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A static clustering strategy for reducing energy consumption in a wireless sensor network

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Abstract

Sensors are little devices that detect and perceive a variety of chemical and physical occurrences in the environment. A Wireless Sensor Network (WSN) is a collection of sensors that can be used to solve a variety of problems at a minimal cost. Because most WSNs operate in an unsupervised environment with no practical supervision, one of the most difficult challenges for a WSN is maintaining the network's existence, and lifetime optimization has always been a key factor. There is a lot of research on WSNs being distributed and deployed in a way that is often very dynamic. In this paper, a static clustering strategy is proposed to obtain a better network lifetime. In the proposed method, energy is saved by providing the energy needed to form clusters in each round, where the clusters remain constant throughout the life of the network, while the cluster head (CH) changes in each round and it's the selection is from the nodes of the cluster itself. In this mechanism, the process of transmitting data to the base station (BS) is through multiple hops.

Keywords: wireless sensor network, static clustering, cluster head.

1 Introduction

Sensor networks confront numerous obstacles, including limited resources, an open environment, and wireless communication, all of which contribute to network failure since nodes must function for months or years on limited battery power without interference[1]. Reduce energy consumption by building energy-efficient protocols that can communicate and process information effectively and efficiently is a significant design problem in WSNs.

One of the most prevalent techniques to maintaining a WSN topology is clustering. Nodes are grouped into clusters depending on a set of specified criteria such as resource usage optimization, network load balancing, and so on[2],[3]. One node from each cluster is chosen to represent CH whose responsibility is to collect data from other nodes and send it to the station[4] as shown in Figure 1.

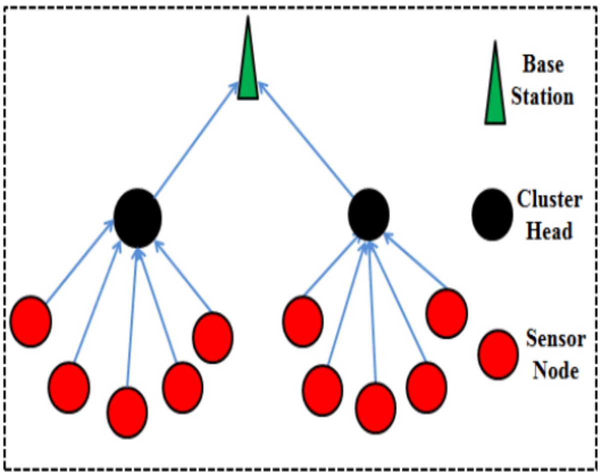

Figure-1 clustering wireless sensor network

Dynamic clustering protocols have proven to be useful methods for organizing large, distributed networks, but they are less effective in low-number networking applications such as home automation, healthcare, and others[5]. Since the clustering process is separated into multiple rounds in dynamic clustering techniques and as a result of repeated clustering, a large amount of sensor energy is consumed. Therefore, the static clustering strategy is more effective to address these problems, as clusters remain constant and only the CH is changed each round.

2 Related work

LEACH[6] is a periodic hierarchical routing algorithm that splits the domain of a sensor network into numerous groups known as clusters. The cluster head is the node in charge of gathering and sending data in each cluster. The cluster head receives data from the cluster's member nodes, aggregates and compresses it, and then sends it to the base station. These chores need a lot of mental energy. The LEACH protocol comprises of a setup phase that defines the clusters configuration and transmission schedule, followed by a static transmission phase that follows the setup phase. The LEACH protocol rotates clusters and their heads in each cycle to evenly distribute power consumption without requiring a high power cluster leader. During the setup phase, the CHs are selected by assigning a random integer between zero and one to each node. If the number is below than the threshold, the node is a potential header candidate. The equation(1) is used to compute the threshold.

$$T(n) = \begin{cases} \dfrac{p}{1 - p \times \left(r \bmod \dfrac{1}{p}\right)} & if\ n\ \in G \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots.\ldots (1) \\ 0 & otherwise \end{cases}$$

where, P is the CH probability, r is the number of the current round and G is the set of nodes that have not been CHs in the last 1/p rounds.

