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Research Article

A NEW METHOD FOR ROUTING IN ENERGY-BASED WIRELESS SENSOR ACTOR NETWORK

Fatemeh Shakiba[1], *Fazlolah Adibnia[2] and Sima Emadi[1]
[1]*Department of Computer Engineering, Yazd Branch, Islamic Azad University, Yazd, Iran*
[2]*Department of Computer Engineering, Yazd University, Yazd, Iran*
**Author for Correspondence*

ABSTRACT
Wireless Sensor Actor Network is a collection of large numbers of sensor nodes with very small dimensions which has the abilities of environment sense, sensory information and transferring data between each other wirelessly. Although these nodes have proper capabilities, their lifetime is limited, because their energy is provided by batteries with limited power. Among different factors of energy consumption, data routing is one of the most important consuming energy factors. Most of the energy is related to the way of transferring data from the node inside the network to the base station and it is the best route for transferring data. LEACH algorithm is one of routing algorithms that works based on clustering. In this thesis, LEACH method has been improved, so that if the selected cluster head does not achieve the minimum points of the evaluation function, then the node which possesses the highest score will be selected as cluster head. The amount of energy consumption will be distributed among nodes. The results of suggested method's simulation indicate that in comparison to LEACH method, the suggested method has longer network lifetime.

Keywords: *Network, Wireless Sensor, Routing, Power, Cluster Head*

INTRODUCTION
Wireless Sensor Actor Network (WSAN) is a collection of a large number of small nodes in which there are some sensors or actuator and it strongly interacts with physical environment. It receives the information through sensors, reacts with the environment through actuators and the relationship between nodes is wireless. Each node works independently and without human intervention, it is physically very small and has some limitations in processing power, memory capacity and power supply. These limitations have brought some problems which are the origin of many research topics in this field. This network follows traditional network protocol but due to limitations and differences related to function, protocols in this type of network must be rewritten. This article besides introducing sensor network, describing features, limitations, functions, ideas and challenges, also talks about the subject of clustering (Iyer and Ath, 2008).
The recent improvements in the technology of construction of small-scale integrated circuits on one hand and development of wireless communication technology on the other hand created the base of designing wireless sensor actor network. Traditional networks have provided the connection between human beings and data stations, while sensor network is directly in relations with physical world, it can observe the physical environment using sensors and do the suitable operations based on its observations. Wireless Sensor Actor Network is a general name for various types which are designed for special targets. In contrary to traditional networks which are multi-purpose, sensor networks are single-purpose. If the nodes are able to move, the network can consider a group of small robots which work as a team and are designed for a special goal like playing football or fighting enemy. In another point of view, if we remove base stations from mobile phone networks and consider each phone as node, then the connection among nodes should be directly done through one or some nodes. This is one type of Wireless Sensor Actor Network. Although the history of sensor networks goes back to cold war and its idea was first created by US defend industry military planners, this idea could have been also formed in the minds of Independent mobile robot designers or mobile wireless networks designers. However, since this technology is the meeting point of various points of view, its realization can be the base of implementation of future

applications. Several functions of this type network and its relation with different topics presented in computer and electronic such as network security, Real-time communication, voice and image processing, data mining, robotics and automatic digital embedded system provides an extensive field for researchers with different interests.

This article, concerning theoretical basis about the general structure of Wireless Sensor Actor Network, nod construction, protocol stack, routing in Wireless Sensor Actor Networks, LEACH protocol and also the background of previous studies, introduces network routing and its challenges. With regard to this point that the most important challenge in Wireless Sensor Actor Networks is the network's active time, and one of the most important factors keeping the network active is the amount of nodes' energy consumption. At first we have introduced the energy model and then in part 3, fully explained the suggested method. This model has been used for all simulations and experiments. In part 4, the results achieved from simulation have been discussed.

Theoretical Basis and Research Background

Sensor network is a collection of sensor nodes and actuator or sensor/actuator which is the general state of all discussed networks. In other words, sensor network is a network that includes a large number of nodes and each node can normally have some sensors and some actuator. According to figure 1.Taskmanagement can be centralized or distributed. Regarding this point that in what level decisions are made for reaction, there are two structures of automatic and semi-automatic, in which their combination is also usable (Iyer and Ath, 2008).

