An Energy Efficient and Secured Cluster Head Selection in MANET using EESSC Technique

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Abstract

Ad hoc Network (MANET) is an autonomous model where numerous nodes are associated with each other through remote associations. Energy productivity and security are considered two significant matters in the plan of MANET. Thus, in this paper, we have involved an energy effective steady and secure clustering (EESSC) strategy for MANET. The introduced EESSC procedure utilizes a fuzzy logic system to choose the group heads (CHs) appropriately by the utilization of five factors to be REL, node degree, distance, trust factor, and node mobility. As a backup node a standby cluster head (SBCH) will be used as CH is additionally acquainted with finding value in the event of coincidental cases as CH dies, CH leaves the group, or CH is comprised. In such a case, SBCH is conjured to go about as CH, and again another SBCH is picked. The energy efficiency and security appeared through certain variables like packet delivery ratio, throughput, and dropping proportion. That means when the packet delivery ratio, throughput is high, and dropping ratio is low then we can say that the information moved is secured and energy effective. This process helps with accomplishing network accessibility without any interruptions alongside the extra level of safety when compared to previous models.

Keywords: *Clustering, Routing, Fuzzy logic, Cluster head, MANET, Energy efficiency, Security.*

1. Introduction

A mobile ad hoc network (MANET) is a free model where numerous nodes are connected to each other by means of remote connections. This organization did not depend on a static framework and comprises the nodes on the fly which go through sending of specific applications. These organizations are exceptionally relevant where the framework is inaccessible or arrangement is costly like calamity the executives, vehicles, military applications, etc. In any case, it is hard to manage the association because of the features like self-configurable and non-presence of concentrated control. Furthermore, security and strength are additionally significant elements present in the correspondence regions. Bunching is a significant procedure applied to determine more issues of MANET and offers energy productivity and stability. The nodes are grouped into a variety of clusters and a pioneer named cluster head (CH) is selected in each group. It offers a nearby control inside the cluster. The message passed from nodes to objective happens through CHs and passage nodes that lie inside the correspondence area of numerous CHs; thus, the energy of different nodes can be saved.

Cluster based MANET upgrades the organization the board sine development of courses becomes simpler, and size of the routing is reduced. It prompts faster energy weariness and demise of CHs that basically partitions the organization and influences the lifetime of MANET. Simultaneously, the portable idea of nodes is likewise a fundamental explanation of connection disappointment, hence, in a clustering model, mainly the condition when a picked CH is sensibly more versatile contrasted with different nodes, it will frequently separate the coordinated group and needs a novel between-group way arrangement between two finishes. The continuous disappointment of connections in light of the versatility of CHs decreases energy efficiency. It additionally prompts high control upward and decreases energy productivity. In this way, the plan of a successful clustering procedure with negligible upward turns into a compelling approach to improving the lifetime of MANET

With such a large number of viewpoints, this study proposes an energy efficient, consistent, and secure clustering (EESSC) technique for MANET. The EESSC approach makes advantage of fuzzy logic. With such a large number of viewpoints, this study proposes an energy efficient, consistent, and secure clustering (EESSC) technique for MANET. To choose the right CHs, the EESSC technique employs a fuzzy logic framework. Furthermore, the fuzzy logic method incorporates portability and trust aspects, as well as the necessary boundaries, to achieve stability and security. Furthermore, a backup CH (SBCH) is well-known for being helpful in the event of unexpected events such as CH death or CH containment. In such a circumstance, SBCH is summoned to act as CH once more.

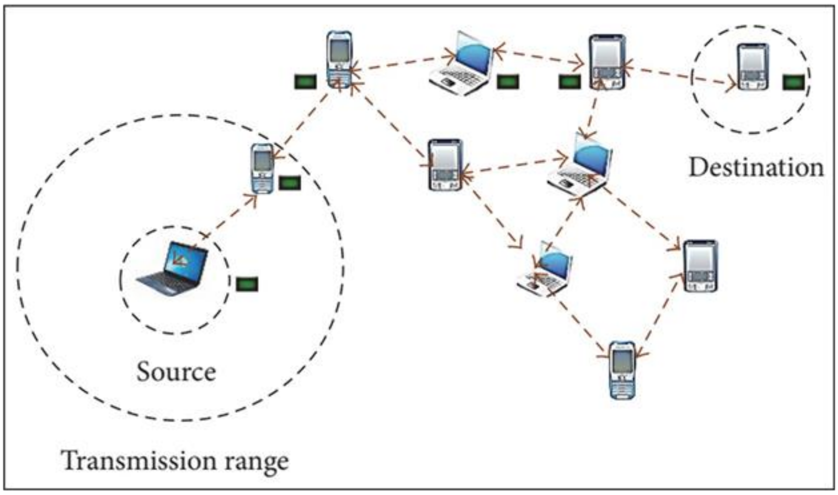

Fig. 1 MANET Architecture

Clustering is a key strategy for resolving MANET's most serious issues and ensuring efficient performance and stability. It organizes the nodes into clusters and assigns a leader to each cluster, known as the cluster head. It provides cluster-wide local control. The transfer of data from source nodes to destination nodes that takes place through CHs and gateway nodes that lie inside the communication area of many CHs as shown in Fig. 2 Thus, the excess hubs' energy can be rationed. The design of routes will be easier because to MANET's clustering, and the size of the routing database will be reduced. However, due to intra-cluster and inter-cluster communication, the CHs will be subjected to increased stress, resulting in faster energy exhaustion and CH death, resulting in network division and a reduction in the MANET's lifetime. Furthermore, the mobility nature of the nodes is a major cause of node link failure. As a result, choosing a CH with higher energy efficiency and stability in a clustering model is a difficult challenge when compared to other nodes.

