Using Consensus Estimate Technique Aimed To Reducing Energy Consumption and Coverage Improvement in Wireless Sensor Networks

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Abstract
Wireless Sensor Network (WSN) is composed of hundreds or thousands of small devices called sensor nodes that interact with each other to perform certain task or tasks. A node obtains environmental data through its sensors and sends it to a center called base station through its communicational equipments (antenna) for more processing and final decision making. Resource limitation of a node, including supply resource leads to new challenges for wireless sensor network. With completion of node energy, node exits from network practically and will remain unused. In this situation, some information may not be readable, and coverage disappears in this area. Hence, a technique must be considered that in addition to complete coverage in wireless sensor network, nodes blackout occurs later. This study is aimed to reduce nodes consumed energy and improve coverage in wireless sensor networks using consensus estimate technique, so that network performance is greatly enhanced. According to the results obtained from simulation, suggested method could increase network efficiency to a reasonable degree. In assessment section, suggested method is compared with two LEACH and ECRM in different conditions and scenarios. Based on obtained result , the proposed method has improved to an acceptable level using environment zoning , task cycle , multi-step routing, converge consensus estimate in wireless sensor network ,and this value has been measured using MATLAB software.

Keywords
Wireless Sensor Network, network coverage, nodes consumed energy, task cycle, consensus estimate, clustering.

1. Introduction

According to increasing growth of sensors application in electronic and communicational circuits, these systems optimization are studied and some strategies are provided. These small sensor, which are able to do some actions such as receiving, processing and sending different environmental data based on sensor type, are the main cause of emergence of an idea to develop Wireless sensor networks (WSN). A sensor network is composed of a large number of sensor networks, which are distributed in an environment and collect environmental data. Sensor nodes position is not predetermined essentially. According to this feature, it is possible to leave them in hazardous or inaccessible areas. On the other hand, this means that sensor networks protocols and algorithms must have self-regulation abilities. Other unique features of wireless sensor networks include the ability of cooperation and coordination between sensor nodes. Each sensor node has a processor on its board and processes some obtained data and then sends semi-processed data instead of sending all raw data to center or a node, which is responsible for information processing and deduction. Although each sensor has little ability, combining hundreds of small sensors provides new facilities. In fact, wireless sensor networks are able to use a large number of nodes, which are able to be organized and they can be used in different cases such as simultaneous routing, monitoring environmental conditions, monitoring the safety of structures or equipments in a system. Wireless sensor network is composed of hundreds or thousands of small nodes called sensor nodes that interact with each other in order to perform a specific task. Wireless sensor networks are based on sensor technology, wireless communication, small embedded devices and distributed computations. These networks exchange the data with environment through sensors, and conduct operations of data collecting and processing. Wireless sensor networks are used extensively in environment monitoring, target tracking, military applications, natural disasters management, etc. Wireless sensor network has specific features that separate it from other wireless networks [1] [2]. Some of the unique features of wireless sensor networks include large number of nodes, hardware limitations due to network application decreased expenses, existing in inaccessible environments by human, failure potential, etc. There are numerous challenges in wireless sensor networks, the most important of which include limited supply resource, non-rechargeable and irreplaceable nodes. As a result, suggested strategies for

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energy consumption reduction must be considered as a priority. If an area is not covered in wireless sensor network, or in other words information cannot be received in some parts of environment, network efficiency would be jeopardized. Therefore, coverage in the wireless sensor network is considered as one of the main challenges [3]. Proposed strategies to control coverage in wireless sensor network are used so that energy consumption reduces and thus some nodes have little energy and their activities do not jeopardize the coverage. In order to have complete coverage, the network is divided to different areas and in each area one node is in awake mode and others are in sleep mode. Awake node must have the maximum energy. Clustering is an efficient method to reduce energy consumption. This means that instead of sending data by an individual node, some nodes are known as cluster head, and other nodes, which are cluster members select the nearest cluster head as cluster head. Cluster head sends cluster members data to well or base station after integration. Clustering algorithm increases network life time that LEACH is one of the most popular clustering algorithms. This study regarding using a technique based on consensus estimate is aimed to decrease energy consumption and improve coverage in wireless sensor networks, hence the remainder of this paper is organized as follow. In section 2, literature review and conducted studies in this area are considered. In section 3 , proposed method considered in this paper is provided completely and in section 4 proposed model simulation results and obtained results evaluation are presented and finally in section 5 , summary of all presented topics in this study is provided[4].

