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Enhancing Lifespan and Energy Efficiency in Mobile Smart Dust Networks

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ABSTRACT

Mobile Smart Dust Networks play a crucial role in the Internet of Things (IoT) ecosystem, with their nodes contributing significantly to various tasks. However, these nodes primarily deplete energy, raising concerns regarding the overall lifespan of the system. The primary objective of this research is to reduce the energy consumption of these nodes, thereby extending the lifespan of the entire Smart Dust Network. This study proposes a novel clustering approach specifically designed for Smart Dust Networks aimed at reducing network energy consumption, which, in turn, significantly extends the network lifespan. The methodology primarily focuses on the allocation of Cluster Heads among the mobile nodes within the network. Simulations conducted in Network Simulator 2 (NS2) demonstrate a significant reduction in network energy consumption, consequently extending the network lifespan.

1. INTRODUCTION

Mobile Smart Dust Networks (MSDNs) have been increasingly recognized as a pivotal technology in recent years [1-3]. Over the past years, MSDNs have garnered significant attention from both industrial and academic sectors worldwide. Characteristically, an MSDN consists of several low-power, low-cost, multi-processing smart dust mobile nodes, endowed with capabilities for observation, sensing, computation, and wireless communication [4-6]. Through a wireless medium, these smart dust nodes communicate information remotely to accomplish tasks. MSDNs serve as exceptional instruments for applications in defense, disturbance detection, monitoring, and data collection from various structured environments. Additional applications such as location detection and personal health monitoring are facilitated by smart dust mobile networks [7-10].

A number of clustering methodologies have been proposed to enhance the lifespan of mobile smart dust networks. In these methodologies, the MSDN is divided into clusters and a single node from each cluster is chosen as the cluster-head (CH). All data aggregation takes place within the cluster, after which the CH transmits the data of the respective cluster to the base station (BS). To balance energy consumption within each cluster, periodic CH selection is proposed [11]. A uniformly distributed CH placement can maintain balance in energy consumption among nodes and extend the network lifespan. However, methods that aim to balance power consumption and extend network lifespan are not always successful due to non-uniform node distribution. Uniformly distributed CHs allow clusters to maintain a consistent energy consumption among nodes. Nevertheless, imbalanced power consumption persists in CHs due to non-uniform node distribution.

In this study, a novel clustering approach for MSDNs, known as ERSCH (Effectual Remote Secured ClusterHeads), is proposed in conjunction with the LEACH method [12, 13]. For the purpose of highlighting the different improvements achieved, ERSCH is divided into ERSCH1 and ERSCH2. ERSCH essentially involves optimal allocation of CHs across the network. Results indicate an increase of up to 53.13% in energy conservation and an extension of network lifespan by up to 128.62% compared to LEACH.

The remainder of this paper is organized as follows: Section II provides an overview of the LEACH method. Section III introduces the proposed ERSCH1 and ERSCH2. Simulation performance evaluations are presented in Section IV, and the paper concludes in Section V.

2. RELATED WORKS

The primary clustering methodology is LEACH. The entire network's nodes are grouped into clusters, with one node acting as the central hub (CH), while the rest of the network's nodes gather data and broadcast it to the CH. The CH gathers data from all smart dust nodes, performs data aggregation within the cluster, and broadcasts data to a remote BS. As a result, CH has more power than the cluster's nodes. The network's complete nodes stopped broadcasting when CH lost vitality. Consistency in energy exploitation and network exploitation is the challenge of the LEACH technique. The architecture of LEACH methodology shown in Figure 1. Utilizing LEACH methodology diminish broadcasting energy dissolute by CH and smart dust nodes as probable eight times calculated with direct communication and least broadcasting power utilization among routing algorithm [14].

To regulate dropping nodes battery in network, LEACH strategy circles randomized eminent energy CH position among smart dust nodes. Between smart dust nodes, a CH-related approach energy burden is constantly circulated. When a cluster is recognized by CH, a TDMA-(Time-Division Multiple-Access) slot is created that accurately alerts each node when to broadcast its sensed data. The LEACH methodology's process is divided into revolutions. The entire revolution starts with setup when clusters are organized, and then it moves into steady-state when several frames of information are transmitted from smart dust nodes to CH and BS.