In[7] the energy-saving (EE-LEACH) protocol for data collection is presented. Based on optimum construction, it provides energy-saving routing in WSN. To minimize resource utilization and extend network life in this system, the nodes with the highest residual power are selected as CHs that route data to the BS. This protocol contributes to faster packet delivery and lower energy consumption.

A two-tiered protocol is presented in [8]. The distinction is that cluster heads are divided into two categories. Each cluster's load is evenly distributed by the major and secondary cluster heads. Each cluster has two distance values: the first is the distance between the major CH and station , and the second is the distance between the secondary CH and station. Each node has two possibilities for joining, one to the major CH and the other to the secondary CH. This strategy makes it simple to find the shortest path to lower energy use.

In [5], static aggregation technology is presented to improve the energy efficiency of chosen WSNs that can be readily operated by people and consist of a limited number of devices. The authors describe a hierarchical clustering model in which clusters and their CHs remain constant during the network's operational life. This method is significant because it may aid in determining the initial power distribution to these cluster headers and nodes, leading in improved energy efficiency and longer network life

3 Proposed algorithm

A static clustering algorithm for energy savings in WSN is provided in this paper. In contrast to dynamic clustering, static clustering is not concerned with the energy consumed in the cluster formation process. The clusters in the proposed method remain constant throughout the existence of the network and the shift in the selection of heads from cluster nodes is periodic. Figure 2 represents the flow diagram of the proposed method.

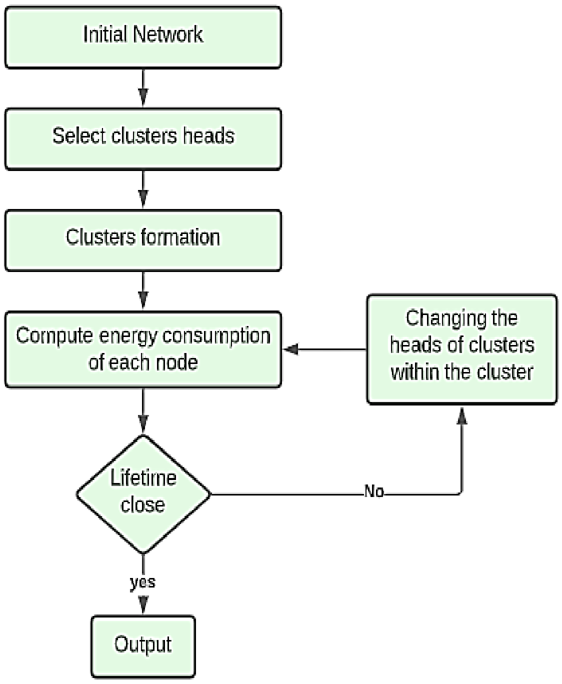

Figure-2 proposed method flow diagram.

A simple model [6] for radio equipment power dissipation is provided, as shown in Figure 3, in which the transmitter dissipates energy to operate the radio electronics and power amplifier, and the receiver dissipates energy to operate the radio electronics. The network nodes are power-constrained and homogeneous. Cluster heads do data compression and merging before sending it to BS.

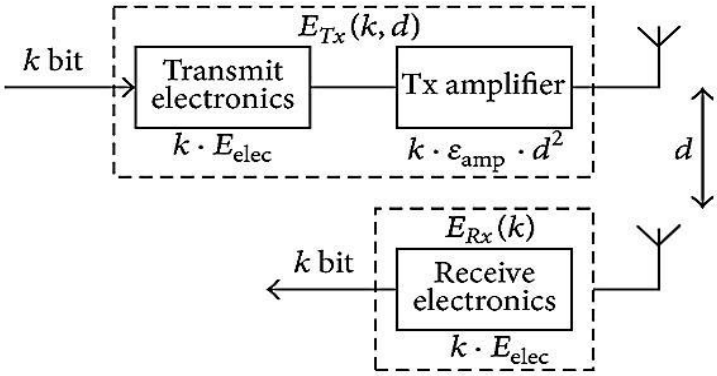

Figure-3 Radio Energy Model

The power consumed by the radio in transmitting a k-bit message at a distance d is provided by equation (2):

