UDC: 621.395.721.5:621.316.11.062-027.44]:[004.722.4.021:528.8
Professional paper

BALANCING POWER CONSUMPTION AT WIRELESS SENSOR NETWORKS

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Abstract

The process of balancing energy in the day-to-day use of wireless sensor networks is a very important element of what is called network node life extension. The energy consumption in a given node depends on many factors such as: - the distance to the base station -the number of network nodes supported by one node when it is the head of the cluster and the work cycle when transmitting data by network nodes. As per these parameters, several sensors consume more power than other sensors. This does not lead to an uneven distribution of energy consumption, which in turn automatically means a reduction in the time after which the first node "dies" in the sensor network. By adjusting these parameters, we can balance the power consumption between the network nodes, which means at the same time increasing the lifespan of the sensor network itself.

Key words: base station, wireless, algorithm, energy

1 Introduction

There are two main categories of sensor networks depending on the routing of the data to the base station. The first category is with multiple jumps while the second is with single jump sensor networks.

Some nodes are used more often in the process of transmitting data to the base station if all forwarded data are mediated by these nodes.

In such a case we need the whole system consisting of the mentioned nodes and which are close to the base station with the goal to avoid the potential problem with the so-called "holes" in energy. This problem has been solved by many researchers using various methods. Haengi [2] proposed in his research four methods to solve the problem of "holes" in energy. In the first method, he suggested the distance between the nodes must be reduced as the nodes move toward the base station.

This technique allows large-capacity data to be transmitted over small distances with the same amount of energy assuming that the nodes are propagated in a finite arrangement in each sensor field. In the second method, he proposed balancing the data in a compressed form, wanting to achieve one packet being delivered from each node. The third method showed how data can be transmitted directly to the base station rather than forwarded to the next node if the base station is within its communication range. In his latest method, he used the end-to-end equalization method with verified data transfer reliability to balance the wireless sensor network. In many applications where wireless sensor networks are used, single-layer or double-layer sensor networks are used. The two-layer architecture of sensor networks is a solution for the so-called problem - "holes" in the energy of the sensor networks.

LEACH is one of the first protocols in its implementation to achieve satisfactory results in the process of balancing energy in sensor networks, but there are several drawbacks in its implementation, such as residual energy that is not considered when choosing a cluster head, also important is to note the fact that nodes with cluster heads are not fixed, etc. For example, in LEACH if a node is selected to be a cluster head during the entire period of operation of a given sensor network, then its energy will be depleted first creating problems in the process of data aggregation by the distributed sensor nodes.

In such cases, we need different protocols to balance the power consumption of the network nodes.

Many researchers have sought to balance energy consumption in two-layer networks. In LEACH, the selection of a cluster head between sensor nodes is done in a random order using a two-layer sensor network topology. Although the LEACH algorithm solves the problem with the so-called "Holes" in the energy, however, cluster heads consume their energy faster compared to other nodes.[4]

This is the main reason why we have an unbalanced balance of energy consumption in the LEACH protocol.

Fixed-LEACH is one of the solutions to such a problem where the number of cluster heads is constant.

We will analyze the problems of energy balancing in two-layer sensor networks by presenting new proposals for improving the even distribution of energy between network nodes in each wireless sensor network.

The proposed algorithm in this paper seeks to achieve a state in which the grid system has a balanced power consumption throughout its operation.

2 Problem Formulation

Each node becomes a cluster head once in each period and in the other rounds, it behaves like a normal node. When one node **i** becomes a cluster head and supports **Ni** nodes for data transmission then the power consumption according to the consumption model is

$$E_{CH} = LN_i(E_{RX} + E_{DA}) + E_{TX-amp}(L, d_{itobs}) \qquad (2.1)$$

such as **n/k** nodes in a cluster, node **i** will behave like a normal node for **(n/k -1**) rounds in each period, so the energy consumed by node **i** as a non-cluster head is

$$E_{non-CH} = (\frac{n}{k} - 1)E_{TX-amp}(L, d_{itoch}) \qquad (2.2)$$

The energy consumed for node **i** in a period is the sum of the above relations:

$$\mathrm{E_i}=\left(\frac{\mathrm{n}}{\mathrm{k}} - 1\right) \mathrm{E_{TX-amp}}(\mathrm{L}, \mathrm{d_{itoch}}) + \mathrm{LN_i}(\mathrm{E_{RX}} + \mathrm{E_{DA}}) + \mathrm{E_{TX-amp}}(\mathrm{L}, \mathrm{d_{itobs}}) \qquad (2.3)$$

