An Improved W-LEACH Routing Protocol in Wireless Sensor Network

Farhad Rad, Zahra Moghtaderinasab, Hamid Parvin
1) Department of Computer Engineering, Yasooj Branch, Islamic Azad University, Yasooj, Iran
2) Young Researchers and Elite Club, Yasooj Branch, Islamic Azad University, Yasooj, Iran
rad@iauyasooj.ac.ir; lidakolaei@yahoo.com; parvin@iauyasooj.ac.ir
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Abstract

Energy is one of the important factors in wireless sensor networks. For further usage and to increase the network lifetime, researchers are always looking for ways which tend to reduce energy consumption. Clustering of sensor nodes is one of the best ways that can significantly increase the network lifetime. In this paper, using nodes weighting based on the density and node’s energy that be used in W-LEACH algorithm, a new method is provided. In our method, the effects of weighting in the higher rounds have been decreased so that the nodes with inadequate density but higher energy in the higher rounds do get a fair chance to become a cluster-head. MATLAB simulation shows that the proposed method increases the network lifetime compared to W-LEACH and others protocols.

Keywords: Network Lifetime; Clustering; W-LEACH; Energy Consumption

1. Introduction

Wireless sensor networks (WSNs) consist of many sensors can be used in environmental monitoring and tracking targets as a remote system. These sensors are equipped with a series of wireless interfaces through which they can communicate with others over a network. Designing a WSN Depends heavily on its application and elements such as environment, goal of the design, costs, hardware and system limitation are influential in those networks. The sensors are small and boast restricted calculation and procession resources. Sensor nodes can sense the data, measure them and through some local decision making procedures, aggregate the data out of the environment and can transfer the received data to the user. Since sensor nodes consist of a limited memory and are often developed in places which are hard to access, radio waves are picked to transfer information and data to the base station or the sink within a wireless communication context and then the base station is responsible to process the data of the important challenges in WSNs is the issue of energy, because the sensor nodes which are tasked with aggregating data in the network, works with a limited battery and they die when they run out of energy and get detached from the network. Therefore, it’s necessary to look for energy-wise tacking and aggregation methods so that we could gather the data out of the environment using the least amount of energy. Clustering and suitable ways of positioning nodes could prove useful regarding of this matter. Protocols in WSNs are divided in three groups:
- Data based: this group utilizes three strategies to transfer the data: transferring based on time, request and a combination of both time and request.
- Hierarchical: it is achieved via dividing the network in number of clusters or units.
- Location based: it’s related to those methods which focus on the nodes and because of nod’s random formation; their exact locations are inaccessible and in results is not frequently used.

In this paper, using the hierarchical clustering and measuring weighting of nodes based on node density and internal energy, a method has been introduced which increase network lifetime. The proposed method is based on W-LEACH protocol[1] that be improved.

The remainder of this paper is structured as follows: Section2 provides an overview of the related works. In section3, we explain energy consumption modeling. Proposed method will be present in section4. Simulation results are presented in Section5. Finally; our conclusions are drawn in section6.

2. Related Works

LEACH Protocol[2] was proposed according to which all sensors don’t have to connect to base station in order to transfer information, but they are divided into clusters and each cluster transfers its information to the base station via its cluster-head. To achieve this, while in the phase of selecting the cluster-head a mechanism was utilized that each node in each round creates a random digit of 0 or 1 and this number is compared to threshold function. If the number is a bigger digit, the node will end up a cluster-head on that particular round. When the cluster-head is determined, the closest nodes are selected as the cluster-members.

