JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 1715 - 1730
https://publishoa.com
ISSN: 1309-3452

Spatial Clustering with Dynamic Hops for Data routing in WSN for Enhanced QoS Metrics

Panchikattil Susheelkumar[1], Jayant Nandwalkar[2], Dnyandeo Pete[3], Shubhangi Vaikole[4], Sachin Shinde[5]

[1]Department of Electronics Engineering, Datta Meghe College of Engineering,
Sector-3, Airoli, Navi Mumbai
susheelkumarsredh34@gmail.com

[2] Department of Electronics Engineering, Datta Meghe College of Engineering,
Sector-3, Airoli, Navi Mumbai
10jnand@gmail.com

[3] Department of Electronics Engineering, Datta Meghe College of Engineering,
Sector-3, Airoli, Navi Mumbai
pethedj@rediffmail.com

[4] Department of Computer Engineering, Datta Meghe College of Engineering,
shubhangi.vaikole@dmce.ac.in

[5] Department of Mechanical Engineering, Datta Meghe College of Engineering,
Sector-3, Airoli, Navi Mumbai
sachin.shinde@dmce.ac.in

ABSTRACT

Space and time correlation is more pronounced in data centric wireless sensor networks. One of the approaches towards energy sustenance in wireless sensor network is to identify the nodes with similar readings and maintain the orderly collection of data from such nodes in a time dispersed manner so as to enhance the network lifetime. We try to take advantage of spatial-correlation and apply the same in cluster formation process. Here, we have suggested a scheme or algorithm towards Spatial correlation based clustering and an election of cluster-head determined by the position of cluster-members with reference to Base Station location, node's residual-energy, summative distance of propagation from each cluster-member to cluster head. Also the routing algorithm adopts a dynamic two hop or three hop route to reach the sink or base-station, thereby contributing to the energy efficiency and improved lifetime of sensor network in comparison to that seen in standard schemes or algorithms like Low Energy Adaptive-Clustering Hierarchy (LEACH), Stable-Election-Protocol (SEP) and Distributed Energy-Efficient-Clustering (DEEC) Protocol.

Keywords: 2-hop, 3-hop, Spatial-Correlation, Throughput, Network Lifetime.

I. INTRODUCTION

Wireless Sensor Networks (WSN) [1] employs various algorithms aimed primarily at effecting energy saving and improved network lifetime [2]. These algorithms are the various routing and clustering algorithms implemented in a customized way across various sizes of network. These algorithms include the various standard algorithms used in practice today involving single hop or multi hop data movement [3, 4] as per the WSN Quality of Service (QoS) metrics [5,6] requirement. Here in this paper we have adopted a scheme wherein the nodes are segmented into groups called clusters based on a correlation [7-13] defined for the nodes estimated by the sensing range of each sensor node and the spatial distance of separation. The cluster-leader or head for each cluster is decided by estimating a chance-value at individual node level based on criteria like residual (balance) energy with the node and effective spatial distance from cluster-member (CM) to candidate cluster-head. Further, the data gets routed through a 2-hop or 3-hop step from member nodes of the cluster to stationary base station (BS) or sink. 2-hop or 3-hop route is selected dynamically by our algorithm which is based or dependent on the pre-estimated chance-value for being a cluster-head and distance of separation between the neighboring cluster heads. Thus, in our approach we have implemented a distributed algorithm for cluster-leader or head and route selection while a centralized algorithm implemented at the sink level groups the nodes into clusters which is maintained for the entire lifespan of the network.

Further, related work has been briefly covered in section-II. The implementation models are discussed in section-III and IV while section-V covers our proposed methodology. Section-VI gives a step-wise detail of our proposed algorithms. The findings and results have been discussed at length in section-VII while section-VIII gives the inferences as the conclusion of our research paper.

II. RELATED WORK

The authors of the papers [14-16] have briefly explored the standard algorithms namely LEACH-SEP and DEEC algorithms. In Paper [7], the authors have given detailed information on architectures and correlation models for WSN. In paper [8], the authors have come-up with a distributed algorithm to form clusters using spatial data correlation. They have applied their algorithm on a uniform and a random network topology and studies the comparative effect on key metrics. In paper [9] the authors have come out with an adaptive sampling approach to energy-efficient periodic (ASAP) data collection in which the subset of sampling nodes are changed dynamically and the data from the non-sampling nodes are predicted with the help of probabilistic models. In paper[10], Vuran etal. have developed a theoretical framework to model the spatial and temporal correlation using which they have come out with an efficient low energy MAC approach. In paper [13], the clustering-algorithm makes use of nodes's balance energy, the node's distance from base station and its distance from cluster-centroid in determining cluster head for a denser network.

In this paper, the distributed algorithm evaluates a chance-value parameter for each node, based on which cluster leader or head is elected. This parameter is decided by an algorithm using residual or balance energy of node after each round, the summative propagation distance to reach the each node if it was the cluster head and the distance from the node to sink. The chance value also facilitates the nomination or selection of the cluster's leader as primary (main) cluster-head or secondary (associative) cluster-head, thereby creating a 2-hop or 3-hop route from SN (sensing-node) to base-station.

III. PROPOSED CORRELATION MODEL

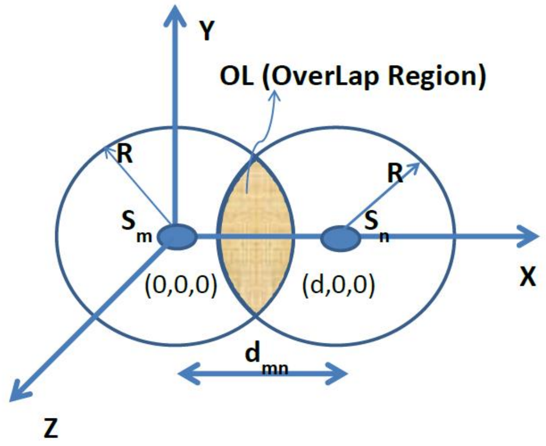

Fig. 1.[19]. Overlapping regions of sensing for two sensor nodes

The correlation model adopted from paper [19] helps us in determining a representational node among the nodes in the event area with minimum distortion constraint [7]. It is observed that as sensing-range of sensing nodes gets higher, the distortion between the readings of sensing nodes located in event-area decreases and when the distortion level is below a certain defined minimal level, we need not communicate the sensor readings of all the nodes to the sink but reading from only one sensor node would suffice the requirement, thereby harnessing on communication power saving in the system. In the correlation model under consideration, we have assumed constant or fixed sensing radii for all sensing nodes in the considered network. When two sensor nodes are located closely, then there is an overlap in their sensing regions which defines the correlation σ between them which is expressed by the following expression:

$$\sigma = \frac{OverlapVolume(Lv)}{joint\ Volume(Jv)} \tag{1}$$

where σ_{xy} is the correlation defined between nodes x and y separated by distance dxy. From the study of spherical geometry, the relation between overlapping sensing regions (volume) , sensing radii of sensing nodes and the distance of separation of two nodes being considered is expressed as[17,19]:

$$Lv = \frac{\Pi}{12}(2R_{sn} - d_{xy})^2 (d_{xy} + 4R_{sn}) \tag{2}$$

$$Jv = \frac{8\Pi R_{sn}^3}{3} - \frac{\Pi}{12}(2R_{sn} - d_{xy})^2 (d_{xy} + 4R_{sn}) \tag{3}$$

$$\sigma_{xy} = \frac{Lv}{Jv} = \frac{(2R_{sn} - d_{xy})^2 (d_{xy} + 4R_{sn})}{32R_{sn}^3 - (2R_{sn} - d_{xy})^2 (d_{xy} + 4R_{sn})} \tag{4}$$

We know that when $d_{xy} > 2R_{sn}$, $\sigma_{xy} = 0$. And for $d_{xy} < 2R_{sn}$, the above expression stand valid and hence is generally expressed as:

$$\sigma_{xy} = \begin{cases} \dfrac{(2R_{sn} - d_{xy})^2 (d_{xy} + 4R_{sn})}{32R_{sn}^3 - (2R_{sn} - d_{xy})^2 (d_{xy} + 4R_{sn})} & if \quad 0 \le d_{xy} < 2R_{sn} \\ 0 & if \quad d_{xy} \ge 2R_{sn} \end{cases} \tag{5}$$

Equation 5 defines the modeled correlation in the MATLAB simulation. Table-1 represents the notations and symbols used:

TABLE 1. NOTATIONS AND SYMBOLS USED IN CORRELATION MODELING

Notations and Symbols used	**Details**
Rsn	Range of sensing of Node
Sx	Sensor-Node X
Sy	Sensor-Node Y
Jv	Combined Sensing Regions
Lv	Overlap Sensing Region Volume
Dxy	Distance of separation between nodes X and Y

IV. ENERGY MODEL

Our energy model in this paper is based on that represented in paper[14]. It deals with the modeling of overall power required in the system. And the major factors that need consideration in the energy model are the propagation energy and the energy expended in associated electronics functioning used for trans-reception of message data. Propagation power is also related to distance between transmitter-end and receiver-end. For transmitting a b-bit message, the total energy spent including the power used for electronics part is equated as:-

$$Enr_{TX} = bEnr_{EX} + b*pl*pd_{TX} (n) \tag{6}$$

where Enr represents energy, b is the standard number of bits considered per message, Enr_{EX}: bit-wise-energy dissipated in the various electronics involved, pl is the propagation-loss, pd is the propagation distance, $b*pl*pd_{TX}^{(n)}$ is the total propagation-energy expended to cover the propagation distance pd_{TX} between the transmitter and receiver for b-bit message with a propagation path loss component of n.

For transmission distances less than or equal to d_0, 'pl' is influenced by free-space expression, thereby expressing the transmission energy [16] as:

$$Enr_{TX1} = bEnr_{EX} + b\epsilon_{fspace}\, pd_{TX}{}^{2} \qquad (7)$$

Here: ϵ_{fspace} = pl, represents free-space(fspace)factor

For transmission distances greater than d_0, the expression becomes:

$$Enr_{TX2} = bEnr_{EX} + b\epsilon_{mpathp} pd_{TX}{}^{4} \qquad (8)$$

where ϵ_{mpathp} represents multi-path-factor 'pl'. Crossover distance d_0 is expressed using the following expression [16]:

$$do= \sqrt{\frac{\varepsilon_{\text{fspace}}}{\varepsilon_{\text{mpath}}}} \qquad (9)$$

here ϵ_{fspace} = 10 pJoules/bit/m2 , ϵ_{mpathp} = 0.0013 pJoules/bit/m4 with a standard frequency (914 k.Hz) at 1Mbps rate.

V. PROPOSED METHOD

Our proposed approach employs a centralized clustering algorithm with the locational information of sensor nodes as input at the base-station (BS) or sink level and a distributed cluster management scheme/algorithm at the node-end. The algorithm at the BS facilitates the cluster formation and informs the GPS enabled sensor nodes about their cluster details like number of cluster-members(CMs), their-ID details including location information and also the sink location information. The cluster grouping process is implemented only once at the beginning of the operation and the same clusters are continued till the lifetime of wireless-sensor-network(WSN). The distributed algorithm facilitates cluster-leader(CL) election, nominating primary and secondary cluster heads among all eligible cluster heads in the network during each round of data transfer.

Thus, in our proposed approach we have adopted a dual process of implementation namely a centralized cluster formation process and a distributed process of cluster management and data movement for each rounds. Centralized algorithm which is run at the BS or sink level, takes in the positional information relayed by all the uniformly charged sensor nodes, groups the sensing-nodes into clusters on the basis of minimum satisfying criterion chosen from the table-3 listed below. The minimum satisfying criterion is the degree of overlap considered in the sensing regions of the two nodes considered and is expressed in percentage overlap of sensing range or the correlation coefficient as expressed in equation 1. The cluster information is relayed by the sink to each sensor node and the information includes the cluster member ids, their locations and the number of cluster members. Using these information as input to the distributed algorithms along with the residual energy of sensor nodes based on which the algorithm estimates a chance-value (CV) proportional to the residual energy and the summative-distance of propagation from neighboring member-nodes to self in each cluster. All member-nodes in a cluster relays this parameter CV and highest valued member-node is elected as the leader of that cluster. The distributed algorithm also provides for nomination of primary cluster-Leaders and secondary cluster-Leaders which is decided by the chance-value relayed by neighboring cluster heads and satisfying the minimum overlap percentage of sensor range specified at 10% or a correlation coefficient σ = 0.1 .Once the cluster head is elected along and is classified as a primary cluster-head or a secondary cluster-head during each round, the data transfer begins. The cluster members which satisfies th e minimum overlap percentage of sensor range specified at 10% or a correlation coefficient σ = 0.1 with the cluster's leader or with the primary cluster-Leader, in case its cluster-Leader is secondary cluster-Leader, the member-node is kept in non- transmission mode, thereby saving on energy. The other member nodes send or transmit their data to its pre-defined Leader or head. The secondary cluster-leader or head relays the aggregated information or data to its associated primary-leader, which in turn aggregates and relays its data to the sink, thereby creating a 2-hop or 3-hop route to sink in this proposed approach.