2. Literature review

A wireless sensor network is consisted of a large number of sensor nodes, in fact its data are considered collectively to measure a parameter, in other words, all collected data for a parameter will be processed in a node of network and real value of parameter will be estimated relatively, in fact, the results obtained from each sensor are sent to one or more well using other sensors for further processing by wireless environment. Well is node, which is different from sensors, it doesn’t have sensors limitations (including energy) and also it is able to process the data sent from all sensors with high processing ability. Sensors can be distributed in environment as structured or unstructured. In unstructured mode, nodes are distributed in environment as compact and without exact monitoring of distribution method. In this case, after distribution, sensors are left and only their data will be collected and processed. This method is often used in military applications. In structured method, each sensor has a predetermined position and the relationship between sensors is relatively planned. In this method, due to exact monitoring of sensors, their management and maintenance is relatively simple and inexpensive, since less sensors are often required compared to wide outdoor areas such as forests. In this network, failure of a node in network is almost not effective in entire network. In wireless sensor networks, a large number of nodes will be placed in considered area to measure desirable parameter. Location of nodes is not predetermined, and they are distributed randomly in the environment. It simply helps placement of nodes in the network, but the protocols, which are used for the network must be self-organized. According to the fact that there is a processor in these nodes, these nodes send the required data toward destination after initial data processing to decrease the volume of data transfer. Designing a network is influenced by several factors. These factors are important in designing sensor networks protocols, including failure tolerance, expanding ability, topology, hardware constraints, reliability, sensors reliability, reliability of communication lines, scalability, production cost, communication media, real-time communication and coordination, security and interventions, unpredicted factors, node consumption power. Among mentioned factors, as the most important factors in designing wireless sensor networks, consumption power of nodes is very important, which is considered as the main objective of this study. Sensor network nodes must have low consumption power. Sometimes, supply resource of a battery is 1.2 volt with an energy of 0.5 amp/h, which should provide the necessary power for a long time, for example 9 month. In many applications, battery is not interchangeable, thus in practice battery lifetime determines the node lifetime. Since a node, in addition to receiving information (through sensor) or running a command (through actuator) also acts as a router. Node malfunction leads to its removal from topology and consequently the network will be reorganized and package will be rerouted. In designing nodes hardware, it is important to use designs and components with low consumption and to provide sleep mode possibility for entire node or each part separately. One of the most important methods in decreasing energy consumption of nodes is clustering. Clustering is a method to save energy and increase sensors lifetime in wireless sensor networks. Clustering has other advantages, including greater security in sensor networks, decreasing redundant data and increasing scalability in these kinds of network. LEACH is a similar clustering method in wireless sensor networks. The main methods of LEACH protocol include some algorithms for cluster distribution, formation of consistent cluster and head cluster reposition. Cluster formation distribution method ensures more self-organization of target nodes. Formation of consistent cluster and head cluster reposition algorithms ensures common energy distribution among all nodes and increases lifespan of the entire system. LEACH protocol is implemented with many rounds. Each round consists of two phases: cluster regulation phase and stability phase. In regulation phase, cluster is formed and in stability phase, data are sent. Second phase duration is usually longer than first phase duration to save protocol traffic load [5]. The process is shown in figure 1.