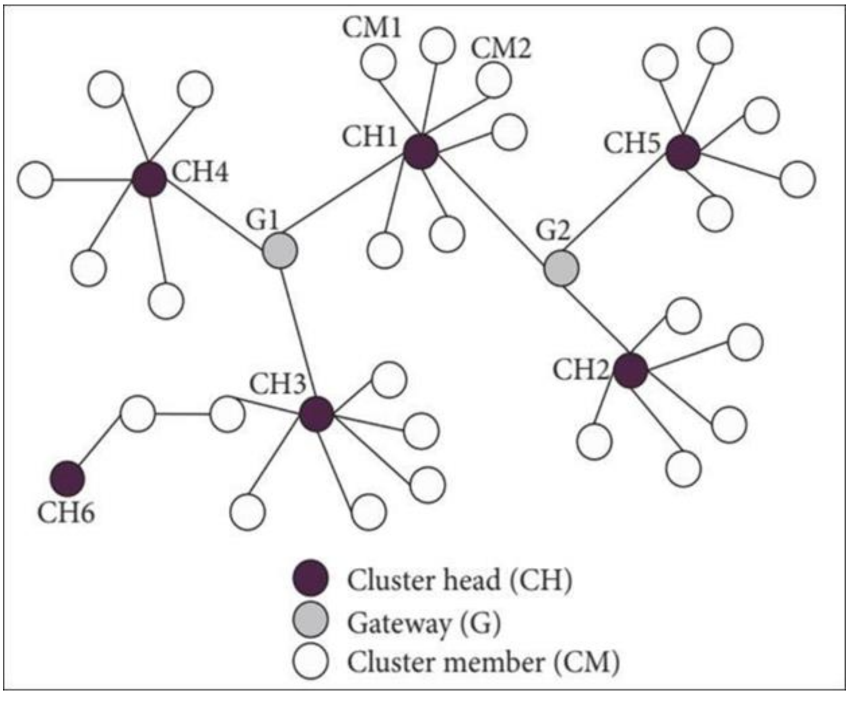

Fig. 2 Clustering process in MANET

Thus, the plan of a strong grouping arrangement with negligible above turns into a reasonable strategy for broadening MANET's lifetime. Cluster Based Routing System (CBRP) is a routing protocol for mobile ad hoc networks in general. In a distributed way, the protocol separates the nodes of the ad hoc network into disjoint clusters. Each cluster has a cluster head who is elected to keep track of cluster membership information. Classification of various Clustering algorithms is based on the nature of algorithms and criteria for cluster head selection as well as the standby cluster head selection among the nodes.

2. Literature Survey

Generally, there are variety of ways or procedures to choose the cluster head and backup cluster head from the nodes. When a cluster head is chosen, it is in charge of forming a dominating set in the network, determining its topology, and ensuring its stability. As a result, a weighted clustering algorithm (WCA) is presented, which considers a mobile node's ideal degree, transmission power, mobility, and battery power. It is adaptable to various types of ad hoc networks and helps to maintain the number of nodes in a cluster around a preset threshold to support the proper operation of the medium access control (MAC) protocol.

To address the trouble of portability and the battery-subordinate person of versatile nodes in MANET, a few models have been contrived [5–8]. [5] Proposed taxonomy of clustering models that can be used in MANET to improve node energy consumption. It maximizes energy efficiency while consuming the least amount of power. However, a solitary boundary of the CH determination process is more straightforward and has a lower above. It is based on a single variable and does not consider other node qualifying criteria for becoming a CH. In MANET, we describe an effective weight-based clustering method (WCA) [6]. The selection of CHs is thought to be influenced by an integrated weight of numerous characteristics. [7] Introduced a distributed weighted clustering algorithm (DWCA) for MANET that restricts the configuration and re-configuration of clusters and limitations of CHs with respect to energy requirement. But no variables represent the node in the selection of CHs, there is consistency. Extended versions of WCA dubbed Enhancement on Weighted Clustering Algorithm were published in [8]. (EWCA). Transmission power, transmission range, mobility, and battery energy are created as parameters for CH selection. Through the elimination of adaptive modification of CHs, the number of cluster creation processes is reduced. It effectively balances the load in order to get the required cluster heads in this while also improving the cluster's stability in MANET.

