Improved Cluster Head Selection Using Enhanced LEACH Protocol

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Abstract—Routing in Wireless Sensor Network (WSN) is an important area of research due to its rapidly increasing application in monitoring various kinds of environment by sensing physical phenomenon. It introduces an energy efficient clustering algorithm for WSN based on Low Energy Adaptive Clustering Hierarchy (LEACH) which will remove some of the drawbacks of LEACH. It utilizes the remaining energy of the current Cluster Head (CH) to make the routing process more efficient. In heterogeneous sensor networks, some nodes become cluster heads which aggregate the data of their cluster nodes and transmit it to the sink. Improved hierarchical clustered heterogeneous network has been proposed where the advanced nodes elect themselves as cluster heads for the increasing number of rounds based on their higher initial energy relative to other nodes. Proposed algorithm is designed and implemented in MATLAB. It is shown that the proposed algorithm provides better results than existing, as we have extended the stability time or when the first node dead time. Also last node dead or network lifetime is also increased. Proposed algorithm has also increased the throughput of the wireless sensor network.

Index Terms—WSN, Advance Nodes, Energy Consumption, Dead Nodes

I. INTRODUCTION

A wireless sensor network consists of a large number of sensor nodes and a base station that serves as a gateway to some other networks. Sensor node senses their environment, collect sensed data and transmit to the base station. It is a network which is wireless and deals with sensors. It consists of nodes that communicates with each other through wireless links sensors that are remotely deployed in large numbers and operates environments. A Wireless Sensor Networks (WSN) includes spatially distributed sensors to cooperatively monitor various environmental conditions, which includes temperature, sound, vibration, pressure, motion or pollutants. It consists of a large number of nodes with a limited energy supply. Wireless Sensor Network (WSN) is an advanced intelligent network which is organized by amounts of functional sensor nodes. The sensor nodes in Wireless Sensor Network can transmit information and cooperate with each other to accomplish some special functions through implementing the self-organization wireless communication manner. In addition, Wireless Sensor Network can be widely applied in the following areas, such as military, industry, agriculture, medical and environmental monitoring area [6]. To reduce the consumption of energy, the network routing protocol is regarded as a new direction being researched for the energy-constrained wireless sensor network. As a result, the routing protocol can reduce communication volume and save network energy. Low Energy Adaptive Clustering Hierarchy (LEACH) is the first implemented cluster-based routing protocol and it is also considered as the base of other cluster routing protocols.

II. VARIOUS HIERARCHICAL ROUTING PROTOCOLS

The main objective of hierarchical routing is to maintain the energy consumption of various sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. Cluster formation is typically based on the energy reserve of sensors and sensor’s proximity to the cluster head. LEACH is one of the first hierarchical routing approaches for sensors networks. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols, although some protocols have been independently developed. We explore hierarchical routing protocols in this section.

A. LEACH

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical cluster-based routing protocol for wireless sensor network which partitions the nodes into clusters, in each cluster a dedicated node with extra privileges called 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 where these data is needed using CDMA (Code division multiple access). Remaining nodes are cluster members [8].

Architecture of LEACH

The operation of LEACH protocol is broken into rounds. Each round begins with setup phase, during which clusters formation takes place and steady phase during which data is being transferred to base station. Steady phase is usually longer than setup phase. Initially at the beginning of each round, each node decides whether it has to be CH or not. The node which decides to be cluster head sends a message. All other nodes other than the CH will keep their receiver on and decide to which CH they need to join [3]. Every node selects a cluster head which is close to it. All nodes send messages to their respective cluster heads. The CH based on the number of requesting node creates a proper TDMA
In our work, we have considered a hierarchical clustered heterogeneous network. The Low Energy Adaptive Clustering Hierarchy (LEACH) is a protocol which is hierarchically clustered where clusters are re-established in each round. In this protocol, new cluster heads get elected in each round and as a result the load becomes well distributed and balanced among the nodes of the network. An optimal percentage of nodes \( p_{opt} \) is considered that has to become cluster head in each round [8]. We have assumed the same distributed algorithms to form clusters in the network. To decide whether a node to become cluster head or not a threshold \( T(s) \) is addressed in which is as follows:

\[
T(\mathcal{R}(\text{norm})) = \begin{cases} 
\frac{p_{\text{norm}}}{1 - p_{\text{norm}} (r \text{ mod. } \frac{1}{\text{norm}})} & \text{if } s \in G \\
0 & \text{otherwise}
\end{cases}
\]

