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Enhancement of Dual-Hop Layered LEACH Routing Protocol with Mobility in Wireless Sensor Networks

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Abstract— *One of the most important challenges in a Wireless Sensor Networks (WSNs) is to enhance energy utilization and also the network lifetime. The routing protocol falls into two categories: Flat routing protocol and hierarchical routing protocol. The LEACH (Low Energy Adaptive Clustering Hierarchy) protocol selects cluster head in every cluster to distribute the energy load among the member nodes within the network. DL-LEACH (Dual-Hop Layered LEACH) protocol is proposed for two-level cluster head selection in the network. In a level-one cluster, the cluster head election process is done within each cluster based on energy. The Cluster Head (CH) and member nodes are statically deployed within the network and the mobility is not considered. The proposed method is enhancing DL-LEACH protocol by using mobility factor at level-two cluster head selection. If the cluster head energy is low at the level-two cluster, the random mobility process is performed. The highest energy node is elected as a cluster head in both inter-cluster and in the new cluster that the node visited. The residual energy of nodes and distance are considered as metrics to select a member node as a cluster head. The simulation results of the proposed protocol are compared with the LEACH protocol using the NS2 simulator and results prove that proposed work outperforms in terms of network lifetime and lower the energy consumption.*

Keywords— *Energy consumption, Enhanced LEACH, Hierarchical Routing Protocol, Mobility of CH, Wireless Sensor Networks (WSNs).*

I. INTRODUCTION

A Wireless Sensor Network (WSN) is comprised of a massive number of nodes which are distributed spatially to monitor ambient conditions like temperature, humidity etc. The sensor devices have the power to communicate either specifically to sink node or one another. In WSN, the most delaying issues are energy efficiency and extending the duration of the network [1].The position of the sensor nodes is deployed randomly in the sensor network. The algorithms and protocols are utilized for self-sorting out capabilities. The sensor network topology changes very regularly. The sensor network is utilized as a part of military services applications, ecological applications, health applications, home applications and other industrial applications [2].

The wireless sensors are outfitted with battery, so it can possess limited mobility. The deployment is not hard and the range can be extended in wireless sensor networks. The small wireless sensors are being used to replace one large wired sensor for the same cost. The member nodes are battery power-driven and have restricted energy and storage facility [3-5]. The primary objective of clustering is used to improve the network lifetime, reducing the node energy consumption and the system overall performance [6]. Based on network structure, the routing protocols are separated into three kinds named

- Flat routing protocol
- Hierarchical routing protocol
- Location-based routing protocol

The cluster-based protocol is known as hierarchical routing protocol [7].

Hierarchical routing protocol supports data aggregation to prolong the network period. It not only advances the network scalability and furthermore it decreases information delay. The network is divided into multiple clusters. Every cluster contains a range of member nodes and one cluster head node. The cluster head role is to collect and aggregate data from all other member nodes and pass that data to sink node [8].

Some of the existing hierarchical protocols are LEACH protocol, SEP, PEGASIS, TEEN, APTEEN, EECS, HEED, and H-HEED. Power performance is one of the crucial challenges in designing routing protocols [9]. LEACH (Low Energy Adaptive Clustering Hierarchy) is an efficient routing protocol which may be used to avoid power intake and additionally increase the lifetime of the network. Depending on the very best residual energy, the cluster head is completely selected in each cluster [10].

LEACH is used to elect group heads randomly. To overcome the issues in LEACH, numerous variants have been proposed. LEACH protocol uses cluster head to effectively deliver the information that is obtained from member nodes to sink node [11]. The variants of LEACH are categorized into two classes: single hop communication and multi-hop communication. DL-LEACH (Dual-Hop Layered LEACH) protocol uses intermediate nodes to efficiently deliver information to sink node. It uses dual-hop transmission method to reduce the leach problems; to decrease the lifespan of the node in the sensor field [12]. Figure 1 represents the LEACH cluster mode.