LEACH-C[3] is a protocol which uses a central algorithm in order to create better levels. Cluster-heads (CHs) choose the information of the node’s location and the amount of energy to determine the efficient level. Therefore, in the beginning of every round base station must receive the data of every node on their location and the energy amount needed for level-building central algorithm. LEACH-M or Multi-hop LEACH is a method in which cluster-members might be more than a cut from a head of a same cluster and communicate the head in a multi-step procedure. Each group must aggregate the data and the relay them[4]. Another method that was introduced was called T-LEACH[5] in which the main idea is reducing the duration of selecting procedure of the cluster-heads via threshold function, as less as possible, the name of this method is based on this very function of threshold. The task was done considering the remains of node’s energy in order to select the head. In this method nodes are look upon as cluster-heads. LEACH-B[6] was provided according to the fact that, when the first of cluster-heads were determined through LEACH protocol, then based on the remaining energy of the nodes and also depends on one certain condition, the number of the cluster-heads become fixed and efficient and this forces energy consumption to reduce. In each round, based on applied condition, the number of cluster heads remains constant. In S-LEACH[7] protocol clustering phase is shaped such as in LEACH and when they do, cluster-head distributes-to-all a single message containing a measured amount over the cluster and then each node considering the significant data they boast, transfer the info towards the cluster-head. This protocol is a randomly hierarchical clustering which helps the node regarding to increase in probability of being selected as the cluster-head being
kept in mind and also its amount of energy, so that the node would boast enough energy to transfer the data to the base station. TB-LEACH[8] was also a proposed method according which selecting the cluster-head is based on random timer, regulated so that no network general information would be required. A method that calls for proper and efficient designing of the clusters considering dimensions of the ground and does its job based on the dimensions and location of the ground, is called P-LEACH[9] which divides the ground in four quarters, each with certain assignments, and tries to distribute jobs available between those quarters. In this method, a moving base station is used which runs among the different parts of the ground.

3. Energy Model of the Sensor Nodes

One of the important challenges in WSNs is energy since sensor nodes that are assigned to aggregating network information. So, it is very important to minimize energy consumption and optimize communication. In wireless communication, the power of sending reduces with increasing the distance. A different set of models exist for the definition of energy consumption in WSNs. In the most common case, the energy consumed for amount of $K$ bit of data is calculated in this way[3]:

$$ETX(k, d) = E_{elec} * k + E_{amp} * k * d^2$$  \hspace{1cm} (1)

$$ETR(k) = E_{elec} * k$$  \hspace{1cm} (2)

In this relation, $ETX(k, d)$ represents the energy consumed to send $k$ bit of information and $ETR(k)$ represents the energy consumed to receive $k$ bit of information. $E_{elec}$ is the energy consumed per bit. $E_{amp}$ is the consumed energy of amplifier which equals 100 Pj/bit/m$^2$ and $d$ is the communicational distance between the sender and the receiver. The consumed energy to receive data is different, while receiving data, $E_{amp}$ is zero.

4. The Proposed Method

In this section, a cluster based algorithm is introduced which is a developed version of W-LEACH Protocol. Nodes have their own weight in this protocol. It works in two phase; establishment and stable. In the establishment phase, $p\%$ of the nodes with more weight becomes cluster-heads (this was done in LEACH randomly). In stable phase only those nodes are able to transfer their data to the cluster-head which are a member of $x\%$ of the nodes that have less energy comparing to the rest of the nodes (in LEACH every node of the cluster sends their data to the head). In a density environment because of the sensors closeness, the possibility of the similarity or sameness data to be sensed have been increased. Weight factor is calculated as follows:

$$w_i = \begin{cases} 
  e_i \times d_i & \text{if } d_i \geq d_{th} \\
  d_i & \text{otherwise}.
\end{cases}$$  \hspace{1cm} (3)

