Improved Differential Evolution in WSN Node Deployment

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ABSTRACT

WSN consists of a large number of tiny sensor nodes distributed over a large area with one or more powerful sinks or base stations collecting information from these sensor nodes. The sensor nodes are equipped with battery and whose battery cannot be replaced after deployment. Therefore, deployment of sensor nodes has serious impact on network lifetime. Deployment can be random or pre-determined. Random deployment of sensor nodes most of the times generates an initial communication gap in the sensing field even in a highly dense network. In either case, the resulting inter-node distances may cause lack of communication and subsequently degrades the network performance. In this paper, we have proposed an enhanced deployment algorithm based on Differential Evolution (DE). The main motive of our algorithm is to reduce energy conservation during deployment & communication between distance nodes and for this purpose; we are using differential evolution optimization method. The algorithm aims at extending network lifetime by using a minimum number of relays. We have measured results on homogeneous and heterogeneous models and the simulation results are showing that heterogeneous models are providing better results as compared to homogeneous models under differential evolution.

Keyword :- *wireless sensor network (WSN), differential evolution (DE), node deployment (ND)*

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1. INTRODUCTION

A wireless sensor network is composed of tens to thousands of sensor nodes which are densely deployed in a sensor field and have the capability to collect data and route data back to base station. WSN consists of a large number of tiny sensor nodes distributed over a large area with one or more powerful sinks or base stations collecting information from these sensor nodes [2]. All sensor nodes have limited power supply and have the capabilities of information sensing, data processing and wireless communication. The nodes consist of the sensor module which senses the data, the processor and memory which perform local computation on the sensed data and store data, the transceiver responsible for exchange information with neighbour nodes and a power supply unit for node’s energy.

2. NODE DEPLOYMENT

Deployment of sensor nodes has serious impact on network lifetime. We aware of, that, a wireless sensor network are a collection of sensor nodes which are deployed in a given area of interest. The sensor nodes are equipped with battery and whose battery cannot be replaced after deployment, so the major concern is to conserve the energy of the sensor nodes. Therefore, deployment of sensor nodes has serious impact on network lifetime. The nature of deployment of sensor node depends on the type of sensors, application and the environment where the network will operate [6]. Deployment of sensor nodes can be random or deterministic:

2.1 Random Node Deployment

In random node deployment, if there are “n” sensors, then they all have equal probability of being located, at any point inside a sensor field. Random node deployment can be done just by throwing sensor nodes from air [5]. As a result of this there is tremendous change in node density because some nodes are placed closer to each other and some are placed away from each other.

2.2 Deterministic Node Deployment

In deterministic node deployment the positions of nodes are predefined i.e. positions of the sensors are calculated before deployment and then the sensors are placed on their respective positions. The deterministic deployment is used in those missions where the deployment area is physically reachable [5]. As compared to random deployment, deterministic deployment uses fewer number of sensor nodes to cover a given area. Therefore it is more preferable over random deployment.

