International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 22 (2018) pp. 15465-15469

A Comparative Analysis of LEACH and HEED in Hierarchical Clustering Algorithm for Wireless Sensor Networks

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Abstract

Wireless sensor network (WSN) is the widely used concept which measures the environmental conditions. WSN include number of sensors which built by sensor nodes for collecting and transmitting data. Hierarchical routing protocols were colossally used in WSN. LEACH and HEED are the leading types in hierarchical routing protocols. This paper presents comparative study of LEACH and HEED based on K-means clustering algorithm to select the clustering head. At the end, the comparative analysis of above two protocols presented to show how the cluster formation improves the lifetime of the network in NS2 simulation tool. The following parameters are evaluated using NS2: average end-to-end delay, packet delivery ratio, average energy consumption, average throughput and control routing overhead.

Keywords: Wireless sensor networks, LEACH, HEED, K-means clustering.

INTRODUCTION

A wireless sensor network can be defined as a network of devices that can communicate the information gathered from a monitored field through wireless links. The data is forwarded through multiple nodes, and with a gateway, the data is connected to other networks like wireless ethernet. WSN is a wireless network that consists of base stations and numbers of nodes (wireless sensors) [1]. These networks are used to monitor physical or environmental conditions like sound, pressure, temperature and co-operatively pass data through the network to a main location. Routing protocol is one of the most important components of WSN. Routing protocol has to monitor the change of network's topological structure, exchange the routing information, locate the destination node, choose the route and transfer the information through route [3]. The main target of hierarchical routing or cluster based routing is to efficiently maintain the energy usage of sensor nodes by involving them in multi-hop communication within a particular cluster. Cluster formation is generally based on the energy reserve of sensors and sensors proximity to the Cluster Head (CH). The main hierarchical protocols are: LEACH, PEGASIS, TEEN, APTEEN and HEED [2].

The rest of the paper is organized as follows: Section II describes the CH selection algorithms, section III explains about the proposed system, section IV is briefing about system design, section V analyses the result and discussion, Finally section VI presents the conclusion and future scope.

LITERATURE SURVEY

This section gives the survey of possible algorithms used to select the cluster heads in various routing protocols. We have to select the CH based on particular algorithm for better efficiency and to improve the energy consumption. This survey helped us to analyse various existing algorithms for CH selection process.

Energy Efficient Fuzzy Logic Algorithm

The fuzzy logic based CH selection approach, used the fuzzy inference system approach to increase the lifetime of the network. In this approach for every round the threshold T(n) to become a candidate of chance (n). Here each node n calculates chance value based on residual energy, expected efficiency and closeness to BS. And select CHs in each round based on maximum chance value, if the maximum chance of n is less than or equal to T(n) then CH(n)← n, end of process. Then the formation of clusters based on received strength signal for each nodes. The cluster members send sensed data to their CH. BS collects the information from CHs. Thus, the fuzzy logic approach selects the cluster head for WSN communication [10].

Genetic Algorithm

Genetic Algorithm (GA) is a search heuristic that mimics the process of natural evolution. Determination of the number and place of cluster heads has always been a challenge. Genetic algorithm is used to determine the place of cluster heads in a way that the minimal amount of energy is consumed. Fitness criterion is based on the minimal consumed energy from network nodes in each generation. In base station, the number of nodes that have introduced themselves as cluster head candidates determines the chromosome's length in genetic optimizing method. Each of this chromosome's genes recognizes some of the sensor network nodes. Chromosome's structure is defined in (1).

$$\boldsymbol{chrom} = \{\boldsymbol{g_i} | \boldsymbol{i} = \mathbf{1}, \mathbf{2}, \mathbf{3}, \dots, \boldsymbol{l}\} \qquad ..(1)$$

Where, l is the chromosome's length

g_i is the i-th gene.

After crossover, mutation happens in a way that a mutation may be created in a bit of one or some chromosomes. Finally, after crossover and mutation, base station selects the chromosome which has the networks least energy difference in proportion to the previous round and introduces the available nodes to network as cluster head and other nodes join to the nearest cluster head [9].

