Traffic-Aware Clustering Scheme for MANET Using Modified Elephant Herding Optimization Algorithm

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Abstract: *Clustering is the prevalent routing method in the large-scale Mobile Ad Hoc Network (MANET). The Cluster-Heads (CHs) play an important role in routing as it is transient through all communications of its associated nodes. To ensure fairness in the use of energy in all clusters, each CH has to deal with same amount of traffic. The previous clustering methods focused mainly on the distribution of equal member nodes in each cluster. They failed to consider every cluster's traffic generated. This paper introduces a novel technique for MANET clustering with Modified Elephant Herding Optimization based on the traffic generated within each cluster. This Traffic-Aware Clustering with Modified Elephants Herding Optimization (TAC-MEHO) produces optimized clusters for stable communication and is experimentally tested with well-known clustering techniques. Assessment metrics such as number of Cluster-Heads (CHs), lifetime of the network, and re-clustering rates are measured using various parameter values such as network size, network traffic and transmission distance. The results show that proposed TAC-MEHO improves the re-clustering rate by 91% and 58% when compared with Weighted Clustering Algorithm (WCA) and WCA-GA respectively. Further, it improves the network lifetime by 89% and 88 % over WCA and WCA-GA respectively.*

Keywords: *Clustering, MANET, traffic-aware, elephant heard optimization, cluster-head, large-scale network.*

Received June 10, 2020; accepted February 25, 2021
https://doi.org/10.34028/iajit/18/5/9

1. Introduction

Ad hoc network is a mobile multi-hop network with the ability to self-organize. Without any preset infrastructure, the mobile nodes can communicate with each other. The mobile nature of the nodes causes these types of networks to be dynamic topology [6]. Ad hoc networks have a vital role to play in military communications, disaster recovery, cognitive radio networks [8] and distributed sensor networks [9, 13]. The confined resources such as battery power, memory and bandwidth make the process of routing the most interesting process of research. Mobile Ad Hoc Network (MANETs) are therefore suffering from the problem of mobility, scalability, depletion of energy and security.

These issues should be addressed in finding a route in MANETs [7, 10] according to a given deployment scenario. There are many problems to be placed during the design of MANET routing protocols. MANET's routing is generally classified as flat and hierarchical routing. The latter one improves the former with better scalability and less overhead [17] as well. The nodes are generally classified as Cluster-Head (CH) nodes, Cluster Gateway (CG) nodes, and Cluster Member (CM) nodes in hierarchical or cluster-based routing. The cluster head assumes important responsibilities for cluster member nodes, such as routing and channel allocation. Cluster gateway nodes lounge at the cluster border and conduct inter-cluster routing from cluster to cluster [30].

In clustering, every mobile node in the network can communicate with other mobile nodes with the help of CHs. In fact, any node in the network may generate data traffic regardless of its position (CM or CH). Also, the amount of traffic generated by each node may be different [5]. Some mobile nodes may produce a tremendous amount of data traffic, while the others may involve in less traffic and this data traffic varies time to time dynamically. When a node is chosen as a CH, its traffic load becomes high as it plays the main role in routing the packets created by its cluster members. This will hugely affect the performance of the CH nodes. Many research works mainly focus on the balancing of cluster-head load by maintaining an equal number of member nodes in each cluster. They failed to address the actual communication traffic load generated by the member nodes in the clusters. The proposed work address this problem by considering the traffic load as the primary clustering metric that guarantees the balancing of the traffic load in each cluster which prolong the cluster's lifespan. The highlights of the proposed work are:

- Clustering is based on the data traffic generated by each node.
- Nodes with almost similar traffic load are identified

as candidate CHs.

- Optimal CH selection by applying Elephant Herding Optimization algorithm.
- Network lifetime is improvised in a better way.

The organization of this paper as follows: section 2 describes about related work; section 3 will discuss the need of traffic based clustering in MANET; section 4 explains the Elephant Herd Optimization algorithm for CH selection; section 5 deals with implementation, results and discussion followed by conclusion.

2. Related Work

There are so many methods proposed in the past. Those are categorized as single-metric, multi-metric and optimization-based clustering.

2.1. Single-Metric Clustering

Initially, the CH selection process was based on a single metric only. The metric used in clustering is based on either its ID [15], or its neighbor count (node degree) [5, 16], or its mobility [27] or its residual energy [24]. The negative aspect of these approaches is that there is no upper limit for the number of nodes grouped under each single cluster and it results in overloading of cluster-head nodes. Hence, the performance of such a clustered network is impulsive.