3. RELATED WORK

G. Horvat et. el. [1] examined the impact of deployment parameters on QOS in a Wireless Sensor Network. Quality of Service (QOS) maintain in large-scale Wireless Sensor Networks (WSNs) is becoming a hot topic in WSN area of research. Alternatively with the excess of nodes in a network, a combined intelligence approach comes into focus for solving different issues. Three deployment parameters: number of nodes, coverage areas size and transmitter power of a node versus QOS metrics. Three collective metrics were selected to study the impact on QOS: collective latency, collective jitter and collective packet loss probability. **C. C. Hsiao et. el. [2]** proposed two methods, path division and path bounding to support in sensor node deployment. In path division, the path is separated into some quasi-linear sub-paths such that the sub-paths can be simply process using path bounding mechanism. In path bounding, three sensor nodes are first deploy for each sub-path such that the area separator along the sub-path can be as little as possible. For paths with higher tortuousness, they can be first processed with path division mechanism to turn into numerous quasi-linear sub-paths. Path bounding mechanisms can then be applied to the sub-paths. **Shuai Yu et. el. [3]** proposed an Artificial Fish School Algorithm which is used to optimize the node deployment of wireless sensor network. The program of optimization based on artificial fish school algorithm is planned to solve this problem. In the recreation research, we use a basic road grid map, and the outcome compared with initial manual deployment, artificial fish school algorithm enhanced the nodes deployment of wireless sensor network for Traffic Monitoring System. **Y. Gu et. el. [4]** CHs is working to reduce energy cost, so as to get better their energy efficiency. A clustering routing algorithm based on uneven node deployment (CRAUND) is presented. The density of sensor nodes in nearer area to the sink node is larger than those in further area. In order that simply designing better strategies to divert traffic, the problem of 'energy hole' could be essentially resolved. The radical reason of energy unbalance in WSN is the link of data transmission between CH nodes. Inner-cluster node competition is introduced to optimize cluster head (CH) selection. **Y. Xu et. el. [5**] studied the density in monitored area to establish the optimal deployment of nodes by taking into consideration of different requirements. The model allows us to get the most capable density for sub-region to attain energy balance and extend the lifetime of network. Wireless sensor networks (WSNs) frequently have many to one pattern and dynamic monitoring requirements, leading to energy imbalance. Working our dynamic deployment scheme, energy balance can be achieved. Simulation outcome confirm that the dynamic placement performs better in prolonging the lifetime of WSNs. **U. M. Kulkarni et. el. [6]** proposed the effect of energy on delay and throughput with respect to different types of deployments like static and dynamic. The major objective of any application using WSN is to use less energy and expand the lifetime of the WSN. For any kind of network communication, quality of service plays a main role. QOS can be either Application-Specific or Network-Specific. Network-specific QOS is measured with respect to different parameters like delay, bandwidth, and throughput. **K. H. Lee et. el. [7]** proposed the protocol of Pair-wise key establishment between sensor node. The proposed way increases the accessibility by clustering the network in three dimensional, which has lesser number of path and better energy than the plane allocation. The protocol of pair-wise key Establishment scheme using Bivariate Polynomial based on cluster. **L. A. Tharakan et. el [8]** measure the efficiency of a network usually defined about how efficient in sensing the given physical ambience. Energy efficient coverage of sensor nodes in Wireless sensor network is necessary and has lot of scopes in the area of research. Finding a greatest node deployment policy that offers high degree of coverage with network connectivity is quite demanding. Sensor nodes are generally battery Operated and expected to work for a longer time without replacing the batteries.

4. PROBLEM DEFINITION

This paper is providing us with the improvement of node deployment in WSN using differential evolution algorithm. As we know, at the time of node deployment, sensor nodes are deployed in two respects: randomly or deterministically. Random node deployment can be done just by throwing sensor nodes from air. As a result of this there is tremendous change in node density because some nodes are placed closer to each other and some are placed away from each other, which increase energy consumption during communication or data travelling. In deterministic node deployment the positions of nodes are predefined i.e. positions of the sensors are calculated before deployment and then the sensors are placed on their respective positions. For reducing energy consumption and improving network lifetime we are adding differential evolution algorithm in the process of node deployment. Differential evolution is an optimization technique which helps in saving energy and improving network lifetime during nodes deployment in WSN. For taking better output we have considered and measured our algorithm on two different models namely: LEACH and SEP.

4.1 LEACH

LEACH is a homogeneous algorithm, Low-Energy Adaptive Clustering Hierarchy (LEACH), is one of the pioneering clustering routing approaches for WSNs. The main aim of LEACH is to select sensor nodes as CHs by rotation in each round, so the high energy dissipation in communicating with the BS is spread to all sensor nodes in the network. Cluster Head (CH) is responsible for creating and manipulating a TDMA (Time division multiple access) schedule and sending aggregated data from nodes to the BS.

