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Cluster Head Selection Using Gradient Descent Algorithm for Wireless Sensor Network

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ABSTRACT

Wireless Sensor Network (WSN) consists of large number of small size sensor nodes having limited battery and power resources. They are used in various applications like health care, military, home and environmental sensing for real time operations. Energy efficiency and network lifetime are main concern of WSN. Clustering is one of most efficient routing algorithm to solve issues of network. Selection of cluster head is one of the main concerns for WSN. Different algorithms have been proposed to find best-suited cluster head with low energy consumption. In this paper, Gradient Descent approach has been used and is compared with modified LEACH. MATLAB 2015a simulation results show improvement in terms of number of dead nodes, optimal number of cluster head and number of packets transmitted to base station.

Keywords: WSN, Gradient Descent, Threshold, Clustering.

1. Introduction

Wireless Sensor Network (WSN) consists of large number of small size sensor nodes have limited battery and power resources and a base station. They are used in various applications like in health care, military, home and environmental sensing for real time operations [1]. Sensor nodes can be deployed in harsh environments and at those places which are not easily accessible. Batteries of nodes need to be changed regularly as they have limited power resource. Thus, energy consumption is one of main challenge and it is required to minimize energy consumption and enhance network lifetime.

Sensor nodes collect the data from real time environment and transmit that data to base station and starts communication. Sensor nodes have characteristics like fault tolerant, scalable, and self-configurable, etc. Data aggregation is performed to reduce transmission of duplicate or redundant data [2]. Different routing protocols have been proposed to improve network lifetime. Clustering is most energy efficient routing protocol used to reduce consumption of energy and for improving lifetime of network. Cluster consist of two types of nodes first is cluster head and second is cluster members. Cluster head perform tasks like data aggregation and transmission to base station [3]. LEACH is mostly used clustering algorithm in which cluster heads are selected randomly. It consist of two phases first is set up and second is steady state phase. In set up phase clusters are formed, cluster head is selected and each sensor node is assigned a TDMA timeslot. During steady state phase communication between sensor nodes and cluster head and communication between cluster heads and base station take place. Cluster head collects data from nodes and remove redundant data and transmit data to base station. Choice of cluster head is one of the main concern and different algorithms have been proposed for this.

The rest of the paper is as section 2 shows literature survey and section 3 shows proposed algorithm discussed. Section 4 present simulation results and analysis. Section 5 is about conclusion and future scope of proposed algorithm.

2. Literature Survey

Tao Liu et al. in [1] have proposed an approach for equal distribution of energy consumption among CHs and this is a routing approach based on gradient method called EBCAG. In this nodes are divided into unequal size clusters and each node has a gradient value that tells about hop counts to sink that are minimum. Mohammad Shurman et al. in [2] have proposed two approaches that will minimizes the power consumption, node having low energy consumption while communicating with other nodes will become Cluster Head in first proposed approach. Second approach is obtained by modifying first approach which depends on distance and energy calculated between present node and other nodes. Jenq-Shiou Leu et al. in [3] have proposed energy aware regional Clustering considering nodes that are isolated, on the basis of weights of nodes, selection of CH is performed. It uses distributing algorithm of Clustering. Remaining energies will help in determine weight of nodes. Network gets its life enhanced. Chinchu T Sony et al. in [4] have proposed modified LEACH and modified Multi Hop LEACH protocols. For modification in LEACH protocols, selection of CH is modified and TDMA time slots are modified by which next node can send data in previous node's timeslot if previous node has no data to send. Yacouba Ouattara et al. in [5] have proposed a new algorithm in which three thresholds are used. This algorithm is also suitable for mobile WSNs. Loss of energy due to death of nodes is also decreased. G. Kannan and T. Sree Renga Raja in [6] have proposed an algorithm called distributed CH scheduling to enhance network lifetime. In this network is divided into two tiers depending on RSSI of nodes from BS. This algorithm helps in selection of cluster heads and gateway nodes for both tiers. Santar Pal Singh et al. in [7] have studied different routing protocols based on Clustering. Comparison of different protocols according to their advantages and disadvantages is discussed. It has provided different design issues of routing protocols. This will help researcher in developing, modifying and optimizing different routing protocols.

