

A Novel Approach to Uniformly Distribute the Load in Wireless Sensor Routing Protocol LEACH

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Abstract—A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. Energy efficiency is the important key for WSN. To lower the energy consumption, the network is divided into several clusters in cluster routing algorithm LEACH (Low Energy Adaptive Clustering Hierarchy). Even though clustering provides energy efficiency, but uneven load distribution still occurs in general. In this paper an approach is presented which divides the deployment region into sub-regions and thereby uniformly distributing the load among the sensor nodes. Different shapes are considered for dividing the deployment region into equal sub-regions.

Keywords—wireless sensor network, energy efficiency, LEACH, load distribution

I. Introduction

WSN consists of tiny sensor nodes with sensing, computation and wireless communication capabilities, as it enables reliable monitoring and analysis of environment. The nodes in WSNs are usually battery operated sensing devices with limited energy resources and replacing or replenishing the batteries is usually not an option. Thus energy efficiency is one of the most important issues and designing power efficient protocols is critical for prolonging the lifetime.

Cluster-based routing protocol has been demonstrated as a good way to meet the requirements of wireless sensor networks, such as scalability, lifetime constraint and energy-efficiency in LEACH [1]. The clustering plays a significant role for reliable and energy efficient data dissemination. In cluster-based network, the networks are partitioned into smaller clusters. As shown in Fig. 1, each cluster has a cluster head node (CH) and some cluster nodes. The CH node is responsible for many activities, e.g., intra cluster communication, data aggregation and inter cluster communication. The CH sends data to the base station (BS).

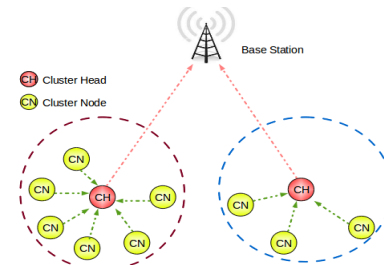


Figure 1. Clustering in LEACH

The LEACH circulates cluster heads as the rounds change to distribute energy consumption and fuses the data within the cluster in the cluster head for reducing communication cost. LEACH clustering algorithm is simple but does not guarantee about even distribution of cluster heads over the network. The idea proposed in LEACH has inspired many other hierarchical routing protocols [2, 3].

The rest of the paper is organized as follows. Section II briefly discusses some relevant algorithms of clustering. Section III then introduces the methodology of the proposed approach, partitioning the deployment region into sub-regions. Next, section IV, presents the evaluation of different shapes that are considered for making the sub-regions. Finally, the study is concluded in section V.

II. Related Work

LEACH [1] has been an algorithm for selecting the cluster head; to prolong the network lifetime. In set-up phase, each node assigns itself a probability which is a number between 0 and 1. If this probability is less than a predefined threshold, that node then becomes a new CH. It then broadcasts this message to all the other nodes in the network. And the other nodes join its cluster based on the signal strength of the broadcasted message. However, there are some problems about this algorithm.

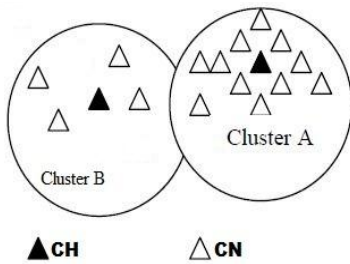


Figure 2. A sensor network with the given scenario

LEACH-C [4] improves LEACH to enhance the network lifetime. The cluster head selection takes place at BS. The selected CHs are chosen by the BS which holds infinite computation-power and infinite energy in order to save the network energy. The merits of this algorithm over LEACH are reducing energy consumption and extending the network lifetime. But it is less scalable than LEACH.

Despite the advantages offered by LEACH protocol for cluster organization, there are few points that must be pondered upon. LEACH assumes a homogeneous distribution of sensor nodes in the given area. But actually, this scenario is not very realistic. Let us consider a scenario in which most of the sensor nodes are grouped together around one or two cluster-heads. As being shown in Fig. 2, cluster head “A” have more nodes close to it as compared to the cluster head “B”. LEACH’s cluster formation algorithm will end up by assigning more cluster member nodes to “A”. This could make cluster head nodes “A” quickly running out of energy, because it has more number of nodes in its cluster.

The solution of the above problem is presented as grid clustering. These algorithm improves the load balancing significantly. The area of interest i.e. the deployment area is divided into minor grids. Now each minor grid has become a cluster area and it holds the same size as others. Zuang et al. [5] considered a transmission range and thus determined suitable grid size. Furthermore, Liu et al. [6] have used multi-hop clustering for the same purpose. It is proposed that how to relay the message from one grid to another grid, towards a sink, by choosing the best optimal next hop routing path with energy efficiency.

