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OPTIMIZED COVERAGE AND CONNECTIVITY FOR RANDOMLY DEPLOYED WIRELESS SENSOR NETWORK FOR LIFETIME CONSERVATORY

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ABSTRACT

The success of any routing protocol in wireless sensor network (WSN) depends upon how best the connectivity is, and the optimization with constraint resources depends upon the issue of coverage. Various techniques have been adopted and suggested for the pattern based deployment, whereas the proposed study has considered the analysis of network lifetime from coverage and connectivity using a random deployment of with higher dimension WSN. The proposed study introduces a protocol termed as MP-ECCNL that address the best possible provisioning and routing the precise information using multi-hop transmission pattern. The protocol extracts the higher dimensionality of route sustainment for the network lifetime, furnishes better routing and higher exploitation of network resources, and also optimizes the utilization of power facilitated on the sensor nodes. The results are accomplished after performing the experiments; by comparing MP-ECCNL with LEACH algorithm, MP-ECCNL found to be highly successful in maintaining coverage and connectivity to a higher extent in large scale WSN environment.

Keywords: Connectivity, Coverage, LEACH, Optimization, Wireless Sensor Network.

I. INTRODUCTION

The Wireless Sensor network (WSN) consists of the autonomous sensors which are spatially distributed in an area to monitor the physical and environmental conditions like the temperature, sound etc. [1]. The prime research topic extends to security aspects of sensor networks, coverage and connectivity problems etc. The usage of applications of sensor networks has increased in the areas like Agriculture, Air pollution, Water wastage monitoring etc. A typical wireless sensor network consists of thousands of sensor nodes, deployed either randomly or according to some predefined statistical distribution; over a geographic region of interest. A sensor node by itself has severe resource constraints, such as limited battery power, limited signal processing, limited computation and communication capabilities, and a small amount of memory; hence it can sense only a limited portion of the environment. However, when a group of sensor nodes collaborate with each other, they can accomplish a much bigger task efficiently [2]. One important criterion for being able to deploy an efficient sensor network is to find optimal node placement strategies. Deploying nodes in large sensing fields requires efficient topology control [3]. Nodes can be either placed manually at predetermined locations or dropped from an aircraft. However, as the sensors are randomly scattered in most practical situations, it is difficult to find a random deployment strategy that minimizes cost, reduces computation and communication, resilient to node failures, and provides a high degree of area coverage [3]. Connectivity is critical for WSNs, as information collected has to be transmitted to data collection or processing centers. This is only possible if there is a path from each node to the collection center. The connectivity of a WSN is usually studied by considering the graph associated. Optimal resource management and assuring reliable Quality of Service (QoS) are the two most essential requirements in ad hoc wireless sensor networks. However, due to severe resource constraints and aggressive environmental conditions, it is nontrivial to design an efficient deployment strategy that would minimize cost, reduce computation, minimize node-to-node communication, and provide a high degree of area coverage, while at the same time maintaining a globally connected network. Hence the coverage and connectivity problems in sensor networks have to be addressed and a very efficient protocol has to be designed for coverage and connectivity problems in WSNs. The notion of coverage and connectivity are completely different but have due impact on each other in the cumulative network lifetime. Degree of coverage at a specific point in the sensing field can be related to the number of sensors whose sensing range covers that specific point. The term 'Connectivity' is similarly significant in WSN just like coverage. If a sensor network is modeled as a graph with sensor nodes as vertices and the communication link, if it exists, between any two nodes as an edge, then, by a connected network we mean that the underlying graph is connected, that is, between any two nodes there exists a single-hop or multi-hop communication path consisting of consecutive edges in the graph. The current work discusses about a model that addresses the issues of coverage and connectivity and simultaneously addresses the impact of it in cumulative network lifetime.

II. RELATED WORK

Dong e.t al. [4] demonstrates a practical graph theoretical framework for connectivity-based coverage problem in wireless ad hoc and sensor networks. They take the first attempt toward designing a distributed coverage algorithm to achieve configurable coverage requirements with using merely connectivity information. They attempt to prove the correctness of this design and evaluate it through extensive simulations and comparisons with the state-of the-art approach.

Kim e.t al [5] demonstrates the WSN connectivity issues and the regular sensor deployment patterns to achieve coverage and connectivity under different ratios of sensor nodes communication range to their sensing range for wireless sensor networks. The information will be retrieved by using the inverse method of the proposed theorems which estimate the coverage level of the target region when sensors are deployed.