2.2. Multi-Metric Clustering

The drawbacks of the single-metric clustering approach leads to the development of multi-metric clustering techniques where several metrics are considered to select a cluster-head. Appropriate weights have been assigned to each metric [12] to compute this process. WCA defines the weighing process clearly in which the CH selection is based on collective metrics such as node degree, the moving speed, its transmission power and the battery power. In FWCA [14], it uses node degree, battery power, transmission range, and mobility for finding out the weight of the node and also applies fuzzy logic to find such a weight. The node with the highest weight value is elected as the CH. The node with the highest lifetime is playing the role of tie-breaker. Hussein *et al*. [19] extended FWCA known as Flexible Weighted Clustering Algorithm based on Battery Power (FWCABP) which prevents nodes with less battery power to become CH. Each node maintains the status of its neighbor count, battery level and average distance to them and exchanges this information with all its neighbor nodes during clustering process. The various metrics considered for determining the weight of the nodes are node degree, moving speed, distance to its neighbors and residual battery power. The re-clustering process is invoked when the battery power of a CH reduces to some predefined threshold value.

Adabi *et al*. [1] proposed the Score-Based Clustering Algorithm (SBCA) which considers the remaining battery, degree of the node, mobility. Using these, the score of each node is calculated and broadcasted to the neighbors. In their approach, the author chosen the highest score node will become CH among its 1-hop neighbors. This work reduced the cluster count and increased the network lifetime. Xing *et al*. [37] proposed a weight-based clustering algorithm called PMW which uses node's power, mobility, and workload. Each node effectively collected this information locally and used that for calculating its weight. Then, this weight is broadcasted to its 1-hop neighbors. The node with the highest weight becomes the CH. PMW has improved the lifetime of the CH nodes. Shayesteh and Karimi [29] suggested a fuzzy-based weighted clustering algorithm. The authors achieved the clustering process in two phases. In the first phase, fuzzy logic is applied to predict the weight of each node. In the second phase, each node finds out its relative mobility and also predicts its future mobility. Using these two factors, the final weight is estimated. In the work [31, 38], the authors discussed a detailed summary of various clustering approaches.

2.3. Optimization Based Clustering

Since the clustering of nodes in MANET considering multiple metrics (multi-objective clustering) is a kind of NP-hard problem [2, 21], optimization techniques got attention in finding out efficient solutions. Many researchers already were given their findings in solving such combinatorial problems [4, 11, 25, 26]. Turgut *et al*. [33] applied Genetic Algorithm (GA) and Simulated Annealing [34] to optimize WCA in terms of CH count, re-clustering rate. Ali *et al*. [3] proposed a MOPSO technique that optimizes the CHs count using the various metrics like node degree, transmission power, transmission range, and battery power of the mobile nodes.

Keerthipriya and Latha [20] applied the PSO technique for finding optimal CH nodes by using the associativity between neighboring nodes, degree and remaining energy and also proved that the number of CHs selected under various environments is reduced compared to existing methods. Latha and Murugesan [23] proposed Firefly Optimization (FO) based clustering algorithm. They tried to find out stable CHs by using node mobility, battery and degree of the node. The authors claimed that their work is best suitable for both static and dynamic environment.

Latha and Murugesan [22] have given out another work in which they predict the mobility pattern of each node from its dynamic neighborhood set which are encountered at different epoch. The battery power and node degree are also taken as additional factors to identify the CH. The weighted geometric mean based weight computation is proposed. Further, the authors have applied the Cuckoo Search (CS) algorithm to optimize the CH selection. A comparison summary is shown in Table 1.

Table 1. Comparison of various categories of clustering methods.

Category of clustering	Existing work	Description
Single-metric	ID-based [15]	Node with least Identifier becomes CH
	Node degree [16]	CH selection based on highest neighborhood nodes
	Mobility [27]	Stable node(less mobility) is elected as CH
	Residual energy [24]	Node with maximum energy is nominated as CH
Multi-metric	WCA [12]	CH selection is done by considering multiple factors such as node degree, their distance, residual energy and mobility
	FWCA [14]	Fuzzy logic is applied to find CH in WCA
	FWCABP [19]	It is the enhancement of Flexible Weight-Based Clustering Algorithm (FWCA) which mainly considers battery energy
	SBCA [1]	Score -based Clustering algorithm is also a weight-based which reduces the cluster count and increases the network lifetime
	PMW [37]	Clustering based on node's power, mobility, and workload
	ECHSA [18]	Trust based clustering approach which eliminates malicious nodes in CH selection
Optimization-based	Simulated Annealing WCA [34]	Optimal selection of CH in WCA using Simulated Annealing
	fuzzy-based weighted clustering algorithm [29]	fuzzy logic is applied to predict the weight of each node and hence select the CHs
	WCA GA [33]	Genetic Algorithm is used for optimizing WCA
	MOPSO [3]	Multi-Objective Particle Swarm Optimization (MOPSO) technique to optimize CH selection using various metrics like node degree, transmission power, transmission range, and battery power
	Associativity based clustering with PSO [20]	PSO technique is applied for finding optimal CHs by considering the associativity between neighboring nodes, degree and residual energy
	CH selection using Firefly optimization[23]	Stable CHs are selected based on node mobility, battery level and degree of the node
	Cuckoo search for optimal selection of CHs [22]	Encounter based CH selection based on Node mobility and optimized using Cuckoo Search algorithm. The battery power and node degree are also considered in CH selection

3. Proposed Work-Preliminaries

This section describes the concept of clustering in MANET, the need of traffic-aware clustering process, and the classical elephant herding optimization algorithm.