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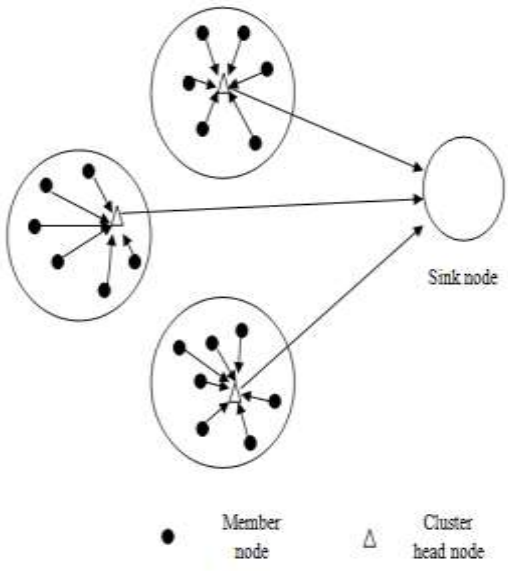

Fig. 1. LEACH cluster mode.

II. Related Works

LEACH protocol in a wireless sensor network is taken into consideration as a dynamic cluster technique. For improving the energy efficiency in LEACH protocol, the cluster head selection is executed. The cluster head selection is one amongst the most objectives of LEACH protocol. LEACH protocol includes two stages: set-up phase and steady-state phase. The cluster formation, the cluster head selection and allocation of TDMA process are done in set-up phase. The cluster head is selected using probabilistic schemes, deterministic schemes, random and base station assisted. To avoid a collision in data transmission process the TDMA (Time Division Multiple Access) is assigned. The cluster head selection is completed using a random number. According to the probabilistic model, the sensor nodes select cluster head at each round. A random number between 0 and 1 is created by each node in the cluster. The random number becomes cluster head at the current round when the number is less than the threshold value T(n). To balance the energy consumption, the node which is elected as cluster head once cannot become cluster head again. The chance is given to all other sensor nodes to become cluster head once. The value of T(n) calculated as follows:

$$T(n) = \begin{cases} \dfrac{P}{1 - P \times \left(r \bmod \left(\frac{1}{P}\right)\right)} & \text{if } n \notin G \\ 0 & \text{otherwise} \end{cases}$$

Where n is the given node, P is the percentage of sensor nodes to become cluster head among all sensor nodes, G is the set of non-elected cluster head nodes in the previous round, r denotes the current number of round and T(n) denotes the threshold.

In steady state phase, the cluster head maintenance and also the information transmission process is carried out. The information transmission could also be inter-cluster or intra-cluster. There are two sorts of communication in LEACH protocol are single-hop communication and multi-hop communication. The cluster head directly passes packets to the sink node in single-hop communication. In multi-hop communication, it uses relay nodes to pass that information to the sink that is obtained from cluster head. The intermediate nodes are toward the sink node. The main goal of the leach protocol is employed to extend the life of the network [13-17].

Dual-hop Layered LEACH protocol (DL-LEACH protocol) is based on both single-hop communication and multi-hop communication. Compared to LEACH protocol, DL-LEACH algorithm is used to extend the life of the network and reduce energy consumption efficiently. It uses two-levels for cluster head selection algorithm for selecting cluster head. Level-one cluster head gathers data from all other nodes in each cluster and passes that data to the level-two cluster head which is closer to sink node. Then, the level-two cluster head passes that information to the sink. The cluster head selection process in DL-LEACH protocol is same as LEACH, but the network is split into several layers for energy consumption [18].

In a wireless sensor network, the sensor nodes may be static or mobile. Due to limited battery power, the lifetime and quality of the network are decreased. It leads to frequent changes in route, results in packet delivery delay. The cluster head, non-cluster head, and base station can be mobile in the network. The inter-cluster and intra-cluster communication process is accomplished in LEACH protocol. If a node mobile from one cluster to different cluster, then it is an inter-cluster transmission. The transmission phase comes under steady-state phase [19]. The data success rate is increased and due to high control overhead, energy consumption is increased in LEACH-M (LEACH-MOBILE) protocol. The LEACH-M and LEACH-ME protocols are one of the mobility based protocols [20]. The mobility of member nodes and cluster head is supported in LEACH-ME protocol. The cluster head election is done based on mobility. The cost will be increased, when mobile nodes are equipped with GPS [21].