VI. ALGORITHM

Assumptions for centralized algorithm at sink end: (Algorithm-1):

- Inputs to this algorithm are the location information of all uniformly charged sensor nodes and a uniform sensing range of 5 unit radii.
- Centrally located Sink (Base Station) has no constraints as far as energy requirement, complex computational ability and storage requirements are concerned. The broadcasting energy on part of sink or base-station is not considered for analysis and also the energy spent in set-up phase during each round is almost identical to that required in other standard algorithms too and therefore it is not taken in to account for comparative analysis.

Centralized Algorithm for grouping of nodes in to clusters can be understood distinctively by the study of its flow-chart given below:

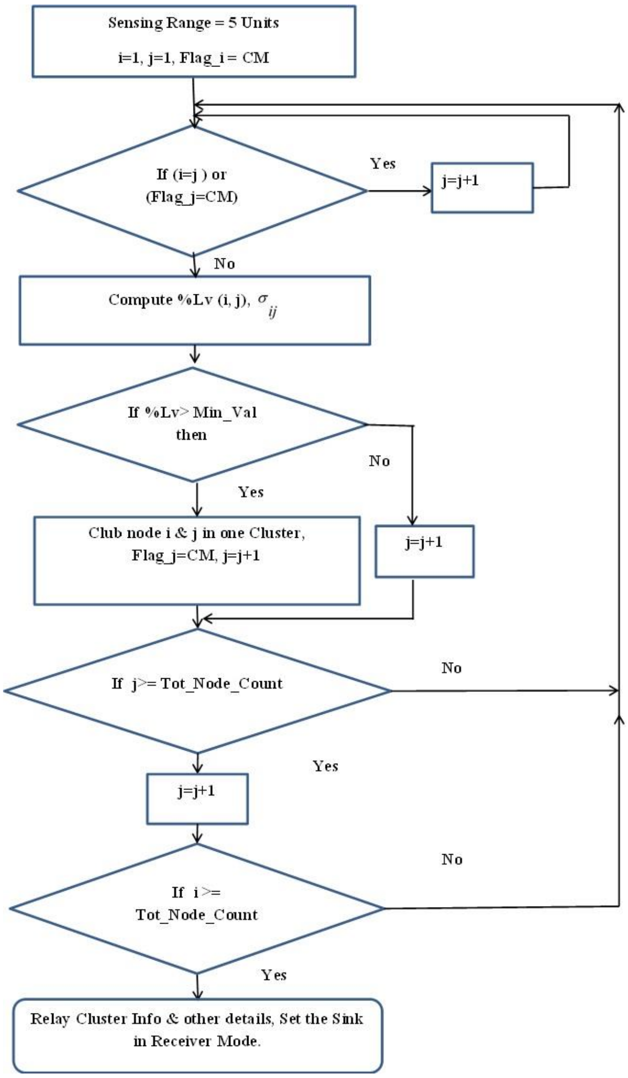

Fig. 2. Flow-chart of centralized Cluster formation algorithm at sink end

Distributed algorithm facilitates cluster head election along with being nominated as the primary leader or associative (secondary) leader. Assumptions for this algorithm which is run at each node for every round of transfer of data from sensing-node(SN) to BS are:

- All sensor nodes have uniform sensing radii of 5 units.
- Sink relays cluster information like total members of each cluster (CMs) along with their CM-IDs and location specifications after Cluster formation process. Sink also relays its location information too
- The nodes are constrained in nature with regards to energy and storage.

Distributed Algorithm at the node level for each round of data transfer:

a. Identify self as active or inactive node based on the residual power left within and relay the status of inactiveness (dead) to fellow cluster members for information
b. Estimate the propagation distances between other live CMs from self, then calculate the total effective distance of propagation.
c. Estimate the chance-value to be cluster-head based on following relation: ((0.7* ResidualEnergy)+0.3*(1/summative-Distance)^2)/ (ResidualEnergy +(1/ summative-Distance)^2)
d. Relay this value to other cluster members and neighboring nodes.
e. Compare own chance-value with that of other members of cluster, which was relayed by them. If the received value of a member node is greater than own value and other member nodes value, then accept that member as its cluster-head and relay acceptance of the node as its CH.
f. Maximum chance-valued member is chosen as the CH for round being considered.
g. CH then multicasts its ascension as Cluster Head along with its other details including ID, location to its CMs and neighboring CHs.
h. Each cluster-leader or head nominates itself as either a primary leader or secondary leader based on the comparison of received chance-values and correlation between them.
i. After all cluster-leaders or heads are marked as primary cluster-leaders or secondary cluster-leaders, round of sensor data transfer is initiated.
j. Cluster-members after sensing data forwards the same to their Cluster-Leader or head (CLs/CHs) provided they satisfy the correlation condition with the CH.
k. CH then forwards its aggregated data to Sink or its associated primary CH based on its own categorization.
l. Jump back, to start from beginning for the next round due.