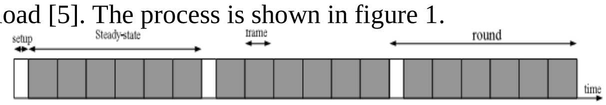

Figure 1. Duration of LEACH operation

In [6], Kerpa and Strein suggest to use sensors local measurement to configure network topology in sensor network with high density. Their goal is to maintain special data deliver ratio, while it allows additional sensors to stay in sleep mode in order to save energy. Achieving this goal requires network configuration in right level of connection capability. Low connection leads to interference in data distribution, but it shouldn't be high, since adjacent nodes interfere with each other, which leads to high collision rate. The approach which is used by sensor networks topology is to allow these sensors to measure their connection capabilities and rate of data losses and activate adjacent nodes based on local measurements. In [7], Kumar et al applied random independent scheduling mechanism (RIS) to extend network lifetime, while they reach to asymptomatic k coverage. RIS assumes that time is divided to cycles based on synchronization method. At the beginning of the cycle, each sensor independently makes a decision in this regard, whether to activate with p probability or stay in sleep mode with P-1 probability. Therefore, network lifetime increases with a coefficient close to p/1. The idea of increased coverage ratio and sensor network lifetime is proposed in this study by introducing mobility in heterogeneous wireless sensor networks, that heterogenic is considered in nodes energy. In [8], authors selected to use heterogeneous wireless sensor network with nodes having local mobility capability, which has different energies. Simulation results indicate that in an algorithm called efficient coverage rate using mobility (ECRM), the maximum area is covered and some nodes stay off to save energy. These nodes cover a large area, while they are reliable in sensor with energy-saving. This algorithm is aimed to schedule sensor data, so that it can monitor the area effectively.

3. Proposed Method

As mentioned, the main challenges in wireless sensor networks include limited energy of nodes. In proposed method, the network is divided to some areas as shown in figure 2. This figure indicates application plan of 100 sensor nodes in a 100*100 flat area. Blue circles show sensor nodes. First, base station coordinates is (50, 0) and distributes the signal at an angle of 35 degrees based on figure 2. The nodes that receive this certain signal are located in first area.

In this point, each node knows about its zone. Then, base station start layered network with send signal this time by fixed length and no restricted degree. Therefore layered and zoning network will build. Each node assigns itself to a layer and a zone called area (figure 3).

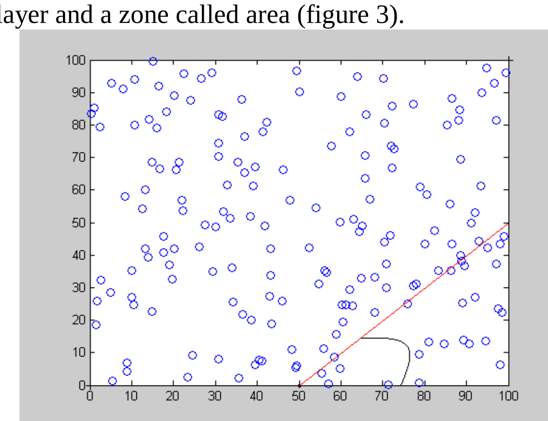

Figure 2. Sensor network application

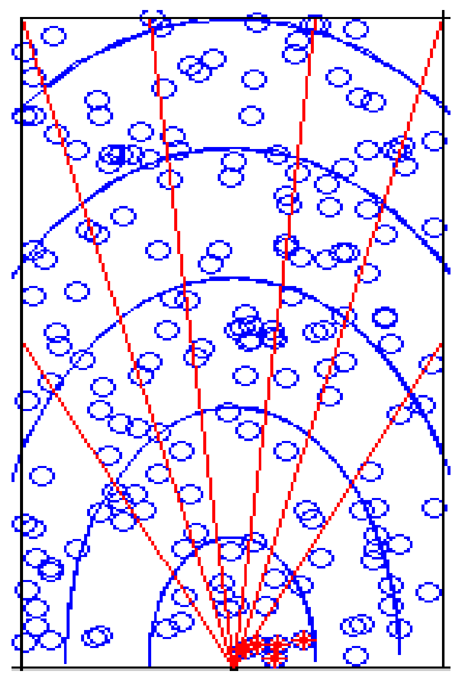

Figure 3. Network zoning

After zoning, in each area, a node with the most energy and most centrality is selected as active node. Active node receives environmental data and sends them to central station. All other nodes are in sleep mode. The node I is defined as follow to determine active node:

Centralityi=MD-DB
MD = Max_Distance
DB =Distance_Between (middle of area and nodei)

$$Value_i = 4 \times \left(\frac{node_i \quad remaining}{initial\_energy}\right) + \left(\frac{centrality_i}{\max\_centrality}\right)$$

Active node in each region uses adjacent areas active nodes to send received date to central station, since base station is away from active nodes in upper layers. Active node selects next node in lower layer. Therefore, different plans are introduced to decrease energy consumption; zoning is the most effective approach.