3.1. Traffic-Aware Clustering

A MANET can be represented as a G={N, E} graph in which N and E are the set of nodes (vertices) and links (edges) respectively. MANET clustering can be defined as the task of partitioning the G network into a set of C_1, C_2, C_3... C_n clusters such that $C_1 \cup C_2 \cup C_3 \ldots \cup C_n = G$.

For a node 'n' $\in$ G, Deg(n) represents the set of its neighbor nodes and is defined in Equation (1) [12]:

$$\mathrm{Deg(n)} = \{\mathrm{n}' \in \mathrm{M} \text{ and dist } (\mathrm{n},\mathrm{n}') < Tx\} \tag{1}$$

Where *Tx* is the transmission range of node *n* and dist (n,n') is the Euclidian distance between nodes *n* and n'.

Let TL_n^C indicates the node *n* traffic load when it plays a cluster-head role and TL_n^M denotes the node *n* traffic load when its role is a cluster-member. The overall traffic load for a node *n* at time *t* is denoted by $TL_n(t)$ in Equation (2).

$$\mathrm{TL_n(t)} = \begin{Bmatrix} \mathrm{TL_n^c} + \sum_{\mathrm{M=1}}^{\mathrm{deg(n)}} \mathrm{TL_n^M}\text{, clusterhead} \\ \mathrm{TL_n^M}\text{, clusterhead} \end{Bmatrix} \tag{2}$$

If a node plays the CH role, it has to forward its traffic as well as all its member nodes. A CH with enormous traffic load will result in an unnecessary delay in response time and will consume more resources. So, the mandatory work of clustering scheme is to select CHs such that the traffic faced by all such CHs must be balanced i.e., each CHs must have equal traffic load irrespective of the number of nodes in each cluster. It can provide all cluster-heads with the guarantee of fairness in terms of workload. Besides, balancing the traffic load in clustering will help prolong the cluster's lifespan, as each cluster head can dissipate the battery energy equally. Each node in MANET can calculate its traffic size in the Medium Access Control (MAC) layer from the length of its interface queue. For that, every node records the queue length at regular intervals. The Traffic Load (TL) of the node n at time t can be calculated by taking the average interface queue length of K samples estimated over a period of time which is given in Equation (3) [28]:

$$\mathrm{TL_n(t)} = \sum_{\mathrm{i=1}}^{\mathrm{K}} \mathrm{queue(i)}/K \tag{3}$$

Where *queue*(*i*) is the ith sample of the queue length. The greater value of *K* gives a better estimation of the node's traffic load. An ad hoc network can consist of various terminal types, and among these end nodes we may find a wide range of heterogeneity. The nodes in their configuration may have different sizes of buffer space.

Most of the current clustering approaches use node degree as one of the metrics shown in Figure 1-a) to frame the clusters. They chose the nodes 4, node 6 and node 11 as CH nodes. These methods of clustering believe that accommodating an equal number of cluster members in each cluster will balance the cluster-head load. But, for further routing, they failed to consider the actual traffic generated by each member node that is accumulated in the cluster-head. As shown in the given scenario the CH node 4 with the three CM nodes {1, 2, 3} will have to face more traffic. At the same time, the CH node 6 with the members {5, 7, 12} has to deal with less traffic since the nodes 5 and 12 are not generating any traffic. In this situation, CH node 4 will lose its energy very quickly than that of CH node 6. Thus, this is not a fair approach for clustering. To overcome this problem, we have considered the actual traffic generated at each node before clustering. Clusters are formed by computing the amount of traffic generated at each node and the cumulative traffic load to be handled by the cluster-head and this scenario is depicted in Figure 1-b). The node 4 and node 10 are chosen as CH nodes by the proposed scheme. Even though the number of CM in each cluster varies in the proposed clustering approach, the traffic is balanced among the cluster-heads. This facilitates the clusters to have a prolonged lifetime

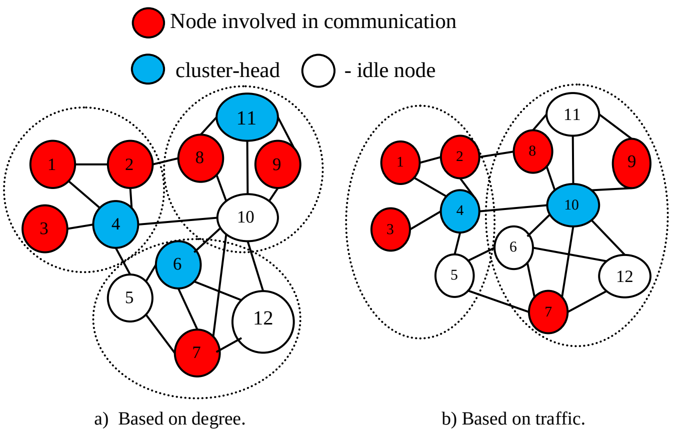


Figure 1. Network model representing CH selection.

