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A New Clustering Algorithm Using Links' Weight to Decrease Consumed Energy in MANETs

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Abstract

One of the most important problems of clustering algorithms in mobile ad-hoc networks (MANETs) is the relatively low stability in generated clusters which are resulted by rapid clusters destruction and high energy consumption in performing the re-clustering processes. Many algorithms have been provided to increase the clusters stability of which the most significant are weight-based algorithms. In weight-based algorithms, only limited information of each node is used to determine its weight and it causes that the best possible option for cluster-head is not selected. The purpose of this paper is providing one weight-based algorithm in which each node's weight determination is performed not only by using its node information but also its neighbor's nodes information and this work is performed by determining the links' weight between nodes that provide connections between nodes. Via this method, the best possible options can be selected as cluster-head. In simulations and performed experiments, it is revealed that the generated clusters by our proposed algorithms have very high stability.

Keywords: *Clustering, Mobile Networks, Nodes' Stability, MANETs, Consumed Energy*

1. Introduction

Clustering is defined in MANET as follows: natural arrangement of mobile nodes in several different groups [1, 2]. Figure 1 shows a MANET after the clustering processes.

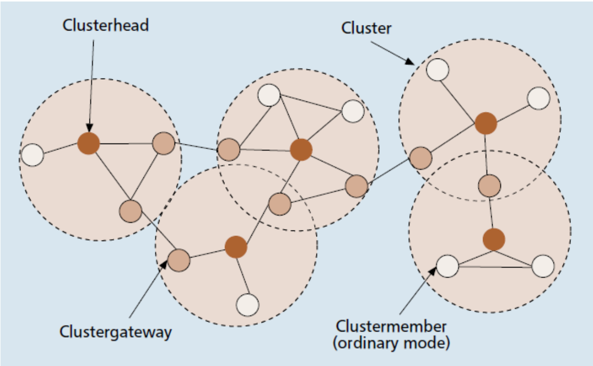

Figure 1. Clustering in MANET [1]

Clustering is applied to increase performance, facilitate routing, decrease energy consumption, increase stability and network spread ability [3, 4]. However, it has some disadvantages including high energy consumption to perform the re-clustering processes.

Each node's energy is limited in MANETs and if this energy is finished, the node will be destroyed. Now, if this node is a cluster-head, not only the node itself will be destroyed but it will also result to its cluster destruction whereby after destroying each cluster, one node is selected as the cluster-head among remaining nodes and a new cluster will be built for remaining nodes. These processes are called re-clustering. Re-clustering is a step which causes high energy consumption and considering the restricted energy; it increases the number of re-clustering results in rapid network destruct. One purpose of clustering algorithms is decreasing the numbers of this step occurrences and its solution in generating more stable clusters.

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Many algorithms relating to clustering in MANETs were suggested of which the most significant are weight-based algorithms. To determine the nodes' weight in weight-based algorithms, only limited information of each node is used for determining its own weight and the best possible option will be selected to become the cluster-head.

In this paper, one clustering algorithm in MANETs is suggested in which each node's weight is performed not only by using its own node information but also its neighbors' information and this work is performed by determining the links' weight between nodes which provide connections between nodes. This method is the best way to measure the mobility prediction of nodes, energy percentage, neighbor share and other factors. In this algorithm, the cluster-heads which have the best factors among their neighbor nodes are selected. In this algorithm firstly, the links' weight between both nodes are determined on the basis of four basic factors and then, the final weight of each node is determined according to the links' obtained weight. Finally, the manners of each node are defined according to their obtained weights.

In the next section, the paper reviews previous mentioned works. Then, the proposed algorithm is provided. In the next section, the simulation results will be evaluated. In the last section, conclusions of the mentioned discussions will be presented.

2. Related Work

Many factors are offered to select the cluster-head. Clustering algorithms are classified according to these factors. The first offered factor is the neighborhood degree (neighbors' number). Among algorithms which are built on the basis of it we can mention the HD (highest degree) by Gerla [1-3] and LLC (least cluster change) by Chiang [1-3] which attempted to select the cluster-head using the neighborhood degree values of nodes.