There are other clustering algorithms that have used the idea proposed by LEACH algorithm. Example for one such algorithm is PEGASIS [7]. Tillapart et al. [8] proposed an algorithm which is an extension of LEACH-C and selects cluster heads by a modified subtractive clustering technique.

HEED [9] is a fully distributed routing algorithm which selects the cluster heads by considering the residual energy as primary parameter and node degree as secondary parameter. The algorithm in [10] is also a distributed algorithm in which cluster heads are selected on the basis of the local information of each node.

The method proposed in this paper aims to facilitate the uniform distribution of load among the clusters.

III. Methodology of the Proposed Work

Below is the methodology of the proposed work, which first proposes that how the deployment region is partitioned into sub-regions and how LEACH is expected to work under the modified conditions.

A. Partitioning the Deployment Region into Sub-regions

Due to random generation and non-uniform distribution of clusters, the energy consumption is uneven in the network. A node might run out of energy very soon as compared to the other node (Fig. 2).

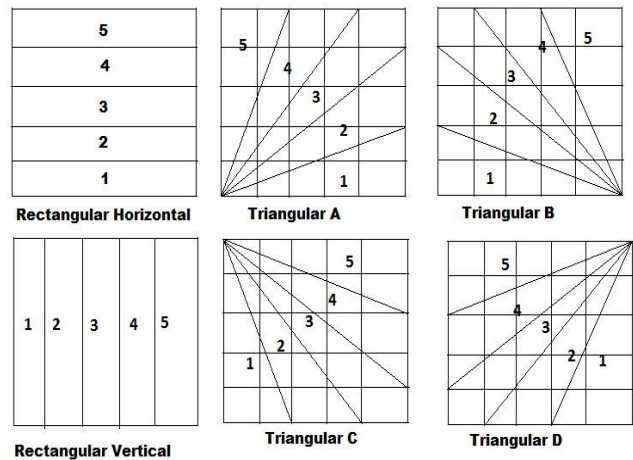


Figure 3. The Considered Shapes

The whole region is partitioned into smaller and equal sub-regions (Fig. 3). Now the cluster heads are chosen within a sub-region. The nodes in one sub-region do not compete with the nodes in the other sub-regions. So the LEACH algorithm now runs in each of the sub-region without affecting the other sub-regions.

Different shapes are considered for this partitioning.

1. Rectangular Horizontal: The region is partitioned into equal horizontal rectangular sub-regions.
2. Rectangular Vertical: The region is partitioned into equal vertical rectangular sub-regions.
3. Triangular A: The region is partitioned into equal triangular sub-regions with partitioning starting from point A of the squared deployment region.
4. Triangular B: The region is partitioned into equal triangular sub-regions with partitioning starting from point B of the squared deployment region.
5. Triangular C: The region is partitioned into equal triangular sub-regions with partitioning starting from point C of the squared deployment region.

- Triangular D: The region is partitioned into equal triangular sub-regions with partitioning starting from point D of the squared deployment region.

Later these shapes are evaluated based on random distribution of the nodes over the deployment area.

B. Enhanced LEACH

The operation of enhanced LEACH algorithm is divided into rounds. Similar to the LEACH algorithm, each round begins with a set-up phase when the clusters are organized, followed by a steady-state phase when data is transmitted from the nodes to the cluster head and on to the base station. The flowchart is shown in Fig. 4.

Each sensor i in the sub-region elects itself to be a cluster head at the beginning of round $r+1$ (which starts at time t) with a probability $P_i(t)$. $P_i(t)$ is chosen such that the expected number of cluster head nodes for this round is k .

Ensuring that all nodes are cluster heads the same number of times requires each node to be a cluster head once in N/k rounds on average. If $C_i(t)$ is the indicator function determining whether or not node i has been a cluster head in the most recent $(r \bmod (N/k))$ rounds (i.e., $C_i(t)=0$ if node i has been a cluster head and one otherwise), then each node should choose to become a cluster head at round r with probability

$$P_i(t) = \begin{cases} k/(N-k*(r \bmod N/k)) & : C_i(t) = 1 \\ = 0 & : C_i(t) = 0 \end{cases} \quad (1)$$

In enhanced LEACH the algorithm runs for each sub-region individually, whereas in LEACH the algorithm runs for the whole deployment area.