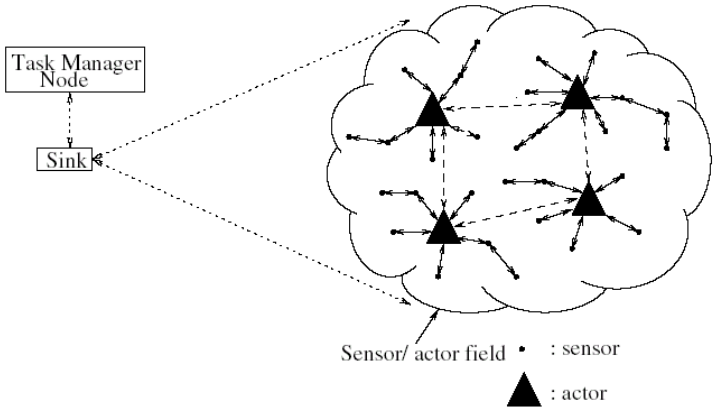

Figure 1: The general structure of sensor network

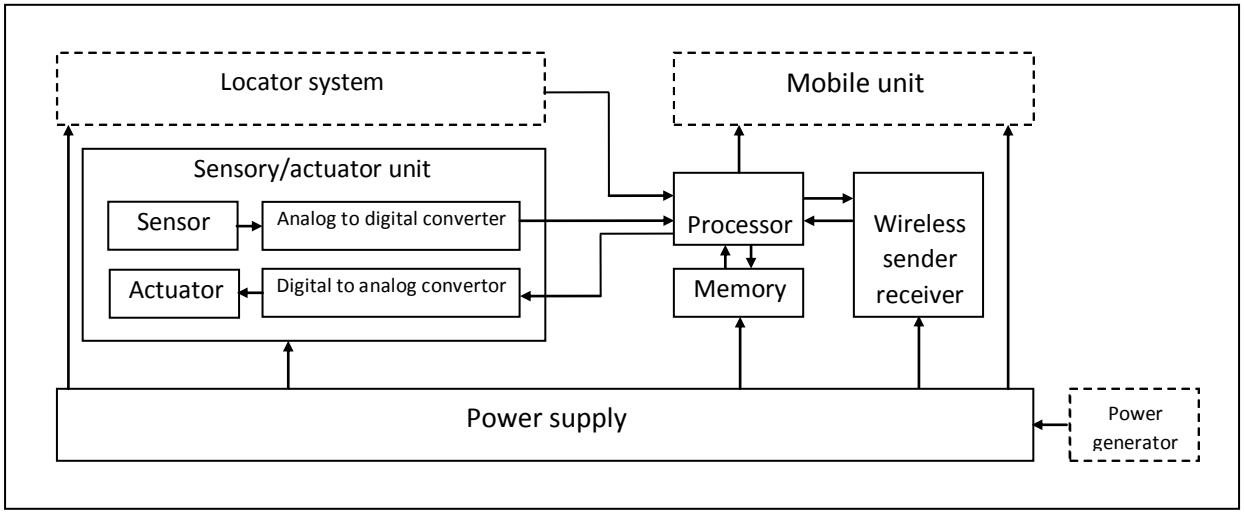

Figure 2: The internal construction of sensory/actuator node

Figure 2 shows the internal construction of sensory node. Each node includes sensor/actuator unit, data processing unit, wireless sender/receiver and power supply. Additional mobile units, locator and power generation systems may exist depending on the application of nodes. The unit of power supply provides the consuming power of all parts which is usually a battery with limited energy. The limitation of energy supply is one of the fundamental hardships which affect all the things in designing sensory networks (Iyer and Ath, 2008).

According to figure 3 protocol stacks, on one hand has five horizontal layers including physical layers, data link, network, transformation and function and on the other hand has three vertical layers of power management, transportation management and task management (Heinzelman *et al.*, 2000). The vertical layer of power management determines the power consumption for each node through getting involved in all horizontal layers. In fact, in order to reduce the energy consumption, we need algorithms and power aware protocols. Another idea that can be used simultaneously is that the node which has reached to the lowest level of energy informs its neighbors that its energy is running out and cannot take part in routing messages. Neighbor nodes will rout messages through other nodes. The vertical layer of movement points to applying location-aware methods; it detects node's transfer and records it. Therefore, a return path is always managed to the user and the trace of movable node is followed, task management schedules and equilibrates nodes' tasks. To guarantee this, we must use application aware algorithms. Regarding the mentioned items, nodes in sensory network can work together using power efficient method and rout the data in sensory movable network and share the resources among nodes.