K – Means Clustering Algorithm

K-means is a statistical, unsupervised, non-deterministic, iterative strategy for grouping the different articles into clusters [4]. It is simplest unsupervised learning algorithms known for its speed, effortlessness, and usability. This algorithm is utilized to desultorily optate K as the initial centre points from the consummate dataset. Then we calculate the Euclidean distance of each data point from the initial cluster centres, pick the sample which is most proximate, and then assign it to the felicitous cluster. The centre is updated till the mean squared error becomes minimum or the cluster centres ceases moving i.e. come in the centre. At this point all the data points have minimum distance from the centre point [5].

Among the above survey the fuzzy logic approach gives better lifetime of the network by selecting the CH. The main drawback over here is time delay. Because the nodes are randomly distributed, the distance will not consider here. Genetic algorithm represents good energy consumption and the missing of time response. We propose the algorithm to reduce the time delay by using K – means clustering process. The CH is selected based on the minimal distance thus reduces the delay response.

PROPOSED SYSTEM

The proposed scheme uses K-means algorithm which forms the clusters of objects based on the Euclidean distances between them. The proposed CH selection scheme consists of three steps as follows.

Initial clustering

K-means algorithm is executed for cluster formation with the target WSN. Assume that the WSN of n nodes is divided into k clusters. First, k out of n nodes is randomly selected as the CHs. Each of the remaining nodes decides its CH nearest to it according to the Euclidean distance.

Re - clustering

After each of the nodes in the network is assigned to one of k clusters, the centroid of each cluster is calculated. Assuming two-dimensional space, the centroid of a cluster of s nodes is calculated by using the equation (2) for the set of clusters K-means(S, k), S = $\{x_1, x_2, x_3, \ldots x_n\}$..

$$\mathbf{V} = \sum_{i=1}^{k} \sum_{j \in s_i} \left\| x_i - \mu_j \right\|^2 \qquad \ldots(2)$$

Where, μ_i = centroid

Choosing the Cluster Head

After the clusters are formed, an ID number is assigned to each node of a cluster according to the distance from the centroid, assigning smaller number to the closer one. The ID number of a node indicates the order to be chosen as the CH. Therefore, the ID number plays an important role in the selection of a node as CH.

Get the nodes with ID number as input

If Energy of cluster head < Energy of threshold

then

All nodes ← CheckID()

Current cluster head = ChangeHeader()

All nodes ← InformMsg()

Send the data to the BS

The residual energy of the CH is checked every round to retain the connectivity of the network. If the energy of the CH is smaller than the threshold, the node in the next order is selected as a new CH. The newly elected CH informs other nodes of the change of the CH. The proposed scheme adopts single hop routing protocol for the CHs to directly transmit the data to the BS. The collected data are them processed by the BS.

SYSTEM DESIGN

Sensor nodes are formed in WSN and capable of sensing the environment, processing the information locally and sending it to the point of collection through wireless links in a particular geographical area. WSNs are scalable and smart. Sensor communication has done within nodes via cluster heads to reach the destination. One of the main goals here is to reduce time delay. Time delay of the network can be reduced by making changes in CH selection process.

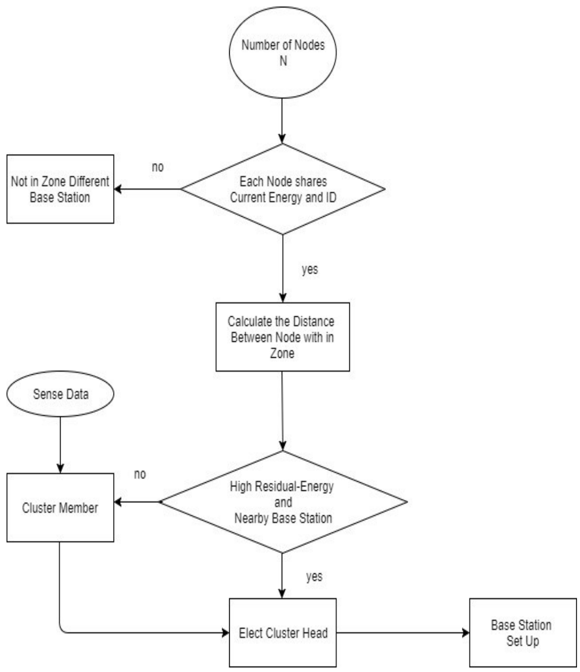

Figure 1. Flow diagram of Cluster Head Selection

Cluster Formation Methodology

- *Each node broadcast (Head message) contains current energy and ID of node*
- *Based on the received Head message, each node determines Zone, Cluster Head for this round (random selection with obstacle).*
- *Received strength is positive gets node's ID + Current energy + header.*
- *Calculate the distance based on their node's ID.*
- *Calculate the distance based on nearby base station and high energy.*
- *Elects cluster head remaining nodes act like cluster member and having ID and low energy to sense data and send to cluster head.*