A few deterministic and stochastic models have lately been proposed [9–16]. The deterministic method is a strategy that is based on the gradient approach. Stochastic approaches are multimodal problem-solving strategies based on biological entities that hunt for solutions in a variety of ways. [9] Gave an overview of various metaheuristic strategies for MANET problem optimization. [10] Proposed a clustering technique based on a breadth-first search tree (BFS) to pick lower load of CHs and interconnect the nodes. [11] Developed the Genetic Algorithm (GA), which is based on Darwin's notion of survival of the fittest. [12] Described a GA-dependent load balancing clustering technique for wireless sensor networks (WSNs), in which the maximum load on gateway nodes is reduced and nodes are joined to form load-balanced clusters. [13] Used particle swarm optimization to create a dynamic clustering structure in MANET (A-PSO). They used a variety of CH selection criteria to create stable clusters. However, the mobility of the nodes could not be managed efficiently. Furthermore, PSO is used to determine effective CHs with no optimization con- centration in the clustering phase. . The PSO algorithm was used to offer an energy efficient routing technique for MANET in [15].

The routing problems are then seen as an optimization problem, and a novel fitness function based on route length and energy level is proposed. The binary PSO (BPSO) method is then used to optimize the MANET routing approach. A MANET clustering strategy based on comprehensive learning particle swarm optimization was presented in [16]. (CLPSO). Here, when deciding on CH stability, the criteria considered to pick CHs are identical to WCA with no direction of node movement. The MEPSO method is a mobility aware energy efficient clustering for MANET employing PSO. Clustering is considered as a productive strategy for supplying energy efficiency and network stability based on an assessment of existing techniques. The use of clustering algorithms improves routing results in terms of reduced overhead and energy consumption. Furthermore, various systems have employed residual energy and distance as selection criterion for CHs. At the same time, security is a critical consideration in MANET architecture. Because fuzzy logic has a number of advantages, like being simple, flexible, and robust, as well as being able to deal with uncertainty, it is widely used.

With all of these considerations in mind, this work proposes an EESSC (energy efficient stable and secure clustering) technique for MANET. To properly choose the CHs, the described EESSC technique employs a fuzzy logic mechanism. In addition, to provide stability and security, the fuzzy logic process incorporates mobility and trust aspects in addition to the basic characteristics. In addition, a backup CH (SBCH) is introduced to help in the event that the primary CH dies, moves out of the cluster, or is compromised. In this case, SBCH is called upon to act as CH, and another is called upon to act as CH. This procedure aids in achieving network availability without causing any disruptions, as well as providing an additional level of protection. The EESSC simulation takes conducted under a variety of conditions, and the results show that the EESSC is improving proposed model over the ones that were compared.

3. Proposed Methodology

The main goal of the EESSC approach in MANET is to provide a clustering technique with appropriate CHs and SBCH in order to accomplish network security and stability. Initially, the nodes are not deployed and begin to move around in the sensing field at will. The information about the mobile nodes is then collected by its nearby nodes in order to complete the clustering process. Once enough data has been gathered, a fuzzy logic technique will be used to determine the CHs using five factors. Fig. 3 depicts this procedure in detail. Following the identification of CHs, neighboring nodes join the CHs to form effective clusters.

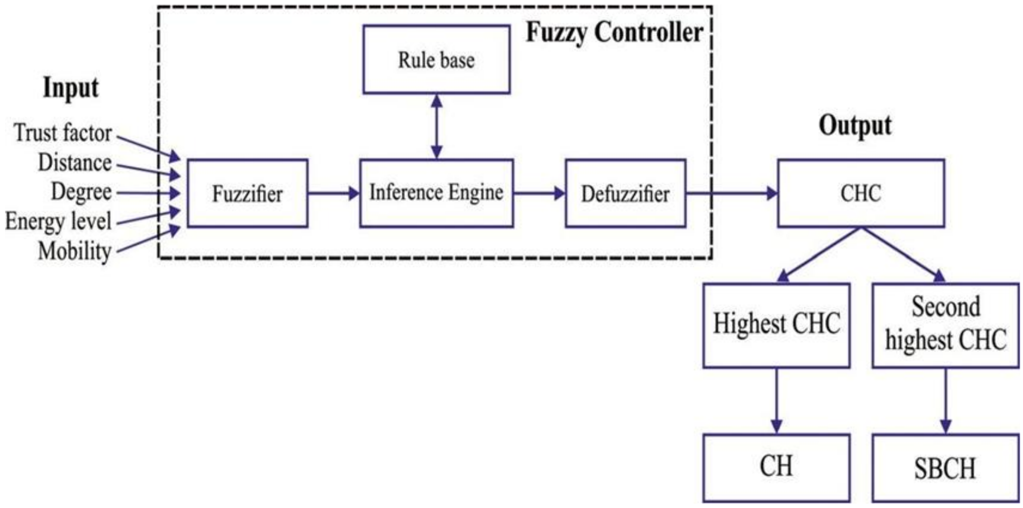

Fig. 3 Architecture of the Proposed Model

The remaining energy level, node degree, distance, trust level, and node mobility are five variables employed by fuzzy logic to elect CHs in the EESSC model. The node's trust level plays an important role in achieving security by preventing suspected and malicious nodes from becoming CH and SBCH.

