \cos\theta_i - v_j \cos\theta_j$$
$$b = x_i - x_j$$
$$c = v_i \sin\theta_i - v_j \sin\theta_j$$
$$d = y_i - y_j$$

The LET gives an upper bound on the estimate of the residence time of a node in a cluster. In the proposed clustering framework, when LET-based prediction is used, a node is allowed to join a cluster only if the predicted LET of the link between the node and the cluster head is greater than the cluster's admission criteria Tj [13, 14]. For every node N that detach from current cluster we check whether the node is a Cluster Head (or) Cluster member.

I. If it is a Cluster Head then call for cluster head election within the particular cluster and form a new cluster.

II. If it is a Cluster member then calculate Link Expiration Time with Cluster Head of each cluster and the node that re-affiliate must be within transmission range of cluster head where transmission range is fixed.

Check whether LET is greater than threshold value (Tj), Here Tj is average of all LET, and if it is greater then the Node is eligible to join the particular cluster which shares greater LET.

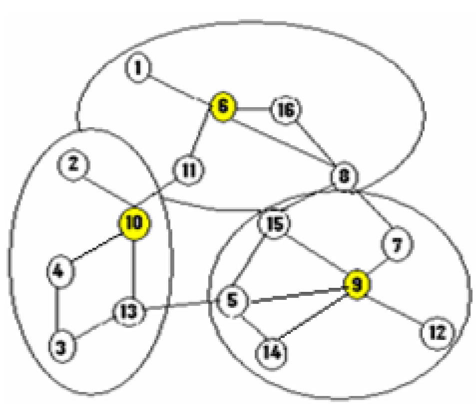

Figure 3

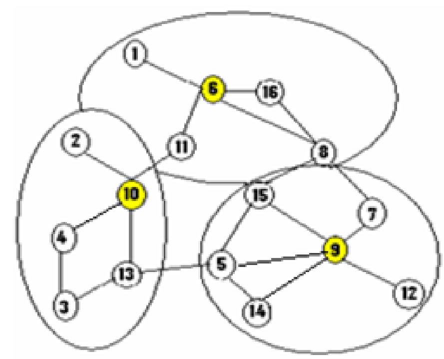

Figure 4

IV. Enhanced Weighted Clustering Algorithm Using Mobility Prediction

Consider Node Ni in transmission range r, positions of node Ni be (Xi Yi), Nj be nodes that detach from current cluster, where 1 ≤ i ≤ n , 1 ≤ j ≤ n and 1 ≤ k ≤ n.

1: calculate degree of node N_i

$$\Omega_i = \sum(C_{ij})$$

where Cij =1, if nodes N_i and N_j are connected else Cij =0 **.** (Where Cij be connection between node Ni and Nj, Where 1 ≤ i ≤ n , 1 ≤ j ≤ n).

2: calculate relative sum of distance $\bar{D}_i$ from nodes N_i to its members,

$$\bar{D}_i = \sum_{N_j \in N_i} \frac{\{dist(N_i, N_j)\}}{\Omega_i}$$

where 1 ≤ i ≤ n, N_j is the node the establish link with the node N_i.

3: M_i is the running average speed for every node N_i till current time T is calculated using formula

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

4: For every node N_i, compute the average speed A_i using formula

$$A_i = \frac{1}{\Omega_i} \sum_{N_j \in N_i} M_i$$

Where $1 \le i \le n$, N_j is the node that establish link with the node N_i

5: compute the speed-difference δ_i as

$$\delta_i = |M_i - A_i|$$

where $1 \le i \le n$.

6: For every node N_i compute the neighbor change NC_i at time t.

$$NC_i = \frac{|\{N_{i_{t1}}\} \cap \{N_{i_{t2}}\}|}{|\{N_{i_{t1}}\} \cup \{N_{i_{t2}}\}|}$$

7: Compute the stability factor S_i as

$$s_i = (a \times NC_i + 1)^{\frac{1}{\delta_i + 1}}$$

where *a* is an adjustable integer which is decided by the stability of the node.