Another offered factor is the node-mobility and we can mention some algorithms built on the basis of it such as the MOBIC (mobility-based metric for clustering) by Khan [1-3], DDVC (dynamic Doppler velocity clustering) and DLDC (dynamic link duration clustering) by Sakhaee et al. [5]. In this algorithm, one node is selected as the cluster-head which has the least mobility among its neighbors or has similar mobility to its neighbors.

Another factor is energy and the algorithms based on which are built from energy efficient clustering algorithms such as the power-aware connected dominant set by Wu [1-3], SCA (stable cluster algorithm) by Sheu [1-3] and DEECF (distributed energy efficient cluster formation) by Kim et al. [6]. In these algorithms, one node is selected as the cluster-head which has the most energy among their neighbors.

Another factor is in fact a compound of previous factors: neighborhood degree, mobility, energy and load-balancing called the weight factor. This factor is the best criterion in selecting the cluster-heads because it covers all the previous factors. Many algorithms are provided according to this factor which are included in the combined-metrics-based clustering class such as the WCA (weighted clustering algorithm) by Chatterjee et al. [7], DSCAM (Distributed Scenario-based Clustering Algorithm for MANETs) by Anitha et al. [8], EWCA (enhanced weighted clustering algorithm) by Chang Li et al. [9], KCMBC (k-hop compound metric based clustering) by Leng et al. [10] and one algorithm proposed by Muthuramalingam et al. [11]. However, this group of algorithms has some disadvantages i.e. the information which are collected to obtain factor values for each node is the same limited information of the node itself and it causes the best option to be not often selected to become the cluster-head. This problem has been removed from the proposed algorithm in this paper.

3. The Proposed Algorithm

In our proposed algorithm firstly a weight for each node is determined according to its links' weight and finally, the cluster-heads are selected according to the obtained weight of nodes and members are admitted and the manners of each node are determined. By using the links' weight, we can obtain the final weight of each node based on the obtained information of neighbor nodes whereas in previous methods, the final weight of each node is obtained by using its own limited information only. We can increase the cluster-heads stability significantly using our proposed method.

The steps of building clusters in the proposed algorithm are as follows:

1. Determining the weight of links which are between two nodes using the following factors: links' neighborhood share, speed of the links, consumed energy between two connected nodes to the link and distance between two connected nodes to the link.
2. Determining each nodes' weight based on its links' weight
3. Selecting cluster-heads according to the obtained weights and determining each cluster's members.

3.1. Determining the links' weight

The first factor is the share of links neighborhood. The more neighbors that one node has, the better candid will be to become the cluster-head. The steps of determining the neighborhood share of link are as follows:

First, each nodes' neighborhood degree is determined which are also called "d" and show the number of nodes which exist in the transaction range [7]:

$$d_v = \sum_{v' \in v, v' \neq v} \left\{ dist(v, v') < tx_{range} \right\} \quad (1)$$

Where dist(v,v') is distance between two neighborhood nodes. Now, factor (1) [percentage of that links' neighborhood share] is calculated according to equation (2):

$$P_v = \frac{1}{d_v} \quad (2)$$

The second factor is the speed of the links. If cluster-heads move faster than their members, they have to outside form their members range constantly [5]. Therefore, more attention should be paid to select cluster-heads, because the cluster-heads should have the least speed [12],[13].

In this step, we obtain the speed of the links as equation (3):

$$N_L = \frac{S_V + S_E}{2} \quad (3)$$

Where V and E are two connected nodes to link. SV and SE are their speed.

In Figure 2, the neighborhood share and the speed of the links related to the nodes V and E are determined.

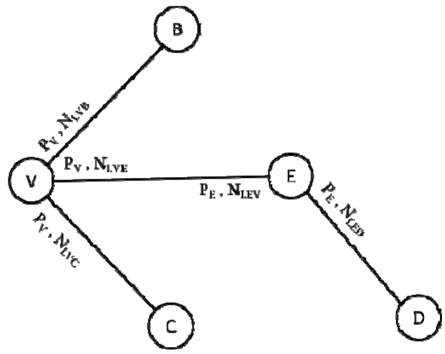

Figure 2. Determining the neighborhood share and the speed of links

The third factor is the consumed energy of the links. Because the cluster-head has the most responsibilities among other nodes, they consume more energy. Hence, the remaining energy should be considered in selecting clusters [14-16]. In this step, the energy of each link is estimated according to its nodes' energy. Equation (4) is used to determine factor (EL):

$$E_L = \frac{E_v + E_E}{2} \quad (4)$$

In which EV and EE are the consumed energy of nodes V and E respectively.

