D-Leach: An Energy Optimized Deterministic Sub-clustering and Multi-hop Routing Protocol for Wireless Sensor Networks

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Abstract. The The introduction of Wireless Sensor Networks (WSN) has brought comfort of uninterrupted wireless networks into many lives. The data transmission nodes are a group of heterogeneous sensor node (SN) fitted with a battery, which are deployed randomly for monitoring of surrounding. Clustering algorithms with effective routing protocols are used to handle the random deployment of nodes. This results in redundant data packets being aggregated and dropped, enabling sound data transfer from sensor node to the Base Station (BS) through Cluster Head (CH). Different Energy optimization Routing Protocols have been introduced in previous years but have not been able to examine protocol behavior in different environments. An adaptive, sub-clustering and multi-hop routing protocol is proposed in this paper with experimental based analysis, taking into consideration energy and distance. That create smooth and simple route from the cluster nodes, cluster head, and sub-cluster head to the base station. Experimental studies show a substantial increase in network lifetime efficiency by comparing the proposed method with the present situation. Proposed protocol behaviour shows deterministic, so it is called Deterministic-LEACH (D-LEACH).

Keywords: Multi-hop routing protocol · Network life-time · Wireless sensor network · Energy efficiency

1 Introduction

Wireless Sensor Networks are networks of sensor nodes that track corporal and environmental condition such as sound, vibration, heat, motion, and pressure. Sensor nodes (SNs) with adequate processing power but insufficient power storage make up WSNs [1, 4]. A sensor node contains three main sections: a processing section for data aggregation and repository, a transmission section for data receiving and sending data, and a sensing section for finding of data from the surrounding [10].

SNs are typically placed at random in areas where humans are unable to track weather conditions. Nodes collect data and relay it to base station (BS), that uses battery power [9]. Continuous battery use causes battery power loss and sensing failure [12]. When nodes are installed in dangerous conditions such as volcanoes, battlefields [13], and so on, replacing SN batteries is virtually impossible. As a result, the network needs a longer life in order to prolong lifetime of networks [15] (Fig. 1).

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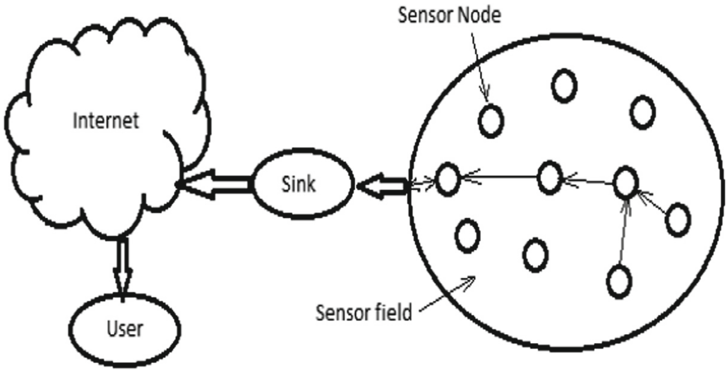

Fig. 1. Typical structure of WSN

Simple structure of WSN shown above. The message or information is routed via the sink node [2], from sensor (source) node, to the base station (destination), where end user can get these data through the internet [14]. When designing clustering protocols, factors such as fault tolerance, power consumption, data aggregation, load balance of nodes, QoS of sensor nodes, node deployment, and data latency are consider into account [4].

Routing protocols based on cluster, which split a big network (cluster) in to small and easily manageable multiple clusters, provide a cost-effective solution to the problem. Clusters and BS can communicate more effectively within this protocols and formation of a simple multi-hop routing path. So that a minimum energy consumption is accomplished by combining the obtained packets from the cluster., In the end, Cluster load balancing as well as network's lifespan also increases.

2 Literature Review

Energy Efficient Multi-hop Routing Protocol proposed by Khanoucheet al. [1] that is based on Clusters Re-organization, which includes different phases of structural type: cluster creation, sub-zone division, and data transmission through multiple path in inter-cluster route. The proposed idea ignores the distance between sensor nodes and sink node.

Cengiz et al. [2] suggested starting with a fixed number of cluster heads and then selecting new cluster heads based on threshold values or energy consumed after a few rounds. Inter-clusters and intra-clusters transmit data through number of relay and that is used to measure the energy change in overall network utilisation. By adding EAMR, they were able to reduce LEACH's unnecessary overhead by implementing a fixed cluster with a low number of cluster head changes.