Wawryszczuk e.t al [6] depicts about the control mechanism in wireless sensor network for particular specific topology such that it reduces the energy consumption without affecting the networks connectivity and coverage. The network shaped by this method capable of detecting object moving on ground and the coverage consistency is guaranteed.

Khan e.t al [7] demonstrates the integration of connectivity and coverage in wireless sensor networks. They moreover demonstrated a method to repositioning multi-nodes based on a novel dynamic load, at this point by involving one or multiple neighbors of the simultaneously failed node to recover network from failure. This approach includes Recovery through Inward Motion or popularly called as RIM and Nearest Neighbor or known as NN algorithm when simultaneous node failure occurs. The final result subsequently will verify the projected method and show efficiency with respect to the moved distance, amount of minimized in field coverage and quantity of substituted messages.

Raha e.t al [8] demonstrated an optimal deployment algorithm of sensors in a given region to provide desired coverage and connectivity for a wireless sensor network. The proposed method divides the given area of interest into two distinct sub regions termed as the central and edge regions. In each region, a unique scheme is used to determine the number and location of sensors required to monitor and completely cover the region keeping the connectivity and coverage ranges of the sensors, their hardware specification and the dimensions of the region concerned as the constraints and their scheme reduces the overhead in determining the position of sensors for deployment by following a coverage and connectivity algorithm of lesser complexity rather than those present in related schemes.

Khalil e.t.al [9] proposed a solution to solve the problem of coverage and connectivity, called Connected Cover Set based on IDentity of node (CCSID). The idea was to adapt a concept from graph theory of connected dominating sets having minimum cardinality MCDS, to build cover sets. The solution CCSID divides the set of deployed nodes into subsets. In each subset, a minimum number of active nodes are selected to ensure coverage and connectivity and the work is based on a graph theory formulation using a Minimum Connected Dominating Sets concept, in order to construct cover sets.

The coverage and connectivity problem in wireless sensor network has become one of hot research topic area in WSN. Although there are many techniques proposed for coverage and connectivity problems in sensor networks still it remains the challenging area for developing new type of protocol that efficiently addresses the coverage and connectivity problems in WSN.

III. PROBLEM FORMULATION

The proposed system considers the problems associated with the design mechanism of coverage as well as connectivity issues in WSN. Let us consider N_{Sen} that represents number of sensors required to measure the transmission and sensing zone in n^{th} data collection i.e.

$$N_{sen}= \{N_{Seni} | N_{seni} \in P_n \text{ and } Q_n=1\} \quad (1)$$

In the above eq. (1), $N_{seni}= \{N_{sen1}, N_{sen2}. N_{seni}\}$, P_n is vector in undirected graph G= (P, X), where $P=P_{seni} \cup \{P_{senD}\}$ and X is the set of edges. Therefore, in order to satisfy the coverage and connectivity issue, it is needed that N_{sen} to be a cover set as illustrated in eq (2).

$$\bigcup_{N_{seni} \in C} CA(N_{seni}) \supset D \quad (2)$$

The above equation (2) shows the condition of cover set that basically interprets that N_{seni} should be inside the set of CA(coverage area), where N_{seni} is randomly distributed to cover the area D with initial power P_o. In order to simplify the problems in eq. (1), the cumulative surveillance area of sensors are classified into a set of disjoint sub-regions (S_{R1}, ..., S_{RL}) and a subset S_{Rl}= (N_{sen1}, N_{sen2}, . . . N_{seni}) is associated with each sub-region, for which reason, it is possible to represent a Boolean variable i_k, where k is cumulative number for data gathered that can be carried by the considered WSN. Hence, the coverage and connectivity condition can be interpreted as:

$$\sum_{i:N_{seni}\in S_{Rl}} i_k \geq 1, \forall l \quad (3)$$

The above equation represents that there should be at least one sensor node encapsulated in one sub-region in every clusters. The proposed system also addresses the power limitations of the WSN too along with coverage and connectivity issue. Considering N_{seni} with initial power P_o, the issues of network lifetime consideration is that at the time of data aggregation, the cumulative drained power by sensor N_{seni} can never be higher than its preliminary power factor P_o.