VII. RESULTS

TABLE 2. PARAMETERS FOR SIMULATION (@MATLAB 2016a)

No	**Design Para-meters**	**Value/Symbol**
1	Total Sensor-Nodes	100
2	WSN Area	100*100
3	Energy of all sensing nodes at start	0.5J
4	Each node’s Sensing Range(SR):	5
5	Distanceof separation between nodes Sx & Sy	Dxy
6.	Spatial-Correlation-Coefficient	σ
7.	Free-Space-factor (for pd less than or equal to d0)	10 nJ/bit/m2
8.	Multi-path-factor (for pd greater than d0)	0.0013 pJ/bit/m4
9.	Energy used in the Electronics for receiving and transmitting purpose	50nJ/bit
10.	Energy used to aggregate received data	5 nJ/bit
11.	Number of bits per message	4000 bits

The simulations are carried out for each Spatial-Correlation Coefficient values listed in TABLE-3:

TABLE 3. VARIOUS VALUES OF CORRELATION VALUES OF CORRELATION-COEFFICIENTS σ_{xy} CONSIDERED TOWARDS FORMATION OF CLUSTERS

Parameter	1	2	3	4	5	6	7
σ_{xy}	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Equivalent Over-Lap %	10%	20%	30%	40%	50%	60%	70%

We have implemented MATLAB@2016 simulations for each of tabulated specific values of σ_{xy} and studied the effects on the whole clustering process in WSN network area of 100 by100 sq. meters with a node density of 100 nodes randomnly distributed in the chosen area. The obtained results are graphically shown below in Fig. 4 to Fig. 10.

Fig. 3 is only for representational purpose depicting the distribution of sensor nodes and cluster formation with $\sigma_{xy} \geq 0.2$.

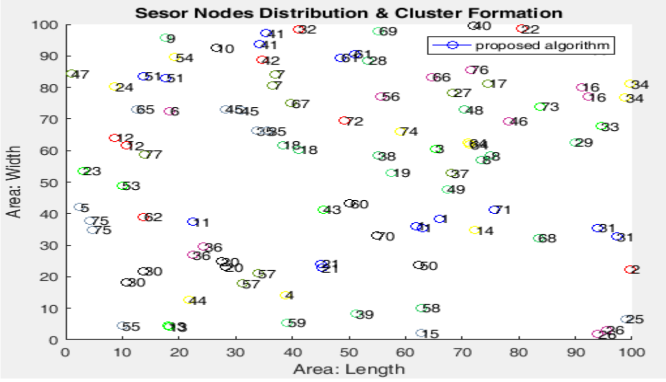

Fig. 3. Distribution of Sensing nodes & cluster establishment $(\sigma >= 0.2)$

For $(\sigma >= 0.1)$ or SR Overlap (SR-OL) percent >= 10%:

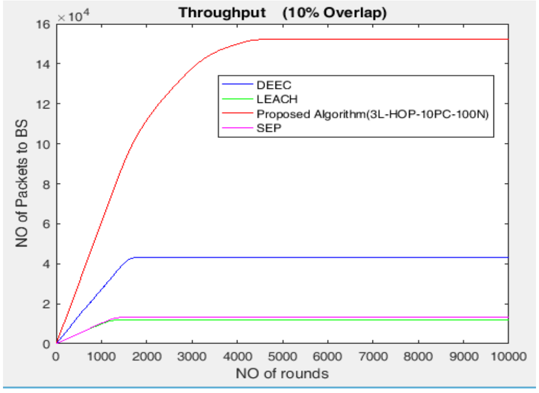

Fig. 4(a). Throughput Measurement and Network-Lifetime for the case $(SN = 100 \vdots \sigma >= 0.1)$

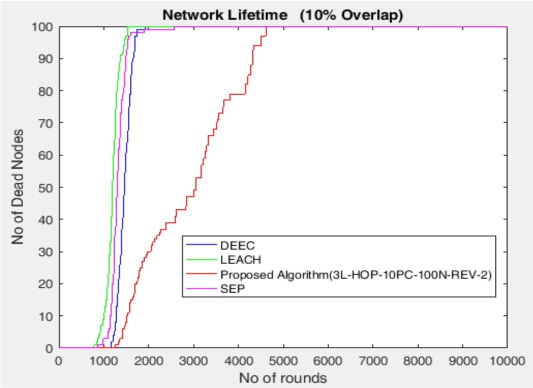

Fig. 4(b). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \;\big|\; \sigma >= 0.1)$

Correlation-Coefficient $(\sigma >= 0.2)$ or SR-OL >= 20% :

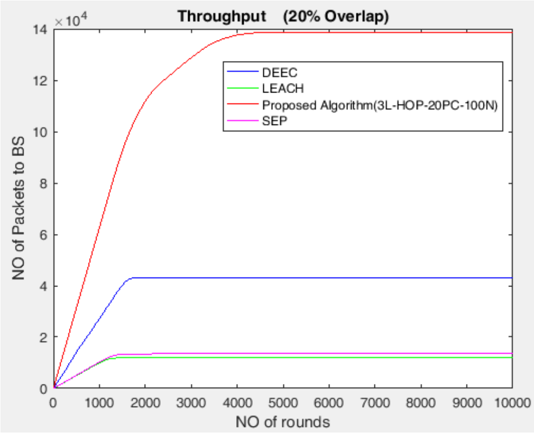

Fig. 5(a). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \; |\sigma >= 0.2)$

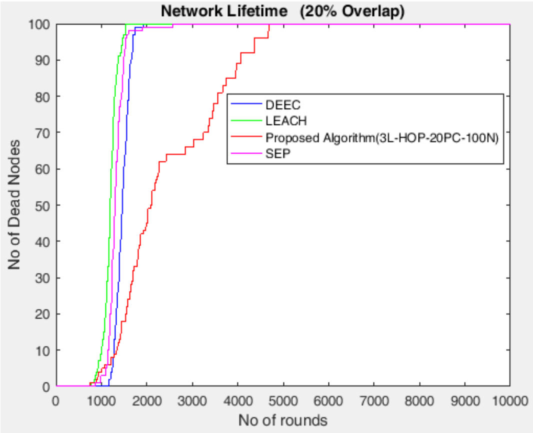

Fig. 5(b). Throughput Measurement and Network-Lifetime for the case $(SN = 100 \vdots \sigma >= 0.2)$

Correlation-Coefficient $(\sigma >= 0.3)$ or SR-OL >= 30% :

