Internal and External factors based clustering algorithm for MANET

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Abstract—Several MANET characteristics that distinguish MANET from other wireless networks and makes routing a challenging task. This paper presents a novel clustering algorithm, which uses both internal and external factors of node in mobile ad hoc network. In Cluster based MANET routing scheme, various mobile nodes are formed as clusters. Each cluster has its own cluster head, which is having more responsibilities like, minimizing the topology changes, stability and re-affiliation of on demand networks. Since the proposed work uses both internal and external factors of node, it is aiming at finding quick response during the routing process Simulations are performed using NS2 simulator. We compare the proposed clustering algorithm with other algorithms, which are Low energy adaptive clustering hierarchy (LEACH) and A Weighted Clustering Algorithm for Mobile Ad Hoc Networks (WCA). Our analysis and simulation results show that, the proposed algorithm efficiently manages cluster head updates, re-affiliation, cluster head stability and it outperforms the other algorithms.

Keyword-Clustering, Cluster head, Mobile ad hoc network, Routing, Cluster.

I. INTRODUCTION

Mobile ad hoc networks (MANETs) are complex distributed systems that include mobile wireless nodes that can dynamically and freely self-organize into temporary and arbitrary ad hoc network topologies[1- 3]. The efficacy of routing protocols in MANET becomes more significant and challenging because of its constraints in resources and for fast response [4]. MANET Routing protocols can be classified into proactive [5], reactive [6, 7] or hybrid routing [8, 9]. In proactive mechanism, updated routing information is maintained periodically in each node. In reactive routing mechanism, information about routing are created and kept periodically, only when it is needed. Hybrid routing method is a mixture of proactive and reactive routing and it is proposed to balance the performance and overhead of above two schemes. As like hybrid routing schemes, Clustering techniques [10, 11] are proposed to improve the routing performance and reduce the complexity. In a clustering scheme, all the nodes in the network are virtually separated into the sub networks, called Clusters. Cluster head of each cluster maintains its cluster members and topology information [12]. Gateway nodes are the cluster members that connect neighbouring clusters [13]. Earlier clustering methods are not designed with the consideration of node's remaining processing and memory capacity. For example, a node in a clustered MANET can give a quick response to its members, if and only if it's remaining power of processing and memory capacity are high. Based on this observation, a new algorithm for cluster based MANET has been proposed. The objective of this article is to provide an efficient cluster head selection algorithm for cluster based MANET. The rest of the paper is planned as follows: Section 2 briefly presents Literature work. In section 3, the details of our routing algorithm are presented. Section 4 shows the simulation results. Finally, section 5 provides conclusion and future work of our proposed work.

II. RELATED WORK

A In this section, we present related works and background information for Cluster head selection methods used in Mobile ad hoc networks. Logical partitioning of mobile nodes in a network into several groups are called clusters. Several clustering algorithms have been proposed to optimize the procedure of cluster head (CH) election. These algorithms are classified as Lowest ID clustering (LIDC) [9, 13], Highest degree clustering (HDC) [13], and Weighted clustering (WC) [11, 13, 16]. In Lowest ID clustering algorithm, distinct ID is assigned to each node and the node with minimum ID is chosen as Cluster Head (CH). In Highest degree clustering algorithm, degree of the node is calculated based on its distance from others. The node with the highest degree of connectivity is chosen as a cluster head (CH). In Weighted clustering algorithm, node parameters like degree of connectivity, mobility, transmission power and available power are considered for Cluster head election. The work proposes a new algorithm, Preference based Head election Algorithm (PHA) based on a weighted clustering (WC) algorithm. A unidirectional connectivity based clustering method, called Cluster based Routing Protocol (CRP) is presented in [19]. Cluster head selection parameters are the number of pendant nodes, node with unidirectional links and node degree. The node with the largest weight in its 1-hop neighbours will become CH. Low energy adaptive clustering hierarchy (LEACH) protocol is presented in [20]. LEACH is an energy-efficient cluster based routing protocol and is based on a hierarchical clustering structure. To prolong energy of Cluster head for long time, it periodically changes Cluster heads. After the election of Cluster head, sensor node broadcast an advertisement message to non-cluster sensor nodes. It selects the most suitable cluster head based on signal strength of the advertisement message. Another clustering algorithm, A Weighted Clustering Algorithm for Mobile Ad Hoc Networks (WCA) based on weighting factor is presented in [11]. This clustering algorithm has the flexibility of assigning different weights and considers a combined effect of the transmission power, ideal degree, battery power and mobility. Based on demand basis, algorithm is executed. This clustering algorithm tries to allocate the load as much as possible. In WCA, there is a gradual increase in the LBF due to the circulation of the nodes among the clusters.