In set-up clusters are positioned and CH is designated. The primary revolution every node designated a arbitrary value with in {0,1} and contrasted with threshold T(n) in Eq. (1) and value is lower than T(v) then node turn into CH.

$$T(v) = F/(1-F*(R*\mathrm{mod}(1/F))), \mathit{if}\,(v \in S), 0, \mathit{otherwise} \quad (1)$$

wherever,

F- Fraction of CH,

R-Current revolution,

S- Group of sensor nodes inside cluster extremely last 1/F revolutions.

Every revolution designated CH exchange a message to entire sensor nodes in network notifies their status. When entire nodes obtains message entire nodes can make a decision to which cluster they go related with potency of obtained signal. CH creates a TDMA slot and broadcasts it to its clustered nodes.

In steady-state, the entire network starts detecting environmental events and broadcasting them to the CH in a distributed broadcasting mode. Information is gathered by CH nodes, fused, compressed, and exchanged to BS. If CH wants to transmit with BS that uses a lot of energy, BS is typically far from the cluster. After transmission is finished, steady state will also be over. Re-clustering occurs in the setup with the next revolution and selects new CHs.

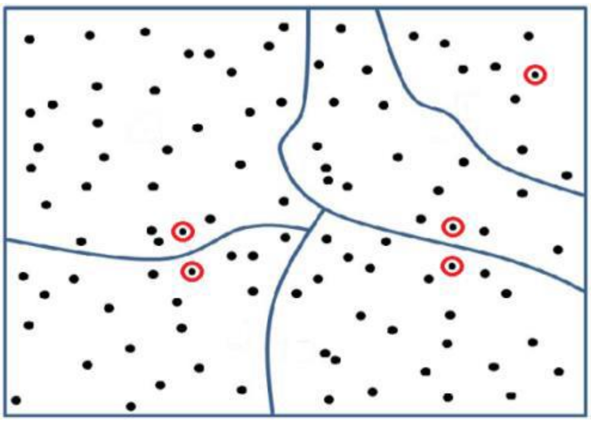

Figure 1. LEACH methodology

Karabekir et al. [15] proposed a LEACH approach in that CH does not designated by position and preeminent feasible one. Centralized LEACH method [8], LEACH-C splits entire revolution into (i) Setup and (ii) Broadcasting phase. In setup entire nodes broadcast their related information like remaining energy and positions to BS. Then BS determines average remaining energy of entire nodes and node contains higher remaining energy than average level such node has a chance to turn into CH. BS utilize annealing procedure to set-up clusters. The clustering should reduce regular energy expenditure while broadcasting to CH. LEACH-Centralized and LEACH LEACH-C are identical [16, 17]. But stimulation consequence demonstrates excellent expansion in LEACH-C than LEACH.

2.1 Energy Efficient and Reliable Routing (E2R2)

E2R2 primarily securities a MWSNs from attacks expressing the multi jump routing, particularly related on shoplifting during repeat routing information. This prototype does not concentrate on the denial of service DoS assails, wherever an aggressor is determined to influence the network by means of its resource. For this incident, E2R2 do not concentrate on the DoS assails of jamming network by retransmitting various packets or physically jamming the system. E2R2 endeavors to reach the subsequent attractive features, High information delivery rate, Energy effectiveness, scalability and flexibility. Conversely, connection breakage situation is also taken into deliberation by E2R2. So, information loss, time interruptions occurs due to connection breakage be supposed to measure and accomplish improved throughput [18].