Dongyao Jia et al. in [8] have proposed a method of selection of CH dynamically to reduce the energy consumption. Energy consumption is based on node redundancy. Energy of nodes is balanced in two states of network. B. Priya et al. in [9] have proposed a protocol which is Cluster based called EEHMAC to enhance Network Lifetime of WSNs. E-TDMA is adopted for transmission in intra Cluster and for inter Cluster FDMA is preferred. For Assignment of frequency and time slot of nodes, IDS (Iterative-Deepening-Search) is preferred which is a Scheduling algorithm. Thus this protocol gives better performance than other MAC protocols.Ahmad A. Ababneh and Ebtessam Al- Zboun in [10] have proposed EDAC algorithm which depends on distance and remaining energy of network. CH is selected with local knowledge about neighborhood. It results in reduction in communication cost and better lifetime than DEEC and LEACH. Amira Ben Ammar et al. in [11] have proposed an improved protocol called multihop clustering cross layer based on LEACH. Signal to Noise Ratio of various links and node's left energy is considered in this protocol. It helps in finding best route between source Cluster Head and destination. Amr Amwary et al. in [12] have proposed a protocol in which modification at setup phase is done by selecting Cluster Head only from advanced sensor nodes which improves overall lifetime of network. Energy harvesting generator can provide power requirement level by sensor nodes in WSNs.

Khalid A. Darabkh et al. in [13] have proposed a protocol called as Modified Threshold Cluster Head Replacement (MTCHR) to overcome TLEACH protocol's drawbacks. In this protocol each sensor node has probability to become a CH. Masood Ahmada et al. in [14] have used honey bee algorithm to find best suited cluster head. During first phase, an objective function is proposed for clustering problem. This scheme helps in forming balanced clusters. Mohamed Elshrkawey et al. in [15] have proposed modified LEACH approach along with modified TDMA scheduling that will minimize energy consumption and will enhance Network Lifetime. Energy is balanced among nodes in different clusters. It uses method of election of CH by changing the threshold value deduction formula.

3. Proposed Approach

Selection of cluster head is one of the challenging problems for WSN. For proper selection of cluster head, Gradient Descent Algorithm has been proposed. In this approach threshold value is adjusted by considering energy, distance, node density, number of times cluster head selection and inter distance cluster. Gradient Descent is an iterative and optimization algorithm and results obtained after this approach are more accurate than other approaches. Number of iterations performed are simple and are less computationally complex. In Gradient Descent approach, we find the fitness parameters. When there is no increase or decrease in threshold value, we will say that it has converged. Number of iterations for convergence can vary a lot.

Fitness function for Gradient Descent Algorithm: The fitness parameters decide the threshold value to acquire the optimal solution. The following fitness values are used to design the fitness function for the gradient based optimized routing.

1. **Distance between node and sink:** The first fitness parameters include the distance between the cluster node and the sink. It is necessary to select the node nearest to CH so as the energy consumption can be reduced significantly. By minimizing distance parameter, the network longevity can be achieved.

$$f1 = D||Node_i - Sink|| \quad (1)$$

Where, $D||Node_i - Sink||$ represents the Euclidean distance of i^{th} cluster node from the sink.

2. **Residual Energy:** It is defined as the remaining energy of the nodes to be selected as CH. More the energy of a node, more it will cover the number of rounds. With the minimization of f2, node with higher energy will be selected as CH.$E_{N(i)}$ represent the energy of i^{th} cluster node.

$$f2 = \frac{1}{E_{N(i)}} \quad (2)$$

3. **Number of neighboring nodes:** It is the third fitness parameter that determines the node with maximum neighbors. The significance of this parameters is the reduction of the average distance of all the cluster member nodes to the current node to be selected as CH.It is determined by calculating the node with minimum average distance from the other nodes in the cluster.

$$f3 = \frac{1}{C\_N}\left(\sum_{i=1}^{C\_N}\sum_{j=1}^{C\_N}\left(D\left|\left|Node_i - Node_j\right|\right|\right)\right) \quad (3)$$

Where, $D\left|\left|Node_i - Node_j\right|\right|$represents the Euclidean distance of i^{th} cluster node from j^{th} cluster node.