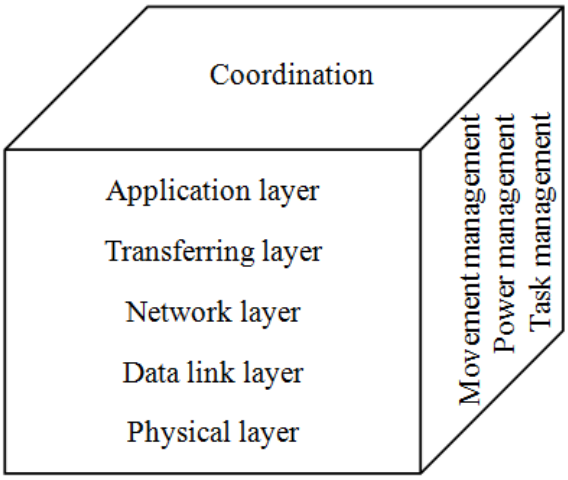

Figure 3: The internal structure of sensor/actuator

The method which moves the data and questions between base station and destination is called routing and it is one important issue for Wireless Sensor Actor Networks. In one approach, routing can be considered as the method of transferring data among sensory nodes and in another approach it can be defined as transferring data among sensory nodes inside the network and the final base station (Iyer and Ath, 2008). One simple method for doing this task is that each sensory node directly exchanges data with base station. However, the single-jumping-based method is costly, because the nodes which are far from the base station will lose energy supply much faster, thus it severely restricts network's lifetime. This matter is so important especially in cases in which wireless sensors are arranged to cover a big geographical area or in which wireless sensors are movable and they may get far from the base station.

In order to encounter deficiencies and defects driven from single-jumping method, exchanging data between sensors and base station is usually done through multi-jump transfer methods on small communicational radius. This method of transferring data leads to significant savings in energy consumption and a significant reduction in noise transmission among sensor nodes that are in competition to access the channel. Figure 4 shows the progression and data exchanging among sensors where the data

has been collected and the base station through which the data is available to the user (Sohraby *et al.*, 2010).

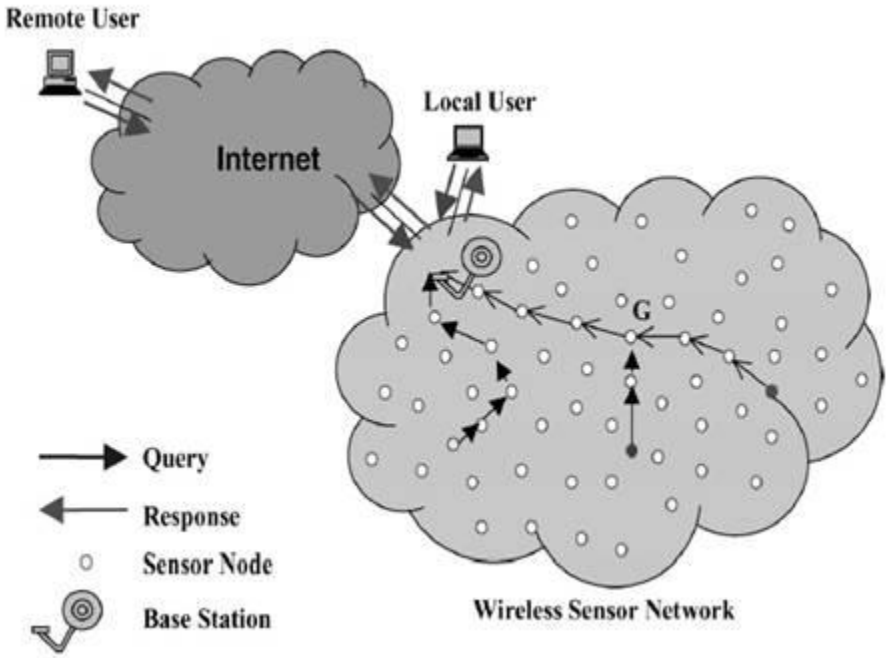

Figure 4: The way of releasing data in Wireless Sensor Actor Network

Routing in Wireless Sensor Actor Networks

Due to the differences between Wireless Sensor Actor Network and other wireless networks, several new protocols are suggested to solve the routing problem. In terms of how to get from environment, routing protocols of sensory networks are categorized into routing protocols based on multipath, quality of servicing, negotiation, investigation and coherence. In terms of how the starting point finds the destination point, Routing protocols are divided into 3 categories of reactive and proactive or the combination of both (Misra *et al.*, 2009).