Similarly, for the j-node, the energy consumption over a period is

$$\mathrm{E_j}=\left(\frac{\mathrm{n}}{\mathrm{k}} - 1\right) \mathrm{E_{TX-amp}}\left(\mathrm{L}, \mathrm{d_{jtoch}}\right) + \mathrm{LN_j}(\mathrm{E_{RX}} + \mathrm{E_{DA}}) + \mathrm{E_{TX-amp}}(\mathrm{L}, \mathrm{d_{jtobs}}) \qquad (2.4)$$

In zones with a small network area, the energy consumption in the process of transferring data from non-cluster nodes to cluster head nodes is approximately the same as the energy consumed for data transfer from cluster nodes to the base station. This assumes that the base station is in the center of the distributed sensor nodes. [5]

We have a case where $\mathrm{E_{TX-amp}}$ is approximately the same for both nodes, and in the case of a transfer from a normal node to a cluster head node or to a transfer from a cluster head node to a base station.

So, for small network zones we have the following relations**:**

$E_{TX-amp}(L, d_{itoch}) \approx E_{TX-amp}(L, d_{jtoch})$ (2.5)

and

$E_{TX-amp}(L, d_{itobs}) \approx E_{TX-amp}(L, \mathrm{d}_{\mathrm{jtobs}})$ (2.6)

In case Ni is much higher than Nj then the energy consumed in the process of receiving and collecting data plays a very important role compared to data transmission, so we have:

$$E_i - E_{j\cong} L(N_i - N_j) \cdot (E_{RX} + E_{DA}) \qquad (2.7)$$

whereas now the main difference between nodes in terms of energy consumption is only the process of receiving and collecting data. If the optimal number of clusters is **k** then the average number of nodes supported by the cluster head is **n/k** for a particular or particular circle. The optimal cluster head number for two-layer wireless sensor networks is defined by Heinzelman and is obtained by deriving the lower expression concerning to k $\frac{d\mathrm{E_{BK}}}{dk}$)

$$E_{total} = k\mathrm{E}_{\mathrm{cluster}} = l(\mathrm{E}_{elec}n + nE_{DA} + \mathrm{k}\epsilon_{mp}d^4{}_{toBS} + \epsilon_{fs}\frac{1}{2\pi}\frac{M^2}{k}\mathrm{n}) \qquad (2.8)$$

$\frac{d\mathrm{E_{BK}}}{dk} = 0 \rightarrow 2\pi\epsilon_{mp}k^2d^4{}_{toBS} = \epsilon_{fs}\, M^2\, n$ hence the following expression

$$k = \frac{\sqrt{n}}{\sqrt{2\pi}} \cdot \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \cdot \frac{M}{d^2\mathrm{toBS}}$$

where **n** is the total number of nodes, M is the length of the edge of the square area and dtoBS is the average distance from different cluster heads to the base station.
The number of clusters in some rounds may be less than k while in other rounds it may be greater than k. If nodes with a cluster head support more than **n\k** nodes, then more energy will be consumed which would be needed in the n / k number of rounds (rounds).

In case the cluster heads are bigger than k then the cluster head nodes will support less than n \ k nodes.

The different number of clusters in WSN (Wireless Sensor Networks) together with the random selection of cluster heads will make the number of nodes in each cluster different and will lead to uneven power consumption for all nodes in each round.

For these reasons, an algorithm based on all previous cluster algorithms will be proposed which will have a different approach to the cluster head determination process. [6]

Cluster heads will be selected using a function that includes two criteria, residual energy, and distance from the base station. So, the sensor nodes with more energy and with a shorter distance to the base station will be selected as cluster heads which will lead us to consumption of approximately one period of energy in an average of one round.

3 Proposed Algorithm

The proposed algorithm has two phases of operation to achieve a better life of the wireless sensor network which is well explained in the diagram shown in Figure 1. The selection phase of the cluster head includes the selection of cluster heads that can stabilize power consumption in sensor networks, considering both the current energy and the distance of the node relative to the base station.

The selection of cluster heads is optimized in each round by considering the residual energy of the network nodes. Excess data transmission can be reduced if the distance between the node and the base station is permanently monitored. Thus, those nodes, which have high residual energy and at the same time have a small distance from the base station, are selected as cluster heads.