III. Improved DL-LEACH Protocol

The cluster head selection with mobility is proposed in the DL-LEACH routing protocol. The two-level cluster head selection algorithm is used to increase the network lifetime and reduce the energy consumption. The cluster formation, cluster head selection in level-one and level-two clusters and also data transmission process are done to improve DL-LEACH protocol.

A. Cluster formation:

The cluster formation is done, when the nodes are deployed in the network area. The network is split into clusters. Each cluster contains a huge number of sensor nodes. Each node has initial energy as same. According to data transmission, the node energy will be reduced. If a node energy level drops completely, then it is considered as a dead node. The cluster formation and cluster head selection process is done in set-up phase.

The two-level cluster head selection algorithm pseudo-code as shown:

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1: Input: Sensor node 1, Sensor node 2…. Sensor node N , Sink
2: Output: Cluster Head Selection
3: Begin
4: Sensor nodes 1….N cluster initialization
5: Cluster formation and cluster head selection
Cluster-One Heads Selection Algorithm
Energy level check to cluster group level
Intra-cluster communication
6: If(threshold<=$value)→true
7: CH is constant
8: Data collection from a CM and CH send to sink node
9: else
10: CH is changed
11: Data collection from a cluster member
12: endif
Cluster-Two Heads Selection Algorithm
Energy level check to CH level
Intra-cluster and inter-cluster communication
13: If(energy level<CH1….N)
14: Random mobility
15: CH interchange from one cluster group to another cluster group
16: else
17: CH is constant
18: Data collection from a CM and CH send to sink node
19: endif

B. *Level-one cluster head selection*

After cluster formation, the two-level cluster head selection process is to be done. In level-one cluster head selection, the energy level is checked for each member nodes in each cluster. Figure 2 describes if node energy is high compared to the other member nodes, then it is elected as a cluster head. The energy level is checked at cluster group level. The intra-cluster communication process is done.

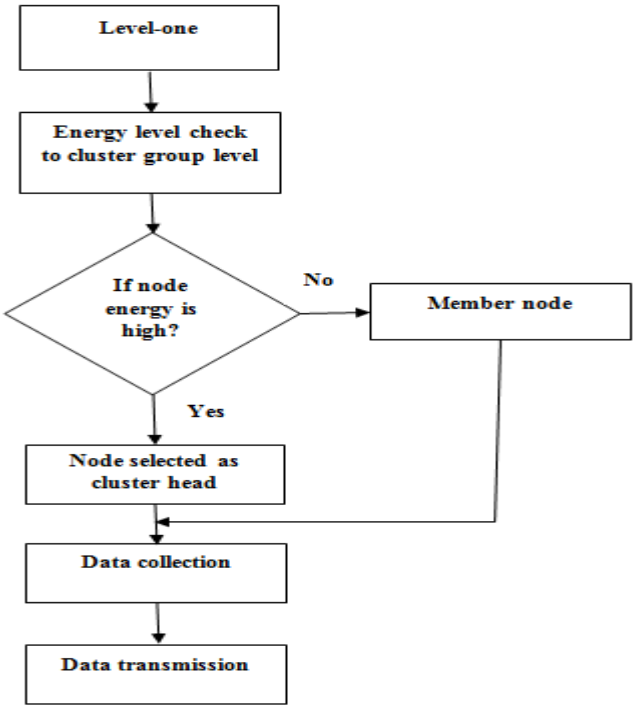

Fig. 2. Level-one cluster head selection process.

If the cluster head energy is low, then it elects next high energy member node as a cluster head and makes the low energy cluster head as member node. Then, the cluster head collects data from the cluster member (CM) nodes and aggregate that data and forward it to a base station.

C. *Level-two cluster head selection*

After level-one cluster head selection, the energy level is checked to all cluster head in the network. The level-two cluster head selection process is done based on checking all cluster head energy level. If the particular cluster head energy level is greater than other cluster heads, then the cluster head is constant and data transmission process is carried out. Otherwise, if the cluster head energy is low then the inter-cluster communication process is carried out by interchanging highest energy cluster head from one cluster group to another cluster group. Then, the low energy cluster head became as member nodes. The random mobility is done for cluster head selection. Both the inter-cluster and intra-cluster communication process is done for cluster head selection. The level-two cluster head selection process is described in figure 3.

