Energy consumption management by clustering and localization of nodes in wireless sensor networks

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Abstract
Sensor networks are wireless networks which include small and low- cost sensors that collect and disseminate environmental information. In order to contribute to the significance of the data nodes and routing algorithms, locating is an important issue in the performance of sensor networks. Most of the proposed algorithms use the guiding nodes for positioning. The guiding nodes equipped with global positioning devices (GPS) have the specified position they can play different roles in positioning others sensors in a variety of ways. Since the guiding nodes are equipped with global positioning, they are inefficient in terms of energy consumption.Also data gathering in wireless sensor networks is one of the important operations in such networks. These operations require energy consumption. Due to the restricted energy of nodes, the energy productivity should be considered as a key objective in design of sensor networks. Therefore the clustering is a suitable method that used in energy consumption management. The method presented in this paper consists of two phases. In the first phase, the nodes gain their geographic location without the need of guiding nodes and with spending slight energy. In the second phase, cluster head selection for increasing the network lifetime has been proposed based on fuzzy theory. The proposed ideas have been implemented over the LEACH-C protocol. Evaluation results show that the proposed methods have a better performance in energy consumption and lifetime of the network in comparison with similar methods.

Key-words:
Clustering, Localization, Positioning, Energy, Sensor Networks.

1. Introduction

Wireless sensor networks are one class of wireless ad hoc networks and in these networks, the sensor nodes accumulate data of the physical environment and process it and then send it to the base station (BS). Therefore, they allow monitoring and controlling physical parameters of this location. Each sensor node has limited energy [6]. In most applications, there is not any possibility of alternative for energy sources. The life of sensor nodes is highly dependent on the energy stored in the battery. Due to the high number of nodes and their energy constraints positioning algorithms must be used more accurately by spending less energy [4]. Most of the proposed algorithms use guiding nodes for positioning. Guiding nodes, equipped with global positioning devices (GPS), has specified location and other sensors can be positioned in a variety of ways. Clustering is one of the design methods which is used to manage the wireless sensor network. In this method, the network is divided into a number of independent sets which are called clusters. Each cluster has a number of sensor nodes and a head cluster node. The nodes , belonging to one cluster, send their data to their respective head cluster node . The cluster head node aggregates data and sends it to the base station. Therefore , clustering in sensor networks has some advantages such as supporting for integration of data [1], facilitating data collection [10], organizing a suitable structure for scalable routing [11] and publishing data efficiency on the network [12] . This study is organized in the following way: In the second section, the review of the related literature will be studied. In the third section , the nodes in the first phase will acquire their geographic position spending little energy without the need for guiding nodes . Having received the positioning of nodes in the network in the second phase, cluster head selection algorithm using fuzzy theory is proposed. Section 4 illustrates the achieved results of applying the proposed localization algorithm and its impact on energy consumption. In section 5, the conclusion and discussion will be offered.

2. Related Works

2.1 LEACH

One of the most popular hierarchical routing protocols, based on clustering protocol, is LEACH protocol [2]. The members of each cluster give their data to the head cluster this location. The head clusters send the data to BS Post after their heir integration. This reduces the cost of communication.

The operation of cluster formation and data transfer in LEACH is conducted in 2. Setup phase is the formation of clusters and cluster head. At this point the cluster and cluster head are selected randomly. After the formation of cluster, head cluster publishes the TDMA scheduler to determine the time of transferring data to the nodes. Steady-state phase then occurs. In the steady-state phase, each node transfers the data to the cluster head at its own time period data and the rest of time periods go into sleep mode to save its energy. In this way, head cluster

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spends more energy for receiving, processing and sending data to the base station. Therefore, it is necessary to replace the role of cluster heads between network nodes in order to increase the lifetime of the network. Many improvements in the LEACH have been provided and possibly the best clustering and head cluster selection can be done and the protocol overhead can be reduced as far as possible. LEACH-C is an example of this method of improvement.

2.2 LEACH-C

In [3] LEACH-C, the formation clusters at the beginning of each period is done by the base station using the centralized algorithm. The base station uses the received data from the nodes which includes their position and energy to find the pre-determined number of head clusters and the network configuration in the clusters during the preparation phase . Then the grouping of nodes in the clusters will be carried out for minimizing the energy consumption to transfer their data to the related head clusters. The results reveal that the overall efficiency of LEACH-C for the optimal formation of clusters by the base station is better than LEACH. In addition, the number of cluster head at each period of LEACH-C equals to the expected optimum value. While the number of head cluster in LEACH is different from one another due to the lack of global coordination. Given that the energy of nodes in LEACH-C at the beginning of each period must be sent to BS. This makes the discharging of energy in the nodes and the reduction of network lifetime. Another improvement that has been done on the algorithm is the application of energy estimation .LEACH-CE is an example of these methods.