$$ET_x(k) = \begin{cases} k \times (E_{elec} + E_{fs} \times d^2) & , \text{if } d < d_0 \\ k \times \left(E_{elec} + E_{mp} \times d^4\right) & , \text{if } d \geq d_0 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit. Free space E_{fs} (d^2 power loss) and the multipath fading E_{mp} (d^4 power loss) channel models are used, depending on the distance between the transmitter and receiver. d_0 can calculated by Equation (3)

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

The amount of energy consumed when receiving a k-bit packet. can be calculated by Equation (4).

$$ER_x(k) = k \times E_{elec} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Equation(5) will be used to compute the amount of energy consumed by a cluster head while receiving, aggregating data, and transmitting a packet to BS.

$$E_{CH}(k) = \begin{cases} k \times (E_{elec} + E_{DA} + E_{elec} + E_{fs} \times d^2 \text{to BS}) , \text{if } d < d_0 \\ k \times \left(E_{elec} + E_{DA} + E_{elec} + E_{mp} \times d^4 \text{to BS}\right) , \text{if } d \geq d_0 \end{cases} \ldots\ldots\ldots\ldots \quad (5)$$

Where E_{DA} is the energy consumed in the process of collecting data before sending it to the station.

Equation(6) will be used to compute the amount of energy consumed by the cluster members

$$E_{member}(k) = \begin{cases} k \times \left(E_{elec} + E_{fs} \times d^2 to\ CH\right) , if\ d < d_0 \\ k \times \left(E_{elec} + E_{mp} \times d^4 to\ CH\right) , if\ d \geq d_0 \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

4 Simulation and results

This part uses MATLAB to investigate and simulate the power dissipation model. Table(1) shows the variables of this simulation, which were used to evaluate the performance of the suggested method when it was applied to a homogenous and energy-constrained WSN with BS at center as shown in Figure 4 .

Table(1) simulation parameters

Parameters	Description	Value
n	number of nodes	100
k	data size	40000bit
E_{elec}	electronics energy	50nJ/bit
E_{DA}	aggregation energy of one	5nJ/bit
d	transmission distance	100m
E_{fs}	amplifier parameters of free space	10pJ/bit/m2
E_{mp}	amplifier parameters of multipath	10pJ/bit/m2