2.2 Mobility Aware Low Energy Adaptive Clustering Hierarchy (M-LEACH)

M-LEACH initiates a power resourceful clustering method which includes characteristics of the LEACH prototype. As LEACH, a clustering related gathering that diminishes energy distribution in mobile sensor arrangements. LEACH beats established by means of adaptive groups and revolving CHs, authorizing the power provisions of the structure to be disseminated surrounded by the entire group contains sensor nodes. LEACH has a level in information gathering to diminish the quantity of information that have to be broadcast to the BS. LEACH makes use of a CDMA/TDMA, MAC to diminish among cluster and intra group arresting. LEACH helps in sustaining resourceful sensor nodes in addition to reducing the consumption of the network resources in each cycle. LEACH-Centralized (LEACH-C) principle is similar to LEACH in function sideways as of group agreement. In LEACH-C CH choice is made at BS. The projected gathering is M-LEACH anywhere elements in the CH has adaptability, component center among one cycle, existing remaining energy and the amount of sensor nodes per group is measured and that are integrated M-LEACH. To support the sketch of cluster estimate, they contain a little assumption. Which are, every mobile sensor nodes are homogenous in substantial aspects, every mobile sensor nodes has mobility and BS is motionless. The amount of information exchanged to the BS and the quantity of energy present in sensor nodes [19].

Rajesh et al. [20, 21] established system of Fuzzy-logic that enhances LEACH technique. Fuzzy-logic related CH determination accomplished in BS. BS utilize two determination procedure from node that is intensity of energy and length of BS to decide on appropriate CH that resolve extend initial node expire (INE) moment and information flow assured for every revolution and furthermore enlarge throughput obtained by BS prior to INE. This approach utilized three things are nodes mid-point, compactness and left-over energy. These two WSNs approaches are centralized.

3. ERSCH-EFFECTUAL REMOTE SECURED CLUSTER HEADS

Segment III consists of ERSCH clustering approach for MWSN. For simplicity ERSCH approach illustrates in two parts as ERSCH1 and ERSCH2 to emphasize divergent uniqueness and success of every segments. ERSCH2 progress enhanced efficiency accomplished by ERSCH1 by modified amount of CH. To conclude an identical power representation as in the study of Rajesh and Rajanna [22] is utilized.

3.1 ERSCH1

In Low-Energy-Adaptive Clustering-Hierarchy-(LEACH) growth, the location of CH is relatively important to avoid using energy. As a result, there may be several revolutions in break through by using a few CH close to or excessively remote from one another. Energy will be slightly lost due to eavesdropping signals or through extended remote broadcasting to complete a CH. In ERSCH, CHs are constantly distributed across the environment to produce roughly the same number of clusters every revolution, with each CH located in the midst of an allied cluster. This can only be done within a certain environmental range and node compactness, which is a nearness *n* factor. Such clusters are in addition next to every other node and one of the two CHs in a revolution with two CHs is smaller than *n* is meant to be deleted. After determining the initial CH using the usual LEACH approach, it is likely that the CH will have a length from the initial CHs in the most recent revolution to the remaining smart dust nodes before broadcasting its own. When remote drops below n, it stops offering both brand-new CHs and CHs that have already been used in previous revolutions. In this case, the arbitrary value of the residual smart dusts produced is lower than the threshold value and is likely to be a CH in the corresponding revolution. Entire outstanding smart dust in cluster will designated as CH in last revolution regardless of their closeness to every other nodes. This procedure is utilized as initial advancement to create clusters with approximately identical size and is labeled ERSCH1. Figure 2 illustrates revolution of CHs determination according to ERSCH1method.

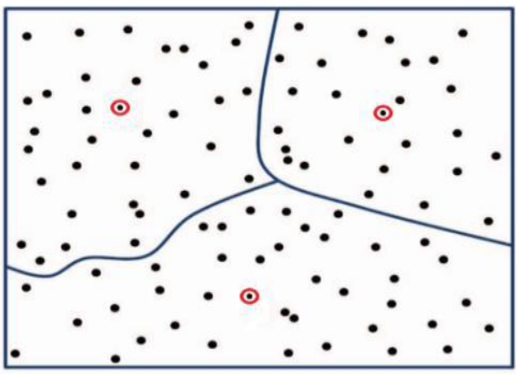

Figure 2. ERSCH1

Constraint *n* acts a crucial task on effectiveness of ERSCH1. Most excellent value of *n* is contingent on network environment, node compactness and amount of CHs. To obtain preeminent value for effectual remote *n* for a scrupulous system new factors in a specified system and examine diverse value of *n*. For illustration in a system of 100 smart dust nodes with an environment of 50×50 and *F* = 0.05 lower energy exploitation is offered while area of *n* is 15m and IL is 25 packets as exposed in Table 1. primary column of Table 1 exhibits diverse examined values for closeness. Columns next and third exhibits system power expenditure in joules (J) for particular revolution and for *IL*=25 and *IL*=250 information every revolution correspondingly. By finest value of *n* ERSCH1 exhibit an important expansion to diminish system energy exploitation and consequently enlarges network lifespan.