III. PROPOSED WORK

Plane structure of MANET will increase routing control overhead and scalability problem. A virtual partitioning of dynamic nodes, called as clustering. Each node contains only the information about the nodes, which belongs to the same group. This section describes three phases namely: Cluster formation, Cluster head election, and Cluster renovation.

A. Cluster formation

Here, a node may hold any one of three states namely cluster member, cluster gateway or cluster head. Initially, all the nodes that form a network are called as cluster member or ordinary node. A node may be promoted from cluster member state to cluster head state only if it is identified as the most stable node among its neighbours in the respective cluster. Else, it is an ordinary node of a cluster. A node that works as a common or distributed access point for two cluster heads are called as a gateway node. Every node in a cluster should broadcast "HELLO" messages to its neighbours. A node in a network will maintain two other tables, in addition to "HELLO" packet, namely Neighbour Table (NT) and Cluster Adjacency Table (CAT). Each node in a cluster will maintain the information of both Trust value, and Stability value in its neighbour table (NT). Time to Live (TTL) is a Timer value used to update the neighbour table after a period of time. CAT, which maintains the information about adjacent clusters and the gateway node. Gateway node information gives the way to identify an adjacent cluster.

B. Cluster head election

This section details the Cluster head election mechanism for truthfully electing the head node. A cluster member may be promoted as a cluster head only if it has better stability (S) value based on its updated neighbour node's list. S is identified based on two aspects, Internal (IF) and External factors (EF) of a node.

1) *External Factors (EF_A):* Each node computes its external factors based on the following parameters:

a) The mobility of node A (M_A): Average distance between node A and its one hop neighbor B is calculated as,

$$\mu_{AB} = \frac{(\sum_{i=1}^{n} d_{AB}^{ti})}{m} \tag{1}$$

Where'd' denotes the distance between A and B at time t_i (t_i value varies from 1 to N), and 'N' denotes the number of times the distance is calculated between A and B. Variance distance: between A and its one hop neighbor B is calculated as,

$$\sigma_{AB} = \frac{(\sum_{i=1}^{n} d_{AB}^{ti} - \mu_{AB})^2}{m} \tag{2}$$

Here at any I value $t_i - t_{i-1}$ will be same, where i>=2; and variable 'i' is assigned a discrete value. Using equation (3) and (4), distance variance between node A and its one hop neighbors (B,C,…) is calculated as M_A, where it is A's mobility.

$$M_{AB} = \frac{(\sigma_{AB} + \sigma_{AC} + .. + \sigma_{AZ})^2}{m} \tag{3}$$

'm' denotes the number of neighboring nodes for node A.

b) Connectivity of node (C_A): Node A and its neighbors belong to the same logical subnet. Number of single hop neighbors denotes the connectivity, and it is calculated as,

$$C_{AB} = \sum_{i=1}^{m} \frac{1}{\omega_i} \tag{4}$$

c) Average distance of node (D_A): Average distance between a probable cluster head, and all its one hop neighbors.

$$D_A = \frac{(D_{AB}^{tN} + D_{AC}^{tN} + D_{AD}^{tN} + .. + D_{AZ}^{tN})}{m} \tag{5}$$

Therefore, end result of External factor of a node (EF_A) is calculated as,

$$EF_A = \alpha_1 (M_A) + \alpha_2 (C_A) + \alpha_3 (D_A) \tag{6}$$

α_1, α_2 and α_3 are weighting coefficients for node's external factors.