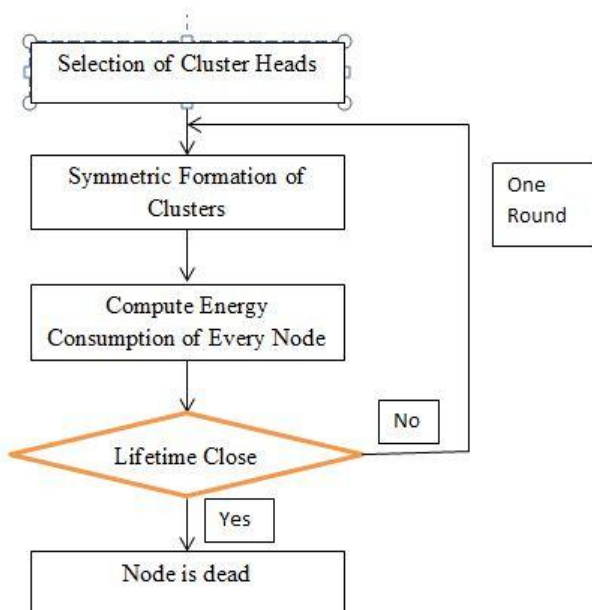


Figure 4. Flowchart

Hence nodes in one sub-region do not affect the activities of other sub-region. The nodes which have advertised themselves as cluster heads broadcast this message to all the nodes in that sub-region using a non-persistent carrier-sense multiple access (CSMA) MAC protocol. Each non-cluster head node determines its cluster for this round by choosing the cluster head that requires the minimum communication energy, based on the *received signal strength* of the advertisement from each cluster head.

The steady-state operation is broken into frames, where nodes send their data to the cluster head. And then the cluster heads send the received data to the base station.

IV. Evaluation of Different Shapes

The deployment region is divided into 5 equal sub-regions by considering 6 different shapes (Fig. 3). And these shapes are compared, for uniformity in the number of nodes per region. For this 5 scenarios are taken into account. In each scenario the nodes are randomly placed in the deployment region. The shape is considered to be good if the deviation in number of nodes is less.

Scenario 1:

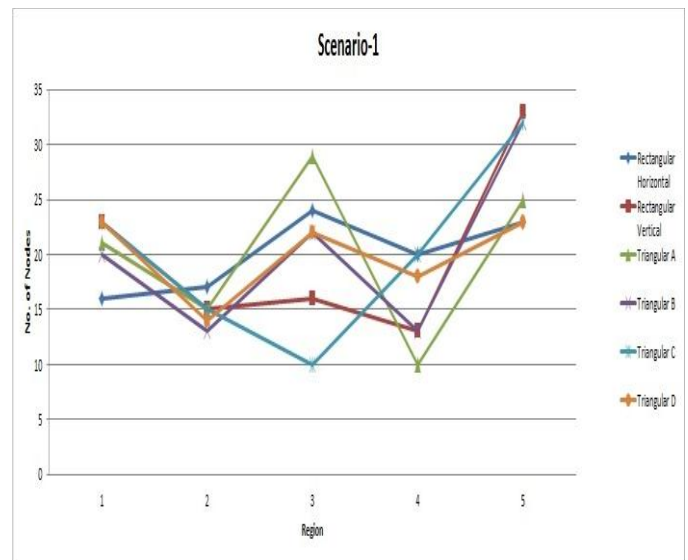


Figure 5. Scenario 1

In the scenario (Fig. 5), the deviation in number of nodes per region is least in rectangular horizontal shape.

Scenario 2:

In this scenario (Fig. 6), the deviation in number of nodes per region is least in triangular D shaped.

Scenario 3:

In the scenario (Fig. 7), the deviation in number of nodes per region is least in rectangular horizontal shape.