$e_i$ is the remaining energy of the $i^{th}$ node and $d_i$ is the density of the $i$ node. The word density of one node is the amount of aggregated neighboring nodes in a place. If the data were to be transferred directly to the base station, it would waste too much energy, and considering that the remaining energy of the cluster-heads differ, so it’s wise to choose the cluster-heads out of the nodes with the most energy remained that they won’t die
quickly. When a cluster-head exist in a place with high density, the nodes are close to the heads and consume the least energy possible to present themselves to the cluster-heads. Nodes privileged to send data are selected from the least weights nodes and since after sending the data, the selected nodes and the cluster-heads lose part of their energy. The rest of the nodes remain boasting more energy and are odds-on to be chosen as the cluster-head in future rounds and very able to send their very own data to the base station. The disadvantage of this method is that the weight assigned to the nodes, the density factor and the energy are the valued in the same way. It is not visible at initial rounds but reflects on future rounds and cluster-heads are not properly selected. Since the nodes exist in a fixed location, the amount of density of all nodes remain the same and unchanged over entire lifespan of the network (unless we’d take that the network’s lifespan is dependent on death of a percentage of the nodes where the density of the nodes drops nevertheless the nodes death is not particularly location-based but they depend on energy). Obviously, under these conditions we’d observe nodes in future rounds which get more weight since being dense and vice versa although they would have less energy comparing to some other nodes. So it is better to decrease the effect of density or make it depends on simulated rounds which gradually decrease the effect of density in future rounds. This idea is our contribution in this paper. So,

\[ w_i = \begin{cases} \frac{1}{\text{round}} 	imes d_i & \text{if } d_i \geq d_{th} \\ d_i & \text{otherwise.} \end{cases} \] (4)

In eq. (4), \( \text{round} \) represents the number of round in which the clustering phase is going to take place. In figure 1 we observe a flowchart of the proposed method. Density of each node is calculated based on eq.5. The weight of each node is regulated based on proposed method eq. (4) with the density being calculated and the internal weight of each node and dependence to the network rounds. The number of cluster-heads are located from the nodes have the greatest weight and will be selected as cluster-heads.

\[ d_i = \frac{(1 + \text{number of alive sensors in range } r)}{n} \] (5)

5. Simulation and Results

The simulation of the proposed method has been performed via the MATLAB. The figure 2 displays models of clustering forms. These figures show that clustering has been done properly, considering the cluster-heads being close to the station, boasting high density and suitable coverage of the ground’s dimensions.

The simulation is based on the parameters have been shown at the table1 and the results was compared with W-LEACH, DE-LEACH[10], L-LEACH, LEACH-C and LEACH protocols.
Figure 1: Flowchart of Proposed method

Figure 2: Models of clustering form in the proposed method
An Improved W-LEACH Routing …

In Figure 3 the network’s lifetime based on alive nodes is shown. The proposed method has longer than the basic idea itself, the W-LEACH, and at the same time, it outperforms four different methods namely DE-LEACH, LEACH-C, LEACH and L-LEACH. The lifetime of LEACH protocol completes about 2422 rounds, while LEACH-C was finished in 2600 all the way, DE-LEACH and L-LEACH ended respectively in 3222 and 3422 rounds. W-LEACH ended up at 5200 rounds. Our proposed method is more efficient and also increase the lifetime to about 6200 rounds.

In figure 3.B, the number of dead nodes in different round is shown. This result shows that our method is better than the other method. One of the important results of the tracking evaluation in the network is the network energy consumption. In Figure 3.C at 4000 round, DE-LEACH, LEACH-C, LEACH and L-LEACH do not have any energy, but in the same way W-LEACH drove about 25 joule of energy of 200 joules and our proposed method has about the same number as 28 joule of internal energy both in 4000 rounds. W-LEACH way ran out of the entire network energy while 5700 rounds has been completed and total energy our proposed methodology at about 6100 round is lost.

In addition to, we will test the results based on different parameters of on the basis of Table 2.

<table>
<thead>
<tr>
<th>Item no.</th>
<th>Parameter</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ground’s dimensions</td>
<td>100*100</td>
</tr>
<tr>
<td>2</td>
<td>Number of nodes</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>( E_{\text{elec}} ) (RADIO ELECTRONICS ENERGY)</td>
<td>100 NJ/BIT</td>
</tr>
<tr>
<td>4</td>
<td>( E_{\text{amp}} ) (RADIO AMPLIFIER ENERGY)</td>
<td>100 PJ/BIT/M^2</td>
</tr>
<tr>
<td>5</td>
<td>( E_{\text{fs}} ) (RADIO FREE SPACE)</td>
<td>0.013 PJ/BIT/M^4</td>
</tr>
<tr>
<td>6</td>
<td>Node’s inner energy</td>
<td>2 J</td>
</tr>
<tr>
<td>7</td>
<td>Node’s energy model</td>
<td>Battery</td>
</tr>
<tr>
<td>8</td>
<td>Node’s message size</td>
<td>200 BYTE</td>
</tr>
<tr>
<td>9</td>
<td>Location of the Base Station</td>
<td>X=50, Y=160</td>
</tr>
</tbody>
</table>