4. **Frequency of being CH:** In order to avoid the absence of CH in the cluster for any round, the following fitness parameter is minimized.

$$f4 = (1 - log_{10}d) \times \frac{1}{CHtimes} \quad (4)$$

$CHtimes$ represents the number of times the node has been CH in the last few rounds.

5. **Assurance of CH in the cluster:** This parameter ensures the condition that when sensor nodes are having energy more than average energy i.e., E_{avg} then they must be in a competition for CH selection. E_i is the energy of i^{th} node and N being the total number of nodes in the cluster.

$$f5 = \left(1 - \frac{1}{E_{avg}}\right) \quad (5)\ E_{avg} = \frac{1}{C\_N}\sum_{i=1}^{C\_N} E_i \quad (6)$$

6. **Inter-cluster distance:** It is the factor that decides the distance between the CHs of various clusters. With this parameter, the cluster size is put under controlled and they are made uniform. Consequently, the smaller sized clusters are avoided that helps in mitigating more energy consumption in those clusters.

$$f6 = \sum_{i=1}^{N}\sum_{j=1}^{N}\left(D\left|\left|CH_i - CH_j\right|\right|\right) \quad (7)$$

Where, $\left(D\left|\left|CH_i - CH_j\right|\right|\right)$represents the Euclidean distance of i^{th} CH node from the j^{th} CH node and N is the number of nodes in the network.

Therefore, the solution for the defined optimization problem is to minimize the following objective function

$$\text{Fitness Function (F(x))} = \frac{1}{\alpha \times f1 + \beta \times f2 + \Upsilon \times f3 + \lambda \times f4 + \Omega \times f5 + £ \times f6} \quad (8)$$

Where α, β, Υ, λ and Ω are the control parameters in the range [0,1] with($\alpha + \beta + \Upsilon + \lambda + \Omega + £ = 1$).Fig.1 shows flow chart of proposed Gradient Descent algorithm.