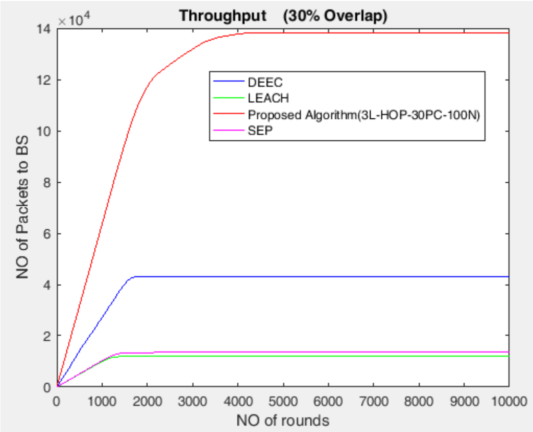

Fig. 6(a). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \; |\sigma >= 0.3)$

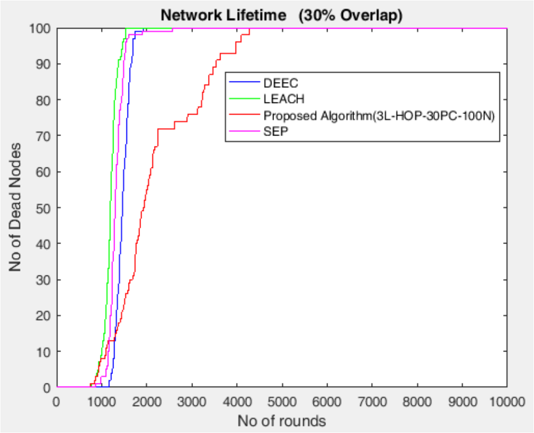

Fig. 6(b). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \,|\, \sigma >= 0.3)$

Correlation-Coefficient $(\sigma >= 0.4)$ or SR-OL >= 40% :

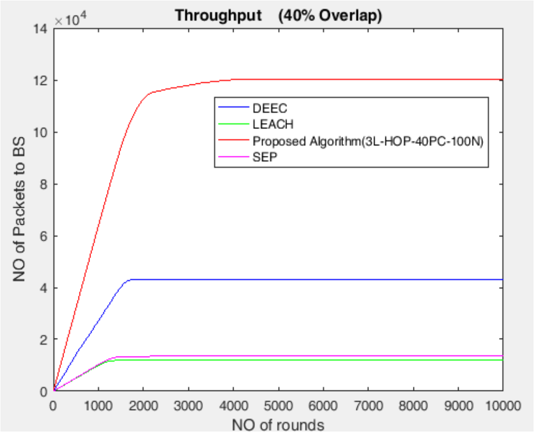

Fig. 7(a). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \,|\, \sigma >= 0.4)$

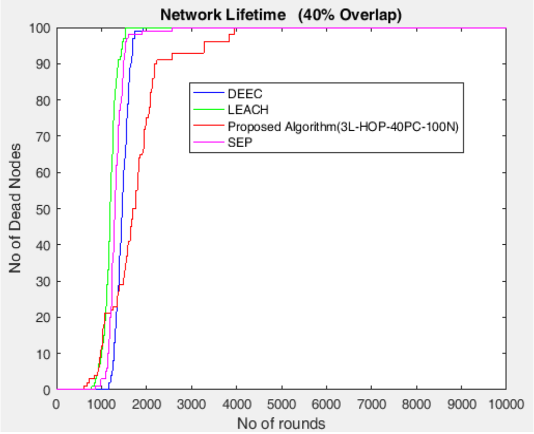

Fig. 7(b). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \,|\, \sigma >= 0.4)$

Correlation-Coefficient $(\sigma >= 0.5)$ or SR-OL >=50% :

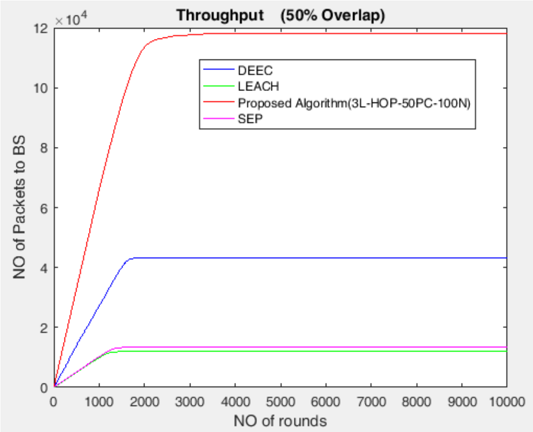

Fig. 8(a). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \;\big|\sigma >= 0.5)$

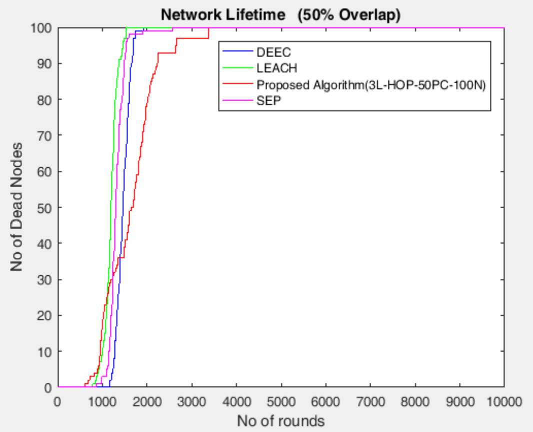

Fig. 8(b). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \;\big|\sigma >= 0.5)$

Correlation-Coefficient $(\sigma >= 0.6)$ or SR-OL >=60% :

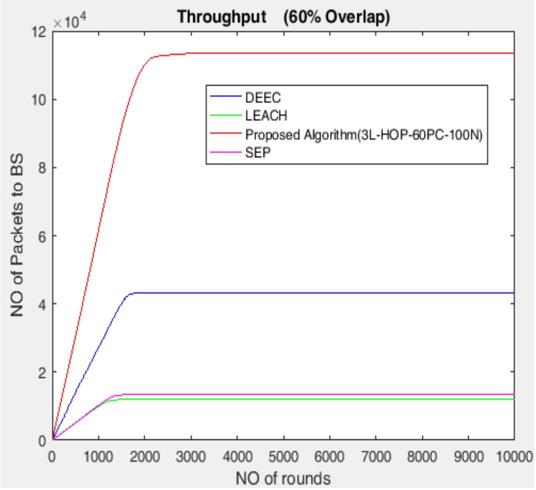

Fig. 9(a). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \;\big|\sigma >= 0.6)$