EE (Exploited Energy)
IL (Information Number)
ER (Effectual Remote)

Table 1. Power exploitation for diverse value of closeness for two diverse values of ML information per revolution

ER	EE in joules (J) IL=25	EE in joules (J) L=250
0	14.417	127.554
1	14.360	126.610
2	14.130	125.710
3	14.011	124.553
4	13.918	123.357
5	13.984	122.277
10	13.639	119.893
11	13.658	119.775
12	13.658	119.866
13	13.648	119.868
14	13.732	120.137
15	13.686	119.605
16	13.710	119.964
17	13.744	120.303
18	13.733	120.208
19	13.850	120.922
20	13.895	121.806
21	13.950	122.723
22	13.982	123.668
23	14.103	124.342
24	14.223	125.189
25	14.341	126.090

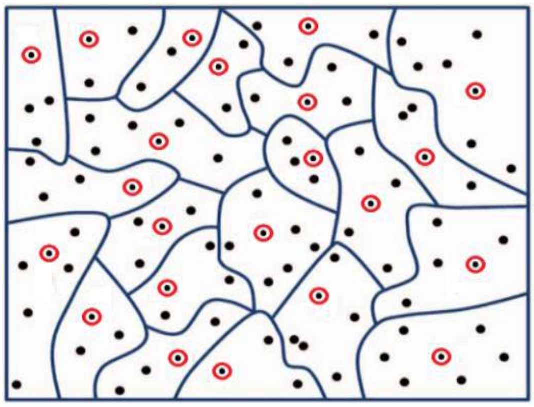

Figure 3. CHs and smart dust nodes in last revolution of ERSCH1 approach

Although significant expansion in ERSCH1 present there is area for improvement. Imagine *F* is finest probable fraction of CHs with entirely nodes. In ERSCH1 remote as in last revolution of recesses amount of chosen CHs in every revolution is enormously probable lower than *F* percent of entire smart dust nodes in network. Since few smart dust nodes may expires from converting it into CH because of their effectual remoteness to remaining CHs and safeguard it from other revolutions. Consequently quantity of clusters will be condensed contrasted with LEACH. That directs to huge clusters range and additional energy utilization among intra-cluster broadcasting. Further in last revolution proportion of CHs is higher than finest value *F*. Subsequently amount of clusters will enlarge and additional CHs broadcast their information to BS for extensive lengthy broadcasting. Figure 3 reveals a model of CHs and smart dust nodes in last revolution of ERSCH1 approach.

This consequence is not utilized in ERSCH2 an improved edition of ERSCH1.

3.2 ERSCH2

The system has access to LEACH's best performance, and the number of CHs chosen for each revolution is exactly *F*. This restriction is not met by ERSCH1, as it consistently excludes a small number of CHs from the final revolution because of their proximity to all other nodes. Raising the threshold and the number of chosen CHs throughout the course of whole rotations equips the ERSCH2 with modification. Therefore, in order to attain the best value of F and prevent a few nodes from dipping owing to adjacent issues, smart dust nodes with a higher value F ratio will be designated as CHs on average during each revolution. When fixing a fresh threshold nearby *F* ratio of smart dust nodes is lastly chosen as CHs in every revolution that are scattered consistently contrasted with LEACH approach. Issue is how to expand threshold to reach finest value in each revolution next instance. Note when enlarging threshold value that is attaching value is not stable for every revolutions but differs with respect to revolutions. As threshold enlarges revolution to revolution from Equation 1attach value reduces when arrive at zero at last revolution. Fresh threshold *T'*(*v*) can evaluated by Eq. (2) is,

$$T'(v)= T(v)+(1- T(v))*c \tag{2}$$

T(v) evaluated by Eq. (1) and stable value c is coefficient. Eq. (2) is utilized by ERSCH2 to determine value of threshold at each revolution.