Consensus estimate: during network process we will reach to a situation, in which the nodes in an area are completely off and the area is not covered anymore. In this condition we should consider a plan, which still maintains the coverage. To this end, a technique called polling technique is selected, which is used in this study. According to the plan, read information of nodes in adjacent areas is more similar to covered area. Thus, by calculation an average of adjacent areas information, we can obtain the value in null area. Since, with less distance between sensors, their information similarities are more, distance is considered in this estimation. Distance of active nodes in covered areas to null area (without node) is used as another parameter in estimation. The following equation is estimation of null area (without node) information, which is computed in base station.

$$Estimated\_Data = \frac{\sum_{area=1}^{k} Sensed\_Data_{area} \times Dist_{\text{area\_node,center of empty area}}}{\sum_{area=1}^{k} Dist_{\text{area\_node,center of empty area}}}$$

In this equation, the distance between adjacent area active node to the center of empty area is indicated with Distarea_node, centerofemptyarea , data received by areas is indicated by Sensed_Dataarea and number of number of areas with active node is indicated with k symbol. Consensus estimate algorithm is shown in figure 4. In this algorithm, the area without node I is considered as input. Then all adjacent areas will be investigated. If null area i have an adjacent area which is not empty, the areas that can cover null area i will be increased. After the cycle, if there will be more than 2 covering areas, the area i cannot be covered by its neighbors, otherwise it can be covered.

Consensus Estimation Algorithm

```
Input: S, Area, I
Output: S, Area
coverage=0
for k=1:1: length (Area (I).nab)
   if Area (Area (I).nab (k)).empty==-1
      coverage=coverage+1
   end
end
if coverage>2
   Area (I).empty=-2
else
   Area (I).empty=1
end
end
```

Figure 4. Consensus estimate algorithm

Before giving an example, neighboring areas must be examined. The pseudo code in figure 5 in intended to identify adjacent areas. This means that for each area, all areas will be examined. If the distance of active node in area2 and active node in area is less than communication radius (R_c), the two neighboring area will be considered, too. In this case, the number of adjacent areas in area increases and area2 will be stored in area neighbors array.

Neighbor Detection Algorithm

```
Input: Area, S
Output: Area
for area=1:1: length (Area)
   k=0
   for area2=1:1: length (Area)
      if Area (area).active node>=0 && Area (area2).active node>=0
         if distance(S (Area (area).active node), S (Area (area2).active node)) <R_c && area~=area2
            k=k+1
            Area (area).nb (k) =area2
         end
      end
   end
end
```

Figure 5. Adjacent area detection algorithm

For example, the null area is distinguished in figure 6. Adjacent areas and active nodes in adjacent areas are indicated in figure 7.