One of the best categories of routing protocols of sensory networks is the categories presented by Akkaya and Younis. Regarding the operation of nodes, available information of each node and network's goals, this classification divides routing protocols into four general categories of "Data-driven", "hierarchy", "the Situation" and "aware of the quality of service and network flow" (Schmitt *et al.*, 2008). Some routing protocols are located in one more category of this classification, because they follow various goals and have their own presumptions. In order to determine which protocol belongs to which category, the most important factor is investigated and regarding protocol's field, it is classified into the related category.

LEACH Protocol

This method is the first method for categorizing sensory nodes which was suggested by Heinzelman *et al.*, (2000). In this method, in order to select the cluster head, we have used a threshold, in this manner that each node produces one number between zero and one, and compares it with the threshold. If the produced number is less than the threshold, then the mentioned node will be selected as cluster head (Heinzelman *et al.*, 2000). Following LEACH method, other methods such as X-LEACH and Improved LEACH have been also developed through being inspired by this method. In fact, in the methods which work according to nodes' classifications, sensory nodes play various roles and accordingly may have different energy consumption level. These types of methods are among the best routing algorithms in such networks and nowadays, through being inspired by them, new methods have been suggested to increase

network life time. A series of low energy adaptive clustering is a routing algorithm which is designed to collect and deliver the data to a base station, and the main objectives of these methods are:

1) Increasing network's lifetime
2) Decreasing energy consumption of each network sensory node
3) Using data gathering and compression to reduce the number of tele-communicational messages.

In order to achieve this goal, LEACH applies a hierarchy method to organize network as a collection of clusters. Each cluster is managed by a cluster head which is selected. The cluster head is in charge of different tasks. The first task of head cluster is alternate collection of data from cluster members. As data is collected, cluster head compresses the collected data through eliminating redundancy among correlated data. The second main task of cluster head is to directly transfer compressed data to base station. Transferring data is done through one jump.

The third main task of cluster head is to make a timing plan based on sharing time in which a time slot has been allocated to each node and each node can use its own time slot to transfer data. Cluster head announces the timing plan through public broadcasting to his own members. In order to reduce the possibility of collision among sensors, LEACH nodes inside and outside of clusters have applied a plan based on multi-access and code-divisions to do their own communications. In short, we can say that the basic operations of this method are organized in two different phases:

The first phase which is the start phase includes two steps: the step of selecting cluster head and making cluster

The second phase which is called stable phase, is focused on collecting, compressing and delivering data to base station. These two phases have been briefly shown in figure 5:

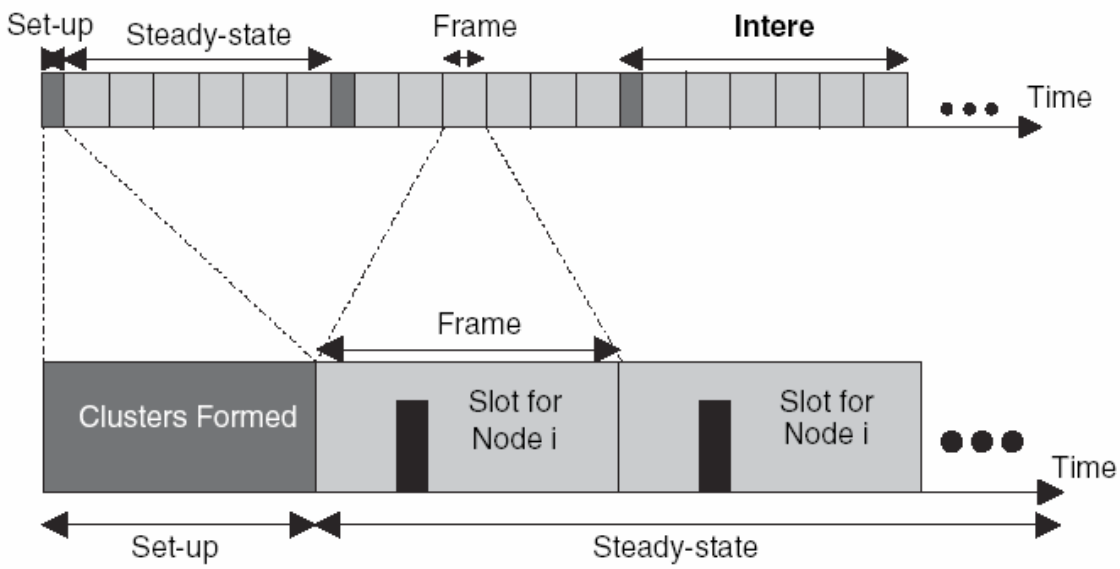

Figure 5: Two phases used in the series of low energy adaptive clustering method

The duration of start phase is assumed quite shorter than stable phase and this is done with the aim of minimization of protocol overhead. At the beginning of start phase, one period of selecting cluster heads starts. The process of selecting cluster head assures us that this role is circulating among sensory nodes and consequently energy consumption is equally distributed among all network nodes. In order to determine whether it is the turn of one node to be the cluster head or not, each node n produces an accidental number between zero and one like v, then compares it with the threshold of selecting cluster head which is T (n).The node will be the cluster head if the produced accidental number (v) is less than mentioned threshold. Threshold of selecting the cluster head is designed in a way in which with high probability ensures that the pre-specified fraction of nodes, for example, p in each period is selected as

cluster head. In addition, the threshold guarantees that the nodes which were used in the last 1/P of previous periods, won't be selected as cluster head in the present periods. In order to achieve this goal, the threshold of T(n) of mentioned node like n is expressed by the help of equation 1:

$$T(n) = \begin{cases} 0 & if \quad n \notin G \\ \dfrac{p}{1 - p(r \bmod (1/p))} & \forall n \in G \end{cases} \tag{1}$$

In this equation, G variable shows a collection of nodes which were not selected as cluster head in the last 1/P of periods 1, and r refers to the present period. Pre-defined parameter P indicated the possibility of being cluster head. It is obvious that if one node was not used in the last 1/P period as cluster head, it won't be selected in this period. At the end of selecting cluster head process, the node which was selected as cluster head, announces its new role to the rest of the network. As it is announced, each remained node selects one cluster to get connected to that cluster. Selection criterion may be based on the power of received signal among other factors. Then, nodes inform the selected cluster head of their decision for joining the mentioned cluster. As the cluster is formed, every cluster head arranges and distributes the timing plan of sharing. This plan, determines the timing slots which were allocated for each member of cluster. Furthermore, every cluster head selects one multi-access code with code 1 division which is sent to all cluster members. This code is selected accurately in which reduces the intervention among clusters. The end of start phase's signals is the beginning of stable phase. In this phase, nodes collect information and apply the slots allocated to them for transferring collected data to cluster heads. Data collection is done alternately (Xiangning and Yulin, 2012).

MATERIALS AND METHODS

Suggested Method

In order to suggest an improved method for routing lowest energy data and consequently, increasing sensory network's lifetime, we have studied LEACH, basic and popular routing algorithms and the enough energy for transferring one bit of information to the base station, then, the same situation has been simulated with the suggested method and the results have been compared.

The Model of Energy

With regard to this point that our aim is to compare the total consumed energy of the network, then, it is necessary to have a standard model for calculating the energy consumed in these networks. In most of applications done on these networks, similar models are approximately used to measure the total energy of the network (Misra *et al.*, 2009; Rashed *et al.*, 2013; Araujo, and Rodrigues, 2006; Amiri and Hanifi, 2010; Rahmanian, 2013; Kofman *et al.*, 2012). In this model, with regard to this point that the energy which is enough to transfer data packs among sensory nodes, is much more remarkable than network's other energies, we assume that the main part of network's consuming energy is related to receiving or sending data, and we will withdraw the consuming energies like the energy which is necessary to sense or process received data or etc. In this model, in order to calculate the energy which is necessary for transferring L data bit distancing d, we have used equation (2):

$$E_{tx}(l,d) = l.E_c + l.e.d^s \tag{2}$$

In this equation, E_c is the basic necessary energy for receiver and sender circuits which equals 50 nJ/bit for a 1Mbps sender. In addition, e is the energy unit which the booster of sender consumes for sending data and it is achieved through equation (3).

$$e = \begin{cases} e_1, s = 2 \; if \; d < d_{cr} \\ e_2, s = 4 \; if \; d > d_{cr} \end{cases} \tag{3}$$

In this equation, d_{cr} does the threshold distance equal 86.2 meters. e_1Equals 10 $^{pj}/_{bit.m^2}$and e_2 equals 0.0013 $^{pj}/_{bit.m^2}$. In addition, we have used equation 4 to receive L data bit distancing d.

$E_{rx} = L.E_c$ (4)

Therefore, in order to calculate the necessary energy for transferring L bit from node I to node j, we have used equation 5.