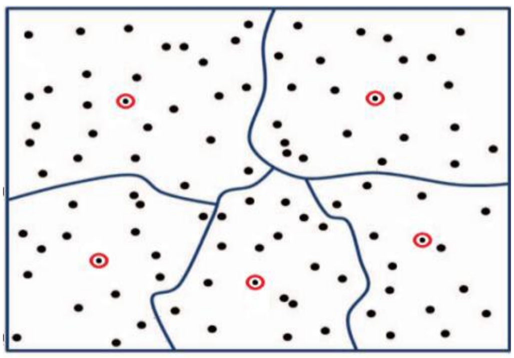

Figure 4. ERSCH2

Coefficient value c is extremely critical to offer best results for ERSCH2 approach this value related with network arrangement and effectual remote *r*. System consists of 100 smart dust nodes with *F*=0.05, *r*=15 and 150 meters, environment coverage of $50\times50m^2$ and $500\times500m^2$, and *IL* of 25 and 250 information for each revolution maximum energy exploitation is offer while *c* is 0.15 as exposed in Table 2. Initial column in Table 2 demonstrates diverse scrutinized for coefficient c. Subsequent column, third, and final columns demonstrate network energy expenditure for particular revolution in three diverse network environments. In system 1 network environment is measured as $50\times50m^2$, *r* is 15m, and *IL* is 25 information for every revolution. In system 2 *IL* is altered to 250 information per revolution. Lastly in system 3 environment ranges is 500 × 500 m^2, *r* is 150m and *IL* is 25 information per revolution.

By finest coefficient value 'c' ERSCH2 demonstrates a considerable enhancement to diminish energy exploitation and consequently to expand network lifespan contrasted with ERSCH1 and PSO-EEC. Figure 4 illustrate CHs and smart dust organization in a revolution of ERSCH2 approach.

Table 2. Network energy exploitation for diverse values of coefficient in dissimilar systems

Coefficient (C)	System 1 (J)	System 2 (J)	System 3 (J)
0.00	13.516	119.50	289.095
0.01	13.301	116.68	260.867
0.02	13.259	116.51	257.118
0.03	13.311	115.140	242.823
0.04	13.170	114.505	237.252
0.05	13.081	113.230	224.146
0.06	12.952	112.720	219.318
0.07	12.905	162.361	216.788
0.08	12.993	142.830	214.220
0.09	12.859	112.297	213.127
0.10	12.850	112.750	218.234
0.11	12.795	111.958	210.052
0.12	12.783	111.940	209.701
0.13	12.737	111.813	208.514
0.14	12.755	111.718	207.568
0.15	12.735	111.627	206.677
0.16	12.764	111.465	207.314
0.17	12.478	111.658	207.112
0.18	12.833	112.653	216.103
0.19	12.940	112.408	215.474
0.20	12.974	112.270	217.813
0.25	12.496	112.821	218.957
0.26	13.041	112.955	220.914
0.27	13.064	113.570	224.102
0.28	13.154	113.988	230.951
0.29	13.158	114.903	236.913
0.30	13.250	115.124	242.904

4. EVALUATION OF ERSCH1 AND ERSCH2

The results are calculated using NS2 simulation to compare the performance of the proposed ERSCH strategy with the PSO-EEC approach. The entire simulation includes 100 intelligent dust nodes in a variety of arbitrary environments with provided normal outcomes. Energy representation is exactly the same as one participated in, as previously indicated [23].

We three groups of Experiments carry out in three system environment to contrast performance of ERSCH1, ERSCH2, and PSO-EEC. In initial system environment region is $50\times50m^2$ while BS is 100m long from network boundary Figure 5. in addition amount of smart dust nodes is 100, F=0.05, r=15m, IL=25 information primary energy of every smart dust is 0.5j, and a=0.15.

Table 3 provides the total energy used by PSO-EEC, ERSCH1, and ERSCH2 at the end of several revolutions. The first column of Table 3 displays the information-accumulating revolution number. The next, third, and fourth columns of Table 3 show how much energy PSO-EEC, ERSCH1, and

ERSCH2 used throughout the network over various time periods. The fifth and final column of Table 3 shows the energy obtained by ERSCH1 and ERSCH2 when they were tested with PSO-EEC.