Deciding optimal cluster heads based on one or more clustering metrics is an NP-hard problem [12]. There has been a fair amount of nature-inspired optimization technique in MANET [20, 22, 33, 34] applied by researchers. The Elephant Herding Optimization (EHO) algorithm was used here to select the set of CHs that can facilitate the traffic load adaptable cluster formation. That means the CHs selected by proposed algorithm are guaranteed to transmit the same amount of traffic. This surely helps to prolong each CH's lifetime and hence the network's lifetime.

3.2. Traditional Elephant Herding Optimization Algorithm

EHO was influenced by herds' elephant social behavior [35]. Wang *et al.* [35] suggested it to solve tasks of global optimization. The authors established a general-purpose heuristic method under the leadership of a matriarch focused on the coexistence of elephants in clans. The matriarch is the clan's oldest female chosen. The clan members are mostly females and calves, while male elephants leave the gathering to live separately upon full growth. Even though they live independently, via low-frequency vibrations, male elephants interact with others from the group.

This hierarchical freedom and social communication in the herding of elephants can be described as two separate environments [35]: the first environment in which all elephants live under matriarchal dominance and the second environment in which male elephants live independently but still interact with the clan. Such environments are designed as update and separate operators.

In EHO algorithm, each solution (elephant) j in clan ci is updated by its current position and matriarch ci by updating operator. Then, the separating operator is applied to enhance the population diversity at the later generations of the algorithm execution.

First the population is divided into n clans. The updating operator is applied to alter the position of each elephant j in the clan ci under the influence of the matriarch ci whose fitness value is the best one in that generation as in Equation (4) [35]:

$$x_{new,ci,j}=x_{ci,j}+\alpha\times(x_{best,ci}-x_{ci,j})\times r \quad (4)$$

Where $x_{new,ci,j}$ and $x_{ci,j}$ refer the newly updated current and previous positions of the elephant *j* in clan *ci* respectively. The term $x_{borst,ci}$ represents the best

Solution found in the clan ci. α is a scale factor used to estimate matriarch ci's effect on $x_{ci,j}$ and takes value [0,1]. The random variable r ∈ [0, 1] is determined by the uniform distribution.

The best solution in each clan ci is updated by the following Equation (5) [35]

$$x_{new,ci,j}=\beta\times(x_{center,ci}) \quad (5)$$

Where β ∈ [0,1] represents the influence factor of the $x_{center,ci}$ on the each individual $x_{new,ci,j}$.

The center of each clan *ci*, $x_{center,ci}$ in d-th dimension is calculated by Equation (6) [35]:

$$x_{center,\,ci,\,d}=\frac{1}{n_{ci}}\times\sum_{j=1}^{d}x_{ci,j,d} \quad (6)$$

Where *d* represents the *d*-th dimension with 1≤ d ≤ D and D represents total dimension in the search space

At each generation of Elephant Herding Optimization (EHO), the worst solutions in the population are updated by the separating operator as follows [35]:

$$x_{worst,ci}=x_{min}+(x_{max}-x_{min}+1)\times rand \quad (7)$$

Where x_{max} and x_{mix} indicate the upper and lower bound of each elephant position, $x_{worst,ci}$ represents the elephant with worst fitness in clan ci, and rand is a random number with the interval [0, 1] decided by uniform distribution. Algorithm 1 represents EHO.

Algorithm 1 Pseudo-code of Traditional EHO algorithm

Generate initial population and Evaluate their fitness.
Repeat
Sort the population based on fitness.
/………Clan updating operator………….*/*

Forall clans in the population do
For all individuals in each clan do
Update its position using the Equation (4)
If the current individual is the best one in the clan
Update its position using the Equation (5)
End if
End for
End for
/…………Separating operator……………….*/*
For all clans in the population do
Replace the worst individual using the Equation (7)
End for
Evaluate the new generation
Until MaxGen is not reached.

4. Proposed Traffic-Aware Clustering with Modified Elephants Herding Optimization (TAC-MEHO) Algorithm

Traditional EHO algorithm has been modified to ensure the finding of efficient CHs selection with a better traffic load balancing. The proposed Traffic-Aware Clustering with Modified EHO (TAC-MEHO) algorithm takes the input of a set of nodes in the MANET and returns the list of CH nodes that enhance the performance of the network. The illustration of TAC-MEHO is given in Algorithm 2.