Because of the battery constraint, Nam et al. [3] suggested the Energy-efficient data transmission that WSN needs. By creating a local cluster head and developing a formula for the number of packets to forward to the sink node, they suggest the optimal number of Cluster Head (CH).

Liu et al. [4] suggested HCNM, a hierarchical clustering method for managing sensor nodes. The networks calculates the distance between every node to disperse the equivalent number of nodes. The proposed model prevents over-fitting as well as under-fitting cluster head in a network by conducting subsequent clustering.

Yang et al. [5] suggested a CH selection algorithm that took into account the effect of the distance between the cluster-head and the base-station, as well as the WSN routing algorithm based on the enhanced LEACH protocol. When comparing simulation results to the LEACH algorithm, it is discovered that there is a gap in node die-time, an increase in its continued existence rate, and a dispersed existence in the position of a dead node. Its average battry consumption has also been enhance, and its lifespan has been extended.

Kumar et al. [6] divides the entire network into smaller network that is based on distance and suggested a good routing algorithm, more structured clusters, each cluster having their cluster head to take care of data transfer. By maximising the battery power of nodes, the proposed framework extends the lifespan of wireless networks. Move the sensed data to the base station after it has been collected.

By selecting cluster-heads with high residual energy through local radio frequency, M. Ye, C. Li, G. Chen, and J. Wu [7] proposed the Energy Efficient Clustering Scheme (EECS) protocol. The competition method achieves uniformity among all cluster and cluster heads without requiring iteration. Cluster foundation phase distributes data transfer load among all cluster head, with CHs handling packet routing to the sink.

Abdellatief et al. [9] find that distribution of nodes randomly is the main reason of battery drain in the network. The problem of different levels of energy at different levels of the region makes the network unbalance. To avoid this problem author proposed a distributed density-based clustering techniques based on sub-regions according to the density of nodes in that region.

Chan et al. [10] proposed a comprehensive survey on hierarchical routing protocols for WSN. It gives a vast idea to upcoming research in this area.

Arunmugam, G.S., Ponnuchamy, T. [11] suggested an energy-efficient LEACH protocol for data aggregation. It proposed an energy-efficient protocol in WSN based on the sorting algorithm residual energy while aggregating nodes.

3 Proposed Model

Since the advent of WSN, various energy-efficient routing protocols have been proposed to date. In most of the existing protocols, researchers did not investigate the protocol's behavior in various environments. Usually, CHs in standard field size are selected as proposed at the time of LEACH [8]. Existing models also did not perform in-depth analysis on dense [9] and sparse [10] environments of WSN with various field sizes and various numbers of nodes.

In this paper, we performed an in-depth performance analysis of existing protocols [7] based on the number of sensor nodes corresponding to the variable network size. Here, the numbers of heterogeneous sensor nodes are increased and decreased according to a sensor network's size. This also changes the number of cluster heads, Sub-CHs, cluster nodes, and the multi-hop routing path formation.

Table 1. Parameters of the suggested model

Parameters	Description	Value
Topography	Dimensions of Field	100 m x 100 m, 300m x 300m 500m x 500m
N	No of Nodes	100, 300 and 500
Rounds	Max no of Rounds	6000
Eo	Initial energy of each node	0.5 J
ETx	Transmission energy of node	50 x 0.000000001 J
ERx	Receiving energy of node	50 x 0.000000001 J
EDA	Data aggregation energy	5 x 0.000000001 J
Efs	Energy dissipation for free space	10 x 0.000000000001 J
Emp	Energy dissipation for multi-path delay	0.0013 x 0.000000000001 J
Packet	Packet size	4000

Table 1 summarizes the initial parameters to implement the proposed model for both scenarios: sparse (field size 100 × 100 with 100 nodes), medium (field size 300 × 300 with 300 nodes) and dense (field size 500 × 500 with 500 nodes) environment. Apart from several topography and node everything is common.

Our proposed protocol is based on a dynamic selection of cluster head (CHs) and subcluster head (SCH) in multi-hop route. In intra cluster formation of sub-route between the cluster nodes to sub–cluster head to cluster head, and to the base station makes proposed protocol scalable andreliable energy efficient tools to face the in real challenges [2].

4 Flowchart and Algorithm

The working algorithm and flow methodology are shown in Fig. 2a and Fig. 2b, whenever data sensed by any node, it transfer data to a nearest node, that forming a link of all intermediate node until the data received by the destination node or cluster head. The main cluster head forms the Cluster head chain, where transmissions allow in the energy-efficient way of the data to the sink.This techniques makes the network more reliable for real-time issues and make it more scalable also.