$E_{i,j}(l,d) = L(a_1 + a_2.d^s)$ (5)

And the variablesa_1,a_2, $a_2$are defined based on equation 6.

$$a_1 = 2.E_c$$
$$a_2 = e_1 \; or \; e_2$$
$$\mathrm{s} = 2 \; or \; 4$$

(6)

Nowadays, the simulation technology has been successfully used for modeling, designing and managing various smart systems. Therefore, several tools and techniques have been created, such as rotary event simulation technique which is the basis of many new simulations' operation. The function of communicational networks' simulation has 15-year background which is still developing. The reasons of using simulation in this field can be summarized in two items:

1- advent and development of networks with complicated technology
2- creation of special tools and soft wares for network simulation

Network simulator software has the capability of simulating communicational networks without the need for coding, usually by providing graphical interfaces. Certain elements of simulation corresponding to the actual elements (routers and switches) not only have increased the accuracy but also convenience and speed in simulation process, thus, it is very suitable for users who are not familiar with programming technique. The simulators used in the field of WSN are: Ptolemy II, OMNeT++, VuSystem and NS (2). Most of the time, many popular protocols have been already applied, so using them can accelerate simulation. Because this suggested method is a new method and two models of LEACH and the suggested method must be applied then get compared preferentially, so MATLAB software has been used for simulation and comparison.

For doing this, we need to compare the suggested method with one standard method in which LEACH method was selected, and we must consider one source model to compare these two methods. In order to apply both models, we have used a space with the dimension of 100×100 sq.m in where the base station is stably located in the middle and 100 nodes are spread in this space accidentally. To apply the suggested method, we have used the semi-code of figure 6.

The suggested method is based on LEACH method. LEACH is a hierarchy method which includes two main phases:

First phase: it is the start phase, has two steps: the step of selecting cluster head and the step of making cluster.

Second phase: it is called the stable phase, and is focused on collecting, compressing and sending data to the base station.

In LEACH algorithm, in the start phase and step of selecting cluster head, the responsibility of being a cluster head is periodically divided among members, in a way in which if node n was a cluster head in period k, then it must not be in period k+1. This method leads the amount of energy to get equally consumed among nodes. The highest amount of consuming energy is related to cluster heads. Because they are in charge of collecting, compressing and sending data to the station and the highest amount of energy consumption is related to sending data to base station.

According to what was mentioned in references (Abbasi and Younis, 2209), determining the best possibility of selecting cluster heads is affected by different factors such as the dimensions of sensors environment's arrangement. But we can almost say that for every node, three to five clusters can lead to the least amount of energy consumption. Therefore, choosing (p=0.05) can have the best possible result in 100 nodes. An objection of LEACH algorithm is that the amount of energy consumption for a cluster located so far from base station is more than the one located much nearer, whereby LEACH algorithm has no control over consuming energy. The suggested method has covered this objection in a way in which in selecting the cluster, the cluster would be not selected as cluster head, if it has energy less than the

average energy of all nodes, or his distance to base station is more than all nodes' distance. Another node that has the highest score of the functional evaluation is defined as the cluster head. The network of suggested method code is shown in Figure 6.

```
Put N nodes in environment
Lbl1: i=1
Lbl2: if rnd[0,1]<T(n)
if Di <Davg or Ei>Eavg
CH=i
Else
        CH=Best
End
i=i+1
if i<=n then return lbl2
Election subset for heads
Steady-state phase
If all of nodes are dead then
End of algorithm
Else
        Return lbl1
End
```

Figure 6: Suggested method semi-code

Suggested Method Simulation
In order to simulate the suggested method, we have used MATLAB software and simulation parameters are presented in table 1.

Table 1: Parameters of simulation

Land area	100×100 sq.m
Number of nodes	100
Primary energy	0.5j
Coordinates of base station	50.50
Amount of sending packs	4000bit
The possibility of selecting cluster head	0.05

If the node selected as the cluster head, has a distance more than the average distance of other nodes from base station or its current energy is less than average energy of all nodes, then, the node which has received the highest score of evaluation function, must be chosen as cluster head. The function of evaluation has allocated to node a point based on the amount of node's current energy and its distance from base station. The calculating formula is based on equation 7 in which d is the distance to base station and e is the amount of node's current energy. Coefficients d and e are considered as x and another as 100-x to determine each one's influence. Then, in every circle, x is considered between 0 to 100 and in each round of circle, the average of nodes' energy is calculated in every step of algorithm in which the coefficient indicated in equation 7 are the best ones.

$$fit = 0.23 \times D_i + 0.77 \times E_i \quad (7)$$

Figure7 is the result of simulation in round 13. Each area includes one cluster head and other nodes are ordinary nodes that are subclasses of cluster head. The divisions which are virtual are created by Voronoi algorithm.