2.3 LEACH-CE

In LEACH-CE[4]، the energy phase is collected from all nodes in in setting phase of two initial period and it is not collected in other periods . Instead, we can measure the mean of energy consumption per node from the data of two initial periods. It means that fraction of the calculated energy of the node's energy level would predict the current level of energy. The problem raised for this algorithm is that, firstly, there is no accurate energy estimates and secondly, if the nodes are correlated and failure to submit the correlated data is considered as the credit of the previous information , this design of clustering will not be suitable and efficient.

Other researchers such as Ziyadi et al. [7] and Jiang et al. [8] introduced the utilization of a popular optimization technique which is the ant colony for clustering WSN in an energy efficient manner. Other researchers such as Hassan et al. [9] implemented a clustering algorithm for mobile AD-Hoc networks. Abbas and Qasem [6] presented an anchor-based localization scheme for wireless sensor networks. Their scheme is distributed, asynchronous, and scalable. They examined the impact of sensors transmission range and the number of anchors on the error of localization. However, they did not Investigate the impact on the energy consumption. Tatham and Kunz [5] investigated the impact of anchor nodes on the positioning error of localization algorithms. They used Curvilinear Component Analysis method for their study. They proposed an anchor-based localization algorithm that utilizes minimum number of anchor nodes.

3. Suggested method:

The proposed method can be expressed in two parts: 1. determining the geographic location of the nodes, 2. Cluster head selection.

3.1 The process of determining the geographic location of the nodes:

The wireless sensor network includes small sensors with low cost which collect the sufficient data and disseminate them. In order to make the data of nodes meaningful and to help the routing the algorithms , the positioning is a main issue in performance of sensor network. Due to the high number of nodes and energy restriction in them, the positioning algorithms must be used more accurately by spending less energy. Most of algorithms use the guiding nodes for positioning. The guiding node, equipped with the global positioning system (GPS), has a specific location and has different roles in positioning of the other sensors. However, these nodes are inefficient in the field of energy consumption and they require a solution with the lowest cost due to energy constraints. In the proposed network nodes, homogenous means of processing power, communication and energy reserves equal and all nodes do not know your geographical location. In the proposed method, the network nodes are homogenous i.e. they have the same ability in processing, communication and they have the identical energy reserves. However, all nodes don’t know their geographical location. This means that there is not any guiding node in the network and all network nodes, using the following method, can obtain their geographic location by losing negligible energy.

The process of determining the geographic location of the nodes

Figure 1 indicates that we select a point as a source. Then suppose that point to consider the geographical location of the base station to the source is (x_1, y_1). Then it is assumed that the base station have placed the geographical location of two virtual points of (x_2, y_2)

and (x_3, y_3) in a package and distribute it to all single-step nodes . Each single-step node calculates its distance with the points of (x_3, y_3), (x_2, y_2), (x_1, y_1). If we call the estimated distance as $d_{3,}d_{2,}d_1$ respectively, in this case each node can obtain its geographical location in the following way:

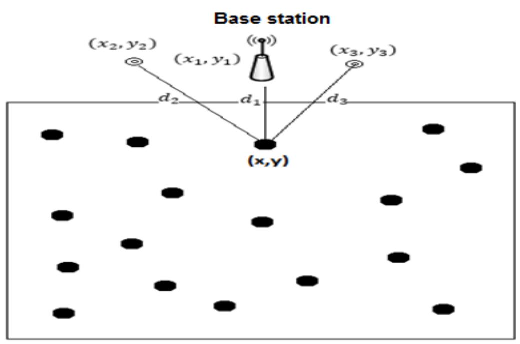


Fig.1 the way of determining the geographical position

Each node can estimate the propagation velocity of data through the signals received from neighbors, and then it can calculate its distance from other nodes using this equation: $\Delta S = V * \Delta t$

Now assume that (x, y) is the position of the unknown nodes which their distance from base station and three known virtual points of $(x_3, y_3), (x_2, y_2), (x_1, y_1)$ are $d_{3,}d_{2,}d_1$ respectively. In this case we have the following equations:

$$(x - x_1)^2 + (y - y_1)^2 = d_1^2 \qquad (1)$$

$$(x - x_2)^2 + (y - y_2)^2 = d_2^2 \qquad (2)$$

$$(x - x_3)^2 + (y - y_3)^2 = d_3^2 \qquad (3)$$

$$x^2 + y^2 - 2xx_1 - 2yy_1 = d_1^2 + x_1^2 + y_1^2 \qquad (4)$$

$$x^2 + y^2 - 2xx_2 - 2yy_2 = d_2^2 + x_2^2 + y_2^2 \qquad (5)$$

$$x^2 + y^2 - 2xx_3 - 2yy_3 = d_3^2 + x_3^2 + y_3^2 \qquad (6)$$

According to equation (6) we have:

$$x^2 + y^2 = 2xx_3 - 2yy_3 + d_3^2 + x_2^2 + y_2^2 \qquad (7)$$

Then we replace above equation with two equations of 1 and 2 and then we have the following equation :

$$\begin{cases} 2x(x_3 - x_3) + 2y(y_3 - y_1) = d_3^2 + d_1^2 + x_1^2 + y_1^2 + x_3^2 + y_3^2 \\ 2x(x_3 - x_3) + 2y(y_3 - y_2) = d_3^2 + d_2^2 + x_2^2 + y_2^2 + x_3^2 + y_3^2 \end{cases} \qquad (8)$$

Finally we will obtain the two unknown equation which have the answer because it is assumed that the three points of $(x_3, y_3), (x_2, y_2), (x_1, y_1)$are not on the same line. Therefore the single-step nodes of the base stations obtain their geographical positions similarly and then the double-step nodes obtain their geographical positions using the geographical positions of single-step nodes. By following this method, all network nodes receive their geographic location. So after a while all nodes on the network receive their geographic location.

3.2 Cluster head selection

Suppose that A= {high energy}, B= {high degree} and C= {low distance} and assume that A (E) , B(D) and C(d) Be fuzzy functions related to above sets. Figure2 Distance

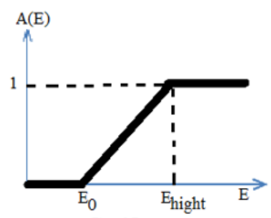


Figure2 Energy

Where $$A=\begin{cases} 1 & E > E_{hight} \\ \frac{E - E_0}{E_{hight} - E_0} & E_0 < E < E_{hight} \\ 0 & E < E_0 \end{cases}$$

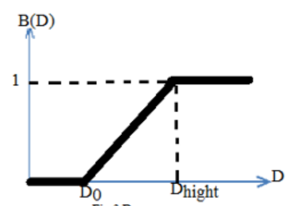
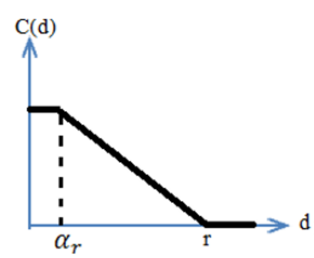


Fig 3 Degree

Where $$B(D)=\begin{cases} 1 & D > D_{hight} \\ \frac{D - D_0}{D_{hight} - D_0} & D_0 < D < D_{hight} \\ 0 & D < D_0 \end{cases}$$

In the next stage this function is calculated.



$0 < \alpha < 1$

Figure4 Distance

Where $$C(d)=\begin{cases} 1 & d < \alpha_r \\ \frac{r - d}{(1-\alpha) r} & \alpha_0 < d < r \\ 0 & d > r \end{cases}$$

d is the distance of node from cluster head in the related cluster. When energy of cluster head node be less than E0 it calculates values of A(En) , B(Dn) and C(d(xn, yn),(xh, yh)) for each node that located in one hop, and (xn, yn) is the coordinates of node, En is the nodes energy, Dn is the degree and dn is the nodes distance to cluster head coordinates that is equal to (xh, yh). Then calculates F(n)= α A(En) + β B(Dn) + ɣ C(d(xn, yn),(xh, yh)) and then obtains max f(ni) and niεC in which C determines the cluster with cluster head coordinates of (xh, yh). If this maximum value be equal to f(nj) then the cluster head informs node nj to introduce itself as cluster head.

In the above formula (α, β andɣ(are energy, degree and central respectively. In the other hand if we suppose values of i th row of the following matrix as energy, degree and the distance of i th node to its related cluster head respectively (by supposing that N nodes exist in cluster C) so:

$$M=\begin{Vmatrix} A(E_1) & B(D_1) & C(d_1) \\ \vdots & \vdots & \vdots \\ A(E_i) & B(D_i) & C(d_i) \\ \vdots & \vdots & \vdots \\ A(E_N) & B(D_N) & C(d_N) \end{Vmatrix} * [\alpha \quad \beta \quad ɣ]^T$$

$$=[\ \alpha A(E_1)+\beta B(D_1)+ɣ C(d_1), \ldots, \alpha\, A(E_i)+\beta B(D_i)+ ɣ C(d_i), \ldots, \alpha\, A(E_N)+\beta B(D_N)+ɣ C(d_N)]$$

And di shows the i th node distance to its cluster head.

$$M=\sum_{i=1}^{N} \alpha\, A(E_i) + \beta B(D_i) + ɣ C(d_i)$$

M=[Mi] , 1≤ i ≤N Mj=max Mi

Node nj introduce itself as cluster head. We must purpose that in order to calculate distance from cluster head it is not essential to know neighboring nodes location. Because the distance can be calculated using received signal strength and many other methods.