8: Thus we can get the improved parameter $\bar{M}_i$ as

$$\bar{M}_i = \frac{b}{S_i}$$

where *b* is an integer decided by the speed of node. Both *a* and *b* are constant to make S_i more reasonable, avoiding to be too large or less.

9: Calculate weight value

$$w_i = w_1\Omega_i + w_2\bar{D}_i + w_3\bar{M}_i + w_4P_i$$

where P_i is the battery power of node, and $w_1 = 0.7$, $w_2 = 0.05$, $w_3 = 0.05$, and $w_4 = 0.2$.

10: The node with minimum weight value is elected as Cluster Head. That is

$$CH_i = \min\{w_i(N_i)\}.$$

11: Now cluster members are added to the cluster head. The nodes that establish link with that cluster head are called cluster members and they are grouped together to form a cluster. Thus cluster is formed by

$$C = [N_i \cup \{N_k | if\, N_i\ and\ N_k\ has\ edge\}] - \{C_{i-1} \cup C_{i-2} \cup \ldots C_{i-n}\}$$

where

$$\{C_{i-1} \cup C_{i-2} \cup \ldots C_{i-n}\}$$

are previously formed cluster, where 1=k=n. Repeat step 1 to 8 until every node is a member of cluster.

12: For every node N that detach from current cluster we check whether the node is a Cluster Head (or Cluster member).

I. If it is a Cluster Head then call for cluster head election within the particular cluster and form a new cluster.
II. If it is a Cluster member then calculate LET (Link Expiration Time) with Cluster Head CH_i of each cluster C_i and N_j must be within transmission range of CH_i .where transmission range is fixed.

LET i be the duration of the link between the two nodes is given by the formula given above in phase II and III.

13: Admission Criteria:

Check whether LET is greater than threshold value (T_j). If it is greater then the Node N_j is eligible to join the particular cluster C_j which shares greater LET (where Tj is average of all LET calculated). Repeat steps 10 and 11 for every node detach from current cluster. Else END.

V. Experimental Setup and Results

In this section, we present the performance of the proposed WCA simulated by NS2.We simulate a system of N nodes on an 1500 m × 1500 m area. The value of N is varied between 10 and 70 and transmission range is 500m. The nodes move randomly in all directions with a maximum speed varied between 20m/s and 50 m/s. The power for each node is varied between 40 to 100 units. Because the mobility of node is an important parameter in our case, the corresponding weight is chosen to be high. The values of the weights used in our simulation are: w1 = 0.7, w2 = 0.05, w3 = 0.05 and w4 = 0.2. Note that the values may be adjusted according to the system requirements.

The performance of algorithms is measured in terms of the number of re-affiliation count and no of clusters formed.