2) Internal Factors (IF_A): Each node computes its internal factors (IF) based on the following parameters:

d) Remaining battery power (E_A):

Available energy of a node A may be identified as,

$$E_A = \alpha \frac{1}{\Delta E_A} + (1-\alpha) RE_A \tag{7}$$

Where $0 < \alpha < 1$; ΔE_A is A's energy consumption, and RE_A is remaining energy of a node A.

e) Remaining Processing power (P_A):

During the cluster head election, the remaining processing power of a node is analysed. Even if the configuration of a node is high, its speed of response is based on processing capability. Assume there are 'n' nodes in a cluster, processing power of nodes in a cluster are $P_1, P_2, P_3..P_n$. For any kind of higher or lower values of processing power, by finding out the median value, we can justify the higher and lower ends. Therefore, from 'n' nodes we can find out remaining high and low processing values and assume P_L -Low, P_M -Median, P_H -high. Next is to find out second level values by P_L and P_M, which are one part and P_M, and P_H which are the other part. The median value (P_{LM}) between P_L and P_M, and another median value (P_{HM}) between P_M and P_H are then found out. Assign values to each category, such as P_L to $P_{LM} \rightarrow K_4$; P_{LM} to $P_M \rightarrow K_3$; P_M to $P_{HM} \rightarrow K_2$; P_{HM} to $P_H \rightarrow K_1$. K_1, K_2, K_3 and K_4 are assigned numerical values based on priority low to high. Thus, P_A value of a node may be $K_1 / K_2 / K_3 / K_4$. Value assignment to variable value of Processor is represented in Table 1.

TABLE I. VALUE ASSIGNMENT TO VARIABLE PROCESSOR VALUES

<table>
<tr><td colspan="4">Processor values $P_1, P_2, P_3..P_n$</td></tr>
<tr><td colspan="4">Finding first level medians values of processors</td></tr>
<tr><td colspan="4">Median values</td></tr>
<tr><td>Low (P_L)</td><td colspan="2">Medium(P_M)</td><td>High (P_H)</td></tr>
<tr><td colspan="2">Processor values ranges from Low to Medium
(P_{LM})
P_L …..to….. P_M
(P_{LM})
(Finding Second level median values of processors between P_L and P_M)</td><td colspan="2">Processor values ranges from Medium to High
(P_{HM})
P_M …..to….. P_H
(P_{HM})
(Finding Second level median values of processors between P_M and P_H)</td></tr>
<tr><td colspan="4">Defining values to the ranges from
P_L to P_{LM} , P_{LM} to P_M , P_M to P_{HM} and P_{HM} to P_H</td></tr>
<tr><td>P_L to P_{LM}</td><td>P_{LM} to P_M</td><td>P_M to P_{HM}</td><td>P_{HM} to P_H</td></tr>
<tr><td>K_1</td><td>K_2</td><td>K_3</td><td>K_4</td></tr>
</table>

f) Remaining memory power (M_A):

Calculate the remaining memory power as like the calculation of remaining processing power (P_A). The first level median M_M and Second level median M_{LM} , and M_{HM} between lower end M_L higher end M_H are found. Assign values to each category, such as M_L to $M_{LM} \to L_4$; M_{LM} to $M_M \to L_3$; M_M to $M_{HM} \to L_2$; M_{HM} to $M_H \to L_1$. L_1 , L_2 , L_3 and L_4 are assigned numerical values based on priority low to high. Thus, M_A of a node may be $L_1 / L_2 / L_3 / L_4$. Value assignment to variable value of Memory is represented in Table 2.

TABLE. 2. VALUE ASSIGNMENT TO VARIABLE MEMORY VALUES

<table>
<tr><td colspan="4">Memory values $M_1, M_2, M_3..M_n$</td></tr>
<tr><td colspan="4">Finding First level median values of Memory</td></tr>
<tr><td colspan="4">Median values</td></tr>
<tr><td>Low(M_L)</td><td colspan="2">Medium (M_M)</td><td>High(M_H)</td></tr>
<tr><td colspan="2">Memory values ranges from Low to Medium (M_{LM})
M_L …..to….. M_M
(M_{LM})
(Finding Second level median values of Memory between M_L and M_M)</td><td colspan="2">Memory values ranges from Medium to High (M_{HM})
M_M …..to….. M_H
(M_{HM})
(Finding Second level median values of Memory between M_M and M_H)</td></tr>
<tr><td colspan="4">Defining values to the ranges from
M_L to M_{LM} , M_{LM} to M_M , M_M to M_{HM} and M_{HM} to M_H</td></tr>
<tr><td>M_L to M_{LM}</td><td>M_{LM} to M_M</td><td>M_M to M_{HM}</td><td>M_{HM} to M_H</td></tr>
<tr><td>L_1</td><td>L_2</td><td>L_3</td><td>L_4</td></tr>
</table>

Therefore, a result of Internal factor of a node (IF_A) is calculated as,

$$IF_A = \beta_1 \frac{1}{E_A} + \beta_2 (P_A) + \beta_3 (M_A) \tag{8}$$

Where $\beta_1 + \beta_2 + \beta_3 = 1$. β_1 , β_2 and β_3 are Weighting coefficients for node A's internal factors.