(1)
Where \( r \) is the current round number and \( G \) is the set of nodes that have not become cluster head within the last \( \frac{1}{k_{\text{opt}}} \) rounds. At the beginning of each round, each node which belongs to the set \( G \) selects a random number 0 or 1. If the random number is less than the threshold \( T(s) \) then the node becomes a cluster head in the current round [8].

**B. Optimum number of clusters**

According to the radio energy model addressed in [7], in order to achieve an acceptable SNR in transmitting an \( L \) bit message over a distance \( d \), the energy dissipated by the radio is given by:

\[
E_{\text{trans}}(l, d) = \begin{cases} 
L \cdot E_{\text{elec}} + L \cdot \epsilon_{\text{fs}} \cdot d^2, & \text{if } d \leq d_0 \\
L \cdot E_{\text{elec}} + L \cdot \epsilon_{\text{mp}} \cdot d^4, & \text{if } d \geq d_0
\end{cases}
\]

Where \( E_{\text{elec}} \) is the energy dissipated per bit to run the transmitter or receiver circuit, \( (\epsilon_{\text{fs}} \text{ free space fading}) \) and \( \epsilon_{\text{mp}} \) (multi path fading) are the energy expenditure of transmitting one bit data to achieve an acceptable bit error rate and \( d \) is the distance between a cluster member node and its cluster head. By equating the two expressions at \( d = d_0 \), we get

\[
d_0 = \sqrt[2]{\frac{\epsilon_{\text{fs}}}{\epsilon_{\text{mp}}}}
\]

So according to [2], the optimum number of clusters \( k_{\text{opt}} \) for our cluster based network, having \( n \) sensor nodes distributed randomly in a \((M \times M)\) sensor field is as follows:

\[
k_{\text{opt}} = \sqrt{n} \cdot \sqrt{\frac{M}{d^2}}
\]

Again, the optimal probability of a sensor node to become cluster head can be calculated as:

\[
P_{\text{opt}} = \frac{k_{\text{opt}}}{n}
\]

**V. PROPOSED PROTOCOL**

In this work, we have analyzed a heterogeneous sensor network environment. Where \( p \) is the percentage of advance and normal nodes having ‘a’ times more energy than the normal nodes that are distributed randomly over the sensor field. A cluster head election process is considered based on the battery power and residual energy of the node. In our approach, advanced nodes have higher probabilities to become a cluster head in a particular round than the normal nodes. The proposed heterogeneous network model doesn’t effect on the spatial density of the network but changes the total initial energy of the network. We have individual initial energy equations for normal and advanced nodes as follows:

\[
E_0 = E_0 \cdot (1 + a)
\]

Where, \( E_0 \) is the energy of a normal node

\[
E_i = n \cdot E_0 \cdot (1 - p - k) + n \cdot p \cdot E_0 \cdot (1 + a)
\]

\[
E_i = n \cdot E_0 \cdot (1 + p \cdot a)
\]

In this work, we have approached to assign a weight to the optimal probability of a sensor node to become cluster head in a particular round. This weight must be equal to the division of the initial energy of each node by the initial energy of a normal node. If all the nodes are homogeneous, all the nodes will become cluster head once every \( \frac{1}{p_{\text{opt}}} \) round which is coined as epoch of the network. In our approach the average number of cluster heads per round per epoch is equal to \( n_s(1+p.a) \). The weighted election probabilities for normal and advanced nodes are defined. In our scenario, the weighted election probabilities for the normal and advanced nodes are as follows:

\[
P_{\text{nrm}} = \frac{p_{\text{opt}}}{1 + p \cdot a} \times (1 + a)
\]