The fourth factor is the distance between two connected nodes to links. The cluster-head which has closer neighbors needs less energy to interchange information. This is due to its energy that does not finish very soon and the cluster stability's increase. According to this factor, parallel k-means clustering algorithm was suggested by L.Thomas and B.Annappa [17, 18] in which nodes with short distance are located in the same cluster [19]. To determine the distance factor, we perform steps as follows:

A message is sent from the source (first) node to the target (second) message and the second node returns a response to the first node as soon as it receives the message. The source (first) node calculates the return-time and considers it as the distance factor (IL).

After obtaining four factors PV, NL, EL and IL the final link's weight (CL) is estimated according to them. We use a weight-equation to estimate it:

$$C_{LV} = (W_1 * P_V) + (W_2 * N_L) + (W_3 * E_L) + (W_4 * I_L) \quad (5)$$

In which W1, W2, W3 and W4 are weight factors that determine the related factor effect amount. The following criteria is considered in determining them.

$$W_1 + W_2 + W_3 + W_4 = 1$$

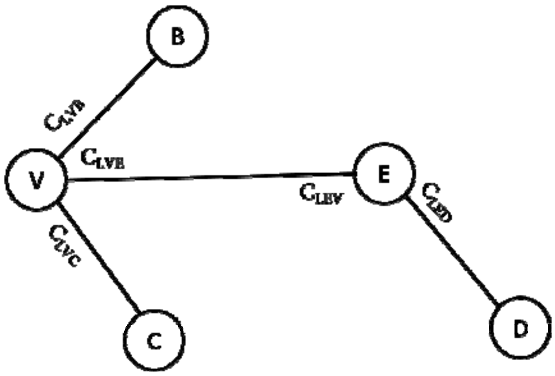

Figure 3. Determining final weight of each node

3.2. Determining the Final Weight of Each Node

In this step, the final weight of nodes are estimated considering the link weight of each node and load-balancing. The work is performed as follows: each node adds up its links' weight and divides into its neighborhood degree (d) [20]:

$$C_{V1} = \frac{\sum_{i=1}^{d_V} C_{LVi}}{d_V} \quad (6)$$

Now, the primary weight (CV1) should be reversed:

In this step, the load balancing factor should be involved such that each cluster-head supports just a limited number of nodes in order for the load distribution to be justified between cluster-heads [21]. First, a criterion called δ is determined. This criterion indicates the number of optimum nodes which should be involved in a cluster to achieve load-balancing. In the following, the difference between node neighborhood degree (dV) and suitable criteria of neighborhood degree (δ) will be calculated and later known as ΔV:

$$\Delta_V = \left| d_V - \delta_V \right| \quad (8)$$

At the end, the final weight of each node (CV) is estimated by exerting the load factor as equation (9):

$$C_V = C_{V1} * e^{-\Delta_V} \quad (9)$$

3.3. Selecting Cluster-Heads

After estimating the final weight of each node, the nodes transmit their weights to their neighbors. When transmission has finished, all nodes know their weights and their neighbors'. In continuation, the node which has the most weight among its neighbors will introduce itself as the candidate of cluster-head. Candidates will be collected to generate a domain set. Cluster-heads will be selected and clusters will be generated.

4. Simulation

To study the efficiency of proposed algorithm, some different experiments have been performed by the simulator NS-2.34 [22]. In these experiments, one mobile ad-hoc network (MANET) in the environment with dimensions of 2000*2000 m whose data is shown in Table 1 has been simulated.