Hence, We can find the stability value of node A (S_A),

$$S_A = S_1(EF_A) + S_2(IF_A) \tag{9}$$

Where $S_1 + S_2 = 1$. S_1 and S_2 are the Weighting coefficients for overall internal and external factors.

3) Cluster renovation: Due to the mobility in MANET, the clusters have to be reorganized and reconfigured. There may be a situation where a cluster may be reconfigured based on Stability value of cluster head (CH), node mobility, and cluster head mobility. Once TTL value of HELLO packet is 0, CH will initiate the stability factor calculation to nodes in a cluster. Each node calculates its stability value and passes it to their CH. Now CH will decide a new CH by looking at all the nodes' stability values. This information is broadcasted to all 1-hop neighbours, and it is updated in all nodes' NAT and CAT. When a node moves to another CH, it broadcasts HELLO message to neighbours in the cluster. The updated value of HELLO packet is verified by CH, and its stability value is analysed by CH. New node joins the new cluster and if necessary CH role is updated with new node. This information is broadcasted to all 1-hop neighbours.

IV. SIMULATION RESULTS

A. *Simulation parameters*

Proposed algorithm is performed using the NS-2 network simulator. IEEE 802.11 standard is used as MAC layer protocol. The radio propagation model used is the Two-Ray ground model. Nominal transmission range is 250 meters. The radio model is simulated with a nominal bit rate of 11 Mbps. The traffic type is CBR (Constant Bit Rate) with a network packet rate of 4 Packets/Sec, and the packet size is 512 bytes. The movement model used is a Random way point model. The pause time used is 0 second. The simulation time used is 800 second. The value of High, Medium, and Low for Trust classification are 1, 0.5 and 0 respectively. The value of weights W1, W2, W3, and W4 for simulations are 0.1, 0.2, 0.3 and 0.4 respectively. The value of weights α_1, α_2 and α_3 for External factors (EF_A) are 0.4, 0.3 and 0.3 respectively. The value of weights β_1, β_2 and β_3 for Internal factors (IF_A) are 0.5, 0.3 and 0.2 respectively. The value of remaining Processor power (P_A) K_1, K_2, K_3 and K_4 simulations are 25, 50, 75 and 100 respectively. The value of Memory (M_A) L_1, L_2, L_3 and L_4 simulations are 25, 50, 75 and 100 respectively. The value of Weights for identifying stability factors S_1 and S_2 are 0.5 and 0.5 respectively. The value of d factors for packet delivery ratio d1 and d2 are 5% and 10%.

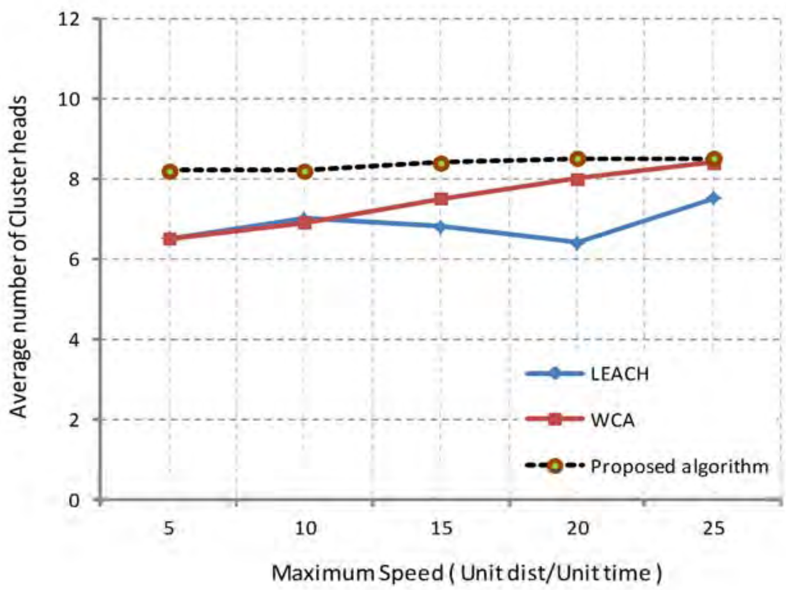

Fig. 1. Average number of Cluster heads vs. Maximum speed of proposed algorithm, LEACH and WCA