We further define the thresholds \( T(s_{\text{nrm}}), T(s_{\text{adv}}) \) for the normal, advanced nodes. In equation (1) we have replaced \( p_{\text{opt}} \) by the weighted probabilities of normal and advanced nodes to obtain the threshold that is used to elect the cluster head in each round. Thus, the threshold for the normal nodes to become cluster head can be evaluated by the following equation:

\[
T(S_{\text{nrm}}) = \begin{cases} 
\frac{p_{\text{opt}}}{1 + p \cdot a} \cdot \frac{1}{P_{\text{nrm}}} \cdot \frac{1}{P_{\text{nrm}}}, & \text{if } s \in G \\
0, & \text{otherwise}
\end{cases}
\]

Where \( r \) is the current round number, \( G^* \) is the set of normal nodes that have not become cluster head within the last \( \frac{1}{P_{\text{nrm}}} \) rounds of the epoch. \( T(s_{\text{nrm}}) \) is the threshold applied to a population of \( n_s \cdot (1-p-k) \) that are normal nodes. This ensures that each normal node will become a cluster head exactly once every \( (1+p.a+k.b)/ P_{\text{nrm}} \) rounds per epoch.

**VI. PERFORMANCE ANALYSIS**

**A. WSN in active stage**

Figure 1 is showing the WSN in active mode where all nodes are active. As it is Leach so all nodes represented by circles are normal nodes and nodes with circle and star (*) are cluster heads.
Figure 2 is showing the WSN in active mode where all nodes are active. As it is Energy Leach so all nodes represented by circles are normal nodes and all nodes represented by plus (+) are advance nodes and with star(*) are cluster heads.

Figure 3 is showing the WSN in active mode in Proposed Leach where all nodes are active. As it is Improved Energy Leach so all nodes represented by circles are normal nodes and all nodes represented by plus (+) are advance nodes, with star(*) are cluster heads. For more clear specification we have used lines to represent the area of given cluster. Once the implementation starts, the first view that comes to be seen is shown in figure above. The screen is divided in to various regions that are called clusters. Each cluster thus formed has a cluster head. The entire network has a base station that is responsible for the collection of data from all other nodes.

Figure 4 is demonstrating the LEACH with active as well as with some dead nodes represented by red diamond.

Figure 5 is represents the Proposed LEACH with active as well as with some dead nodes. It shows the dimension area of 100*100, the red diamonds represent the node dead so far during the life cycle of wireless sensor network. The only differences here are the blue lines which are representing the different clusters and each has its CH

B. Packets sent to Base Station

Figure 6 shows the Packets that are sent to Base Station in Leach Protocol during the lifetime of the Leach protocol. It shows the throughput from 0 rounds to 1457
as 1457 is the overall lifetime of leach in our experiment. Here y axis shows the amount of packets sent during running time. It is clearly shown that the packets goes down rapidly recently after the first node dead, which clearly shows the benefits of the stability period of wireless sensor network.

![Figure 6 Packets that are sent to Base Station in LEACH Protocol.](image6)

Figure 7 is showing the Packets that are sent to Base Station in Energy Leach Protocol during the lifetime of the Energy Leach protocol. It illustrates the throughput from 0 rounds to 2450 as 2450 is the overall lifetime of leach in our experiment. Here y axis shows the amount of packets sent during running time. It is clearly shown that the packets goes down rapidly recently after the first node dead, which clearly shows the benefits of the stability period of wireless sensor network. However it also shows the progress in terms of network life time and stability period than the simple LEACH protocol.

![Figure 7 Packets that are sent to Base Station in Energy LEACH Protocol.](image7)

C. Packets sent to Cluster Head

Figure 9 is demonstrating the Packets that are sent to Cluster head in Leach Protocol during the lifetime of the Leach protocol. It shows the throughput from 0 rounds to 1457 as 1457 is the overall lifetime of leach in our experiment. Here y axis shows the amount of packets sent during running time. It is clearly shown that the packets goes down rapidly recently after the first node dead, which clearly shows the benefits of the stability period of wireless sensor network. However it also shows the progress in terms of network life time and stability period than the simple LEACH protocol.