Trust Factor (TF)

The TF value of 1 is assigned to each node at the start. When a node performs aberrant operations, the anomaly detection technique reduces the value of TF, and the node may be classified as a suspicious or malicious node. The node's TF is expressed in Eq. (1):

$$\mathrm{TF}_x = \begin{cases} Normal, & 0.8 \le T_i < 1 \\ Suspected, & 0.3 \le T_i < 0.8 \\ Malicious, & 1 \le T_i < 0.3 \end{cases} \qquad (1)$$

Hence, the nodes which are having the TF value as normal will act as CH and the nodes having suspected or malicious are not considered as CH.

Distance (D)

The distance from one node to another node can be represented by the following Eq. (2):

$$\sum_{y \epsilon N(x)} \{dist(x,y)\} \qquad (2)$$

where x represents one node and y represents the other node, the distance between those two nodes is calculated and the nodes which are having the least distance are considered.

Degree (Deg)

The Degree of a particular node is nothing but the number of neighboring nodes that a particular node contains. If a node has a greater number of neighboring nodes, then it has a chances of electing as a cluster head because from that node, the process of transferring the data from one node other node will become easy and fast which reduces the time.

Remaining Energy Level (REL)

The Remaining Energy level of a particular node after transmitting a k bits of data to a particular node 'y' from the node 'x' can be represented as given below in the Eq. (3):

$$REL = E - (E_T + E_{R(k)}) \quad (3)$$

Where E represents the present energy level, E_T represents the energy spent for transmitting the data and E_R represents the energy spent for reception.

Node Mobility (M)

The Node mobility which is nothing but the moment of a node at a particular time limit of t and t-1 is represented in the below Eq. (4):

$$M_x = \frac{1}{T}\sum_{t=1}^{T}\sqrt{(i_t - i_{t-1})^2 + (j_t - j_{t-1})^2} \quad (4)$$

Where (i_t, i_{t-1}) and (j_t, j_{t-1}) are the coordinate points during the time interval of t and t-1.

Fuzzifier

The remaining energy level, node concentration, distance, trust level, and node mobility are five variables employed by fuzzy logic to elect CHs in the EESSC model. The fuzzifier receives these input variables and performs the mapping process of the inputs to linguistic variables. The linguistic variables of the input and output parameters are listed in Table 1.

TABLE 1: PARAMETERS AND LINGUISTIC VARIABLES

	Parameters	**Linguistic Variables**
Input Parameters	**TF**	Low, Medium, High
	D	Close, Medium, Far
	DEG	Low, Medium, High
	REL	Low, Medium, High
	M	Slow, Moderate, Fast
Output	**CH chance (CHC)**	Very Low, Low, Rather Low, Medium, Rather High, High, Very High

Fuzzy Decision Blocks

The Fuzzy Rule base or Decision blocks holds certain group of rules which are used for the process of getting the required data from the given inputs. All the five parameter input values are compared within the given set of the rules in the decision table and conclude an output for that particular data item or parameter. From the acquired results, we can get the cluster head choice. The node which is having the highest cluster head choice will elect as a cluster head and the second highest one will act as the standby cluster head. In the cases, when the CH accidently dies then the particular Standby Cluster head will act as the cluster head. Hence, the decision blocks table or the fuzzy rule base table is given in the table given below which is Table 2.

Table 2: Fuzzy Decision Blocks Table

Rule number	Input parameters					Output values
	REL	Deg	D	M	TF	CHC
1	L	FW	Fr	F	L	L
2	L	FW	Fr	F	L	VL
3	L	FW	Fr	F	L	VL
.						
20	L	FW	Nr	S	L	L
.						
28	L	Md	Fr	F	L	RL
57	L	Mn	Fr	F	L	L
61	L	Mn	Fr	F	L	RL
.						
63	L	Mn	Fr	F	L	VL
.						
82	Md	FW	Fr	F	ML	Md
.						
109	Md	Md	Fr	F	ML	RH
.						
127	Md	Md	Nr	S	Md	RL
.						
136	Md	Mn	Fr	F	Md	RH
.						
190	H	Md	Fr	F	H	H
.						
217	H	Md	Fr	F	H	VH
218	H	Mn	Fr	F	H	RH
219	H	Mn	Fr	F	H	Md
223	H	Md	Fr	F	H	RH
224	H	Mn	Fr	F	H	Md
225	H	Mn	Fr	F	H	RL
226	H	Md	Md	Mo	H	VH
227	H	Mn	Md	Mo	H	H
228	H	Mn	Md	Mo	H	RH
232	H	Md	Md	Mo	H	Md
233	H	Mn	Md	Mo	H	Md
234	H	Mn	Md	Mo	H	Md
.						
238	H	Md	Nr	S	H	H
239	H	Mn	Nr	S	H	RH
240	H	Mn	Nr	S	H	Md
241	H	Md	Nr	S	H	RH
242	H	Mn	Nr	S	H	Md
243	H	Mn	Nr	S	H	Md

Where L-Low, Md-Medium, H-High, Nr-Near, Fr-Far, F-Fast, S-Slow, Mo-Moderate, R-Rather, V-Very. The presented Energy efficient secure as well as stable clustering technique involves a set of five input variables, and it results to the generation of a total of 243 rules. It is generated by the simpler and efficient Mamdami interference system.