During the clustering phase, a distance-based approach to selecting cluster heads with a non-cluster master node is implemented. This includes selecting a cluster head that is close to the base point of the base station and the non-cluster node. The cluster head selected in this way and the non-cluster node to be considered should be in the range of sensitivity cooperating with each other.[8]

In the following, we will give all the steps for how the proposed algorithm for selecting cluster heads works in each wireless sensor network. The size of the sensor network and the location of the base station are defined and redefined accordingly. The arrangement of the sensor nodes is realized at random

3.1 *Cluster Head Selection Process*

Initially, the process of selecting a cluster of heads is established by using a given function and includes two criteria, such as residual energy and distance to the base station. The most important parameter in such a decision will be the energy level, where the network nodes with high energy and a short distance to the base station will be potential candidates for the selection of cluster heads in the defined wireless sensor network.

Step 1: At the beginning, the maximum number of rounds for which the test of the proposed algorithm will be executed is defined
Step 2: This is followed by the generation of a random number for each node.
Step 3: The calculation of the threshold that determines whether a given sensor node will be a cluster head is realized in this step. When clusters are created, then each node decides whether to become a cluster head for a given current round.

The defined decision is based on the proposed percentage of cluster heads for a given sensor network and how many times the node has been a cluster head. This decision is made from the node by choosing a random number between 0 and 1. If the number is less than a given threshold T (n), then the node becomes a cluster head for the current round. The said threshold is determined using the formula below [11] (used by Heinzelman)

$$T_n = \begin{cases} \dfrac{\mathbf{p}}{\mathbf{1-p}\left(\mathbf{r\cdot mod}\frac{\mathbf{1}}{\mathbf{p}}\right)} & \text{if n is in G} \\ \mathbf{0} & \text{other cases} \end{cases} \qquad (3.1)$$

where p is the desired percentage of cluster heads (example p = 0.05) and G is the set of nodes that were not clustered heads in the last 1/p rounds of the process. Using this threshold, each node will be a cluster head at some point inside the 1/p rounds.

Step 4: Go to the next node and check again the same procedure for determining the next cluster head in the next round