4. Simulation results

4.1 Simulation Environment

Simulation is done over the Linux Fedora core.10 operating system using network simulator of NS2. LEACH and LEACH-C protocols from UAMP project in MIT University are simulated over NS2. Determined scenarios for a real simulation environment are as follows:

- Sensor network topology using 100 nodes
- Environment dimension is 100m*100m
- Cluster number is 5
- Data transfer speed is 1Mbps
- Base station located in position (100,50)
- Period length is 20 seconds
- Wireless transmission speed is 3*108 m/s
- Primary energy of each node is 2 J

Receivers and senders follow the model [3] with these parameters:

$$E_{elec} = 5.0\times10^{-8}\ J/bit, E_{tx} = E_{rx} = 5.0\times10^{-8}\ J/bit$$

$$\varepsilon_{free-space-amp} = 1.0\times10^{-11}\ J/bit/m^2, \varepsilon_{two-ray-amp} = 1.3\times10^{-15}\ J/bit/m^4$$

E_{tx}, E_{rx} Parameters are sending and receiving energy for each Bit. Our experiment accomplished with LEACH, LEACH-C, LEACH-CEC and the proposed method.

4.2 Simulation Results

In the NS2 simulator and LEACH and LEACH-C protocols, data generated with uniform distribution. But phenomenon that observed by sensor nodes usually continuously change with time. So data received by sensor node are dependent. Therefor data generated in simulation must have normal distribution. We have run each of protocols 20 times and resulting diagrams are the average of runs.

Figure 5 shows energy consumption in each period. In this figure we compared LEACH, LEACH-C, LEACH-CEC with proposed method. Then calculate energy consumption values for each of them. As simulation results show our proposed method algorithm has better operation in contrast to other methods.

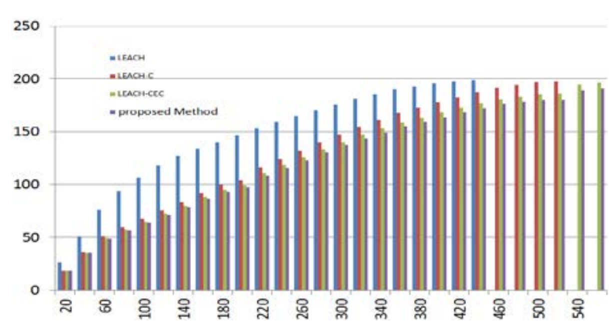


Fig. 5 energy consumption value in total of network topology

Figure 6 shows number of live nodes in different times. In this figure, 4 methods mentioned above surveyed in each period from the viewpoint of live nodes number. As seen in figure 8 in our proposed Method, number of live nodes in each time slot is more than other methods. In the

LEACH protocol sensor nodes death stared in time 300, but in distributed protocols this time is 100.

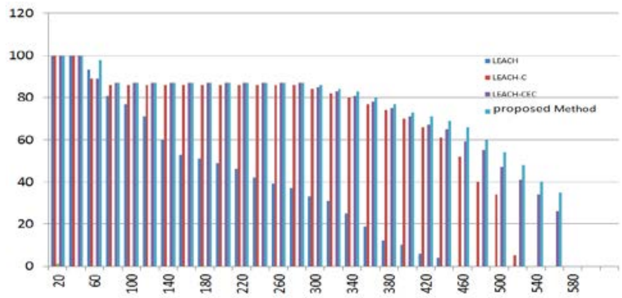


Fig. 6 Number of alive

5. Conclusion and future work

In this paper, we proposed an improved localization algorithm for wireless sensor networks in terms of energy dissipation. The main goal of the proposed algorithm is to reduce power consumption and hence prolong the network survive in this paper we solve the problem of cluster head selection in all of discussed methods. So using a fuzzy method, cluster head selection is done efficiently as network lifetime increases. Also in LEACH protocol we have eliminated periodic transfer of nodes data. Using proposed Method there is no need that all nodes send their data to base station in every period. Nodes send their position to base station only when network starts. Base station creates network topology and using fuzzy method determines cluster head in each period. In this paper using fuzzy algorithm, we have improved network lifetime in LEACH-CE protocol and restricted energy waste. There are many open issues need to be addressed as future works. One of these open issues is to modify the proposed algorithm to work with mobile sensor networks. Moreover, we may investigate the capability of modifying the algorithm for localization in three dimensional spaces.

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