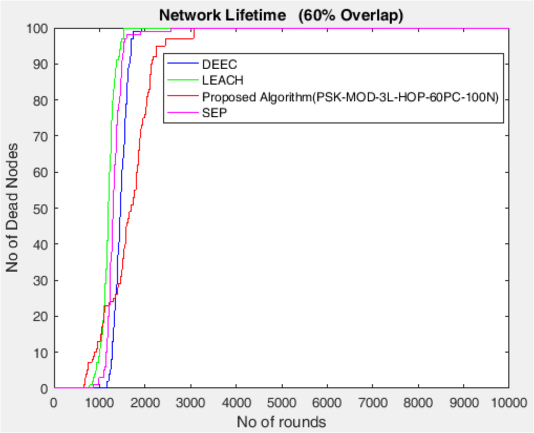

Fig. 9(b). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \;\Big|\sigma >= 0.6)$

Correlation-Coefficient $(\sigma >= 0.7)$ or SR-OL >=70% :

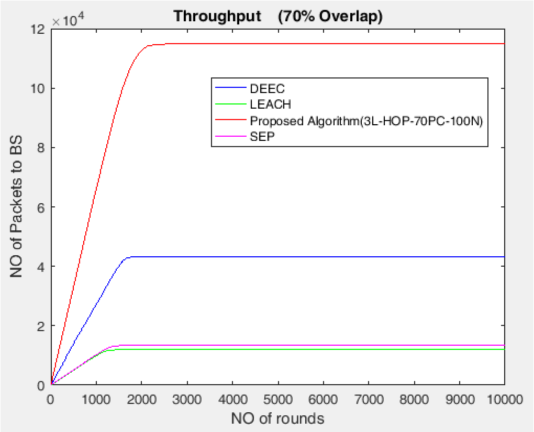

Fig. 10(a). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \;\Big|\sigma >= 0.7)$

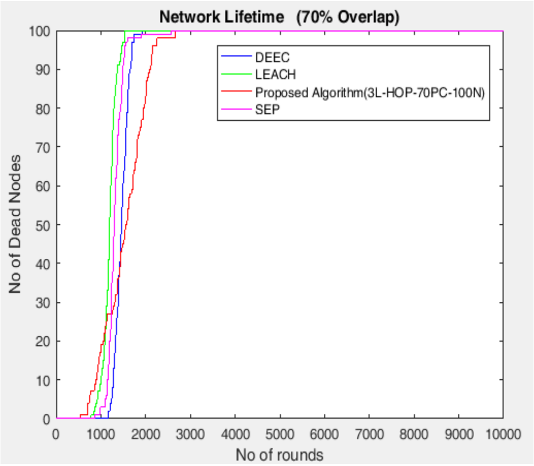

Fig 10(b). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN) = 100 \;\Big|\sigma >= 0.7)$

Simulation results for fixed correlation coefficients of $\sigma >= 0.3$ are shown below fig. 11 and fig. 12 with varied node density of 300 sensing-nodes and 400 sensing-nodes across WSN network of dimension 100 by100 sq. meters and tabulated in tables below:

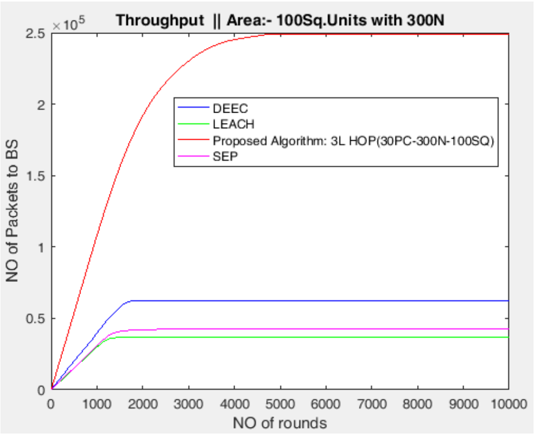

Fig. 11(a). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN)) = 300\ \big|\sigma >= 0.3)$

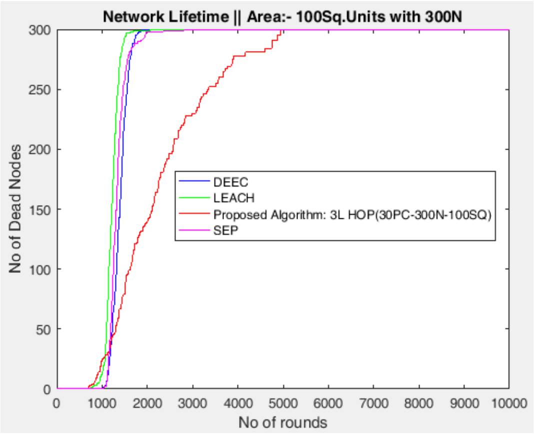

Fig. 11(b). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN)) = 300\ \big|\sigma >= 0.3)$

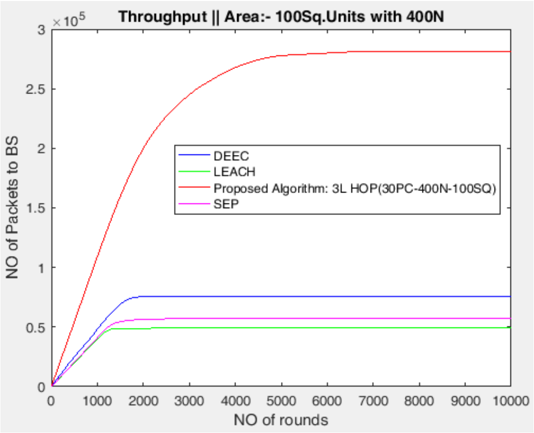

Fig. 12(a). Throughput Measurement and Network-Lifetime for the case $(Sen\sin gNodes(SN)) = 400\ \big|\sigma >= 0.3)$