Algorithm 2 Traffic-Aware Clustering with Modified Elephant Herding Optimization (TAC-MEHO)

Input: Set of nodes N in the network, each node's neighborhood list, and their traffic details
Output: List of CH nodes with an almost equal amount of traffic load.
Calculate the traffic load of each node considering its neighborhood by using Equation (1).
Initialize population (Pop) for nclan solutions and each solution is generated using randperm() with N dimensions.
Calculate the fitness value of each solution using Equation (8)
Store the best solution.
While MaxGen is not reached
Sort the population based on their fitness value.
For each ci in (1: nClan) do
For each j in (1: nci) do
Generate new solution $x_{new,ci,j}$ *for each* $x_{ci,j}$ *by using Equation (4)*
Check if the newly generated solution is better than the current one ($x_{ci,j}$*). If so, replace*
$x_{ci,j}$ *with the new one (*$x_{new,ci,j}$*)*
Generate new solution $x_{new,best,ci}$ *for the best solution* $x_{best,ci}$ *in the current generation*
by using Equation (5).
Check if the newly generated best solution ($x_{new,best,ci}$*) is better than the current one (*$x_{best,ci}$*). If so, replace the current best with the new best(*$x_{new,best,ci}$*).*
For each ci in (1: nClan) do
Replace the worst solution using the Equation (7)
Evaluate the new population and calculate the fitness value of each individual
Identify the Cluster-heads(CHs) generated from the best solution.

The proposed TAC-MEHO algorithm used for the efficient CH selection has been modified to increase the network performance. The changes introduced in the original EHO algorithm are given below:

- Traditional Elephant Herding Optimizer has been modified in finding out CH nodes for the given MANET in our model.
- Each solution (elephant) in TAC-MEHO gives out a different set CHs for the given MANET. The procedure for selection CHs for each solution has been explained in the work [32]. Objective function: The proposed Traffic-Aware Clustering algorithm mainly differs from the existing clustering schemes in finding out the load balanced CH nodes. The proposed TAC-MEHO identifies the nodes with almost the same amount of traffic as Cluster-head nodes. To achieve this, the standard deviation (σ) of the traffic accumulated at each selected CHs is calculated. The proposed work employs minimization of the objective function which is given by Equation (8):

$$\mathrm{fitness}(x_i)=\sigma_{CHs}=\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(TL_i-\overline{TL_{CH}}\right)^2} \quad (8)$$

Where $\overline{TL_{CH}}$ - Average traffic load served by each CH
TL_i- Traffic Load of each selected CHi for i = 1, 2,…n

The selected nodes by TAC-MEHO are set as cluster-heads and the entire MANET is clustered around them. During the network simulation, both the cluster-members and the cluster-heads can move from one cluster to another. When the CM moves, the membership details are updated by the old and new CH nodes. Similarly, when the CH moves out of a cluster, then the rest of the members will join themselves and elect a new cluster-head.

5. Implementation of the Proposed TAC-MEHO

In this section, results and discussions are explained based on metrics CH count, re-affiliation rate, re-clustering rate and so on.

5.1. Environmental Setup

The proposed TAC-MEHO was implemented in MATLAB version7 [36] and Network Simulator NS-2.34. All the experiments were done in an Intel i5 processor machine with 2.4GHz speed and 4GB RAM capacity. The simulation area setup was 100x100 sq.m. The experiments were conducted for different transmission ranges, simulation times, and the number of nodes in the network. Moreover, to prove the proposed traffic-aware clustering is well-suited for any situation, the number of nodes in MANET generating traffics is varied from 20% to 80%. The transmission range of each node is varied from 10m to 40m. All simulations up to 800s and the average of twenty independent runs were taken to plot each point in the results graph. The simulation parameters are given in Table 2.

The initial parameters for Modified EHO algorithm are set as follows:
Population size (pop): 50
Maximum generation (MaxGen): 500
No. of clans (nclan): 5
Constants α and β: 0.5 and 0.1 [as in EHO]

Table 2. Simulation setup.

Parameter	Value	Description
Area	100 x 100 sq. meter	Simulation area
Tx range	10 meter to 40 meter	Transmission range
Energy	10 Jules	Node's initial energy
Tx and Rx power	0.5 Watts and 0.3 Watts respectively	Transmit and Receive power
STime	300 secs to 800 secs	Simulation Time
Nodes	30 to 60	Numbers of nodes in the network
Packet Size	512 bytes to 4 KB	Size of data packet

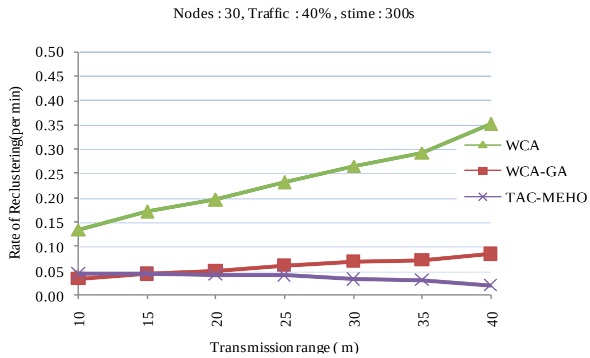
5.2. Metrics for Evaluation

The performance of the TAC-MEHO is validated against the standard WCA and its optimized GA version WCA-GA. The various metrics used for comparing the results are:

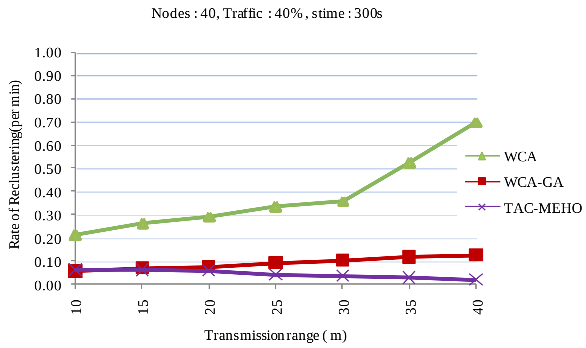
- Re-clustering rate: re-clustering happens when a CH node moves out of its cluster's communication range. This results in the election of a new CH node. The performance of any clustering scheme depends only on the CH nodes. If the selected CH nodes are stable, then it increases routing performance and hence decreases the clustering overhead. Re-clustering rate is calculated by taking the ratio of the number of re-clustering happened over the entire simulation time. A minimum value of this metric is preferred.
- Alive nodes: in cluster-based routing, all traffics are made through the CH nodes. Only these nodes are participating in routing and their energy is depleted very soon. Once their energy gets exhausted, they are said to be dead nodes and further they could not participate in any communication. A good clustering algorithm is the one which retains more number of alive nodes.
- CH Count: it denotes the total number of clusters formed in the network. A minimum number of clusters may result in the attachment of more members in a cluster. This creates more load on the CH and causes quick energy depletion. On the other hand, the maximum number of clusters may increase the length of the route and hence the delay during routing. An optimum number of clusters and hence CH nodes is always required.

5.3. Results and Discussion

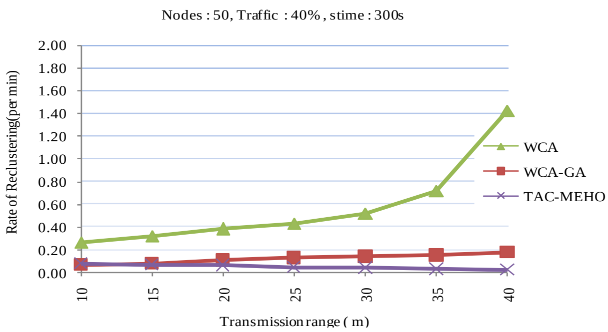
Figure 2 shows changes in the re-clustering rate against the transmission range. These experiments were conducted for 30, 40, 50, and 60 nodes. In each network scenario, 40% of the nodes are involved in traffic generation and the simulation was carried out for 300 seconds. From the graph, it is evident that when the transmission range gets increased, the re-clustering rate gets increased in the existing WCA and WCA-GA [33] algorithms. The reason is that these clustering algorithms mainly used the node degree in cluster creation. They produce clusters that consist of more or less equal cluster members. But, the traffic generated by the nodes inside a cluster is not always similar. So, the actual traffic accumulated across each CH is not always balanced.



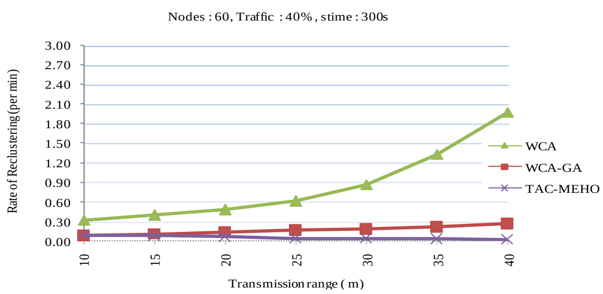
a) 30 nodes.



b) 40 nodes.



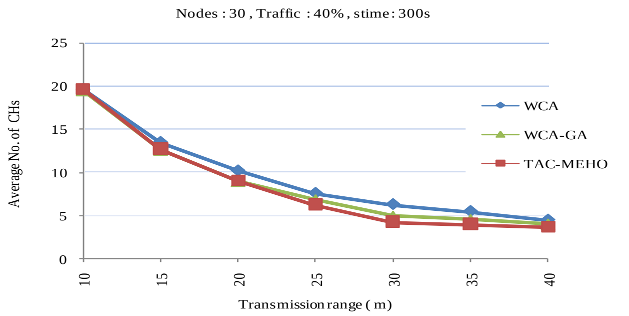
c) 50 nodes.



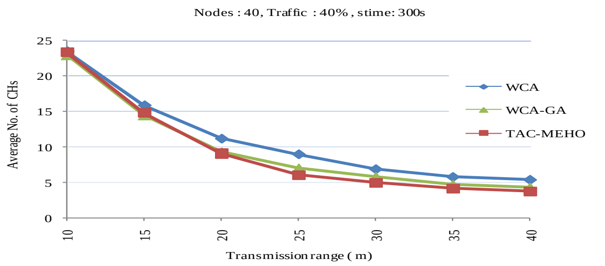
d) 60 nodes.

Figure 2. Effect of Transmission range on re-clustering rate.