The cluster head collects and aggregates information from sensors in its own cluster and passes on information to the mobile sink. The node with highest residual energy is selected as cluster head. If the nodes have equal or full energy, then centrality is calculated for each node as the difference between the location of node (i) and the centre of the cluster (j) of squared distances from other nodes to the candidate node using the following equation (3)

$$(S_i) = \sqrt{\left(\left(x_{c_j} - x_i\right)^2 + \left(y_{c_j} - y_i\right)^2\right)} \quad \ldots(3)$$

$\forall\ i \neq j \quad where\ i = 1 \ldots n_{Cj},\ j = 1 \ldots k$

Where x_{c_j} and y_{c_j} is the center of a specified cluster j. S_i indicates selected neighbour node and C(S_i) denotes the distance between nodes. The lower distance means higher value of centrality, resulting in the lower amount of energy required to transmit the data.

Clustering in LEACH protocol

LEACH is a hierarchical protocol in which most nodes transmit to cluster heads, and the cluster heads aggregate and compress the data and forward it to the base station (sink). All nodes that are not cluster heads only communicate with the cluster head in a TDMA fashion, according to the schedule created by the cluster head. They do so using the minimum energy needed to reach the cluster head [6]. All nodes in the network organize themselves into local clusters, with one node in the local cluster acting as cluster head. All nodes communicate only to the cluster head, and the cluster head conveys data to the base station. Nodes with higher capability advertise themselves as cluster heads, other nodes join the cluster head which is nearest to them. As cluster head has to spend lot of energy ,after certain time, randomized rotation of the cluster head is done, so that only node does not drain its energy. Every cluster head will prepare a schedule, to each of its members. The members communicate with the head only during that duration and sleep for the rest of the time.

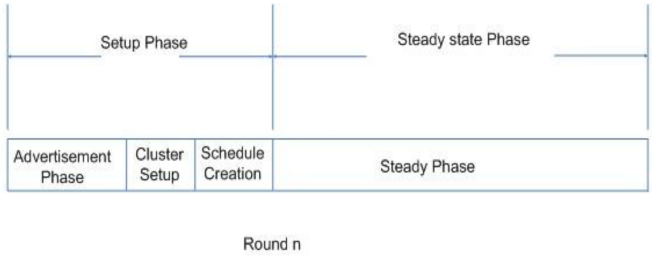

Figure 2. Setup Phase and Steady State Phase

Setup Phase

In the first phase, cluster heads are selected and then the clusters members are determined. In this phase, each node calculates its chance parameter based there main characteristics through K means clustering process: its time response, density and centrality in comparison with neighbours. Nodes with higher capability introduce themselves to base station as cluster head candidate, so they prevent those nodes which are not capable of being cluster head from sending their information. The network uses nodes with different factor after being launched. Nodes that remaining energy in comparison with network's total energy is less than threshold level are recognized as dead nodes and can't participate in competition. In base station, cluster heads are determined among cluster head candidates using genetic algorithm. Also, the number of times in which a node is selected as cluster head is considered. Then, base station sends a message including cluster head's ID to each node. If a node's cluster head ID conforms to the node's ID, that node is a head a cluster. Base station creates a time division multiple access tables and this table is sent to cluster heads. TDMA table is used to time the data transfer of sensor nodes and also enables sensor nodes to turn off their radio antenna and save their energy until it's time for them.

Steady State Phase

In the second phase, cluster members send the received data to cluster head according to TDMA table and after receiving data, cluster heads compress and send them to base station. Figure 2 explains the architectural view of setup phase and steady state phase of LEACH [7].