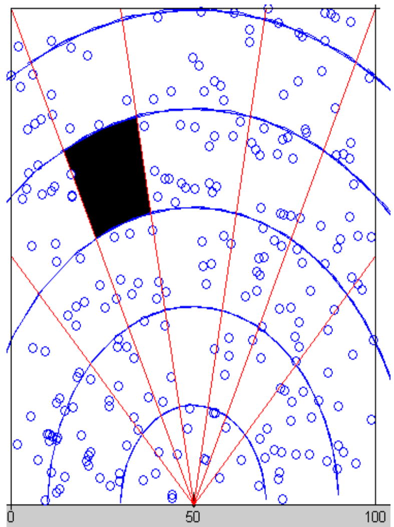

Figure 6. The area without node

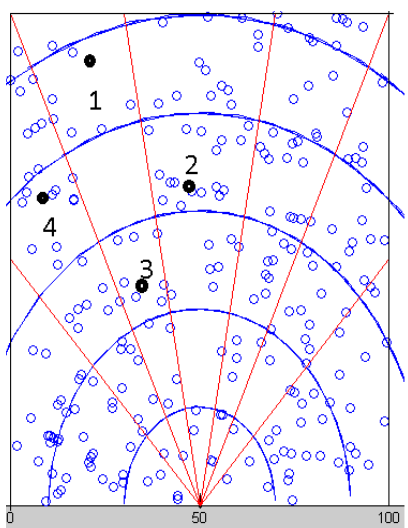

Figure 7. Adjacent areas and active nodes in each area

In mentioned network model, the flat area is considered two dimensional. Sensor networks are randomly distributed in environment and zoning is implemented in area. The node, which has the most energy in each area, is selected as active node and other nodes stay in sleep mode. Active nodes receive environmental data and send the received data to base station using multi-step routing. After completion of energy, all nodes in an area will be maintained using coverage consensus estimate technique in the network. In general, it can be said that proposed method increases wireless sensor network efficiency considering some factors such as multi-step routing, task cycle, zoning, consensus estimate, etc. In the next section, proposed plan will be evaluated and also it will be compared with few reliable plans.

4. Simulation

In order to assess the proposed plan, a simulator is required in order to implement the proposed method. In this paper, MATLAB software is used. MATLAB is one of the high level programming languages, which is focused on computation techniques. In this section, several different scenarios are examined to assess proposed plan, and proposed plan is also compared with LEACH and ECRM methods. First, we consider a case, in which 200 sensor nodes are distributed randomly in a 100*100 environment. Figures 8 and 9 indicate distribution view of 200 and 300 nodes in a 100*100 environment. In this figure, blue circles represent sensor nodes and the symbol + indicates base station.

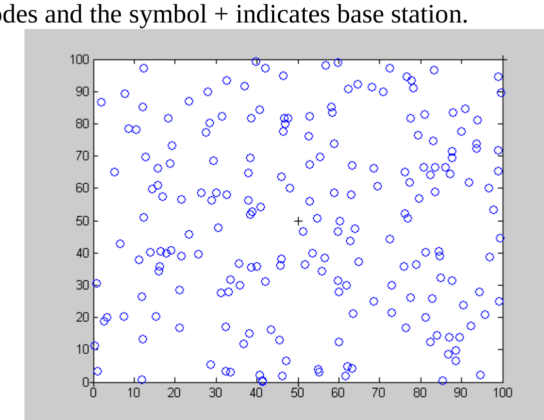

Figure 8. Random distribution of 200 nodes in a 100*100 environment.

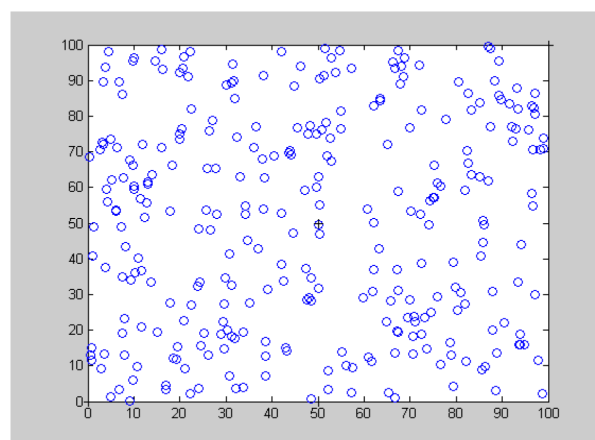

Figure 9. Random distribution of 300 nodes in a 100*100 environment

Another issue, which is considered in implementation of wireless sensor network, is (E) parameter that is initial energy of sensor nodes. Initial energy in first scenario is 0.05 J. Another scenario is also considered, in this scenario as the first scenario the number of nodes, which are distributed randomly in a 100*100 environment is 200 nodes. If primary energy of sensor nodes increases to 0.1 J, the changes will be investigated in simulation results. In third scenario, primary energy did not change compared to first scenario and is considered 0.05 J. The third scenario is defined as follow: It has a network containing 250 sensor nodes and these nodes are distributed randomly in a 100*100 environment. Each of the sensor nodes has a primary energy to 0.05 J. The primary parameters of network for first scenario implementation are indicated in table 1. Primary parameters include the number of nodes, dimensions of environment, primary energy of node, well coordinates, etc.