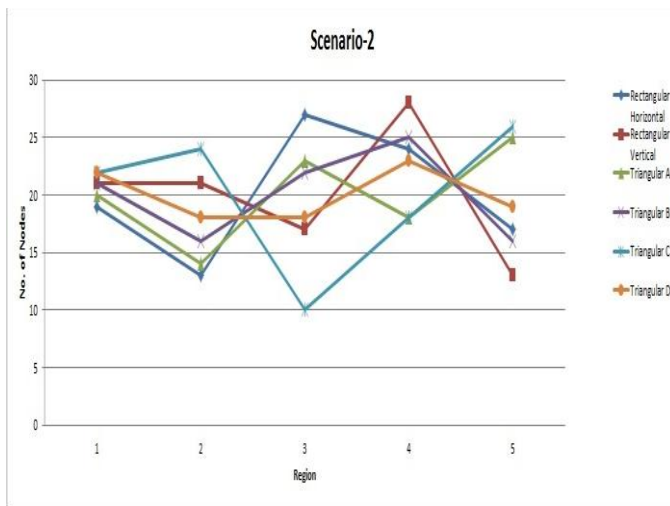


Figure 6. Scenario 2

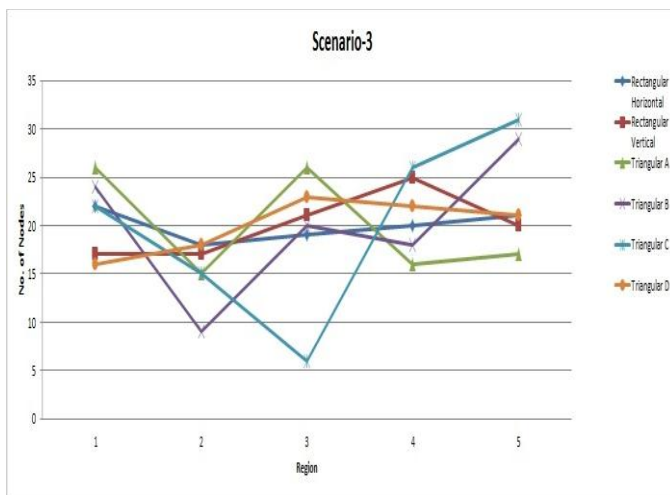


Figure 7. Scenario 3

Scenario 4:

In the scenario (Fig. 7), the deviation in number of nodes per region is least in rectangular horizontal shape.

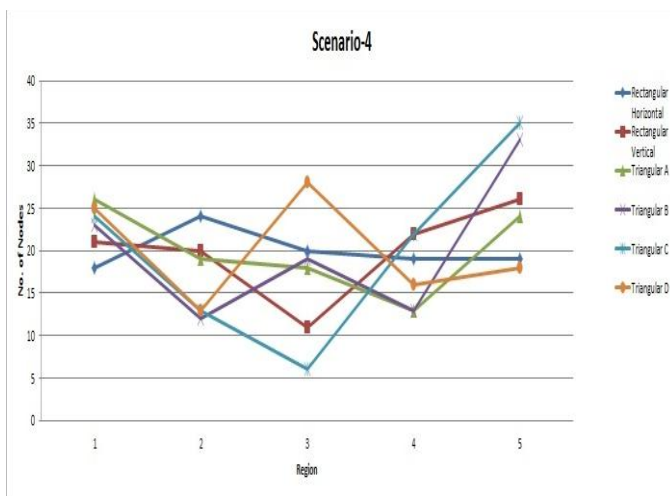


Figure 8. Scenario 4

Scenario 5:

In the scenario (Fig. 7), the deviation in number of nodes per region is least in rectangular horizontal shape.

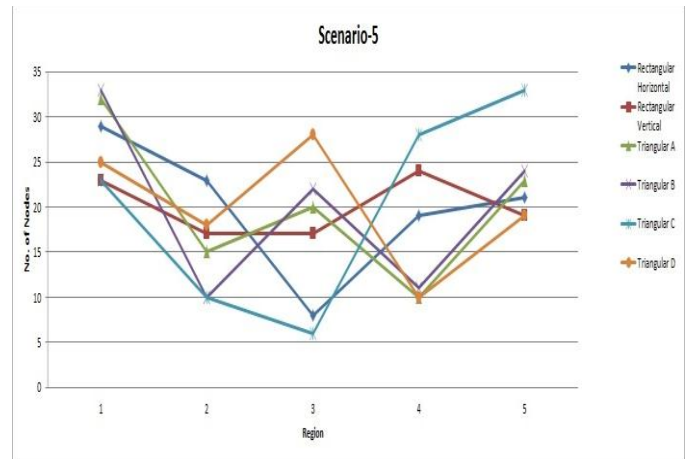


Figure 9. Scenario 5

v. Conclusion

In LEACH (Low Energy Adaptive Clustering Hierarchy), the cluster head is selected on the basis of the random number generated by the nodes in the hierarchical routing protocol. As a result, the cluster head may be chosen randomly and be distributed asymmetrically. The proposed method to overcome this flaw is simple to use. The results in the graph shows that most of the times, the rectangular horizontal shape shows the best results among all the shapes. This method along with uniform load distribution can even help in prolonging the lifetime of the network.

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