Network lifespan in the PSO-EEC, ERSCH1, and ERSCH2 is shown in Table 4. The first column that shows the number of nodes expires after 100 intelligent dust nodes. The fourth and subsequent columns indicate how many smart dust nodes in the network perish after a revolution. The last two columns show how much energy ERSCH1 and ERSCH2 obtained in relation to extending network longevity as measured by LEACH.

Analysis of PSO-EEC and ERSCH1 from Tables 3 and 4 shows an average reduction in energy exploitation of 4.41% and an average increase in network longevity of 5.15%. ERSCH2 shows an average reduction in energy use of 11.7% and an average increase in network longevity of 16.47%.

In simulation next set of values to scrutinize ILs on ERSCH2 approaches. Consequently enlarge IL to 250 information and also primary energy of each smart dust is 5.0 j. Consequences illustrate an average of 6.89% reduction in energy exploitation and 8.85% enlarge network lifespan by ERSCH1 contrasted to PSO-EEC approach and also ERSCH2 illustrates an average of 15.88% reduction in energy exploitation and 29.95% enlarges network lifespan.

In simulation next set of values Network environment is enlarged to 500×500m^2 and remoteness from BS to 1000m. The r is enlarged to 150m and primary energy of entire smart dust is 50.0 j. Consequences demonstrate an average of 25.06% reduction in energy exploitation and 53.45% enlarges network lifespan by ERSCH1 contrasted with PSO-EEC. Alternatively ERSCH2 demonstrate an average of 38.43% reduction in energy exploitation and 128.46% in enlarges network lifespan. Figure 6 and Figure 7 represents enhancing network region ERSCH2 considerably improvement than LEACH methodology in provisions of energy expenditure and network lifespan.

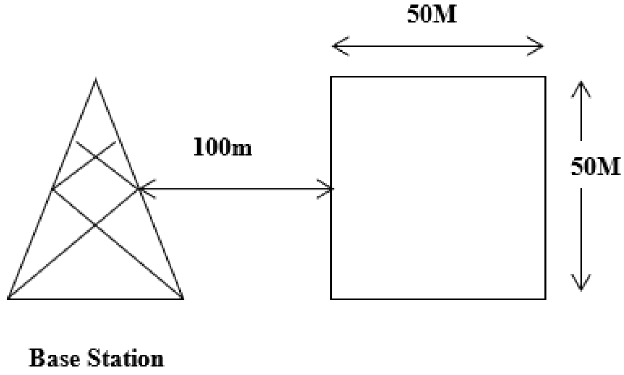

Figure 5. BS with environment

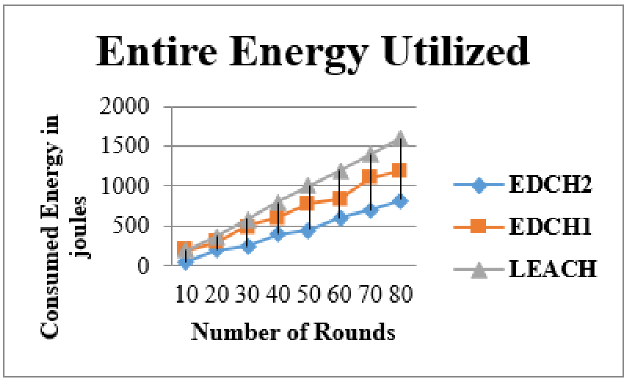

Figure 6. Entire energy utilized in network

Table 3. Attained energy by ERSCH1 and ERSCH2 in diverse revolutions

Round	LEACH	ERSCH1	ERSCH2	ERSCH1 Attained Energy (%)	ERSCH2 Attained Energy (%)
10	7.224	6.902	5.528	2.737	13.041
20	13.945	13.614	11.833	5.630	11.421
30	21.594	20.959	19.142	4.313	12.476
40	29.215	26.644	25.684	4.918	11.960
50	36.228	34.422	31.974	5.132	11.858
60	42.592	40.594	38.440	4.543	10.536
70	50.617	48.245	43.754	3.824	10.805
80	57.247	55.094	51.025	4.184	11.713

Table 4. Attained energy by ERSCH1 and ERSCH2 to lengthen network lifespan over diverse steps of network existence