Table 1. Initial Parameters of simulation

Parameters	Values
Number of Nodes(First)	200
Network Size	100*100
Well coordinates	(50,50)
Initial Energy	0.05 Joule
Eelec	50*0.000000001 Joule
Emp	0.0013*0.000000000001 Joule
Efs	10*0.000000000001 Joule
Data Packet	4000 bit
Control Packet	32 bit

First scenario: In three figure (10, 11, 12), first scenario output is indicated. In this scenario, the number of sensor nodes is 200 nodes and their primary energy is 0.05 J, which is distributed in a 100*100 environment. According to obtained results, proposed method has better performance compared to LEACH and ECRM methods in terms of energy consumption in all rounds of network, and the number of off nodes in proposed algorithms is less than LEACH and ECRM in different rounds.

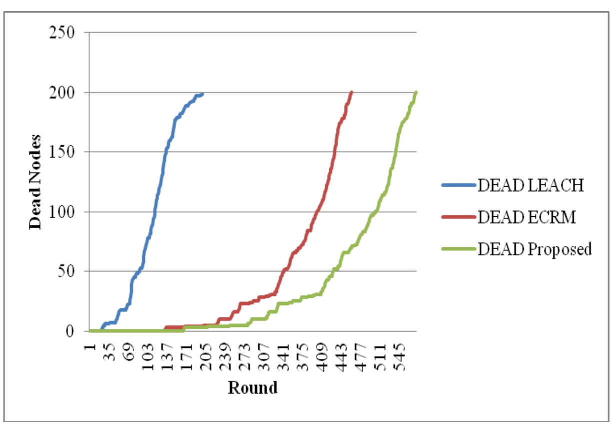

Figure 10. Dead nodes in the first scenario

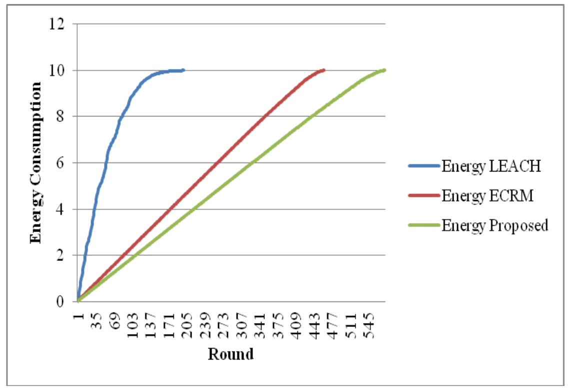

Figure 11. Consumption energy in first scenario

Other parameters, which are examined in comparison of different methods in wireless sensor network include FND (First Node Die), HND (Half Nodes Die) and LND (Last Node Die) respectively. In figure 12, FND, HND and LND obtained from first scenario implementation are indicated. It is clear that die time of first node in proposed method occurs later than LEACH and ECRM and it represents better effectiveness of proposed method. In addition, HND and LND in proposed method are later than LEACH and LEACH and it shows superiority of proposed method.

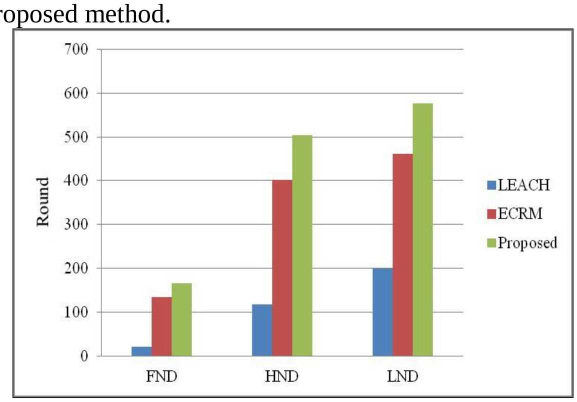

Figure 12. FND, HND and LND in first scenario

Second scenario: This scenario is developed by some changes in first scenario to observe the impact of node primary energy on network implementation trend and its results. In three figures (13, 14, 15) second scenario output is shown. In this scenario as the first scenario, total number of sensor node is 200 and primary energy of sensor nodes is considered 0.1 J, which is distributed in a 100*100 environment. According to obtained results, proposed method has better performance compared to LEACH and ECRM in terms of energy consumption in all network rounds, and number of died nodes in proposed method is less than LEACH and ECRM in different rounds. In Figure 13, the first died nodes and Half Nodes Die is compared. According to obtained results die time of first node, half of the nodes and total nodes in LEACH and ECRM is faster than proposed method. Therefore, the proposed method in this scenario shows better performance compared to LEACH and ECRM.