4.2 SEP

SEP is a heterogeneity-aware protocol which extends the stability period (e.g. time interval before the first death of the sensors) of WSN. SEP is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. SEP provides longer stability period and higher average throughput than current clustering heterogeneous-oblivious protocols.
Here, we are presenting a working chart of DE, which is showing basic steps of how differential algorithm works and helps in positioning the nodes in a sensor network:

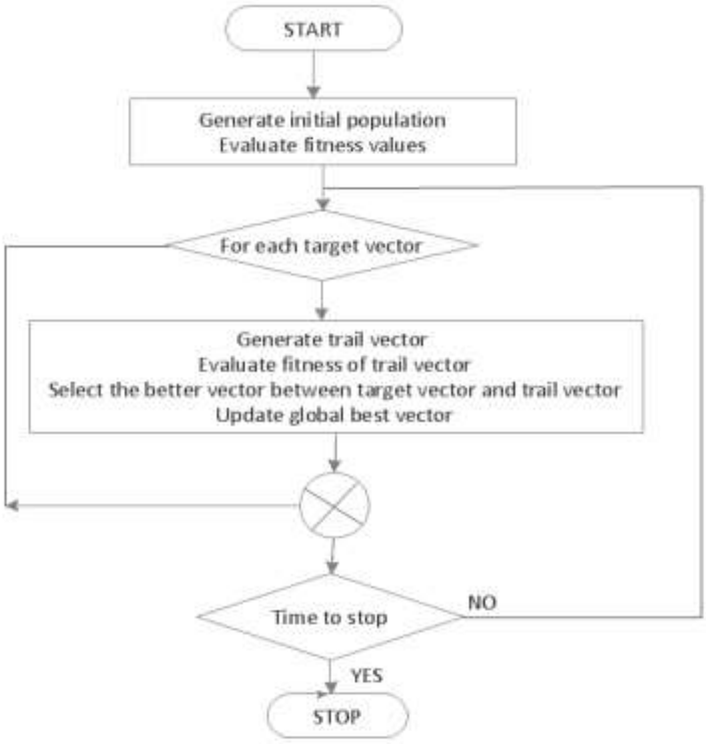

Chart 1: DE Performance Flowchart

5. PROPOSED MODEL

5.1 Objectives

In our research we studied few of node deployment techniques using differential evolution in WSN. The summarized work for the dissertation as follows.

- To study the existing techniques of node deployment in WSN.
- To propose and implement energy efficient based method (DE) for node deployment.
- To compare the existing technique with the proposed technique using the parameter Energy Consumption per Round.

5.2 Objective Function

$$f = \sum_{i=1}^{n} \left(\sum_{j=1}^{numNB_i} E_m + (E_{tx} * d_{i,j}) \right) + (E_{tx} * numNB_i)$$

Where,
f = Fitness function
n = number of nodes in the entire network.

$numNB_i$ = number of neighbour nodes of i.
E_{tx} = Attribute used for information Transmission (Transmitter).
E_{rx} = Attribute used for information Receiving (Receiver).
$d_{i,j}$ = Distance between the nodes from i^{th} node