IV. PROPOSED SYSTEM

The proposed study addresses the issues of cumulative network lifetime maximization considering the situation where the data packet is transmitted across the network from one to another hops till it reaches base station or sink. Usually, majority of the simulation study in data aggregation techniques considers the present of base station in the center of the simulation (in case of static network) or no position is fixed (in case of mobile sink). But, the present work do not consider either of the above two cases, as the focus is purely to understand the impact of coverage/connectivity issues over cumulative network lifetime and thereby the proposed study is termed as Multi-hop-Point Enhancing Coverage / Connectivity with Network Lifetime (MP-ECCNL). Along with the target of provisioning the sensor nodes for measuring the data to engulf the entire area to higher extent, the proposed model also focus on designing the path of transmission in such a way that the simulation takes place by the approach of multi-hop technique till the data reaches the sink. As known from the fundamentals of WSN that sensor nodes have higher limitations of power, therefore, the MP-ECCNL also targets to design an optimal policy for provisioning and routing in order to enhance the cumulative lifetime of WSN. Usually, the term 'lifetime' is the direct interpretation of battery lifetime in WSN, but in the present work it is also defined as the quantity of the logical data gathered that can be processed from the time the sensor network is active (or deployed) to the time that either we do not see a set of sensors (N_{seni}) that engulfs the surveillance area or the measured data in the covered set (CA) cannot be transmitted to the access point.

The fundamental concept of the MP-ECCNL is equivalent to the network lifetime maximization method considering coverage and connectivity issues where the model initially explores the most thinly covered coverage area and performs exploring all the possible routes considering its residual power. In the presence of sensor nodes that engulfs the thinly coverage area, the MP-ECCNL technique explores a sensor node and the associated routes from that sensor node to the base station in order to cover up the thinly coverage area depending upon the score of the residual power of each sensor nodes, which will be now termed as 'connector nodes (CN)'. The CN is chosen based on the presence of highest residual power and spatial distances of the sensor nodes and will be responsible to perform the critical multi-hop data transfer from sensor nodes to base station at other end. The modelling of MP-ECCNL initiates with the design of a communication routes among every potential sensor nodes to the base station and classify the entire region into set of a disjoint vector of thinly coverage area. The model then categorize a thinly coverage area and selects the CN for analyzing data and evaluate its corresponding routes from multiple hops to the base station. However, with random distribution there is a possibility of uncovered nodes (partitioned nodes).The framework removes all the coverage zones from major connectivity to minor connectivity extents considering probability of clustering viewpoint. The process is iterated until all the sensor nodes become subset of coverage area (CA). The model performs better load balancing and minimized power draining by performing multi-hop, where the load of data transmission is equally distributed to the hops using CN. The proposed model also evaluates the route from the chosen CN to the base station for the transmission of data. For proper visualization of impact of coverage and connectivity on network lifetime, cost is associated with every route established in the multi-hop scenario from CN to base station. Only the routes with lesser cost are selected from multi-hop routing of data packets from sensors to the base station.

The proposed study considers cost of the route as the summation of the cost of the link associated in that routes and it closely relates to the issue that which sensor node should the MP-ECCNL selects for prolonging the network lifetime. Using the similar mechanism, if the active sensor node can be seen to cover the whole area, the process is repeated to find N_{seni} or set of wireless sensor nodes for the next cycle of data transmission. The entire process is repeated until the battery of the sensor nodes becomes dead. Hence, the process of MP-ECCNL confirms a complete visualization of the enhancement of coverage and connectivity with improvement of network lifetime.

V. IMPLEMENTATION & RESULTS

The proposed system is executed on 32 bit Windows OS with 1.84 GHz (min) processor speed and programming platform is considered in Matlab. It is also known that 64-bit architectures perform 40% faster computation than 32 bit architectures. Although the computer industry is encountering transition from 32-bit architectures to 64-bit architecture, but still majority of the users (academicians, researchers, commercial user, corporate users) still uses 32-bit windows OS and therefore the proposed study is chosen to experimented over 32 bit windows OS. The accomplished results of proposed study are compared with LEACH protocol considering various numerical values for the performance of the MP-ECCNL.

Figure 1 shows that the proposed simulation framework can be studied from any position of the base station with a distance from CN for performing multi-hop transmission. The figure shows the placement of base station in coordinates (0,0), (100,0), (100,100), and (0, 100). This feature also furnishes higher flexibility and potentiality to the simulation study as compared to LEACH protocol where distance is one of the major factors. The experiment is performed considered 100x100 square units of distance, where 100-500 numbers of nodes that are distributed randomly can be simulated effectively for the study purpose.