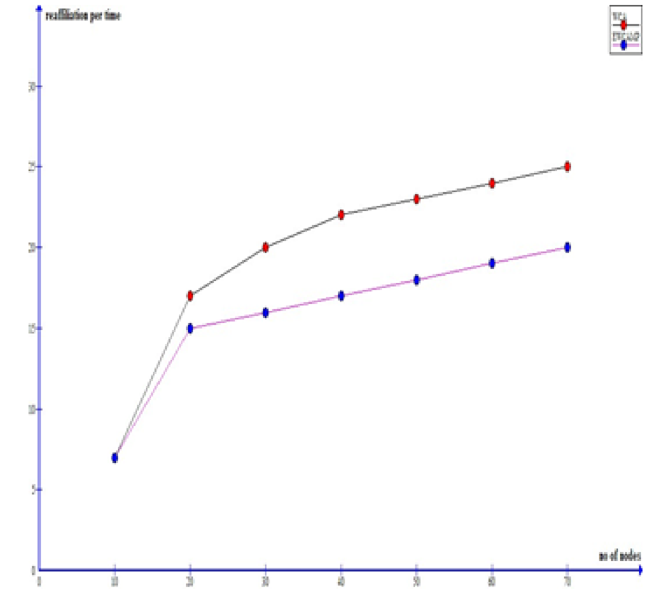

Figure 5: Average re-affiliation frequency vs node number

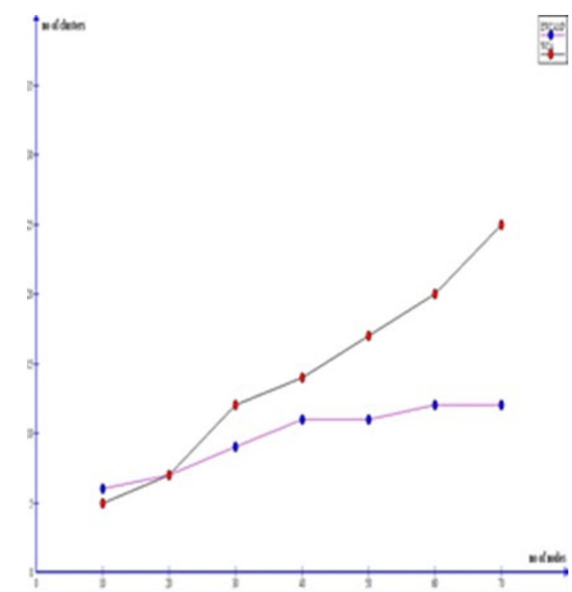

Figure 6: Comparison between WCA and our proposed work on basis of no of clusters formed.

Figure 5 depicts the average re-affiliation count versus the total number of nodes in the network where maximum speed is 50m/s and the transmission range is 500m. Here the nodes are organized into clusters and cluster head is elected. In previously designed clustering framework using weighted clustering algorithm, re-affiliation time for a given number of nodes are determined and plotted. In our enhanced weighted clustering algorithm, nodes form into clusters and elect cluster head and the node which detach from current cluster are joined by predicting their mobility using link expiration time. Here future prediction (mobility) is done on basis of direction and speed of nodes and so re-affiliation frequency is reduced. As the number of nodes increased, the increasing rate of re-affiliation slowed down. According to the result, MWCAMP gives less re-affiliation than WCA especially for the high node density. Thus we form a stable cluster with MWCAMP.

Here the number of clusters formed for a given number of nodes is plotted. The number clusters formed should be reduced. Here no of clusters formed are comparatively reduced.

Comparison between WCA and our proposed work on basis of throughput and simulation time is given in figure 7 and 8. Figure 7 represents the throughput of forwarding message in WCA. Figure 8 represents the throughput of forwarding message in our proposed work MWCAMP.

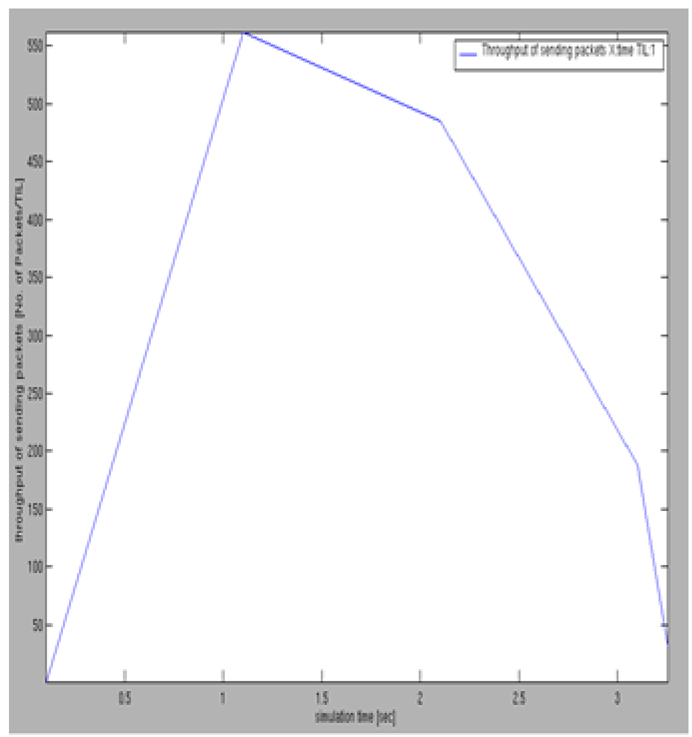

Figure 7: This graph represent WCA output. The Transmission time is from 1sec to 2 sec. Here throughput of forwarding message is decreasing and it is not stable.