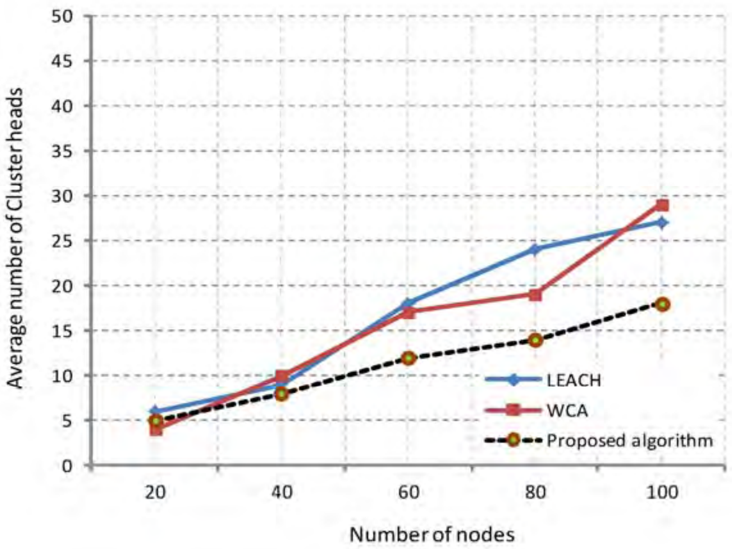

Fig. 2. Average number of Cluster heads vs. Number of nodes of proposed algorithm, LEACH and WCA

B. Average number of cluster heads

It is defined as the ratio of average number of cluster heads varies as a function of maximum node velocity and number of nodes. First, we defined the minimum speed of node as 0 unit distance per unit time. Here, we analysed our algorithm by varying maximum speed ranges from 1 to 20 unit distance per unit time. We observed that in our proposed clustering algorithm, the number of cluster heads was relative stable, when maximum velocity is varied compared to other clustering algorithms. It is illustrated in Fig. 1. Second, average number of cluster heads is formed with respect to the total number of nodes in MANET. As the density of the node is increased, our clustering algorithm produces constantly minimum cluster heads in compared with existing algorithms. It is illustrated in Fig. 2.

C. Average number of cluster head updates

It is defined as, when the node speed is increased, the nodes in cluster roam more frequent outside the transmission range of their cluster head. Because of this, the structure of cluster becomes more unstable. Also, the cluster change events and cluster head updates become increasingly more frequent. The work analyses the average number of cluster head updates in our proposed algorithm, LEACH, and WCA. Proposed algorithm's cluster head updates are stable than LEACH and WCA. It is illustrated in Fig. 3.

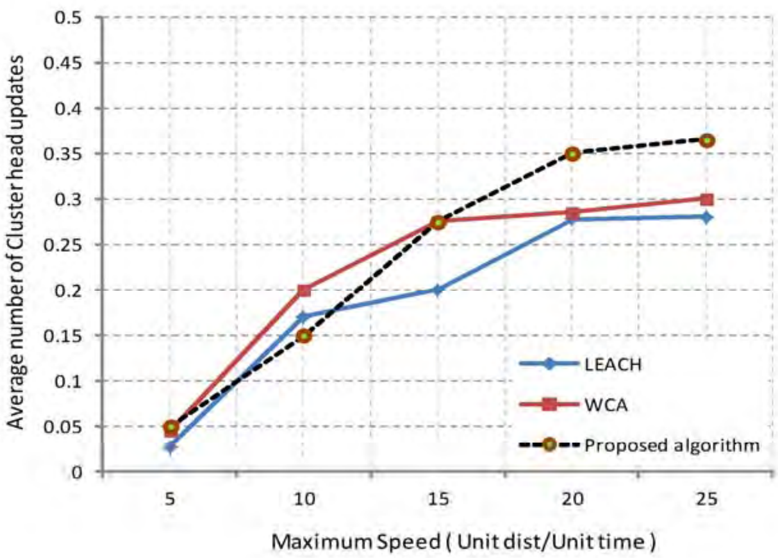

Fig. 3. Average number of Cluster head updates vs. Maximum speed of nodes of Proposed algorithm, LEACH and WCA