Table 1. Simulating Parameters in Simulator NS2

Parameter	Meaning	Value
N	Number of Nodes	100-500
X*Y	Size of network	2000*2000 m
S_Range	Speed Range	0-5 m/s - Randomly
T_Range	Transmission Range	100-200 m
Run Time	Time of Simulation	600 s
W_1, W_2, W_3, W_4	Weights	0.21, 0.37, 0.21, 0.21

In all experiments, the proposed algorithm was compared to two algorithms: WCA (Weighted Clustering Algorithm) by Chatterjee et al. [7] and LEACH (low-energy adaptive clustering hierarchy) by Heinzelman et al. [23]. The results indicated that our algorithm is the most stable algorithm among them.

4.1. Clusters' Life-Time (LT)

When a given node is selected as the cluster-head and a cluster is generated, this period until the cluster is destroyed is called the cluster's life-time and it indicates the network clusters' stability and it is expressed in proportion to seconds.

In this experiment, the number of node was considered as 100-500 and Figure 4 was obtained when the experiment is finished.

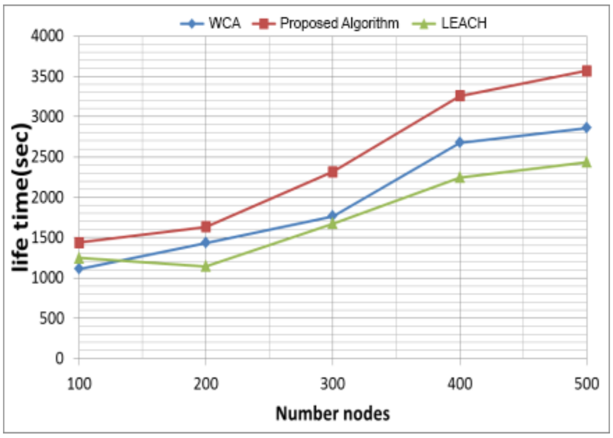

Figure 4. Life-time parameter with increasing number of node in network

It is shown in Figure 4 that the proposed algorithm has longer life-time than algorithms WCA and LEACH and this life-time will be increased by the increasing number of network nodes. Its reason is the proper selection of cluster-heads such that they have the highest scores in their group. Adding up scores in contrast with algorithm WCA has been performed by link information between nodes and this includes other nodes information. Meanwhile, only the node's limited information is applied to estimate its score in algorithm WCA. The load-balancing factor which is also applied in the proposed algorithm enables the algorithm to transmit less information for cross-network communication and contributes to maintain stability and decrease the network life-time.

In Table 2, a comparison has been done in two parts of diagram and the differences between life-times have been investigated.

Table 2. Comparing Proposed Algorithm for Parameter Life-Time

Algorithm	Life-Time with 200 nodes	Life-Time with 400 nodes
Proposed Algorithm	1632 s	3253 s
WCA	1416 s	2688 s
Increment %	15.25 %	21.01 %

Considering Table 2, it is known that the proposed algorithm life-time has been improved in comparison to two other offered algorithms and this improvement is about 21% in some points and finally, it results in high stability of the network in the proposed algorithm.

4.2. Consumed Energy Amount (EN)

The consumed energy amount in network nodes in the given time to transmit information is called the upload or consumed energy amount of the network. The lesser the amount, the more stable the clusters are. This amount is expressed in mill joule.

In this experiment, the transmission range was 100-200 m, and then we performed this experiment until Figure 5 is obtained.