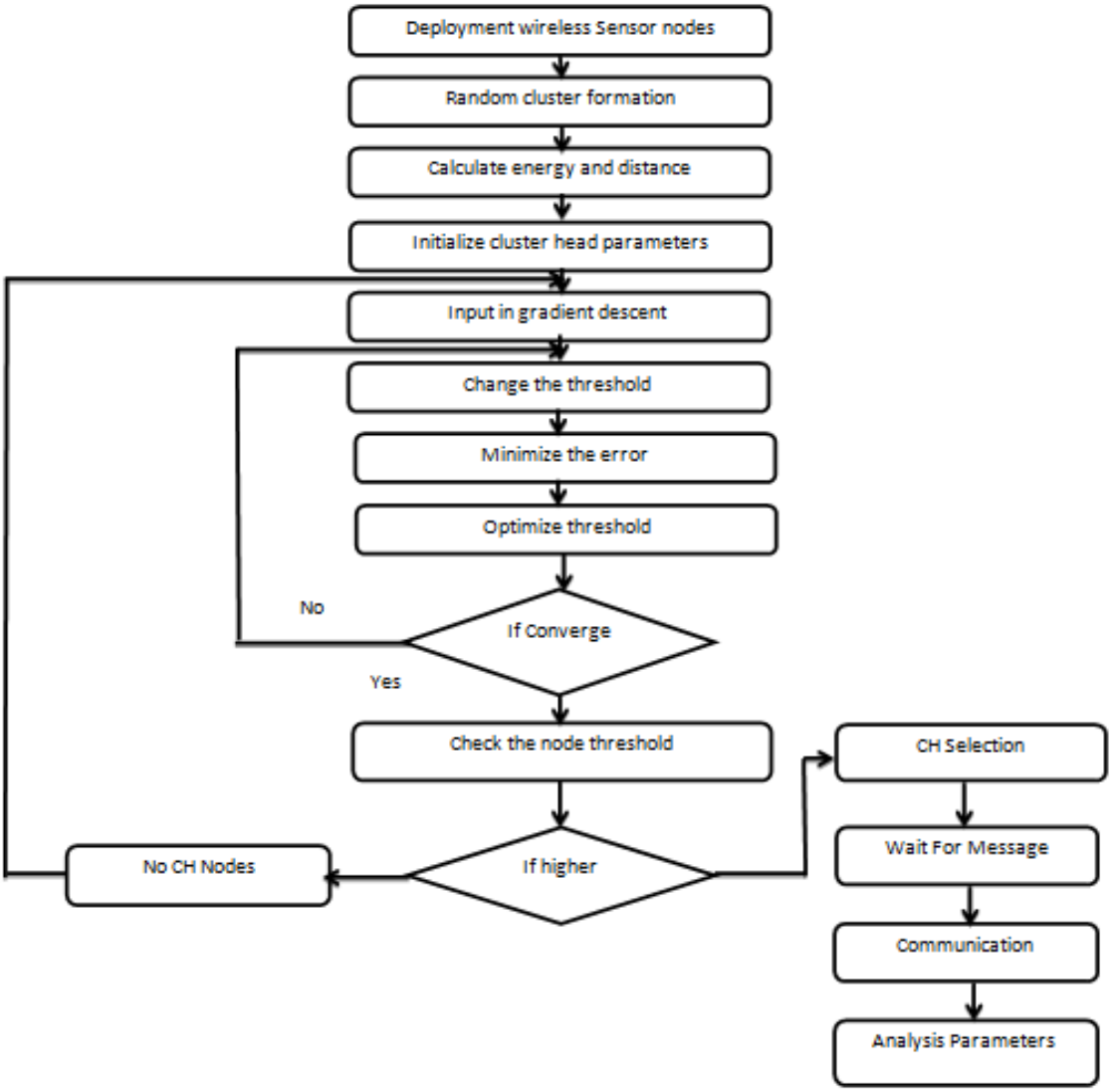

Fig. 1 Flow chart of proposed algorithm

Methodology Steps

These are methodology steps being followed in order to get improved threshold value for finding best suited cluster head and make data communication more efficient.

- **i.** Step 1: Deployment the wireless sensor nodes.
- **ii.** Step2: Random cluster is formed after deployment.
- **iii.** Step 3: Calculate the energy and distance of the clusters.
- **iv.** Step 4: After this initialize the parameters of the cluster head.
- **v.** Step 5: Input the parameters in the gradient descent and change the threshold.
- **vi.** Step 6: Gradient descent change the threshold and minimize the threshold.
- **vii.** Step 7: Optimize the threshold by minimizing fitness function and give the best threshold.

viii. Step 8: Check the threshold converges or not. If it is converge then check the convergence of node otherwise change the threshold.
ix. Step 9: If threshold of node is high select the cluster head. Otherwise no cluster head node is found.
x. Step 10: Communication process is start receiving after message.
xi. Step 11: Analyze the parameters.

4. Simulation results and analysis

MATLAB 2015a has been used to analyze proposed algorithm. 100 nodes have been deployed in 100*100 square meter area. The sink node is placed at the network of the network area at (50, 175). All the nodes and sink node are static in nature. The proposed simulation parameters are presented in table 1.

Table 1 Simulation parameter

Parameter	Value
No. of rounds	100
P	0.1 or 100%
E_{elec}	50nJ/bit
E_{fs}	10pJ/bit/m^2
E_{DA}	5nJ/bit/message
E_{mp}	0.0013pJ/bit/4
Initial Energy	5 J
packet size	4000
Number of iteration	100

4.1Results

4.1.1. Number of cluster heads

Numbers of cluster heads are an impactful factor for WSNs. Fig.2 shows number of cluster heads versus number of rounds. Results show that optimal number of cluster head is around 5 with less variations resulting reduced energy consumption. Table 2 shows comparison between existing modified LEACH and proposed Gradient Descent algorithm.