Defuzzification

Defuzzification is the process of transforming the required output values into user-understandable values from which we can obtain the actual results. The method involved in separating a solitary number from the result of a collected fuzzy set is known as defuzzification. Changing over the discoveries of fluffy induction into an unmistakable output is utilized. To put it another way, defuzzification is accomplished using a decision-making algorithm that selects the best crisp value from a fuzzy set. Each mobile node broadcasts its CHC value to the nodes in its transmission range after it has been determined. A node with a high possibility of being CH is chosen, and it transmits the CH to the nodes around it. Many CH may be received by the mobile node from its neighboring mobile nodes. It will send a join message and connections to the nearest CH in such circumstances. The node with the most CHC is designated as CH, while the rest nodes are designated as CM. SBCH is picked as the node with the second lowest CHC value.

4. Experimental Results and Discussion

The Network Simulator 3 is used to test the performance of the presented EESSC model (NS3). The first step involves changes to the pause time (mobility), whereas the second stage involves changes to the speed. In terms of variance in CH, CM, and clustering overhead, the presented EESSC model is compared to the existing EWCA [8] and MEESC [16] models. The Fig.4 shows the results that are obtained in the virtual box of the ns3 simulator after successful execution of the code where the throughput and packet delivery ratio are high which indicates that the energy efficiency and security of the nodes which transmits the data from one node to another node is easy and secured. These experimental results are broadly classified into the required data that has given to the nodes.

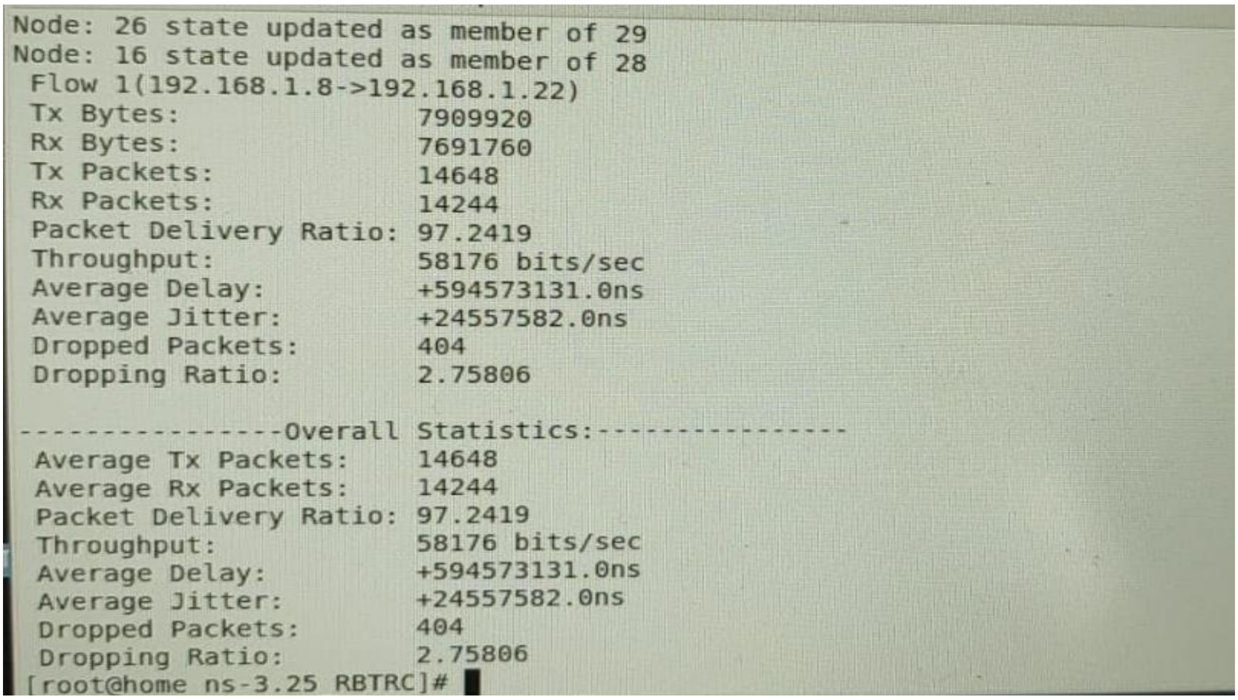

Fig. 4 Experimental Results

Network Simulator 3 is used to test the performance of the presented EESSC model (NS3). The first stage comprises changes to the pause time (mobility), followed by changes to the speed. Table 3 lists the parameter values that were used in the simulation. In terms of variance in CH, CM, and clustering overhead, the current EESSC model is compared to the available EWCA [8] and MEESC [16].