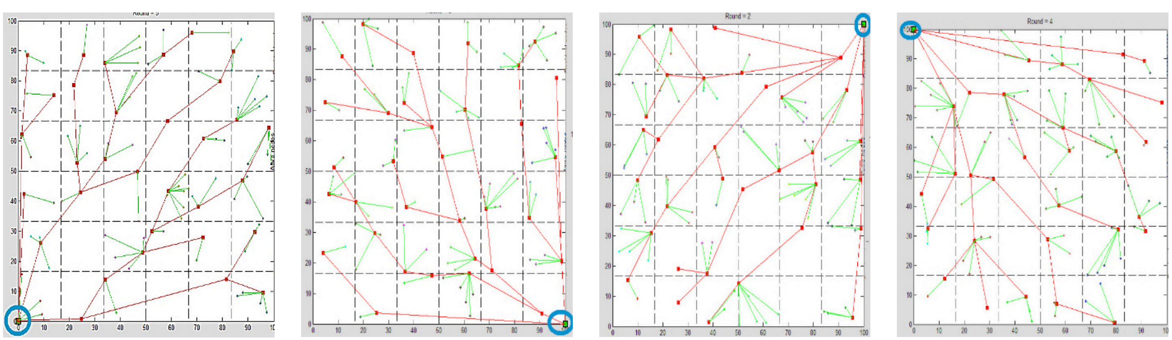


Figure 1. Placement of the base station in the MP-ECCNL

The simulation considers the coverage range of R_{CA} and highest communication range of $R_{High\_CA}=2R_{CA}$. The preliminary power allocation value for every sensor is considered as 0.1J uniformly. For the purpose of evaluating the power efficiency of the cumulative network, we consider that,

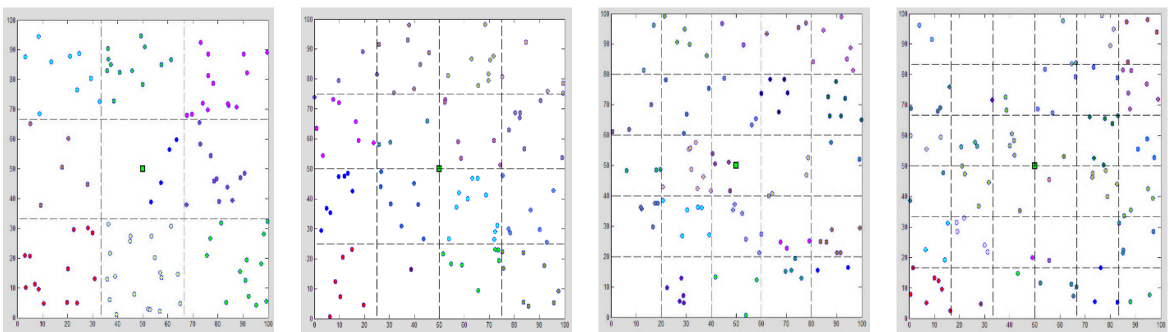
$$p_t^{i,j} = \alpha . Dist_{i,j}^{\beta} \qquad (4)$$

In the above eq. (4), *p* is power drained for transmitting data packet from N_{sen_i} to $N_{sen_j}$with distance $Dist_{i,j}$, while the constant α is considered as 0.001 and path loss factor β is considered as 2. The performance evaluation is performed on MP-ECCNL to analyze the cumulative network lifetime with broad visualization of nodes with higher battery reduced to dead nodes.

The analysis is classified into two types:

1) Evaluating MP-ECCNL (Proposed Model)
2) Evaluating LEACH (Standard Model)

The analysis considers the investigating the power depletion phenomenon of the sensor nodes, where the simulation area is divided into set of probabilities of the clusters to magnify the understanding of the MP-ECCNL.



P=0.1 P=0.2 P=0.3 P=0.4

Figure 2. Visualization of Probabilities of Clusters

The above figure shows that probability factor of the design of cluster formulation of the MP-ECCNL model, which means that with the defined set of probability of selection of CN; the clusters will be automatically formulated to facilitate coverage and connectivity. Another interesting fact is this clustering will lead to generation of disjoin clustering zones that ensures reduced power consumption for transmission, where each zone (cluster) S_{RL} is explored from,

$$\sum_{i \in S_{RL}} \frac{P_o}{Pc} \qquad (5)$$

Here, P_o is the initial power of the sensor which we have considered as 0.1J and P_c is power required to perform transmission from N_{seni} to its nearest node found spatially. Considering power dissipation of the transmitter hardware as zero (as we do not consider that power is drained even in measuring data from micro-level), therefore eq. (5) can be evaluated for its minimum value. Setting the coverage and connectivity with different integer values and evaluating with various types of power (initial), the simulation is conducted with different placement of base station. The accomplished output of the MP-ECCNL is shown from Fig 3 to Fig 5.