In Figure 4.A, the network lifetime based on living nodes in network rounds is illustrated. In second scenario, proposed method could do better than the W-LEACH a little more in terms of efficiency. In this study, we have increased ground dimension and distance of nodes to the central station and we set the internal energy on 0.9 joule.

In this experiment, the nodes consume more energy and they will endure more pressure to transfer information to their base station. The trial protocol LEACH had a lifetime of about 900 rounds, C-LEACH method had about 1050 rounds of lifetime, L-LEACH and DE-LEACH methods had respectively about 1250 and 1350 of rounds. W-LEACH had a lifetime of 2600 and our proposed method had 2750 rounds of lifetime.
Figure 3: A) Network’s lifetime, B) Number of dead nodes, C) residual Energy, D) Energy Consumption chart for different methods

Table 2: Experienced parameters in second scenario

<table>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>2</td>
<td>Number of nodes</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>$E_{\text{ELEC}}$ (RADIO ELECTRONICS ENERGY)</td>
<td>100 NJ/BIT</td>
</tr>
<tr>
<td>4</td>
<td>$E_{\text{AMP}}$ (RADIO AMPLIFIER ENERGY)</td>
<td>100 PJ/BIT/M$^2$</td>
</tr>
<tr>
<td>5</td>
<td>$E_{\text{FS}}$ (RADIO FREE SPACE)</td>
<td>0.013 PJ/BIT/M$^4$</td>
</tr>
<tr>
<td>6</td>
<td>Node’s inner energy</td>
<td>0.9 J</td>
</tr>
<tr>
<td>7</td>
<td>Node’s energy model</td>
<td>Battery</td>
</tr>
<tr>
<td>8</td>
<td>Node’s message size</td>
<td>200 BYTE</td>
</tr>
<tr>
<td>9</td>
<td>Location of the Base Station</td>
<td>X=150, Y=250</td>
</tr>
</tbody>
</table>
In figure 5 the number of alive nodes in 100th round based on different energies in the first scenario has been shown. The result demonstrates that in smaller amounts of 0.4j, the proposed method and w-leach have the best results. In other methods, in this range of energy, the number of alive nodes has been decreased and dead nodes increased. So, networks lifetime with different amounts of energy is shown in figure 6. As it has been seen, the proposed method has better outcomes rather than others.

In figure 7-8 the size of land in second scenarios is changed. The results show that, purposed method has the best amount of alive nodes and network life time.
Figure 5: Number of alive nodes in 100th round

Figure 6: Network lifetime
Figure 7: Number of alive nodes in 100th round

Figure 8: Network life time
6. Conclusion

In recent years, many studies have tried to improve clustering protocols, and all researchers tried to avoid the weakness of randomly clustering of LEACH algorithm. One of these studies is W-LEACH method that is based on the weight nodes. Cluster nodes that have the highest value will be the cluster-head in each round. In the higher rounds, each node which has the highest weight has the highest chance of being cluster-head.

The higher the rounds go; the density effect declines in initial influence. With this mechanism, the nodes that have high energy density are appropriate and yet have a good chance to be chosen as a cluster-head. The proposed algorithm is implemented in MATLAB and we discussed the results in terms of alive nodes, dead nodes and the network energy. The result of the proposed method was compared with L-LEACH, DE-LEACH, LEACH-C, LEACH and W-LEACH. Comparison results showed that the proposed algorithm have been the best performance among others methods.

References


