A Qualitative Study of Various Improvements in Cluster Based Routing Protocols for WSN

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Abstract—A wireless sensor network is comprised of hundreds and thousands of small tiny devices called sensor nodes which are distributed in such a way so as to monitor real environment conditions likewise temperature, pressure, humidity, etc. But most of the wireless sensor networks are constrained to their low network lifetime due to high energy consumption. In this paper a qualitative study has been made regarding various improvements carried out in Low Energy Adaptive Clustering Hierarchy (LEACH) routing protocol.

Keywords—Clustering, Cluster head, LEACH, LEACH-E, LEACH-EX.

I. INTRODUCTION

In the current era, wireless sensor networks have been introduced as one of the most important technologies. In WSN, there is a networking of sensor nodes which are deployed randomly in the field under observation. The usage of WSN is increasing every day but it has to bear the problem of limited network lifetime. For long term and effective utilisation of WSN, it is necessary to design energy efficient routing protocols so as to enhance the network lifetime of a WSN.

In general, data transmission in wireless communication takes more power than data processing. Whenever the nodes are transmitting large number of data, correspondingly their battery Power also gets reduced. One of the energy efficient routing approaches is clustering [1].

II. CLUSTERING

Dividing the sensor networks into small manageable units is called as clustering. Clustering scheme improves the scalability of the network as well as act as an important factor in achieving energy efficient routing of data [2].

A. LEACH

Low Energy Adaptive Clustering Hierarchy (LEACH) is a popular energy efficient adaptive clustering algorithm that forms node clusters on the received signal strength. LEACH is broken up into rounds where each round begins with a set up phase, followed by a steady phase.

The set up phase follows the following sequence:
- Cluster Head (CH) selection
- Cluster Formation
- Transmission Schedule Creation

In the steady phase, the nodes transmit the sensed data to the cluster head and the cluster head aggregates the original data to carry only the meaningful information. The aggregated data is then transmitted to the base station by cluster heads.

The selection of cluster head depends on decision made by the node by choosing a random number between 0 and 1. If the number is less than the threshold value \( T(n) \), the node becomes a cluster head for the current round. The threshold can be calculated as:

\[
T(n) = \begin{cases} 
p, & \text{if } n \in G; \\
1 - p\left(1 - (1/p)^r\right), & \text{else} \\
0, & \end{cases}
\]

(1)

Where \( p \) is the probability of the node to be selected as a cluster-head node, \( r \) is the number of passed rounds, and \( G \) is the set of nodes that have not been cluster-heads in the last \( 1/p \) rounds, mod refers to modulo operator. Nodes that are cluster heads in round \( r \) will not be selected in the next \( 1/p \) rounds [3].
III. OVERVIEW OF LEACH IMPROVEMENT

Although LEACH protocol increases the network lifetime considerably, still it suffers from many problems, a few of which are as follows:

- Random selection of cluster heads leads to uncertainty in optimal number and distribution of cluster heads.
- High residual energy nodes as well as low residual energy nodes have same priority to be cluster head. Hence, nodes with less remaining energy chosen as cluster heads will die first due to which LEACH can’t be used in large scale wireless sensor networks[4].

A. Improved LEACH Algorithm

The proposed algorithm takes into account the residual energy of nodes as well while selecting a cluster head normally. The new threshold level is proposed as:

$$T_{new}(n) = \begin{cases} \frac{p_{head}}{1-p\times r \mod (1/p)} & \text{if } n \in G; \\ 0, & \text{else} \end{cases}$$

Where $p$ is the percentage of cluster heads in the sensor networks, $r$ as the number of current round, $G$ is set of nodes that have not been cluster head in the last $1/p$ rounds. $E_{current}(n)$ refers to the current energy of the node $n$ and $E_{max}$ refers to the initial energy of each node. Also, in this algorithm independent node mechanism is considered in which sink node is treated as cluster head when a non-cluster head node joins a cluster. The non-cluster head nodes decide whether to join in a cluster or to communicate directly with the sink node as shown in Fig. 2.