Fig.3 exhibits that with the increase number of iterations of the data collection, the instances of network lifetime is found with gradual growth although it has maintained uniformity till 50th of iteration. The higher rate of network lifetime was found at 500th iteration. Fig.4 exhibits the analysis of iterations with power depletion of the connector nodes with respect to the increment of the iterations. The results show that while the curve was found to maintain uniform availability of highest degree, the curve exhibited its gradual descent from 50th iterations. Fig.5 highlights the analysis of the iterations with route sustainance where it can be seen that curve makes a gradual descents without any abnormalities or ireguarites.Fig.3 exhibits that with the increase number of iterations of the data collection, the instances of power depletion is found with gradual growth although it has maintained uniformity till 50th of iteration. The higher rate of power depletion was found at 500th iteration. Fig.4 exhibits the availability of the connector nodes with respect to the increment of the iterations. The results shows that while the curve was found to maintain uniform availability of highest degree, the curve exhibited its gradual descent from 50th iterations.

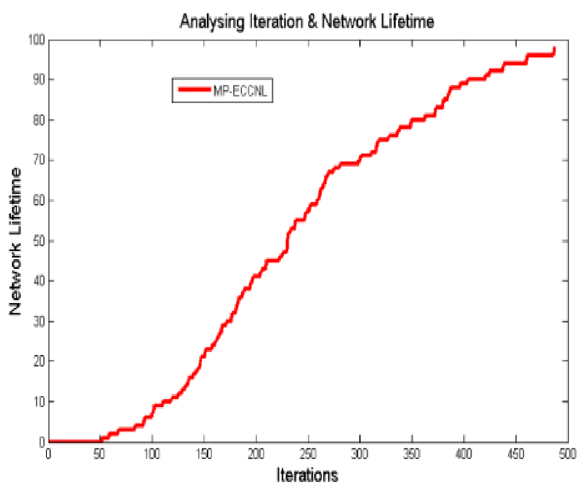


Figure 3. Analyzing Iteration and network lifetime of MP-ECCNL

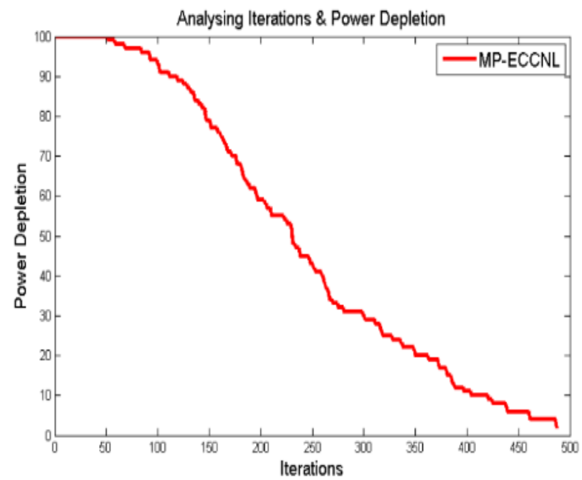


Figure 4. Analyzing Iteration and power depletion of CN of MP-ECCNL

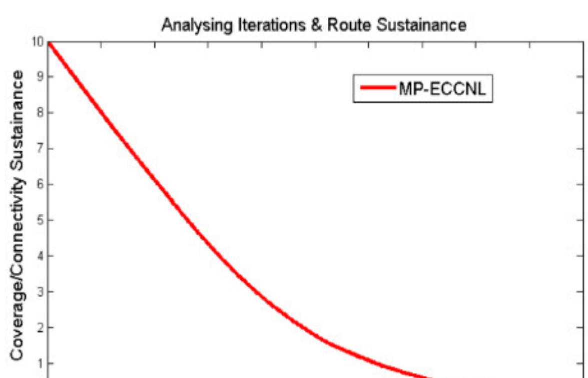


Figure 5. Analyzing Iterations and route sustainance of MP-ECCNL

Fig. 6-8 exhibits the results accomplished from standard LEACH algorithm. Although, it can be seen that the proposed MP-ECCNL has outperformed in network lifetime and optimal route sustainance, the extent of power depletion of CN is better in LEACH. It can be considered from the fact that the proposed model has initially allocated uniform power to all the sensor nodes, where the data transmission is considered from multi-hop viewpoint, hence, it requires power for performing multi-hop transmission till the data reaches its destined base-station.