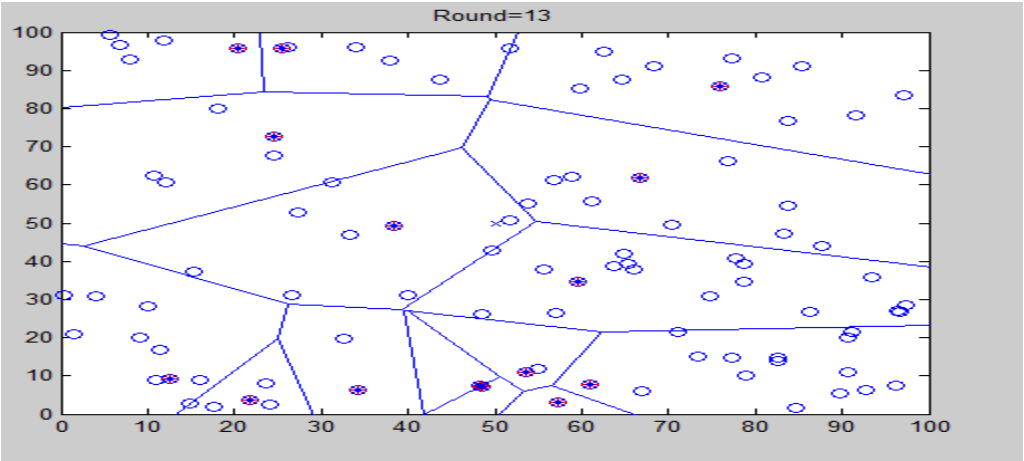

Figure 7: Nodes' distribution and the area covered by cluster head

Since all the sensors are considered similar and stable in the function of Wireless Sensor Actor Networks, we have also used some similar sensory nodes which are accidentally arranged in a quadrangular area for doing its simulations. Figure 8 shows the general view of sensors' accidental arrangement in the quadrangular area. The number of nodes is different depending on this point that the experiment investigates what kind of parameter. Furthermore, the dimensions of sensors' arrangement area which is shown in measure of 100×100 in the figure are studied as one influential parameter in energy consumption. In addition, the base station is considered stable and in the middle with the 50×50 coordinates.

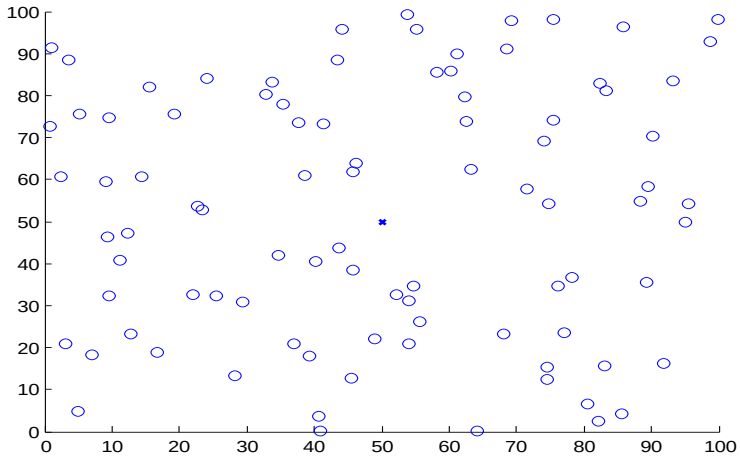

Figure 8: Nodes arrangement and base station's position in the middle

In this section, we study the function of suggested method compared to LEACH method. With regard to this point that the suggested method claims increasing network's lifetime, then, we must have a certain criterion to calculate network's lifetime. In many researches done on network's lifetime, there are two important criterions to measure lifetime. The first criterion is FND criterion and the second one is LND criterion. FND criterion is defined as the time it takes for the first node to die in the network or as the number of time periods when the network acts with all its nodes. LND criterion is defined as the time it takes for all nodes to die in the network or lose the whole energy.

Figure 9 shows the number of dead nodes in LEACH method and the suggested method which obviously indicates that the suggested method works better based on FND criterion. In fact, through applying some corrections in selecting cluster head phase, network's lifetime has increased and the energy consumption

has been equally distributed among nodes, so, the time it takes for the first node to die has become longer. Because due to transferring data to far distances, cluster heads consumes energy more than ordinary nodes and their accidental selection may lead to quick discharge of energy, so network's lifetime will increase.