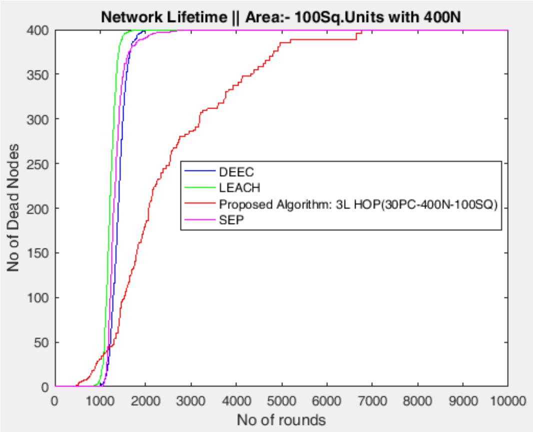

Fig. 12(b). Throughput Measurement and Network-Lifetime fo $(Sen\sin gNodes(SN) = 400 \mid \sigma >= 0.3)$ r the case

TABLE 4. σ or OL % AND ITS RELATED RESULTS FOR 100 (SN) DISPERSED IN A GIVEN NETWORK-AREA (100-SQ.UNITS)

(OL)%	**1*10**	**2*10**	**3*10**	**4*10**	**5*10**	**6*10**	**7*10**
Clusters Available	66	71	84	86	97	92	97
1st Node-Death(ND) Round	1250	748	752	621	621	671	550
10th ND Round	1533	1340	1111	981	960	900	890
20th ND Round	1687	1543	1441	1069	1026	1099	1054
50th ND Round	3047	2091	1941	1713	1650	1691	1570
75th ND Round (Network-Lifetime)	3670	3451	2912	2001	1970	1962	1880
100th ND Round	4621	4683	4281	3961	3380	3080	2661
Throughput[No. of Packets sent-to-BS in its Network Lifetime]	147301	134170	130800	112532	11282	109191	110086

TABLE 5. OBSERVED PARAMETERS DURING SIMULATION OF 3-STANDARD-ALGORITHMS

Parameters/Algorithms	**100-SensorNodes in area of 100*100 Units**			**300-SensorNodes in area of 100*100 Units**			**400-SensorNodes in area of 100*100 Units**		
	1.LEACH	***2.SEP***	***3.DEEC***	***1.LEACH***	***2.SEP***	***3.DEEC***	***1.LEACH***	***2.SEP***	***3.DEEC***
Clusters-formed-Round-wise between:	1-18	1-18	1-36	1-46	1-63	1-107	1-62	1-84	1-149
1st Node-Death (ND)Round	783	863	1165	738	1037	1010	827	1048	999
10% ND Round	1007	1143	1277	1073	1155	1178	1085	1166	1208
20% ND Round	1084	1195	1333	1112	1202	1240	1123	1203	1262
50% ND Round	1192	1296	1456	1215	1316	1391	1211	1298	1396
75% ND Round (Network-Lifetime)	1268	1388	1564	1306	1409	1495	1298	1407	1500

100% ND Round	1543	2565	1916	2064	2819	1867	2578	3281	2049
Throughput[No. of Packets sent-to-BS in its Network Lifetime]	11688	13081	41410	35958	40207	57737	48097	53614	69030

TABLE 6. PARAMETERS OBSERVED FOR σ = 0.3 or OL % = 30% AND WSN-AREA(OF 100SQ.UNITS) WITH VARYING SENSOR NODES

No of Sensor Nodes in WSN	100	300	400
No of Clusters present	84	187	214
1st Node Death (ND) Round	752	698	447
10% ND Round	1111	1111	1142
20% ND Round	1441	1366	1434
50% ND Round	1941	2102	2070
75% ND Round (Network-LifeTime)	2912	2832	3189
100% ND Round	4281	4951	6766
Throughput[No. of Packets sent-to-BS in its Network Lifetime]	130800	225751	250639

We draw the following inferences from the study of our simulation results tabulated above with regards to the two parameters or QoS metrics: throughput measurement and network life-time:

Through-put measurement in simulation study refers to packet quantity forwarded to BS by primary leader (CH/CL). Network life-time on other hand is defined in terms of total number of data transfer rounds facilitated by our proposed algorithm until the death of 75% of sensing-nodes present.

With regards to throughput, it is observed from table-4 and 5 that simulated scheme outperforms the standard-algorithms while considering the results for all conditions of correlation coefficients. The throughput of our simulated scheme is between nine-times to thirteen-times of that observed inLEACH, while it is between eight-times to eleven-times of that observed inSEP. Similarly it is three-times to four-times of what is observed in DEEC-algorithm. In our proposed algorithm, there are increased number of clusters formed and subsequently there are more number of CHs available in our proposed algorithm implementation, hence more energy is utilized for CH to sink communication in comparison to standard algorithms and the effect of this result is observed in our throughput measurements which is clearly higher than all other standard algorithms considered here.

In regards with network lifetime, it is seen that for correlation-coefficient value greater than 0.1, proposed-algorithm has improved features over the 3 standard-algorithms as depicted in table-4 and table-5 for all reference node deaths considered as network lifespan. For a network lifespan of 75% NDs i.e. node-deaths, our approach allows around two-to-three times the network-lifetime seen in SEP and LEACH respectively and around one and half to two times the network-lifetime achieved in DEEC. For correlation-coefficients varying between 0.2 and 0.7, the first sensor node-death (ND) is reported first in our suggested scheme or algorithm wherein DEEC algorithm shows enriched performance in comparison with our suggested scheme for the instance of first node-death.

In case of 30% Overlap or value of σ greater than 0.3, the networkLife-time for 10% NDs in our technique is somewhat enhanced than that observed in LEACH while SEP and DEEC is slightly improved than our simulated technique.

While, for a sensor-network life-span beyond 10% ND (node-deaths) i.e 20% NDs or 50% NDs or 75% NDs or 100% NDs, our proposed algorithm (with correlation-coefficient value greater than 0.3) exhibits a better performance with an increased number of data transfer rounds supported in the WSN system in comparison with the standard algorithms considered here.

If we consider a network life-span defined till the death of 50% node-deaths, our proposed algorithm with values of correlation coefficients greater than 0.4 exhibits a poor performance in comparison with the standard algorithms considered. But if we take into consideration a network life-span till the death of 75% sensing-nodes, our suggested scheme or algorithm gives an improved performance against the standard algorithms.