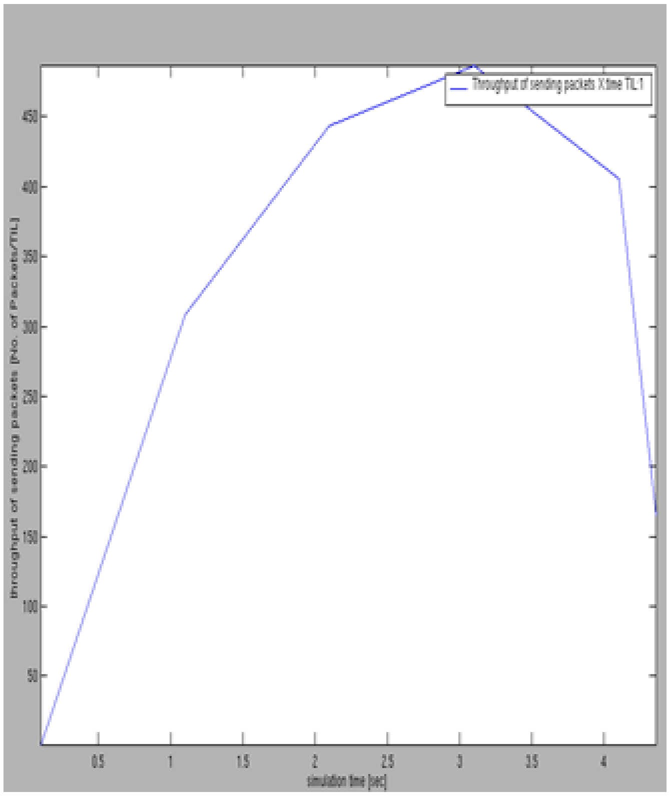

Figure 8: This graph represent MWCAMP output. The Transmission time is from 1sec to 2 sec. Here throughput of forwarding message is increasing and stable.

VI. Conclusion

In this paper we have presented an enhanced weight based clustering algorithm using mobility prediction (MWCAMP) that can be applied in MANETs to improve upon their stability and to reduce re-affiliation of the nodes. MWCAMP mainly focuses on reducing the instability caused by high-speed moving nodes, by taking relative mobility of node and its neighbors into consideration. Since WCA support stable cluster head election and the disadvantage is re-affiliation of nodes which is reduced by mobility prediction, it results in stable clustering. The performance of the proposed MWCAMP demonstrated that it outperforms WCA in terms of re-affiliation count.

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S. Muthuramalingam has over 6 years of teaching experience and is currently working as a Asst Prof in Thiagarajar college of Engineering. He finished his bachelor of Engineering (computer science) at Shanmugha college of engineering, Thanjavur in the year 1997. And he completed his M.E in Kalasalingam University in 2002. He published two papers in International journal on applications of graph theory in wireless ad hoc networks and sensor networks, and IJCEE. He has published papers in the national and IEEE international conferences such as IEEE AMS 2008 IEEE Netcomm2010, NCCN'09,VIT, NCACT,SAATRA and NCIM 2007. He is pursuing PhD degree in the field of Mobile communication at Anna University Chennai, India.

R. Rajaram completed his PhD in TCE, Madurai Kamaraj University in the year 1979, and the MTech degree in IIT Karagpur in the year 1971. He has published about 100 papers in a number of journals such as the International journal of Computational Engineering Science, Journal of Optics and Journal of the Institute of Engineers. He is a life member of Institution of engineers, Computational Society of India, India Society for Tech Education. Currently working as the Dean CSE/IT & Head of the Department of IT in Thiagarajar college of engineering..