Table 3: Parameters Settings

Parameter	Values
No. of Mobile Nodes	100
Simulation Time	50 – 200 sec
Pause Time	5 – 25 sec
Maximum Speed	2 – 10 mps

Fig. 5 displays the findings obtained by comparing the performance of the presented EESSC to the CH variation count across a number of repetitions. The variances in CH count reduce as the number of iterations increases. As seen in the image, the provided EESSC model achieves the least amount of CH change when compared to the EWCA and MEESC models. Because MANET nodes move quickly within a cluster, the chances of CH changes, CM, and SBCH are significant. Reclustering occurs when mobile nodes move from one cluster to another, or SBCH becomes CH, in order to preserve network availability.

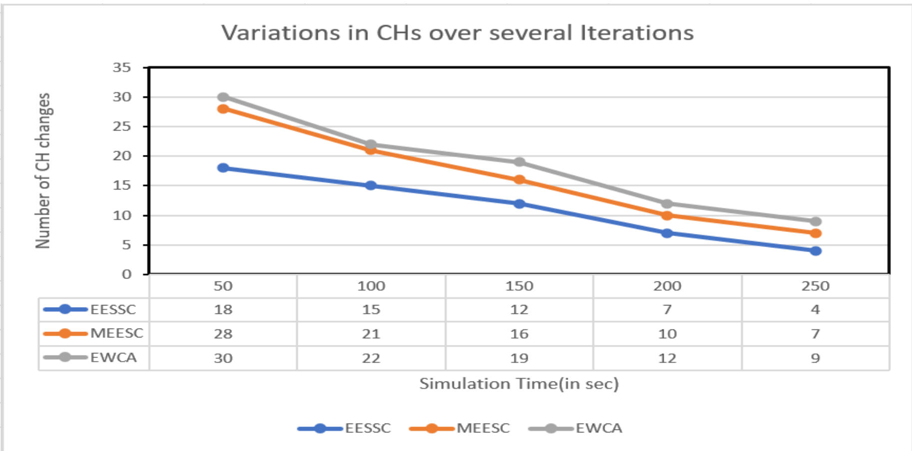

Fig. 5 Variations in CHs

The performance of the provided EESSC approach in terms of pause time adjustments. In the beginning, during the respite season of 5-10 days, the CM adjustments in EWCA, MEESC, and the newly introduced EESSC are reduced. The interruption time increased from 10 to 20 m/s, which is clear. In EWCA and MEESC, the rate of CM adjustments will continue to decrease; however, in EESSC, the rate of CM modifications will continue to decrease. In MANET, the aforementioned grouping is a fundamental test. The data trade approach of choosing CH and SBCH groups the bunches with an expansion in the above grouping. This technique builds a cluster with good stability while reducing clustering overhead.

The variation in CMs throughout a number of iterations is depicted in Fig. 6 below. The CM count decreases as the number of iterations increases. Looking at the experimental data, it's clear that the current EESSC methodology beats the others by reducing CM alterations throughout multiple repetitions. The variations in CM decrease as the number of iterations increases, and the EESSC methodology beats the provided method.

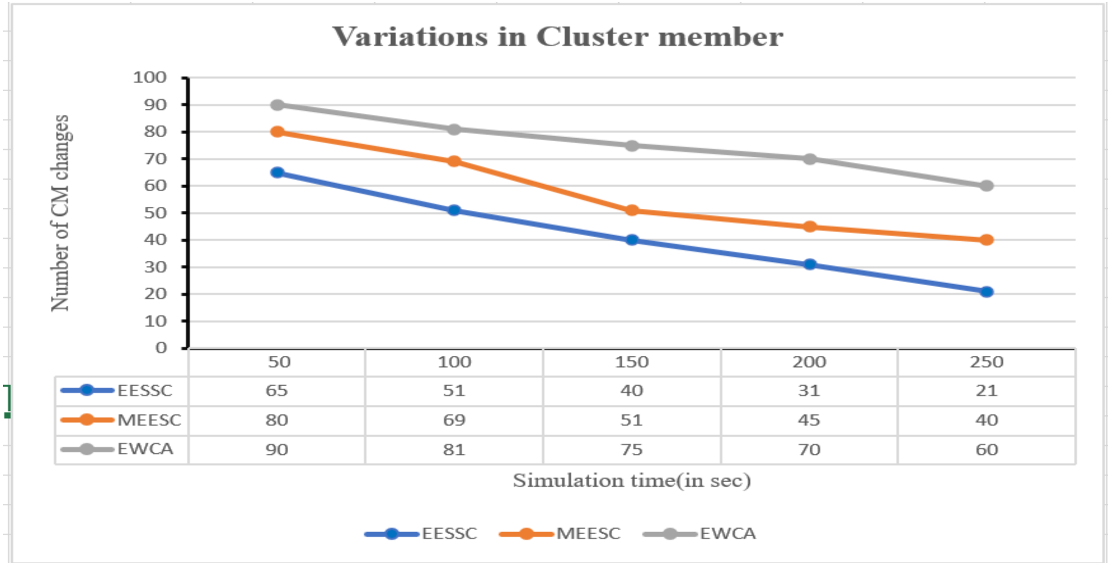

Fig. 6 Variations in CMs

This proposed approach is applicable in transferring the data from one device to another device wirelessly and securely. The main application of this approach is in transferring the data from one person to another person in military where the data to be transmitted in military is very secured. As it is wireless communication, people in rural area can also be used without any network issues. It can also be used in hospitality sectors, Navy sectors for transferring the data from one device to another device accurately and securely. Hence, this proposed approach can be used wisely throughout the process of the required applications where we want to share the information wirelessly from one place to another.