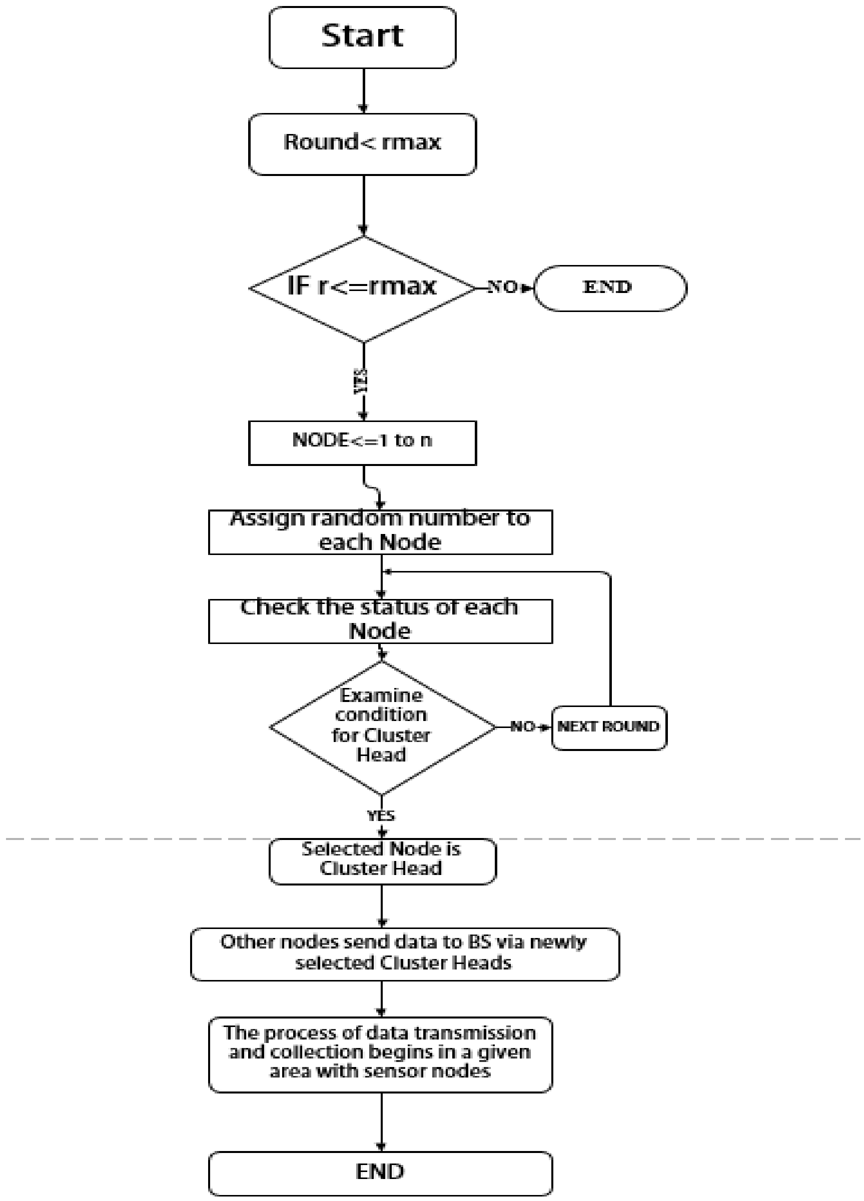

Figure 1. The proposed diagram for the algorithm

3.2 *Phase of Cluster Head Creation*

After completing the process of forming cluster heads, in each wireless sensor network, the process begins when the non-cluster sensor nodes will select those cluster heads that have the shortest distance to the base station of that node. In case the given node and cluster head selected in this way do not merge with each other, i.e., are not in a common range, then the next cluster head is selected which has a shorter distance to the base station. For each sensor node that is not a cluster head, its distance from the base station is always calculated, and when the distance is the shortest and within the range of a given cluster head, it "connects" to the corresponding cluster head. The process continues for all other non-cluster nodes until the end of the whole process and then it starts again from the beginning.

4 Results and Discussion of the Obtained Values

In the process of experimental simulation with the proposed algorithm, we will use the Matlab 2016 application and below are the parameters that will be used for the simulation environment:

Table 1. Parameters for experimental simulation

Parameters	Values
E_{elec}	50nJ/bit
ϵ_{fs}	15 pJ/bit/m^2
ϵ_{mp}	0.0016 pJ/bit/m^4
Initial energy E_0	0.7 J
Energy for data collection E_{DA}	5 nJ/bit/message
Energy for data collection	250 x 250 m^2
Base station coordinates	150 m, 250 m
Number of nodes	400
Simulation time	200 rounds
Node distribution	Random deployment

Figure **2** shows the distributed sensor network nodes on an area of 250 x 250 m^2 in a random arrangement. The performance analysis of the proposed algorithm is based on various parameters, such as the number of dead and living nodes, residual energy, the first node that "dies", the number of data packets transmitted in relation to the rounds , the total energy of the network nodes in relation to the rounds, etc.

Figure **3** (in the x-axis is the number of rounds, while in the y-axis are the packet values) is given a graphic showing the number of data packets sent to the base station from all distributed sensor nodes and we see how it increases the number of ores (rounds) and the number of transferred packages is growing significantly.

Rounds

[1]