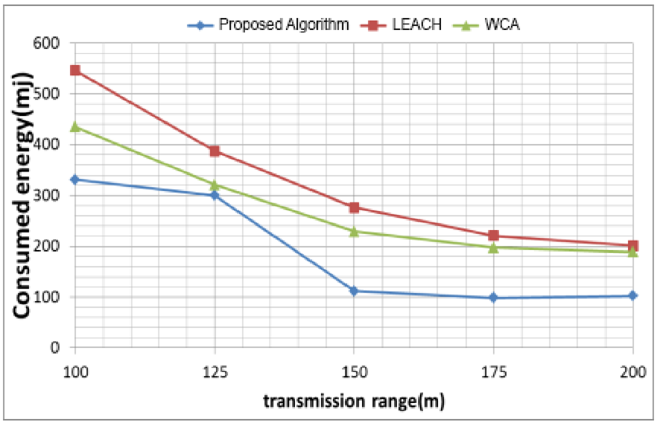

Figure 5. Consumed energy amount with increasing transmission range

In Figure 5, it was indicated that less energy was consumed in the proposed algorithm than algorithms WCA and LEACH and in this case by increasing the transmission range of nodes energy consumption decrease. At first, the algorithm WCA performs efficiently, however when the transmission range of network nodes increased, the energy consumption increased significantly in this algorithm and showed lower efficiency than our algorithm. This shows that the proposed algorithm consumes very little energy because of the proper structure of its steps and selecting the best cluster-heads which are superior than their neighbors' information leads to the increase of stability and life-time of clusters.

4.3. Number of Clustering and Re-clustering Operations

If a cluster is destroyed (removed), the re-clustering phase will be initiated and one is selected as the cluster-head among available nodes and a new cluster will be generated. It results in consuming high energy and finally destroying the whole network stability; the less this amount, the more stable the network is.

In this experiment, the number of re-clustering operations of each algorithm was investigated in different transmission ranges. We regulated the transmission range from 100 to 200 m until Figure 6 is determined.

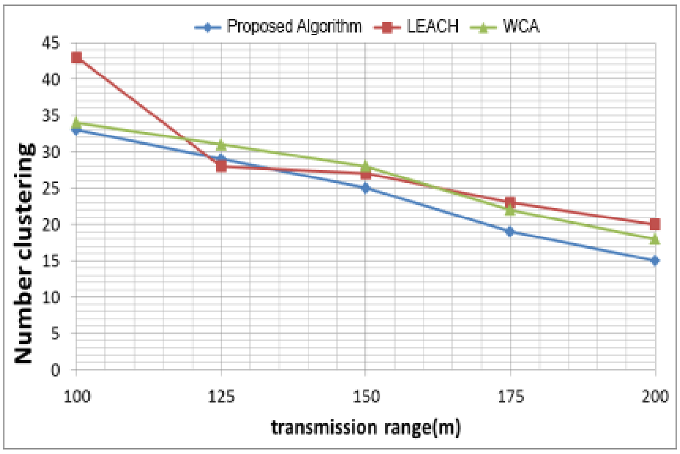

Figure 6. Number of clustering and re-clustering operations with increasing transmission range.

From Figure 6 it reveals that less re-clustering operations are performed in the proposed algorithm than algorithms WCA and LEACH and by increasing the Transmission range, this number will decrease. Regarding to the fact that this parameter is one of the most significant parameters for which clustering algorithms search, and then it can be proposed that the proposed algorithm can obtain a significant diagram. It was improved because the cluster-heads were determined properly and the clusters maintaining phase was planned efficiently such that after the failure of one cluster, the next cluster-heads are selected correctly.

In Table 3 there is a comparison in two parts of the diagram and the differences between numbers of generated clusters are studied.

Table 3. Comparing the Proposed Algorithm for Clustering and Re-Clustering Parameter

Algorithm	Number of clustering with 140 Transmission range	Number of clustering with 175 Transmission range
Proposed Algorithm	26.5	19.1
LEACH	27.2	21.9
Decrement %	2.57 %	12.78 %

Considering Table 3 it is clear that the number of re-clustering operations in the proposed algorithm has been improved in comparison to two other mentioned algorithms. Even at some points, we see 12% decrement which finally leads to high stability of network in the proposed algorithm.

5. Conclusion

In this paper, an algorithm to cluster nodes in mobile ad-hoc networks (MENETs) has been suggested in which some nodes are selected as cluster-heads whose links have the highest value. To determine the links' value between nodes, four factors are applied i.e.: energy, mobility, neighborhood share and link's length. To estimate the final value of each node, the obtained links value and load-balancing factor are used.

Using the links' weight estimation, the final weight of each node can be estimated based on obtained information from its neighbor nodes whereas in previous methods, the final weight of each node is estimated by using only its own limited information.

In performed simulations, it was revealed that our proposed algorithm stability was improved significantly in comparison to previous algorithms and it resulted in increasing the clusters' life-time and decreasing energy consumption.

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