D. *Data transmission*

The data transmission process is done based on distance parameter, after cluster initialization, cluster formation, and cluster head selection. The cluster head collects and aggregates data that are obtained from member node of each cluster and pass that data to the base station. The energy level is checked at both the cluster group level and cluster head level in the network. The data is forwarded to the base station based on distance calculation.

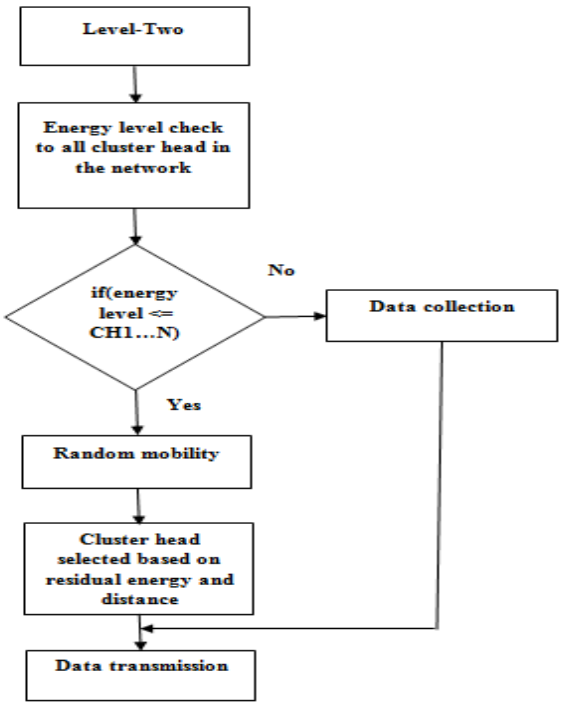

Fig. 3. Level-two cluster head selection process.

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IV. Simulation Results and Analysis

The simulation results of proposed protocols are compared with LEACH protocol in NS2. The network size is 100×100 m^2 and the initial energy of each node is same. Table I represents the simulation network environment parameter table. If the energy of a node is 0J, then it is considered as a dead node. Figure 4 represents the average end to end delay of LEACH and DL-LEACH protocol. The average end to end delay is 273.63ms. The network lifetime is increased compared to LEACH protocol. Figure 5 represents the network energy consumption of LEACH and DL-LEACH protocol at each round. The smaller slope indicates that the speed is slow and the survival time is increased. The DL-LEACH protocol energy consumption slope is less than the LEACH protocol shows that it can effectively balance node energy consumption.

TABLE I. Simulation parameters.

PARAMETER	VALUE
Network grid	100 × 100 m^2
Base station position	(541,430)
Network interface	Channel/wireless
Node distribution	Random
Mobile node specification	IEEE 802.11, MAC protocol
Mobility	853ms
NS version	NS-2.34
No of nodes	100
Initial energy(j)	1000
Transmitting energy(J)	0.175
Receiving Energy(J)	0.175
EDA	5PJoule/bit/signal
Efs	10PJoule/bit/m^2
Emp	0.0013PJoule/bit/m^4
Control packet size	512b

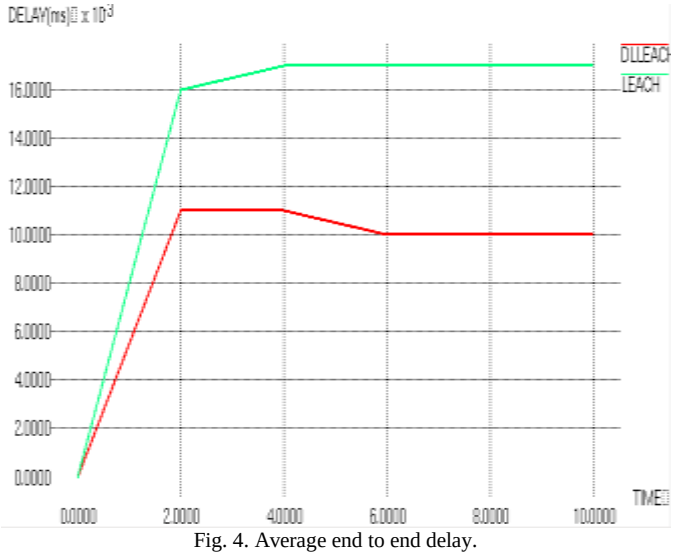

Fig. 4. Average end to end delay.