The impact of increase in sensor node density is reflected in table-5 (part-2 and 3) and table-6. It is observed that crossover at which our algorithm (with $\sigma >= 0.3$ as a study case) betters the other three standard algorithm is still seen at around 15% to 20% of node deaths. Also it is observed that as the node density increases, the difference in terms of number of rounds supported for 20% node deaths and above further increases, thereby favoring our algorithm.

VIII.CONCLUSION

As detailed in the results and findings, as far as throughput metric is concerned, our suggested scheme is better off than the 3-standard schemes or algorithms for all cases considered here. In regards with network lifetime QoS metric, we can conclude that our proposed scheme with $\sigma = 0.1, 0.2$ fares better than the standard algorithms for all the multiple network lifespan definitions considered here. But for higher correlation coefficients, it is observed that our proposed algorithm starts performing well for network lifetime characterized by 20% node deaths and above. Also the performance of our algorithm is seen to be falling for higher values of correlation coefficient say $\sigma =, 0.7$. Hence we can say that the suggested algorithm or scheme gives an improved performance concerning network-lifetime for correlation-coefficients spanning from $\sigma = 0.1$ to $\sigma = 0.6$.

The impact of the increase of sensor nodes density on network lifetime is seen in the increased data transfer rounds supported in network lifetime defined by 20% node deaths and above.

Hence we can conclude that the suggested scheme or algorithm gives a boosted throughput and network lifetime for a small wireless sensor network area and would suit any wireless sensor network application that is characterized by a network lifetime defined by higher percentage of node deaths.

From future development view-point, we may check the application of the proposed algorithm for a wider or larger wireless sensor network area and the impact of higher valued node sensing range on the output.

REFERENCES

[1] C. Poellabauer Dargie, Waltenegus, “Fundamentals of WSNs: Theory & Practice”, John Wiley and Sons,2010.

[2] Eyad T., F. Awad and H. Ahmad, “Location-Aware and Mobility-based performance optimization for WSN”, *Journal of Wireless Mobile Networks, Ubiquitous Computing, & Dependable Applications*, Vol. 8, No. 4, pp. 38-59, 2017.

[3] Zhihua Li and Ping Xin, “Evidence-Efficient multihop clustering routing scheme for large-scale Wireless Sensor Networks”, *Wireless Communications and Mobile Computing*, Vol. 2017, Article-ID:1914956, 2017.

[4] S. Ebadi, “A Multihop Clustering Algorithm for energy saving in Wireless Sensor Networks”, *International Scholarly Research Network - ISRN Sensor Networks*”, Vol. 2012, Article ID 817895, doi:10.5402/2012/817895, 2012

[5] D. Izadi, J. Abawajy, and S. Ghanavati, “An alternative clustering scheme in wsn,” *IEEE Sensors Journal*, vol. 15, No. 7, pp. 4148-4155, 2015.

[6] R. Sinde, F. Begum, K. Njau and S. Kaijage, “Refining network lifetime of WSN using energy-efficient clustering and DRL-based sleep scheduling”, *Sensors-2020*, Vol. 20, No. 1540, doi:-10.3390/s20051540, 2020

[7] Floriano, Nunzia, Simona, “Spatial Correlation based low rnergy aware clustering (LEACH) in a WSN”, *Information and Communcation Technologies and Services*,Vol. 13, No. 4, 2015.

[8] Bhavana, H. T., and Jayanthi K. M., "Spatial Correlation based clustering-algorithm for random & uniform topology in WSNs." *Int.Journal of Research in Engg.&Tech. (IJRET)*, Vol. 3, No. 6, pp. 83-87, 2014.

[9] B.Gedik, L. Liu and Philip S., "ASAP: An adaptive sampling approach to data collection in Sensor Networks", *IEEE Trans. On parallel and distr. Sys*., 2007.

[10] Vuran, Mehmet C., Ö.B. Akan, and Ian F. Akyildiz, "Spatiotemporal correlation: theory & applications for WSNs." *Comp.Networks*, Vol. 45, No. 3, pp. 246-258, 2004.

[11] Ming-Hui Tsai and Yueh-Min Huang, “A Sub-Clustering Algorithm based on spatial data correlation for energy conservation in Wireless Sensor Networks”, *Sensors*, Vol. 14, pp. 21858-21871; doi:10.3390/s141121858, 2014.

[12] Zhidan L., Wei X., Bo Z., Yongchao W., D. Lu, “Distributed spatial correlation-based clustering for approximate data collection in WSNs”, in *Proceedings of IEEE 27th International Conference on Advanced Information Networking and Applications*, doi: 10.1109/AINA.2013.26, 2013.

[13] Ali J., S. El Fkihi, B. Elbhiri and Driss A., “An Energy-Efficient clustering routing algorithm based on geographic position and residual energy for WSN”, *Journal of Computer Networks and Communications*, Vol. 2015, Article ID-170138, http://dx.doi.org/10.1155/2015/170138, 2015

[14] V.K. Arora, Vishal Sharma, and Monika S, "A survey on LEACH and other routing protocols in wireless sensor network ", *Elsevier Optik Journal*, Vol. 127, pp. 6590–6600, 2016.

[15] Xu, Lina, R. Collier, and Gregory MP, "A survey of clustering techniques in wsns and consideration of the challenges of applying such to 5g IOT scenarios", *IEEE IoT Journal*, Vol. 6, No. 1, 2017.

[16] Frank C, N. Aslam, "Analysis of LEACH Energy Parameters", *ELSEVIER Science Direct*, pp. 933-938, 2011.

[17] Salman D., Khalid & Zubair., "Distance distributions in regular polygons", *IEEE Transactions on Vehicular-Tech*.”, Vol. 62, pp. 2363-2368, 2013.

[18] Tamilarasi N., K. Parvathi, "Extension of network Lifetime using fuzzy c-means model and cluster hierarchy concept" , *International Journal of Recent Trends in Engineering & Research*, Vol. 2, No. 8, pp. 302-308, 2016.

[19] S.S. Panchikattil and Dnyandeo J. P., "Spatial Clustering with sequential CH selection for energy-efficient WSN", in *Proceedings of International Conference on Wireless Communication, Lecture Notes on Data Engineering and Communications Technologies 36*, https://doi.org/10.1007/978-981-15-1002-1_30 © Springer Nature Singapore Pte Ltd. 2020.