Clustering in HEED protocol

Hybrid Energy Efficient Distributed protocol was designed to select different cluster heads in a field according to the amount of energy that is distributed in relation to a neighbouring node. In each cluster one node acts as a cluster head which is in charge of coordinating with other cluster heads. To increase energy efficiency and prolong network lifetime intra cluster communication is used and it communicates with other cluster heads. HEED distribution of energy extends the lifetime of the nodes within the network thus stabilizing the neighbouring node and it operates correctly when nodes are not synchronized [8]. In HEED clustering algorithm, each node is mapped to exactly one cluster. The node can directly communicate with its cluster head (via a single hop). Each node independently makes its decisions based on local information. Clustering terminates within a fixed number of iterations. At the end of each TDMA, each node is either a cluster head, or an ordinary node that belongs to exactly one cluster. Clustering should be efficient in terms of processing complexity and message exchange and cluster heads are well-distributed over the sensor field.

RESULTS AND DISCUSSION

In this section we have discussed the results of the system implemented and performance analysis using novel clustering based on K means algorithm. We have given screenshots of clustering approach applied over the LEACH and HEED protocols. In the following Figures 3 and 4 explains the clustering process done by using K means clustering process over LEACH and HEED correspondingly.

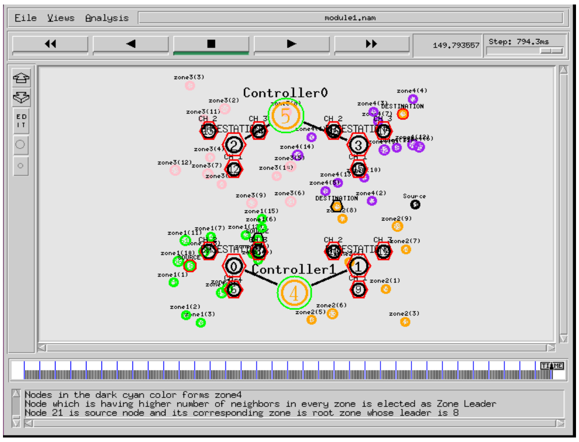

Figure 3. CH selection and signal transfer in LEACH protocol

Figure 3. shows the routing process done in LEACH protocol. At first, from the random nodes the clustering head had been selected using K-means clustering algorithm. Here there are 50 random nodes and 4 clusters for transmission process. And also there are 2 controllers placed for controlling the segmentation and congestion problem by fixing threshold value. Finally the routing process will be initiated by the base station to reach the destination.

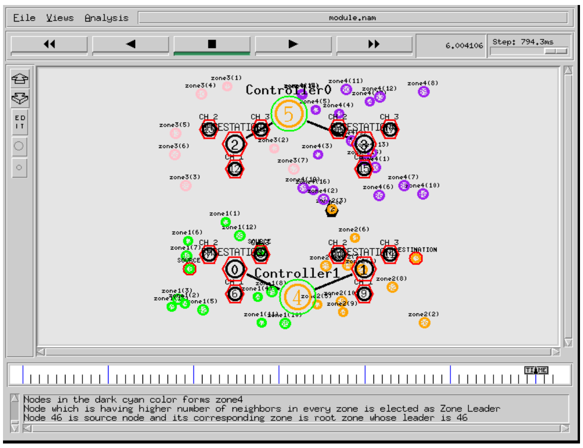

Figure 4. CH Selection and signal transfer in HEED

Figure 4 shows the HEED routing process by using K-means clustering algorithm. Among 50 given nodes the 46^{th} node is selected as source node and 29^{th} node is root node for transferring signal to destination. This communication done efficiently with minimal time delay via CH which was elected based on K – means algorithm.

Performance Analysis

To analyse the efficiency of LEACH and HEED protocols important parameters, Average end to end delay, whole system delay, Throughput and Packet Delivery Ratio are considered. Main aim here is to reduce the time delay while focusing on that.

The threshold value T(n) can be calculated by the equation (4) for LEACH protocol.

$$T(n) = \begin{cases} 1 - p * (r * mod\,(1/p)), & if\ n \in G \\ 0 \quad , & else \end{cases} \quad ..(4)$$

Where p is probability for cluster heads (selected by cluster), r is current round, 1/p is a set of nodes which were selected as cluster heads in previous round.

The probability of becoming cluster head in HEED is represented in equation (5)

$$CH_{prob} = C_{prob} \frac{E_{residual}}{E_{max}} \quad ...(5)$$

Where, $E_{residual}$ is the estimated current residual energy in the node

E_{max} is a reference maximum energy, which is typically identical for all nodes.