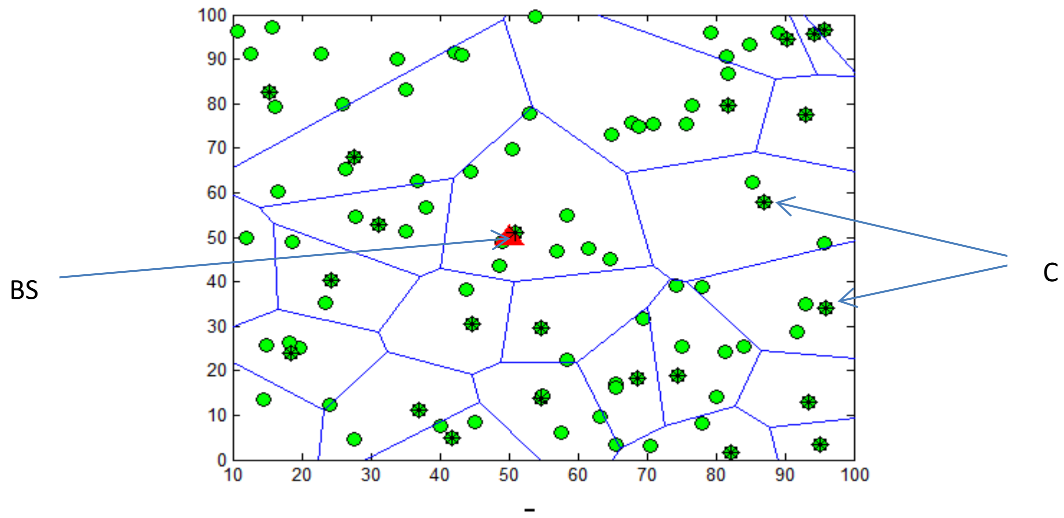

Figure-4 Wireless sensor network with 100 sensor node.

Figure 5 shows a comparison in terms of network life between the proposed method, Leach protocol, and PEGASIS protocol, as the new strategy is 60% superior to the Leach protocol and 30% over the PEGASIS protocol.

In terms of energy usage, the suggested technique outperforms the Leach protocol and the PEGASIS protocol, as seen in Figure 6.

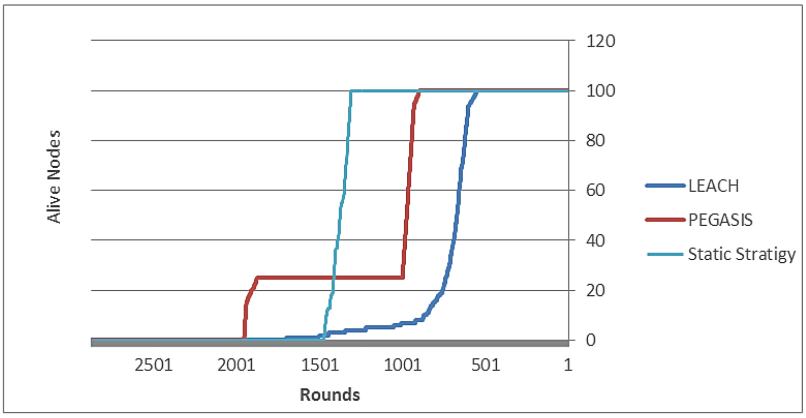

Figure-5 comparison number of alive nodes.

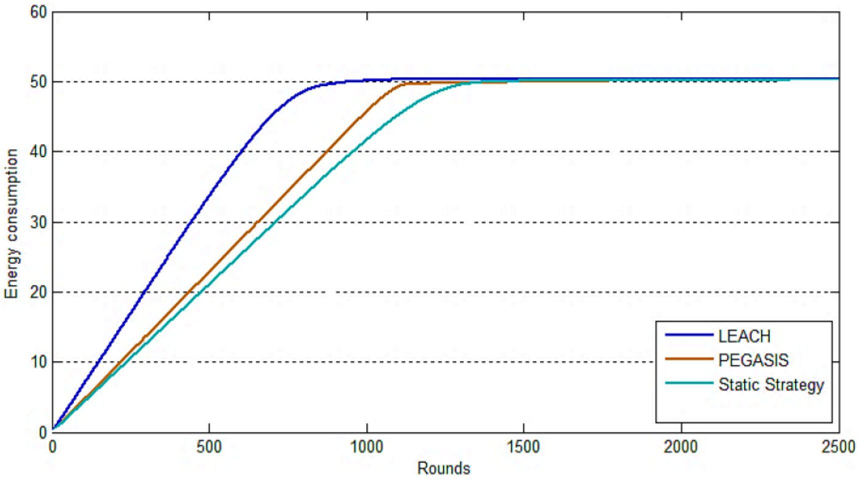

Figure-6 comparison energy consumption

5 CONCLUSION

In this paper, we presented a fixed cluster strategy aimed at extending the life of the network and balancing the energy load by saving the energy consumed for the cluster formation in each round. The cluster structure remains fixed and the change is at the head of the cluster and within the cluster nodes itself.

The method has proven its efficiency in terms of saving energy and extending the life of the network compared to the Leach and Pica protocols.

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