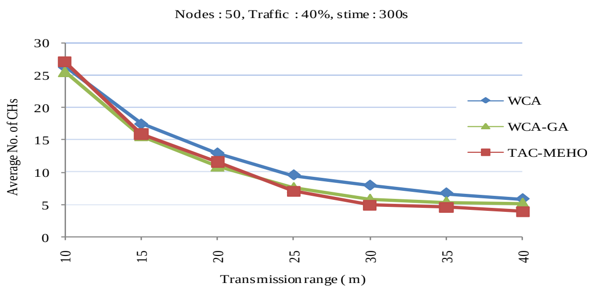
A cluster where only fewer member nodes involved in traffic generation makes the cluster-head to withstand its role for a long time, whereas, a CH node which handles more traffic lose its role very quickly. This initiates a new re-clustering process and hence increases the re-clustering rate. But, the proposed work TAC-MEHO identifies the cluster-heads such that the traffic load on every selected cluster-head is maintained at most equal level. So, the lifetime of all the cluster-heads gets extended and results in a minimum re-clustering rate. Compared to WCA and WCA-GA, the proposed TAC-MEHO reduces the re-clustering rate on an average by 91% and 58% respectively.



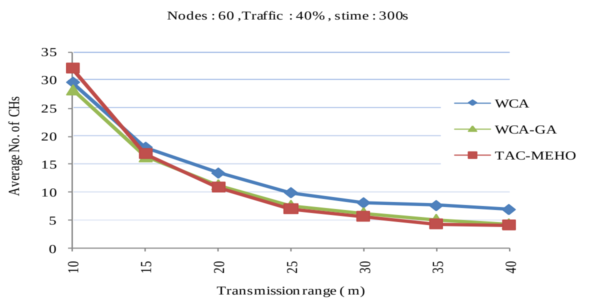
a) 30 nodes.



b) 40 nodes.



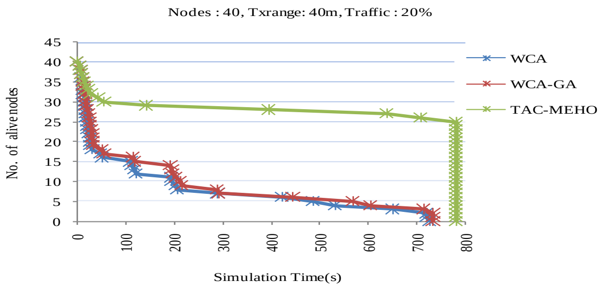
c) 50 nodes.



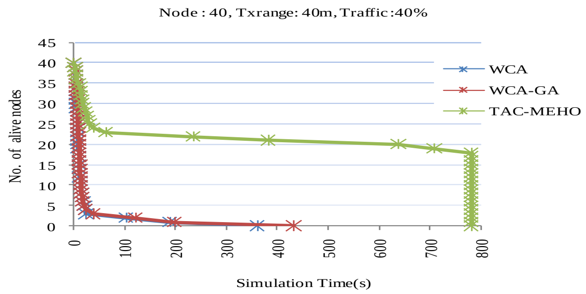
d) 60 nodes.

Figure 3. Effect of transmission range on CH count.

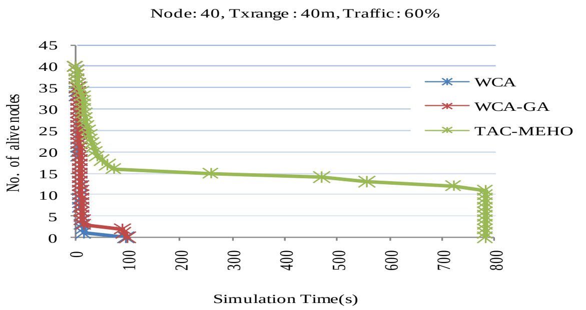
Figure 3 illustrates the changes in CH count by varying the transmission range from 10m to 40m. The experiments are conducted for 30, 40, 50 and 60 nodes and the traffic is generated by 40% of nodes in each scenario. From the figure, it is clearly known that the average number of CH nodes decreases when the transmission range gets increased. The cluster-head covers more area in the network by increasing its transmission range. This makes a large number of neighboring node appears under each CH node. So, only a few number of clusters CHs are formed. The average number of CHs in the proposed TAC-MEHO is the same as that of WCA-GA and is better than WCA. This indicates that TAC-MEHO could able to identify load balanced CHs and produces a minimal number of clusters.



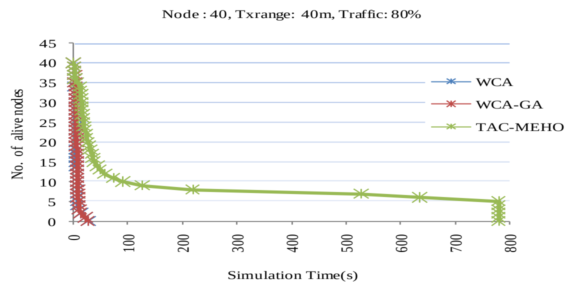
a) 20% traffic.



b) 40% traffic.



c) 60% traffic.