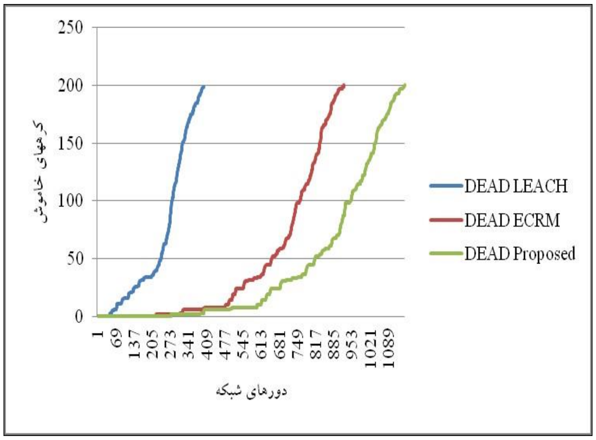

Figure 13. Died nodes in second scenario

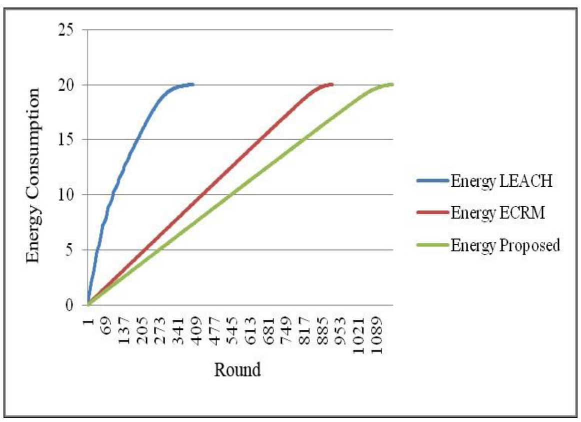

Figure 14. Energy consumption in second scenario

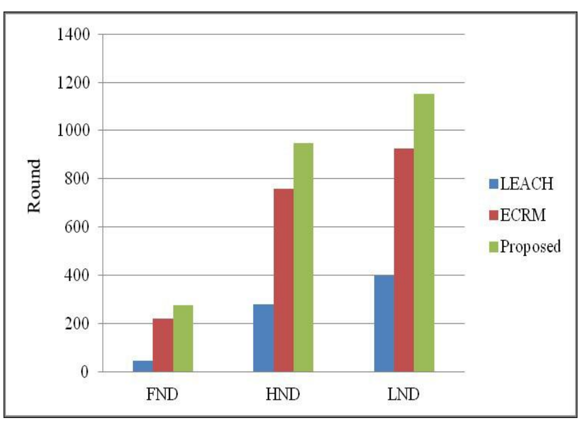

Figure 15. FND, HND and LND in second scenario

Third scenario: In figures (16, 17 and 18), third scenario output is indicated. In this scenario, the number of sensor nodes changes to 250 and primary energy of sensor nodes is 0.05J, which is distributed in a 100*100 environment. According to obtained results, proposed method shows better performance compared to LEACH and ECRM methods in terms of energy consumption in all network rounds , and number of died nodes in proposed algorithm is less than LEACH and ECRM in different rounds. In figure 18, comparison of first died node, half died nodes and last died node in this scenario is indicated. Based on obtained results , die time of first node , total nodes and half nodes in LEACH and ECRM methods is faster than proposed method. Thus, proposed method shows better efficiency in this scenario compared to LEACH and ECRM.