5. Conclusion and Future Enhancement

This work presents the EESSC technique for MANET, which is an energy efficient, stable, and secure clustering technique. Once enough data has been gathered, a fuzzy logic technique will be used to determine the CHs using five factors. Following the identification of CHs, neighboring nodes join the CHs to form effective clusters. The node's trust level plays an important role in achieving security by preventing suspected and malicious nodes from becoming CH and SBCH. The performance of the provided EESSC model is measured using different mobility speeds and iteration counts. According to the simulation results, within a simulation time of 250 seconds, CH changes occur 19 times, but the previous EWCA and EESSC methods only change 28 and 30 CHs, respectively. The extensive simulation results validated the superiority of the presented EESSC model in a number of ways. The provided module can be enhanced in the future by incorporating a safe routing protocol based on the firefly algorithm.

References

[1] Reddy AP, Satyanarayana N (2017) Energy-efficient stable multi- path routing in MANET. Wirel Netw 23(7):2083–2091

[2] Alfa AA, Sanjay M, Damaševičius R, Maskeliūnas R, Ahuja R (2018) The implications of deploying MANETs routing protocols in WLANs setup. International Journal of Pure and Applied Mathematics 119(16):2233–2243

[3] Arjunan S, Pothula S, Ponnurangam D (2018) F5N-based unequal clustering protocol (F5NUCP) for wireless sensor networks. *International Journal of Communication Systems 31*(17):e3811

[4] Arjunan S, Sujatha P (2018) Lifetime maximization of wireless sensor network using fuzzy based unequal clustering and ACO based routing hybrid protocol. Appl Intell 48(8):2229–2246

[5] Bokhari DM, Hatem SH, Shams TS (2012) A review of clustering algorithms as applied in MANETs. International Journal of Advanced Research in Computer Science and Software Engineering, 2(11)

[6] Chatterjee M, Das SK, Turgut D (2000) An on-demand weighted clustering algorithm (WCA) for ad hoc networks. In *Globecom'00- IEEE. Global Telecommunications Conference. Conference Record (Cat. No. 00CH37137)* (Vol. 3, pp. 1697-1701). IEEE

[7] Choi W, Woo M (2006) A distributed weighted clustering algorithm for mobile ad hoc networks. In *Advanced Int'l Conference on Telecommunications and Int'l Conference on Internet and Web Applications and Services (AICT-ICIW'06)* (pp. 73-73). IEEE

[8] Bednarczyk W, Gajewski P (2013) An enhanced algorithm for MANET clustering based on weighted parameters. Universal Journal of Communications and Network 1(3):88–94

[9] Low CP, Fang C, Ng JM, Ang YH (2008) Efficient load-balanced clustering algorithms for wireless sensor networks. Comput Commun 31(4):750–759

[10] Goldberg DE (1989) Genetic algorithms in search, optimization, and machine learning, Addison Wesley, Reading, MA. *SUMMARY THE APPLICATIONS OF GA-GENETIC ALGORITHM FOR DEALING WITH SOME OPTIMAL CALCULATIONS IN ECONOMICS*

[11] gupta SK, Kuila P, Jana PK (2013) GAR: an energy efficient GA- based routing for wireless sensor networks. In *International confer- ence on distributed computing and internet technology* (pp. 267-277). Springer, Berlin, Heidelberg

[12] Keerthipriya N, Latha RS (2015) Adaptive cluster formation in MANET using particle swarm optimization. In *2015 3rd International Conference on Signal Processing, Communication and Networking (ICSCN)* (pp. 1-7). IEEE

[13] Jamali S, Rezaei L, Gudakahriz SJ (2013) An energy-efficient routing protocol for MANETs: a particle swarm optimization ap- proach. Journal of applied research and technology 11(6):803–812

[14] Kuila P, Jana PK (2014) Energy efficient clustering and routing algorithms for wireless sensor networks: particle swarm optimiza- tion approach. Eng Appl Artif Intell 33:127–140

[15] Shahzad W, Khan FA, Siddiqui AB (2009) Clustering in mobile ad hoc networks using comprehensive learning particle swarm optimi- zation (CLPSO). In *International Conference on Future Generation Communication and Networking* (pp. 342-349). Springer, Berlin, Heidelberg

[16] Khatoon N (2017) Mobility Aware Energy Efficient Clustering for MANET: A Bio-Inspired

Approach with Particle Swarm Optimization *Wireless Communications and Mobile Computing*, 2017

[17] S. Murugan and M. Jeyakarthic, "An Energy Efficient Security Aware Clustering approach using Fuzzy Logic for Mobile Adhoc Networks," 2020 Fourth International Conference on Computing Methodologies and Communication (ICCMC), 2020, pp. 551-555, doi: 10.1109/ICCMC48092.2020.ICCMC-000102.