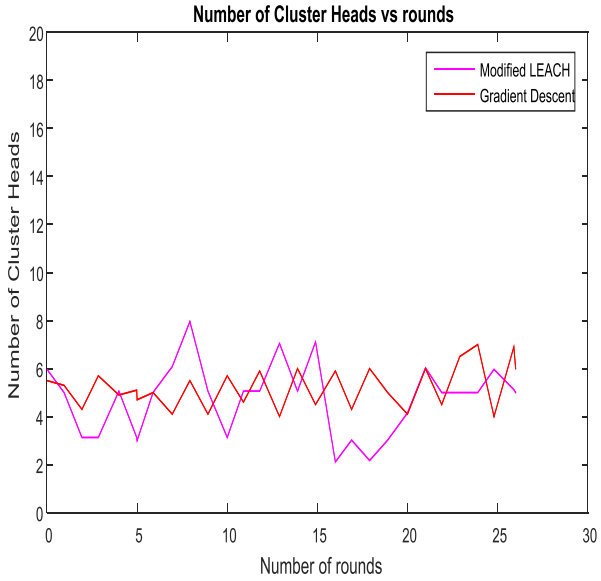

Fig.2 Number of cluster heads versus number of rounds

Table 2Cluster head counts

Rounds	Modified LEACH [15]	Proposed Gradient Descent
5	3	5
12	5	5
26	5	5

4.1.2. Network lifetime based on number of dead nodes

Network lifetime can be defined as the time until the first sensor node dies or runs out of energy in the network. Fig.3 shows network lifetime in terms of number of dead nodes versus number of rounds. First node dies at round 18 in proposed approach whereas in existing approach first node dies at round 15.There is significant reduction in number of dead nodes. Table 3 shows comparison between existing modified LEACH and proposed Gradient Descent algorithm.

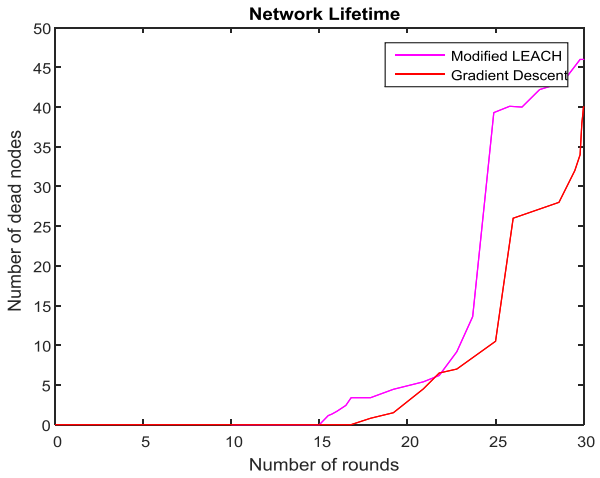

Fig.3 Network lifetime based on number dead nodes

Table 3Dead nodes counts

Rounds	Modified LEACH [15]	Proposed Gradient Descent
14	0	0
24	14	11
30	46	40

4.1.3. Number of packets at the base station

In the proposed approach number of packets delivered at base station is more than in existing approach. By considering the energy consumption number of packets are estimated. Fig. 4 shows the simulation result of proposed Gradient Descent approach and existing modified LEACH method. Result shows that number of packets delivered by Gradient Descent approach is more than Existing approach.

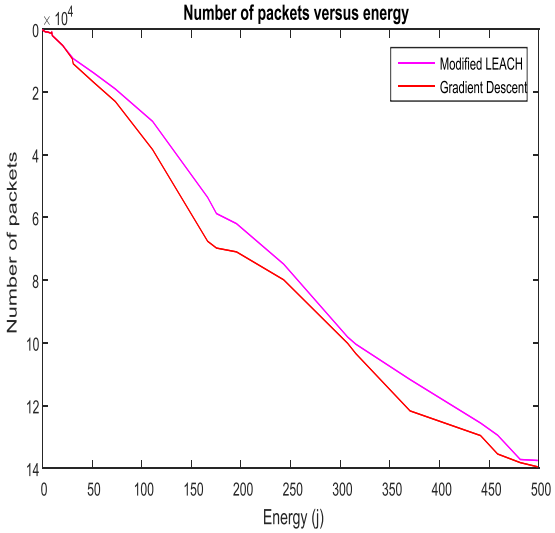

Fig.4 Number of packets versus Energy (J)

5. Conclusion and Future Scope

In this paper, Gradient Descent approach has been proposed and is compared with modified LEACH. Gradient Descent helps in finding optimum value of threshold by considering both remaining energy and distance. Results are simulated using MATLAB 2015a. Results have been improved in terms of optimal number of cluster heads, network lifetime in terms of number of dead nodes and number of packets delivered at base station. We have considered network to be static but how this algorithm will work if network is not static can be discussed in future. This algorithm does not provide any security and privacy to network, thus work on security can be done in future.

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