Figure 6 represents the data transmission of LEACH and DL-LEACH protocol. The LEACH protocol sends total data only over at 2,5000 units and it stopped growing at 20,0000 round. DL-LEACH protocol sends data over 3,7000 units. Comparison with LEACH and DL-LEACH protocol, the DL-LEACH protocol increase the network lifetime by 20% and reduce the energy consumption by 70%.

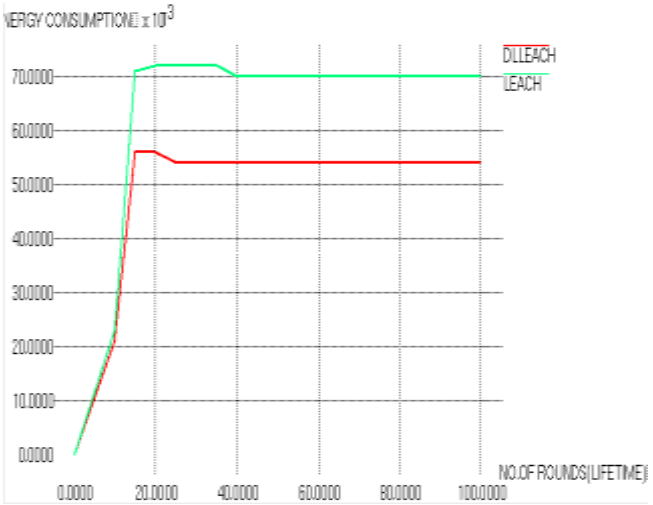

Fig. 5. LEACH AND DL-LEACH network energy consumption.

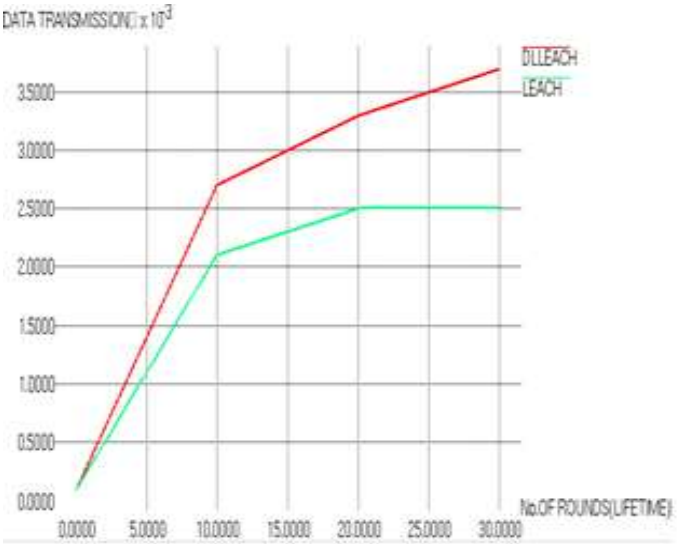

Fig. 6. LEACH AND DL-LEACH data transmission.

V. Conclusion

In this paper, DL-LEACH routing protocol is proposed. The two-level cluster head selection algorithm is used to effectively deliver the data to sink node. In level-one cluster head selection, the energy level is checked at cluster group level. In level-two cluster head selection, the random mobility process is carried out. The energy level is checked for every cluster head in the network and the highest energy cluster head are interchanged from one cluster group to another cluster group and performance parameters are analyzed. The intra-cluster and inter-cluster communication are done for cluster head selection. Based on the parameters residual energy and distance, the performance parameters are analyzed. The simulation results between both the LEACH and DL-LEACH protocol is compared, it shows that DL-LEACH results in network lifetime enhancement with minimized energy consumption.

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