5.3 Algorithm Flowchart

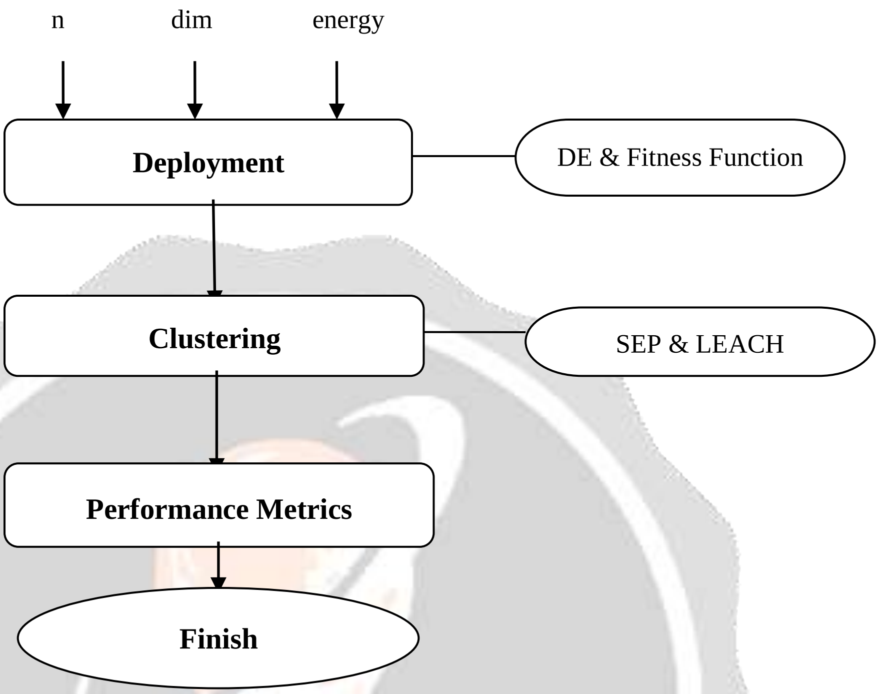

Chart 2: Algorithm Flowchart

As we have stated above, this paper is providing us with the improvement of node deployment in WSN using differential evolution algorithm. For the more clarification of our work we are providing a flowchart of how actually the whole process is working:

- Our first step is deployment, deployment of nodes in the desired area. As we know, at the time of node deployment, sensor nodes are deployed in two respects: randomly or deterministically. Random node deployment can be done just by throwing sensor nodes from air. As a result of this there is tremendous change in node density. In deterministic node deployment the positions of nodes are predefined i.e. positions of the sensors are calculated before deployment and then the sensors are placed on their respective positions. We are using differential algorithm and a new fitness function which are helping in reducing energy consumption.
    - Initially we are giving three inputs:
    - n – number of nodes in the network
    - dim – dimension of the area where we are going to deploy are nodes
    - energy – initial energy which will we be equal for all the nodes in that network
- Second step in our process is clustering means distributing all the sensor nodes of the network in clusters. Clustering technique is one of the effective approaches used to save energy in WSN. Clustering means organizing sensor nodes into different groups called clusters. Grouping nodes into clusters has become an interesting issue for the research community in order to achieve network scalability. In each cluster, sensor nodes are given different roles to play, such as cluster head, ordinary member node. A cluster head (CH) is a group leader in each cluster that collects sensed data from member nodes, aggregate, and transmits the aggregated data to the next CH or to the BS. The role of ordinary member node is to sense data from the environment they deployed and send them to cluster-head.
- The final step is to check performance of proposed model and to compare the new algorithm with the old ones. For making it more clear, we are providing snapshots of our finale results based on alive nodes, dead nodes and remaining energy and also showing a performance comparison between LEACH and SEP algorithms because we derived our algorithm for homogeneous and heterogeneous environments.

6. EXPERIMENTAL RESULTS

In this paper, the simulation of the proposed algorithm was carried out under MATLAB environment and the final output has shown some better results as compared to the base paper and the LEACH protocol.

Table 1: Parameters Detail

Parameter Name	Value
Network Area	100 * 100
BS Location	50 * 50
Number Of Nodes	100
E_0(Initial Energy)	0.5 J
Packet Size	4000 bits
Eelec	50nJ/bit
$E_{tx} = E_{rx}$	50nJ/bit
E_{fs}	10pJ/bits/m2
E_{mp}	0.0013pJ/bits/m2

The given table is concerned about all the parameters which we have used to define radio model of our technique. The Table is providing us with a basic overview of our sensor network nodes, the names of parameters and their corresponding values.

6.1 OUTPUT Comparison between LEACH & SEP

Low-Energy Adaptive Clustering Hierarchy (LEACH), proposed by Heinzelman is one of the pioneering clustering routing approaches for WSNs. The main aim of LEACH is to select sensor nodes as CHs by rotation in each round, so the high energy dissipation in communicating with the BS is spread to all sensor nodes in the network. Cluster Head (CH) is responsible for creating and manipulating a TDMA (Time division multiple access) schedule and sending aggregated data from nodes to the BS. In this paper, we are using LEACH as well as SEP for taking our results and then at the end we are going to measure that which will function better when the nodes will be deployed in the real geographical area [1].