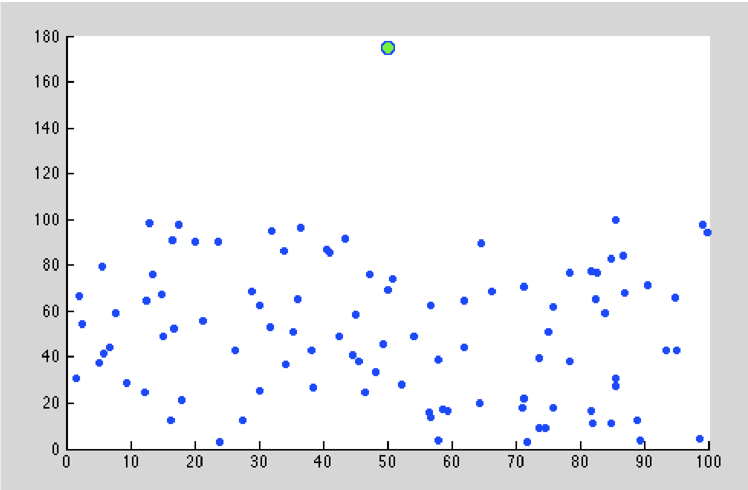

Figure 2. Wireless sensor network with random deployment

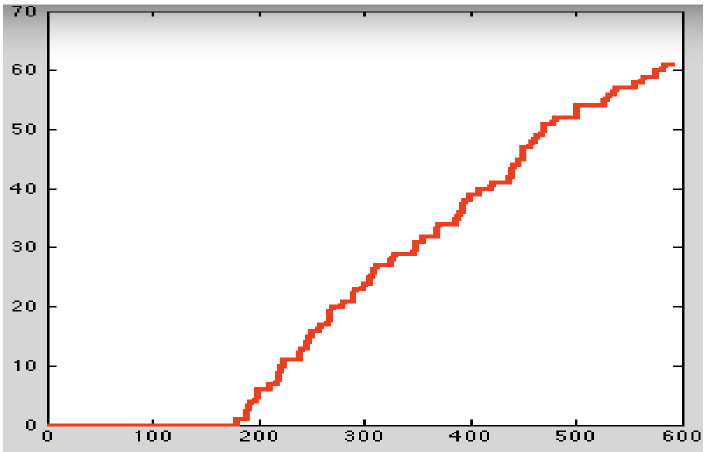

Figure 3. Number of packets transferred to the base station versus the used rounds

Figure **4** shows the lifespan of several sensor nodes where so-called "dead" sensor nodes appear in the wireless sensor network with an increasing number of rounds [12]. Otherwise, one of the most used definitions of sensor wireless network lifetime is when the first network node runs out of power to send a packet to the base station because then a lost node could mean that a given sensor network may lose some functionality necessary for the operability of the whole system defines. The results show that by the 200th round we have almost no 'dead' nodes which indicates that the sensor network is relatively optimal in terms of functionality and operability of the sensor networks themselves in its mission to transmit data to the base station.

Nr of dead nodes

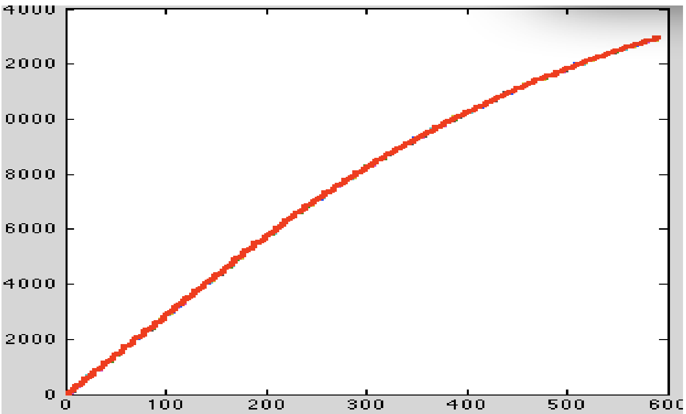

Figure 4. Number of "dead" sensor nodes versus completed rounds

Conclusion

This work proposes a new algorithm whose main intention is to enable relatively low power consumption and at the same time prolong the life of the distributed sensor network nodes, while at the same time introducing a new approach for centralized grouping in wireless sensor networks. In much of the research to date, because the choice of cluster head is random, the lifespan of the sensor network has moments when it is not stable. In the proposed algorithm for balancing energy consumption, the sensor node with maximum residual energy and optimized distance to the base station will become a cluster head in the initial stage of cluster formation. At this stage, the non-cluster sensor nodes will select those cluster heads that have the shortest distance to the center point of that node and the base station. The simulation results are presented using simulation parameters. The simulation results were obtained using the Matlab 2016 application. From the obtained results, it was noticed that the proposed algorithm improves the lifespan of the wireless network during several completed rounds. The next improvement can be achieved if the mobility of the base station is considered to ensure the successful delivery of data from the network nodes. If more distant nodes transmit information with a reduced duty cycle compared to nodes closer to the base station, then a more balanced power consumption can be achieved. The given methods enable the increase of the life of the nodes by 10%, reduction of the average energy consumption, and at the same time balancing of the consumption itself in all the nodes involved in the sensor network. Finally, let us emphasize that if a comparison is made with other algorithms used for the same purpose (such as LEACH, F-LEACH, HEED) can be seen an improved performance of a given sensor network in terms of the number of "dead" nodes that are reduced and the increased number of transmitted packets [13]. Also, the energy balance in all network nodes is improved and the performance of the sensor network itself in terms of sending and receiving packets is at a higher level. In LEACH, because cluster head selection is random, the lifespan of the sensor network will not always be stable, which will affect the overall operation of the wireless sensor network.

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