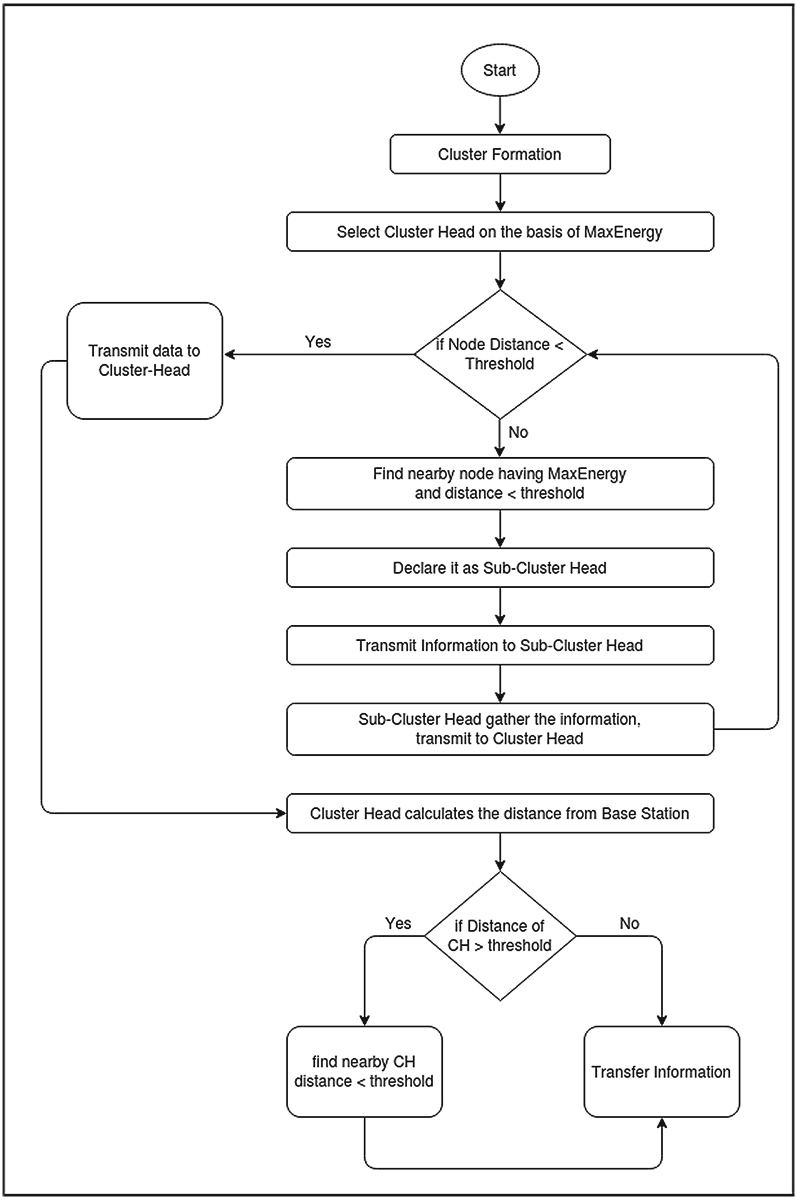

Fig. 2. Flowchart of proposed model

```
•  Start
•  Cluster Head Selection
   Initialize the cluster neighbor node, Set -> S_nbr-CH
   For (eachnode € S_nbr-CH )
      If (S_nbr-CH = φ):
            Select the sink as the next hop
      else:

            Compute the distance of each CH of S_nbr-CH by :

            D_i = √((X2-X1)^2 + (Y2-Y1)^2)
            If(D_i [S_nbr-CH] < D_i+1 [S_nbr-CH]) :
                  Set Nexthop <- D_i [S_nbr-CH ]
            else :
                  Set Nexthop <- D_i+1 [S_nbr-CH ]
            endif

      endif

   endForLoop

•  Sub-cluster Head Selection
   Initialize distance threshold as D_thershold
   ClusterNode energy as CN_energy
   For (each CN € Cluster)
      If (CN_Distance < D_thershold ):
            Transmit data to CH/BS
      else :
            Select Sub_CH
            If (Node_distance > D_thershold ) AND
               (Node_energy = Node_MaxEnergy ):
                  Declare Node as Sub_CH and gather
                 information
            endif
      endif
   endForLoop
•  End
```

Fig. 3. Algorithm of proposed model

Furthermore, we will make intensive comparisons of proposed energy-efficient protocols with the existing researches proposed in the literature. In this paper, parametric analysis of energy efficiency, data aggregations, and throughput of the network are focused on in the next section.