B. E-LEACH

To overcome the limitations of LEACH, another improvement is done and a routing protocol based on LEACH is proposed to solve the overload energy consumption problem by balancing the energy consumption of sensor nodes. The performance of routing protocols is greatly affected by the number of cluster heads. As the energy requirement is more in carrying out communication between cluster heads and the base station than the common nodes, the more number of cluster heads will increase the energy consumption of the whole sensor network and network lifetime decrease remarkably.

But in E-LEACH, the minimum spanning tree technique is used for cluster head selection and the cluster head with the largest residual energy is taken as the root node.

The threshold used in this protocol is given as:

$$T_1(n) = \begin{cases} \frac{p}{1-p\times r \mod (1/p)} \times \frac{E_{current}(n)}{E_{max}}, & n \in G; \\ 0, & \text{else} \end{cases}$$

In this algorithm, after improving cluster head selection, the simulation results yield a remarkable decrease in energy consumption of the whole network as compared to LEACH [6].

C. LEACH-EX, an improvement of LEACH-E Algorithm

In LEACH-E, threshold is calculated by taking the square root of the ratio of current energy and residual energy but the use of square root decreases the overall probability of number of cluster heads getting elected. Due to reduction in number of cluster heads, farther nodes have to send data across larger distance and hence their individual energies get reduced while the overall energy consumption of network get increased.

LEACH-EX is an extension to LEACH-E. The formula used for threshold in LEACH-EX is given as:

$$T(n) = \begin{cases} \frac{P}{1-P \times r \mod (1/P)} \times \frac{E_{current}}{E_0}, & n \in G; \\ 0, & \text{other} \end{cases}$$

LEACH-EX yields better performance than LEACH-E and also simplifies the formula for calculating threshold thereby reducing the computational complexity of cluster head selection [7].

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**Fig.1 LEACH and Improved LEACH technology**

While comparing with LEACH algorithm the simulation results conclude that there is considerable reduction in consumption in the proposed improved algorithm as compared to the original LEACH algorithm [5].
D. The Energy-Efficient Cooperative MIMO scheme

In EE-LEACH MIMO scheme, energy efficient LEACH (EE-LEACH) protocol and cooperative MIMO are combined. The location and the residual energy of each node is taken into account when cluster heads for clustering and cooperative nodes for MIMO system are selected. The system model is shown as:

![Network Model in EE-LEACH MIMO](image)

The nodes are randomly distributed over a measured space. The network is divided into many clusters and each cluster is comprising of one cluster head and many member nodes, among them a few are chosen as cooperative nodes for cooperative MIMO system to distribute packets to the sink which is located far away from the observation area.

All the operations are arranged in rounds and each round undergoes three stages: cluster head generation, cooperative node selection and data transmission. The simulation results yields a well balanced energy efficient sensor network having prolonged lifetime in comparison to LEACH, LEACH-E[8].

E. LEACH protocol using Nearest Neighbour Algorithm (NNA) for WSN

This algorithm is proposed basically as improvement in EE-LEACH-MIMO in which transmission of data from sensor nodes is done by choosing shortest path through nearest neighbour algorithm in multi-hop manner. The algorithm includes:

- Selection of random node as starting node for the path.
- Node having minimum distance from the starting node is added as the second for the path.
- Again node nearest to second node is added as third node and the whole process is continued until it reaches to the cluster head by covering all the nodes once.

The simulation of proposed algorithm results in considerable increase in network lifetime and network is more energy efficient in comparison to those which are discussed earlier [9].

IV. CONCLUSIONS

In this paper a collective study of various improvements made in LEACH protocol is done and is found that each improvement have remarkable effect in prolonging the network lifetime of a wireless sensor network and making it more energy efficient.

REFERENCES