[18] Chunlin Ji, Yangyang Zhang, Shixing Gao, Ping Yuan and Zhe Li, "Particle swarm optimization for mobile ad hoc networks clustering," IEEE International Conference on Networking, Sensing and Control, 2004, 2004, pp. 372-375 Vol.1, doi: 10.1109/ICNSC.2004.1297465.

[19] Gupta A.K., Prakash S. (2018) "Secure Communication in Cluster-Based Ad Hoc Networks: A Review". In: Lobiyal D., Mansotra V., Singh U. (eds) Next-Generation Networks. Advances in Intelligent Systems and Computing, vol 638. Springer, Singapore.

[20] Gupta S.K., Kuila P., Jana P.K. (2013) "GAR: An Energy Efficient GA-Based Routing for Wireless Sensor Networks". In: Hota C., Srimani P.K. (eds) Distributed Computing and Internet Technology. ICDCIT 2013. Lecture Notes in Computer Science, vol 7753. Springer,Berlin, Heidelberg.

[21] W. El-Hajj, D. Kountanis, A. Al-Fuqaha and M. Guizani, "A Fuzzy-Based Hierarchical Energy Efficient Routing Protocol for Large Scale Mobile Ad Hoc Networks (FEER)," 2006 IEEE International Conference on Communications, 2006, pp. 3585-3590, doi: 10.1109/ICC.2006.255628.

[22] J. Y. Yu and P. H. J. Chong, "3hBAC (3-hop between adjacent clusterheads): a novel non-overlapping clustering algorithm for mobile ad hoc networks," 2003 IEEE Pacific Rim Conference on Communications Computers and Signal Processing (PACRIM 2003) (Cat. No.03CH37490), 2003, pp. 318-321 vol.1, doi: 10.1109/PACRIM.2003.1235781.

[23] S. Singhal and A. K. Daniel, "Fuzzy logic based clusterhead selection protocol under Competence level, Goodness funciton and Mobility for mobile ad hoc network," 2014 Conference on IT in Business, Industry and Government (CSIBIG), 2014, pp. 1-6, doi: 10.1109/CSIBIG.2014.7056988.

[24] Jun Liao, Hong Zhang, Liming Jiang and Yaozong Liu, "A clustering algorithm based on subjective trust in MANET," 2011 International Conference on Electric Information and Control Engineering, 2011, pp. 3817-3820, doi: 10.1109/ICEICE.2011.5777958.

[25] J. Liu, L. Shen, X. Wang and X. Zhu, "Adaptive Cluster-Head Algorithm for Bluetooth Ad Hoc Networks," 2007 International Conference on Wireless Communications, Networking and Mobile Computing, 2007, pp. 1453-1456, doi: 10.1109/WICOM.2007.368.

[26] S. Adabi, S. Jabbehdari, A. Rezaee and S. Adabi, "Distributed Fuzzy Score-Based Clustering Algorithm for Mobile Ad Hoc Networks," 2008 IEEE Asia-Pacific Services Computing Conference, 2008, pp. 193-198, doi: 10.1109/APSCC.2008.245.

[27] Qilian Liang, "Clusterhead election for mobile ad hoc wireless network," 14th IEEE Proceedings on Personal, Indoor and Mobile Radio Communications, 2003. PIMRC 2003, 2003, pp. 1623-1628 vol.2, doi: 10.1109/PIMRC.2003.1260389.

[28] M. Siwach and A. Singh, "Fuzzy based parametric clustering model for mobile network," 2015 International Conference on Soft Computing Techniques and Implementations (ICSCTI), 2015, pp. 49-53, doi: 10.1109/ICSCTI.2015.7489603.

[29] E. Thenmozhi and S. Audithan, "Trust based cluster and secure routing scheme for wireless sensor network," Second International Conference on Current Trends In Engineering and Technology - ICCTET 2014, 2014, pp. 489-494, doi: 10.1109/ICCTET.2014.6966345.

[30] E. Suresh Babu, C. Nagaraju, and MHM Krishna Prasad. 2015. "A Secure Routing Protocol against Heterogeneous Attacks in Wireless Adhoc Networks". In <i>Proceedings of the Sixth International Conference on Computer and Communication Technology 2015</i> (<i>ICCCT '15</i>). Association for Computing Machinery, New York, NY, USA, 339–344..

[31] W. G. Theresa and S. Sakthivel, "Fuzzy based intrusion detection for cluster based battlefield MANET," 2017 IEEE International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM), 2017, pp. 22-27, doi: 10.1109/ICSTM.2017.8089121.