5 Result and Discussion

As compared through simulation result of D-LEACH with other routing protocols LEACH and EE-LEACH in sparse, medium and dense environment considering all condition and standard parameters.

Figure 3 shows the representation of the performance analysis with the network lifetime of the node. In terms of network lifetime, the proposed protocol is outperformed the other two protocols.

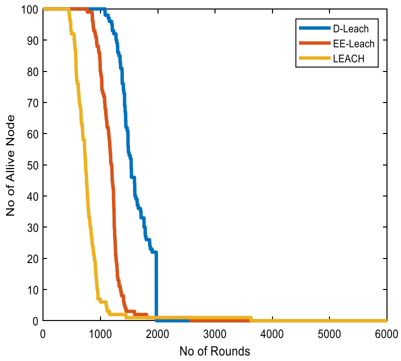

Fig. 4. Alive nodes vs. round for 100 nodes and field size (100 × 100).

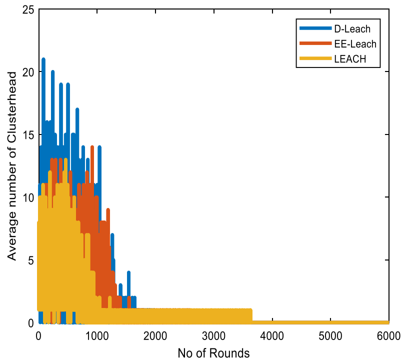

Fig. 5. Average no. of cluster head selection vs. round for 100 nodes and field size (100 × 100)

Figure 3 shows that the number of dead node performance of the proposed protocol is better than the other two protocols in terms of a long life of all nodes and no. of rounds to the beginning of the first dead node.

Figure 4 shows the average number of selected cluster head with respect to the number of rounds, keeping the selection probability the same for all protocols $p = 0.05$. The proposed protocol can exploit it fully and maintain the maximum cluster selection since the beginning. Cluster heads quantity goes down as the number of surviving nodes reduced. From the analysis of the small scenario network 100 m × 100 m with 100 nodes, that shows our proposed D-LEACH protocol is the most stable network performance.

After satisfaction result in sparse environment of proposed protocol, let us see the simulation result in medium (300 × 300) and dense (500 × 500) environment with 300 and 500 nodes respectively.

Figure 5 shows the comparison simulation result of the proposed protocol with LEACH and EE-LEACH, in terms of network lifetime. We can see from the graph that LEACH and EE-Leach's performance decreases as we increased the field size. For LEACH, 90% of nodes die before 800 rounds, unlike the smaller field size where they survive for 1000 rounds. Same downgrade the performance of EE-Leach as field size increases. Moving toward our proposed protocol D-Leach. We see that protocols show not only scalable behavior but also their performance increase in terms of network lifetime.

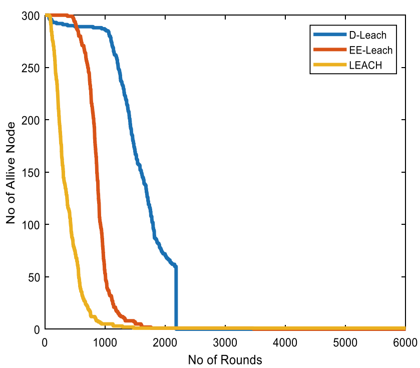

Fig. 6. Alive nodes vs. Round for 300 nodes and field size (300 × 300)

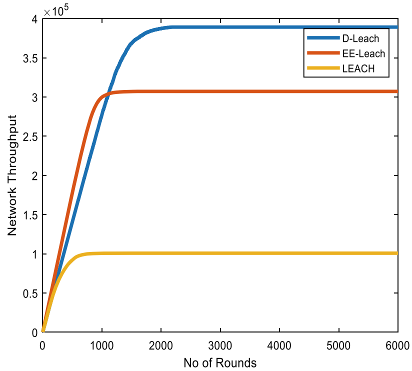

Fig. 7. Network throughput vs. number of round for 300 nodes and field size (300 × 300)

90% of nodes die in 2000 rounds for smaller network size, while for medium field size, 90% of nodes survive for more than 2200 rounds.