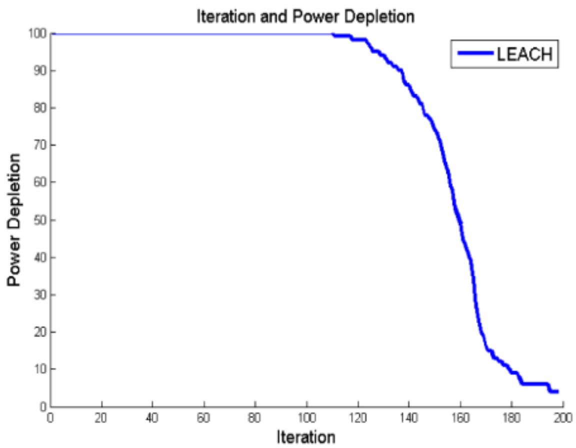


Figure 6. Analyzing Iteration and network lifetime of LEACH

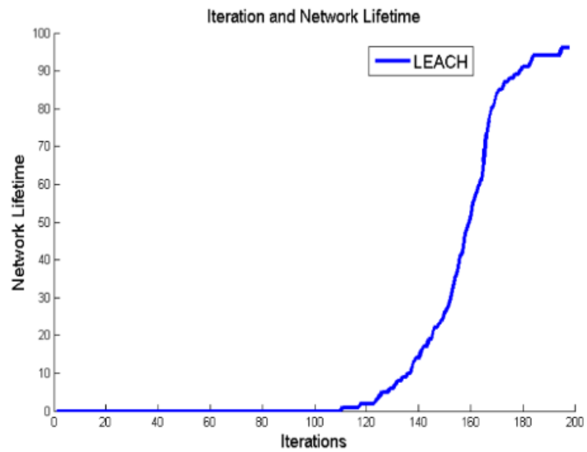


Figure 7. Analyzing Iteration and power depletion of CN of LEACH

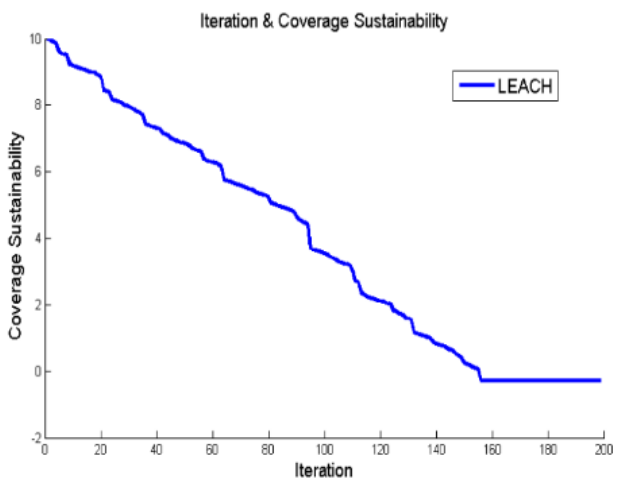


Figure 8. Analyzing Iterations and coverage sustainability of LEACH

However, it can be see that coverage and connectivity issues are highly resolved to a larger extent in comparison to LEACH algorithm. One of the prime reason behind this fact is that LEACH protocol allows the cluster node to be elected randomly, whereas we have considered the criteria of selection of connector node and not the cluster head, as we are performing the communication in multi-hop technique that ensures the optimal number and distribution of CN. The proposed model has considered probability of CN node with multiple values as seen in Fig 2; however, LEACH considers every node, inspite of their low residual power to have equivalent chances to perform data collection and forwarding to base station. Because of this adoption, the proposed model ensure higher network lifetime even comparing with standards LEACH algorithm and on the other hand it can be seen that node death rate is faster in LEACH. Moreover adoption of CN to perform multi-hop transmission gives better dynamicity as well as flexibility to the proposed MP-ECCNL model to be adopted by large scale WSN, in which case LEACH is not found with higher extensibility in large scale WSN that has negative effects on its coverage and connectivity issues. Hence, it can be seen that the proposed system has better coverage and connectivity factors with positive impact of cumulative network lifetime.

VI. CONCLUSION

The current paper has discussed the problems of cumulative network lifetime maximization in connection with coverage and connectivity issues in WSN. The proposed evaluation has considered multihop transmission that deliberately reduces the energy drainage and maximizes the network lifetime of WSN. The final accomplished results are compared with that accomplished from LEACH algorithm to find the proposed algorithm has outperformed LEACH with respect to coverage sustainability and network lifetime.

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