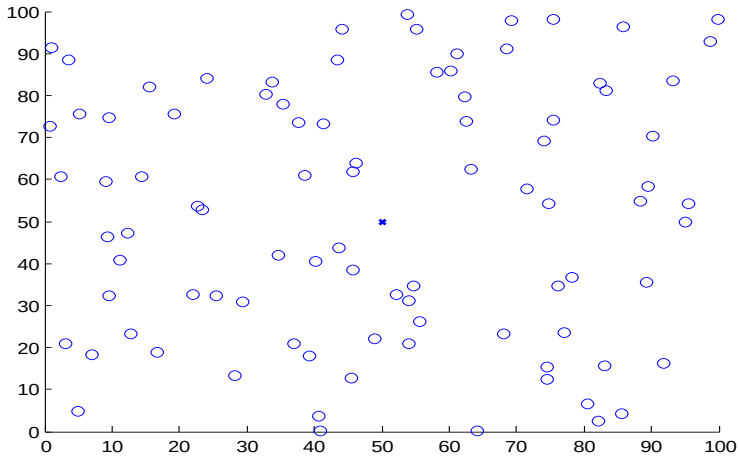

Figure 9: Comparing the number of dead nodes in LEACH method and suggested method

Figure 10, shows the average nodes' energy in each round. The average energy is calculated in this way: total energy of nodes divided to the number of live nodes. We can see in the diagram that the average energy of nodes in each round is more in the suggested method. Round's horizontal and vertical axis relatively shows algorithm's function and the average of nodes' energy.

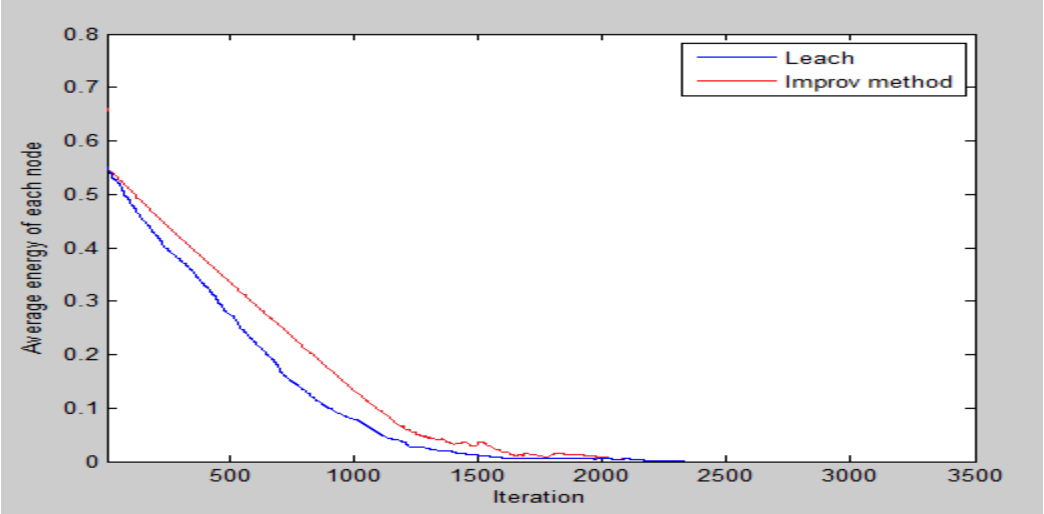

Figure 10: The average of nodes' energy in each round

Conclusions and Recommendations

In this article, we have suggested a method of routing in Wireless Sensor Actor Networks in which minimizes nodes' energy consumption. The results of studies on LEACH model show that selecting cluster head is totally accidental, in a way in which it tries to equalize energy consumption among nodes through distribution of cluster head's role among them, but the main problem is that in order to select cluster head, it doesn't notice the current energy and the distance from base station.

In the new method, LEACH method has been applied to select the cluster head, if the amount of node's current energy is higher than the average of nodes' current energy and also its distance from base station

is less than average of nodes' distance from base station. The results of applying and comparing two methods of LEACH and suggested method clearly shows that the level of network's survival in suggested method is more than LEACH level. It seems that for the future projects, we can reach to favorable results such as reduction of energy consumption through combining chain-based energy and nodes' clustering, or through other methods based on clustering nodes and energy-informed. In addition, we can notice the amount of node's current energy for selecting cluster head in chain- based methods whose main problem is lack of attention to node's current energy. As an instance, through defining a threshold, we can prevent selecting nodes that have current energy less than threshold.

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