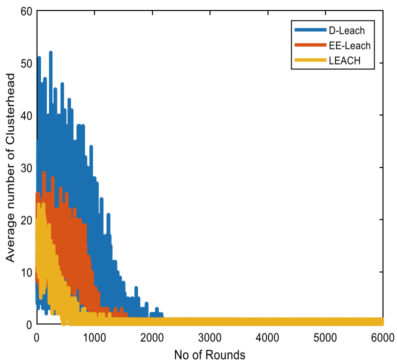

Fig. 8. Average no. of cluster head vs. round for 300 nodes and field size (300 × 300)

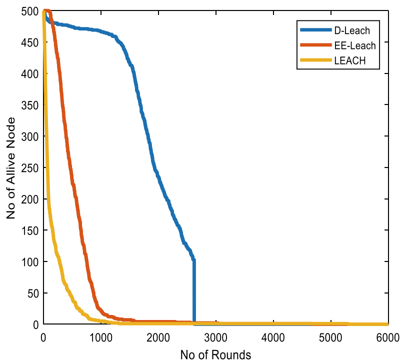

Fig. 9. Alive nodes vs. round for 500 nodes and field size (500 × 500)

Cluster selection in each round is showing the same performance as all protocols show for smaller field sizes. The simulation performance of network throughput for our proposed protocol is also significantly high, as shown in Fig. 6 and 7.

In the analysis for larger field size (500 × 500) and node count 500, our proposed protocol shows exciting and significant improvement in network lifetime and network throughput, as shown in Fig. 8 and 9 respectively.

Figure 8 shows the performance graph of the proposed protocol with LEACH and EE-Leach, in terms of network lifetime. We can see from the graph that LEACH and EE-Leach's performance decreases as we increased the field size. For LEACH, 90% of nodes die before 500 rounds. Unlike the smaller (100 × 100) field size where they survive for 1000 rounds, performance remains only 50% as we have increased the network size 5-times and the performance of EE-Leach remain 50% as field size increase. In contrast, our proposed protocol shows a 25% increase in network lifetime performance as we increased the network field size 5-times.

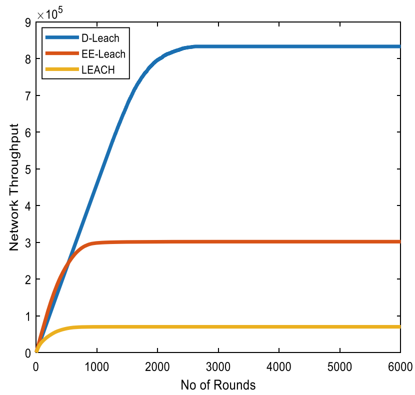

Fig. 10. Network throughput vs. Round for 500 nodes and field size (500 × 500)

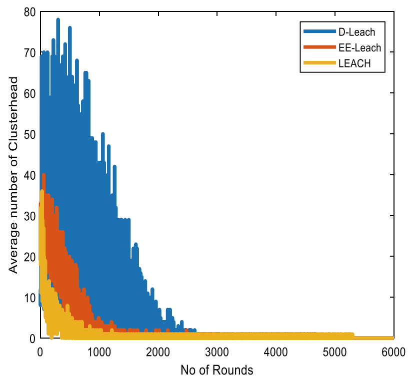

Fig. 11. Average no. of cluster head selection round for 500 nodes and field size (500 × 500)

The network throughput is increased two times from the large field size network, and the average number of cluster head performances shown in Fig. 9 and Fig. 10 respectively. The cluster head selection for each round remains constant, showing almost similar performance for all field sizes (Fig. 11).

6 Conclusion and Future Work

The simulation analysis of a current energy optimized protocol with different environment and different number of nodes was the starting point for this paper. The simulation depicts the performance of existing protocols, which indicates a substantial reduction in performance due to the fact that none of them are flexible and reliable to sustain in various scenario and are statically designed for a static field size with a static number of nodes. We developed a protocol for a dynamic network based on multi-hop sub-clustering and clustering routing path for transmission of data to a base station, taking into account all of these limitations. Simulation and experimental results represent that the suggested protocol well performed in all field sizes, with performance gradually increasing as we transition to dense environment, unlike other protocols, which perform worse as field sizes grow larger. The parameters we considered in this study were a longer lifespan and a higher throughput. The protocol's end-to-end delay and protection will be investigated further.

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