Table I. Parametric Analysis between LEACH and HEED

Parameters	**LEACH**	**HEED**
Average end to end delay	50 nodes/305ms	50 nodes/279ms
Whole system delay	33sec	9.9sec
Packet delivery ratio	98%	98.3%
Throughput	440packets/51sec	500packets/43sec

The table - I. shows the parameter value analysis between LEACH and HEED protocol and gives the result as HEED is the better efficiency protocol while comparing with LEACH. The cluster heads selected by HEED have low time delay response. HEED is completely distributed; a node can become a cluster head according to its CH_{prob}, or join a cluster according to overheard cluster head messages within its cluster range and thus node decisions are based solely on local information. In HEED, cluster heads are selected using K means clustering process. Thus the life time of the network in HEED protocol is more compared to other protocols in wireless sensor networks.

Whole System Delay Analysis

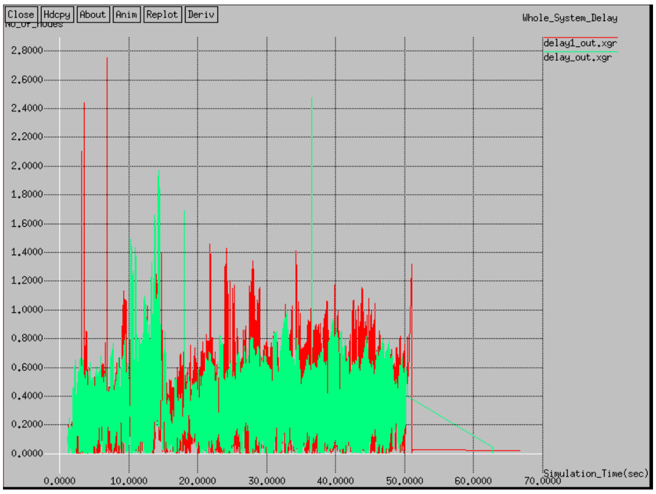

Figure 5. Comparative analysis of whole system delay over LEACH and HEED

The red plot and green plot represents LEACH and HEED correspondingly in Figure 5. The peak value of HEED protocol is 3.5×10^3 nodes for 10sec of time response. Time delay difference between LEACH and HEED is nearly 25sec.

Average End to End Delay Analysis

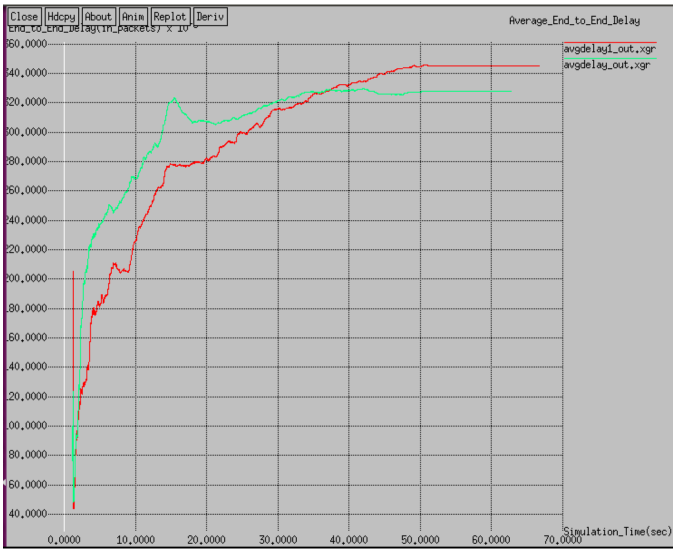

Figure 6. Average end to end delay comparison between LEACH and HEED

Figure 6 shows the HEED protocol communicates faster than LEACH within nodes. (i.e.) Average delay time for 50 nodes communication in LEACH is 305ms and in HEED is 279ms.

With respect to the above plotted graph, the HEED protocol in K means clustering process communicate more faster than LEACH in wireless sensor networks.

CONCLUSION

LEACH and HEED are the more representative protocols used by WSN. Though both having randomly distributed nodes, the improved clustering algorithm based on K-means here is to choose the better cluster head selection process. This makes the LEACH and HEED to work with more efficiency by finding the minimal distance between nodes on the Euclidean distance base. Finally these protocols were compared and the test result proven that the HEED protocol is having better efficiency than the LEACH protocol. In future this work can be enhanced by changing various algorithms to reduce the energy consumption in routing process.

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