Expire	LEACH	ERSCH1	ERSCH2	ERSCH1 Attained Energy (%)	ERSCH2 Attained Energy (%)
1	39.821	40.575	51.736	2.336	30.031
5	49.729	51.123	61.782	2.283	19.545
10	56.493	56.878	64.732	1.439	15.144
20	61.336	63.346	70.579	3.422	14.936
30	62.855	65.243	71.690	4.140	15.351
40	64.998	69.247	75.723	7.079	15.730
50	68.441	71.916	78.838	5.488	14.930
60	70.760	74.679	79.657	4.946	13.984
70	72.840	76.739	83.235	6.434	14.837
80	72.654	77.944	84.141	7.139	14.421
90	75.179	80.440	86.078	6.931	14.468
95	74.820	79.845	86.934	6.663	15.322
99	76.314	81.633	88.531	6.591	15.985
100	76.242	82.456	87.587	7.225	15.951

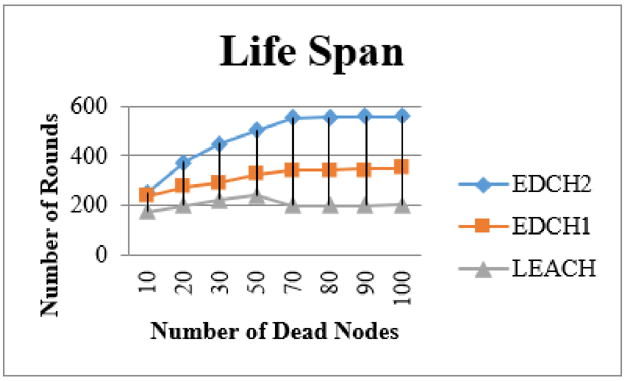

Figure 7. Network lifespan

5. CONCLUSION AND FUTURE WORK

Energy efficiency is a key factor in the longevity of smart dust networks. Clustering is a convincing strategy to increase the network's energy competence. Similar to LEACH, the ERSCH protocol is a type of hierarchical routing mechanism that accomplishes the clustering of smart dust nodes. Hierarchical routing methods choose CHs at random, which expands the re-clustering process and consumes more energy while shortening network lifespan. The ERSCH CHs are chosen based on the surrounding area and remoteness. In order to reduce energy consumption in smart dust nodes and lengthen network longevity, ERSCH studied the LEACH technique.

Future studies should consider dynamic contexts like Internet of Things (IoT) devices for effective distance and threshold. In addition, new technology is being developed to detect malevolent smart dust in dynamic environments and to improve energy efficiency.

REFERENCES

[1] Rajesh, D., Jaya, T. (2019). Exploration on cluster related energy proficient routing in mobile wireless sensor network. International Journal of Innovative Technology and Exploring Engineering (IJITEE), 8(4): 93-97.

[2] Riadi, I., Herman, Siregar, N.H. (2022). Mobile forensic analysis of signal messenger application on android using Digital Forensic Research Workshop (DFRWS) framework. Ingénierie des Systèmes d'Information, 27(6): 903-913. https://doi.org/10.18280/isi.270606

[3] Rajesh, D., Jaya, T. (2020). A mathematical model for energy efficient secured CH clustering protocol for mobile wireless sensor network. Wireless Personal Communications, 112(1): 421-438. https://doi.org/10.1007/s11277-020-07036-4

[4] Kiruba, D.G., Benitha, J. (2022). Fuzzy based energy proficient secure clustered routing (FEPSRC) for IOT-MWSN. Journal of Intelligent & Fuzzy Systems, 43(6): 7633-7645. https://doi.org/10.3233/JIFS-212014

[5] Rajesh, D., Jaya, T. (2021). Enhancement of network lifetime by fuzzy based secure CH clustered routing protocol for mobile wireless sensor network. Journal of Ambient Intelligence and Humanized Computing, 13: 2795-2805. https://doi.org/10.1007/s12652-021-03170-4

[6] Rajesh, D., Kiruba, D.G. (2021). A probability based energy competent cluster based secured CH selection routing EC2SR protocol for smart dust. Peer-to-Peer Networking and Applications, 14: 1976-1987. https://doi.org/10.1007/s12083-021-01144-z

[7] Chandrakanth, H.G., Anand, D.G., Peter, T.J. (2017). Research challenges and characteristic features in wireless sensor networks. International Journal of Advanced Networking and Applications, 9(1): 3321-3328.