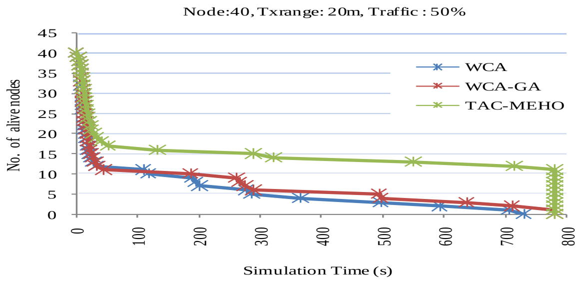


d) 80% traffic.

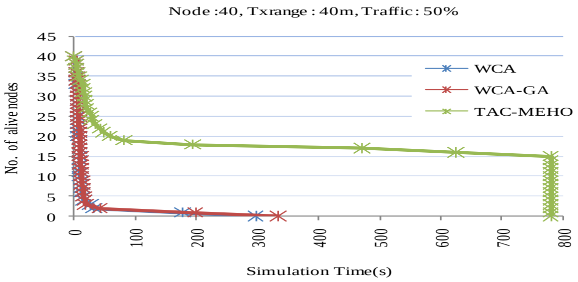
Figure 4. Effect of traffic level on the number of alive nodes.

Figure 4 shows the analysis of the number of alive nodes while varying the traffic level during the entire simulation time. For these experiments, the number of nodes is fixed to 40 and the transmission range is 40m. The traffic level is varied from 20% to 80%. The nodes which generate traffic are picked up in random. When the traffic level is low, the nodes retain their for a longer period. But, when there is high traffic in the network, the nodes drain their energy very soon because of their involvement in forwarding and routing of that traffic. In every simulation experimented in Figure 5, the number of alive nodes in the network at a particular time is high in the proposed TAC-MEHO algorithm than WCA and WCA-GA. The existing clustering algorithms didn't consider the actual load to be handled by the cluster-heads when doing the CH selection process. Due to this inefficient CH selection, the CHs handling high traffic will die sooner. The number of alive nodes is more at the initial time. But, when the simulation is going on, the alive nodes are reduced quickly. At 20% (low) traffic level, nodes live up to 720 seconds in WCA and WCA-GA whereas it is 780 seconds in TAC-MEHO. At a 40% traffic level, the network lifetime in WCA-GA is up to 430s, at 60%, it is reduced to 100s and at 80%(high) traffic, it is only up to 50 seconds. Though the number of alive nodes also gets reduced while increasing the traffic in the proposed TAC-MEHO, still it increases network lifetime up to 780s. Since the proposed work concentrates on traffic-aware clustering, the number of nodes retains their energy over a period is high in TAC-MEHO than the other clustering schemes. On an average, TAC-MEHO increases the network lifetime by 89% and 88% when compare with WCA and WCA-GA respectively.

In Figure 5, the effect of transmission range is tested against the number of alive nodes. For this, a network of 40 nodes is considered and the traffic level is set to 50%. The transmission range of each node gets varied from 10m to 40m. In small transmission range (20m), the network area covered by each node is very less and the number of neighbors found for each network node is only a few. This results in the creation of more number of clusters. TAC-MEHO produced results which are very similar to the existing WCA. When increasing the transmission range above 20m, the performance of WCA and its GA version was declining. The reason is that more member nodes will be attached under a cluster-head when the transmission range gets increased, and the amount of traffic produced by them is not considered. But, the proposed method provides an efficient cluster formation by choosing the cluster-heads with a balanced traffic load and supports a prolonged network lifetime up to 780 seconds during the simulation. When compared to WCA and WCA-GA, TAC-MEHO increases the network lifetime by 77% and 73 % on an average when increasing the transmission range.



a) Transmission range-10 m.



b) Transmission range-20 m.

Figure 5. Effect of Transmission range on the number of alive nodes.

6. Conclusions

The proposed Traffic-Aware Clustering scheme with Modified Elephant Herding Optimization is tested under a variety of traffic load environments. To prove the effectiveness, the proposed work is compared under different network conditions. The number of nodes, the level of traffic load, and the coverage area of the nodes are varied during the simulation. The results of the TAC-MEHO are compared with the existing WCA and WCA-GA. Under all the conditions, the proposed TAC-MEHO outperforms the existing ones in terms of re-clustering rate, the number of alive nodes and also the network lifetime. Since this proposed algorithm has assured a fair distribution of the traffic load on the CHs, TAC-MEHO achieves a significant improvement in the results. Compared with the existing WCA and WCA-GA, the proposed TAC-MEHO improves the re-clustering rate on an average by 91% and 58% while varying the number of nodes and the network lifetime on an average by 89% and 88 % while varying the traffic level respectively. Further, this proposed work also produces minimal number of CHs and this will help in reducing the routing delay. This work can be further extended by considering various parameters such as node degree, mobility and energy along with the traffic load to obtain better results depending upon the application scenarios. Security aspects can also be included as future work.

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