Stable Election Protocol abbreviated as SEP is a heterogeneity-aware protocol which extends the stability period (e.g. time interval before the first death of the sensors) of WSN. SEP is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. SEP provides longer stability period and higher average throughput than current clustering heterogeneous-oblivious protocols. In order to prolong the stable region, SEP attempts to maintain the constraint of well balanced energy consumption. Intuitively, advanced nodes have to become cluster heads more often than the normal nodes, which is equivalent to a fairness constraint on energy consumption. Due to extended stability, the throughput of SEP is also higher than that of current (heterogeneous-oblivious) clustering protocols [8]. The performance of SEP is observed to be close to that of an ideal upper bound obtained by distributing the additional energy of advanced nodes uniformly over all nodes in the sensor field. SEP is more resilient than LEACH in judiciously consuming the extra energy of advanced nodes—SEP yields longer stability region for higher values of extra energy.

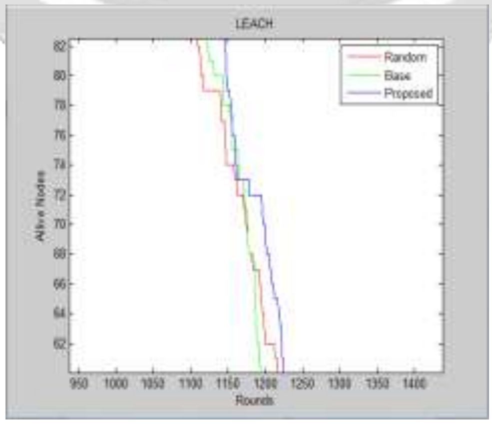

Figure 1: ALIVE Nodes (LEACH)

Figure 1 is concerned about the number of nodes which are alive with respect to all the three algorithms at the end of their processes. When we measure the output of our proposed algorithm with LEACH then it is providing better results as compared to other algorithms. The simulation results have shown that with respect to LEACH, the proposed model is working 2.58% better than previous models.

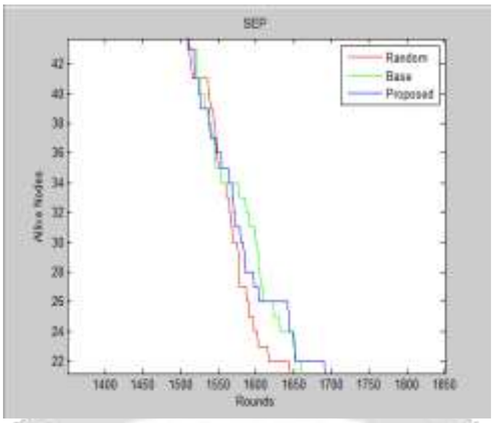

Figure 2: ALIVE Nodes (SEP)

Figure 2 is concerned with the nodes which are still in working conditions after completion of task. The proposed model is showing tremendous growth in the network stability capabilities and lifetime. The simulation results are showing that the proposed model is performing 4.98% better than previous algorithms with respect to the stable election protocol (SEP).

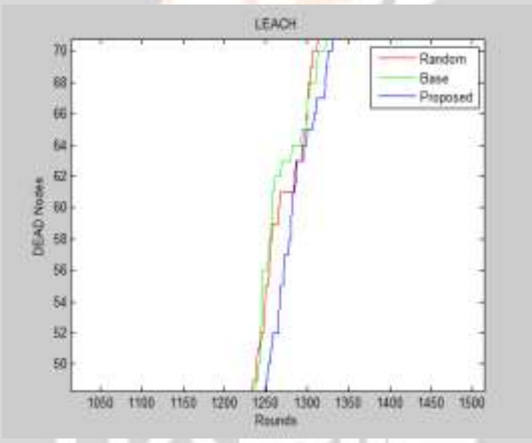

Figure 3: DEAD Nodes (LEACH)

Figure 3 is providing us with the information of how many nodes have dead and also showing a comparison between the proposed and the previously proposed algorithms. With respect to LEACH, the proposed model is showing improved results as compared to other ones. Final results are showing that the proposed model is performing 2.99% better than previous models.