[8] Kiruba, D.G., Benita, J. (2022). A survey of secured cluster head: SCH based routing scheme for IOT based mobile wireless sensor network. ECS Transactions, 107(1): 16725. https://doi.org/10.1149/10701.16725ecst

[9] Rajesh, D., Jaya, T. (2021). ECIGC-MWSN: Energy capable information gathering in clustered secured CH based routing in MWSN. Materials Today: Proceedings, 43: 3457-3462. https://doi.org/10.1016/j.matpr.2020.09.100

[10] Kiruba, G. (2022). A comparative study on energy efficient secured clustered approaches for IoT based MWSN. Suranaree Journal of Science & Technology, 29(4): 1-18.

[11] Kiruba, G., Benita. (2021). Energy capable clustering method for extend the duration of IoT based mobile wireless sensor network with remote nodes. Energy Harvesting and Systems, 8(1): 55-61. https://doi.org/10.1515/ehs-2021-0006

[12] Rajkumar, Chandrakanth, H.G. (2018). Energy efficient routing clustering algorithm for WSN. Int. J. Advanced Networking and Applications, 10(3): 3880-3887. https://doi.org/10.35444/IJANA.2018.10036

[13] Wang, Y., Zhang, G. (2022). EMEECP-IOT: Enhanced multitier energy-efficient clustering protocol integrated with internet of things-based secure Heterogeneous Wireless Sensor Network (HWSN). Security and Communication Networks, 2022: 1667988. https://doi.org/10.1155/2022/1667988

[14] Elizebeth Zachariah, U., Kuppusamy, L. (2022). A novel approach on energy-efficient clustering protocol for wireless sensor networks. International Journal of Communication Systems, 35(9): e5137. https://doi.org/10.1002/dac.5137

[15] Karabekir, B., Aydın, M.A., Zaim, A.H. (2021). Energy-efficient clustering-based mobile routing algorithm for wireless sensor networks. Electrica, 21(1): 41-49. https://doi.org/10.5152/electrica.2021.20035

[16] Ahmad, H., Kohli, N. (2021). LBCM: Energy-efficient clustering method in wireless sensor networks. Engineering and Applied Science Research, 48(5): 529-536.

[17] Giji Kiruba, D., Rajesh, D. (2018). Analysis on clustered energy organized in mobile wireless sensor networks. International Journal of Engineering and Robot Technology, 5: 37-42.

[18] Giji Kiruba, D., Joselin, B. (2023). TSO clustered protocol to extend lifetime of IoT based mobile wireless sensor networks. The International Arab Journal of Information Technology (IAJIT), 20(4): 559-566. https://doi.org/10.34028/iajit/20/4/1

[19] Zulaeha, I., Subyantoro, Hasanudin, C., Pristiwati, R. (2023). Developing teaching materials of academic writing using mobile learning. Ingénierie des Systèmes

d'Information, 28(2): 409-418. https://doi.org/10.18280/isi.280216

[20] Rajesh. D., Firoja Banu, M., Stella, D., Grace, A.P. (2016). CH panel based routing scheme for mobile wireless sensor network. International Journal of MC Square Scientific Research, 8(1): 188-198. https://doi.org/10.20894/IJMSR.117.008.001.017

[21] Rajesh, D., Jaya, T. (2022) Energy competent cluster-based secured CH routing EC2SR protocol for mobile wireless sensor network. Concurrency and Computatation: Practice and Experience, 34(1): e6525. https://doi.org/10.1002/cpe.6525

[22] Rajesh, D., Rajanna, G.S. (2022). CSCRT protocol with energy efficient secured CH clustering for smart dust network using quantum key distribution. International Journal of Safety and Security Engineering, 12(4): 441-448. https://doi.org/10.18280/ijsse.120404

[23] Rawat, P., Chauhan, S. (2021). Particle swarm optimization-based energy efficient clustering protocol in wireless sensor network. Neural Computing and Applications, 33(21): 14147-14165. https://doi.org/10.1007/s00521-021-06059-7