![Figure 8 Packets that are sent to Base Station in Proposed LEACH Protocol.](image8)

Figure 10 illustrates the throughput from 0 rounds to 2450 as 2450 is the overall lifetime of leach in our experiment. Here y axis shows the amount of packets sent during running time. It is clearly shown that the packets goes down rapidly recently after the first node dead, which clearly shows the benefits of the stability period of wireless sensor network. However it also shows the progress in terms of network life time and stability period than the simple leach protocol.

![Figure 9 Packets that are sent to Cluster head in LEACH Protocol.](image9)
Fig 10: Packets that are sent to Cluster Head in Energy LEACH Protocol.

Figure 11 is showing the Packets that are sent to Cluster head in Proposed Leach Protocol during the lifetime of the Proposed Leach protocol. And it is clearly shown that they are quite more than figure 10 and 9 which is proving that proposed protocol is better with respect to packets send to cluster head.

Fig 11: Packets that are sent to Cluster head in Proposed Leach Protocol.

D. Comparison

The below graphs shows the comparison between Leach, Energy Leach and Proposed Leach Protocol. Comparison is made on the basis of dead nodes, dead normal nodes, dead advance nodes, alive nodes, alive normal nodes, and alive advance nodes in case of LEACH, Energy LEACH and Proposed LEACH Protocol.

Fig 12: Shows the dead nodes in Leach, Energy Leach and Proposed LEACH Protocol.

Fig 13: Shows the dead normal nodes in Leach, Energy Leach and Proposed Leach Protocol.

Fig 14: Shows the dead advance nodes in LEACH, Energy LEACH and Proposed LEACH Protocol.

Fig 15: Shows the alive normal nodes in Leach, Energy Leach and Proposed LEACH Protocol.

Fig 16: Shows the alive advance nodes in Leach, Energy Leach and Proposed LEACH Protocol.
We considered a protocol for WSN called LEACH protocol which is the most essential protocol in wireless sensor network which utilizes cluster based upon broadcasting technique. Followed by an overview of LEACH and Energy LEACH protocol implementations, then we proposed a new version of LEACH protocol called Enhanced LEACH protocol (Proposed LEACH). The concluded research work implemented a new improved clustered heterogeneous network where advanced nodes elect themselves as cluster heads, for the increasing number of rounds based on their higher initial energy relative to other nodes. In Enhanced LEACH, the cluster members are informed about the status of their CH. This provision is missing in LEACH and Energy LEACH protocol. Enhanced LEACH is more effective. It also improves the stable region of the clustering based hierarchy process using the parameters of heterogeneity like the fraction of advanced nodes (m) and secondly the additional energy factor between the advanced nodes and normal nodes (α). Comparison of proposed algorithm is also drawn with existing methods to evaluate the performance of proposed algorithm. It is found that proposed algorithm provides better results than existing, as we have extended the stability time or when the first node dead time. Also last node dead or network lifetime is also increased. The work done on the implementation of the protocol as part of this thesis has future implications where in near future the proposed algorithm will be implemented in real time systems by using the embedded systems. The results can be further generalized if database includes higher number of nodes as division; nodes will come up with some potential overheads so in near future we will try to reduce these overheads. Moreover future works may concentrate on achieving better energy efficiency in routing mechanism for wireless sensor nodes.

VII. CONCLUSION & FUTURE WORK

REFERENCES


AUTHOR BIOGRAPHY

Nikita Sehgal received her B.tech degree (Electronics and Communication Engineering) in 2011 from IET Bhaddal, Ropar, India. Currently she is pursuing her M.Tech degree from Department of ECE, Yadavindra College of Engineering (YCoE) Punjab University Gurugram Campus, District Bathinda, and Punjab, India. Her area of research is Wireless Sensor Networks.

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