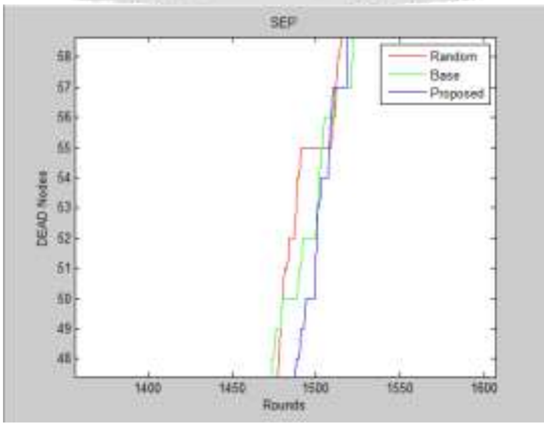

Figure 4: DEAD Nodes (SEP)

By using stable election algorithm, network's stability power is continuously increasing which is helping in improving network lifetime and performance. Figure 4 is providing us with the information of how many nodes have been dead since the task started to its ending. The simulation results are showing that as compared to previous algorithms, more nodes are in alive mode and are working for extra rounds as compared to previous ones & is providing the network a stable performance and improving network's lifetime.

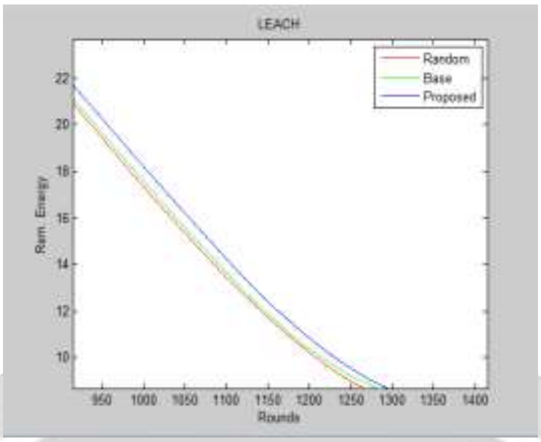

Figure 5: Remaining Energy (LEACH)

The main motive of our algorithm is to reduce energy consumption of the nodes which are deployed in a large geographical area so that they can work appropriately for a long time. Figure 5 is concerned about the same fact of remaining energy. The output of the model is showing that the algorithm is helping the deployed nodes of the entire network to save energy and to work for a long time. The simulation results have shown that the proposed algorithm is increasing the node's battery by 2.79% which directly improving the network lifetime.

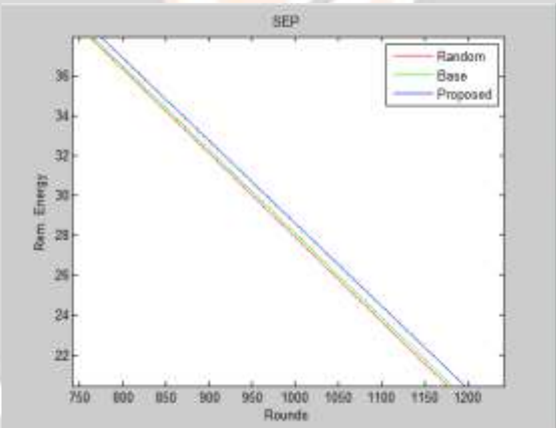

Figure 6: Remaining Energy (SEP)

Figure 6 is concerned with the remaining energy in network's nodes after completion of its tasks. The proposed algorithm is providing with a nice growth in saving network energy. As we can see that the nodes in our proposed model, performing for more rounds as compared to other models. So, the proposed model is giving better saving energy results.

7. CONCLUSION

The energy is the important segment in the process of designing and deploying WSNs. Several clustering algorithms are exists, which may help in designing WSNs. In this paper, we are using two different protocols which are LEACH and SEP & measuring their results. LEACH is a homogeneous protocol, uses the probability model to distribute the concentrated energy consumption of the cluster heads. SEP is a heterogeneous protocol, which is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node.

After comparing results from both the protocols we can say that heterogeneity based models are working better in the area of saving energy. SEP is providing better results as compared to LEACH, increasing the stability period of WSN and nodes in the network are working for long time & for more rounds with heterogeneous based SEP model.

8. REFERENCES

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