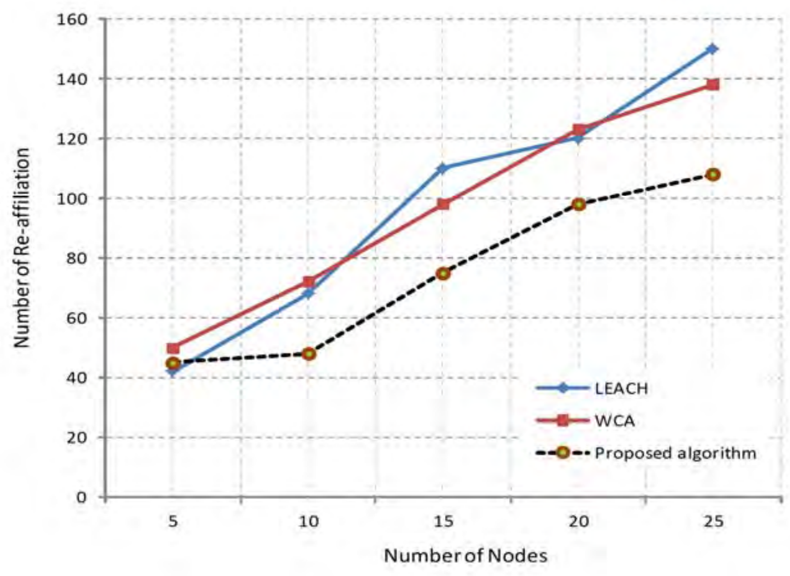

Fig. 4. Number of Re-affiliation vs Number of nodes of Proposed algorithm, LEACH and WCA

D. Number of Re-affiliation process

It describes, when a node of nodes or transmission ranges of node are increased, re-affiliation is automatically called by clusters. The main purpose of this measure is to limit re-affiliation process so that it must not exceed the factor, which automatically increases network overhead. The number of re-affiliation versus number of nodes is shown in Fig. 4. As a result, the proposed algorithm outperforms LEACH and WCA in terms of re-affiliation. Fig. 5. illustrates the comparison of re-affiliation rate with various transmission ranges. Here, we considered 30 nodes statically. The results show that, the number of re-affiliation is marginally lower than LEACH and WCA algorithms.

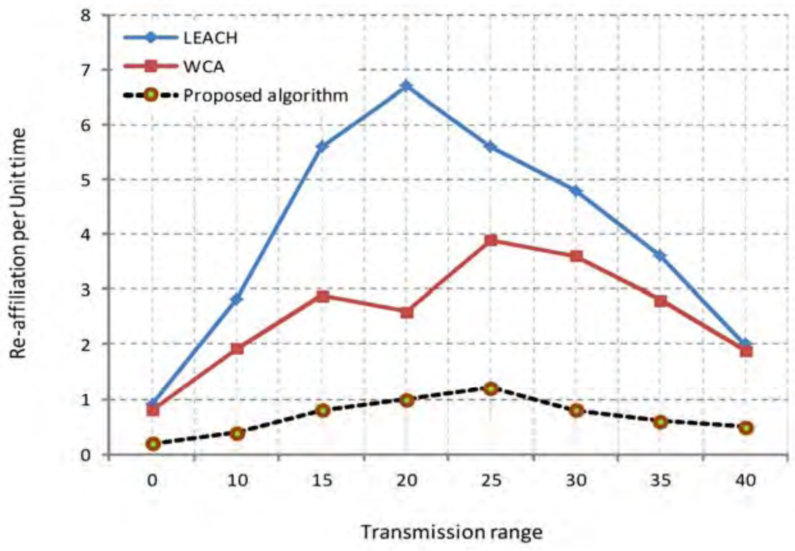

Fig. 5. Re-affiliation vs Transmission range of Proposed algorithm, LEACH and WCA

V. CONCLUSION

The work proposes a new clustering algorithm by considering internal factors (mobility, connectivity and average distance) and external factors (battery power, processor power, memory power) of a node. Because of quick response from every member, our algorithm has the capability of maintaining stability in number of cluster heads, cluster head updates and cluster re-affiliation even with higher mobility, transmission range and number of nodes. The proposed algorithm is compared with LEACH and WCA. The simulation results show that the proposed clustering algorithm can able to prolong the lifetime and forms stable clusters with most suitable one as cluster head and forwarder. It can be concluded that, our clustering algorithm would form the foundation for stable communication in MANET. The proposed work can be extended to design trustworthy cluster member to avoid participation of malicious node in a cluster based MANET routing.

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