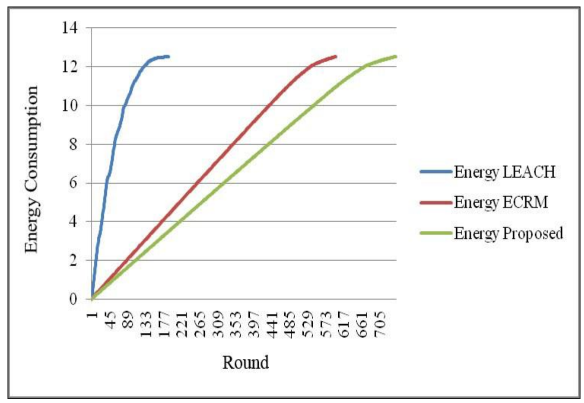

Figure 16. Energy consumption in third scenario

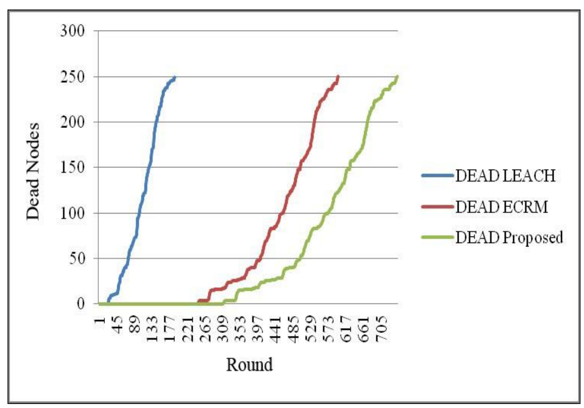

Figure 17. Died nodes in third scenario

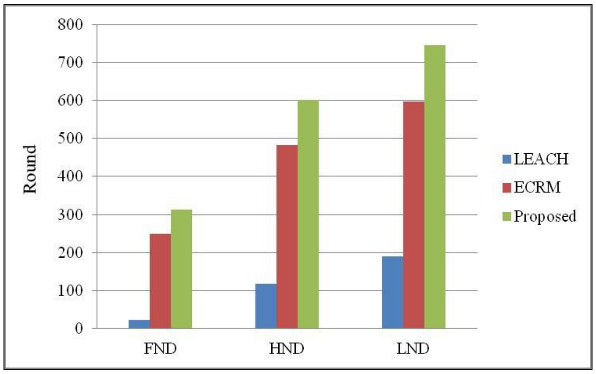

Figure 18. FND, HND and LND in third scenario

Fourth scenario: In figures (19, 20 and 21) fourth scenario output is shown. In this scenario the number of sensor nodes is 250 and primary energy is 0.1 J, which is distributed in a 100*100 environment. This scenario is designed to assess the impact of sensor nodes primary energy on simulation results. According to obtained results, proposed method shows better performance compared to LEACH and ECRM methods in terms of energy consumption in all rounds of network , and number of died nodes in proposed method is less than LEACH and ECRM in different rounds. In figure 21, comparison of first died node, half died nodes and last died node in this scenario is indicated. Based on obtained results , die time of first node , half nodes and all nodes in LEACH and ECRM methods is much faster than proposed method. Therefore, in this scenario, proposed method shows better efficiency compared to LEACH and ECRM.

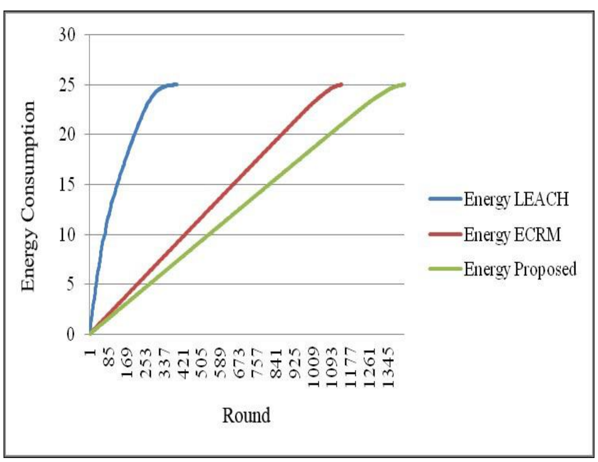

Figure 19. Energy consumption in fourth scenario

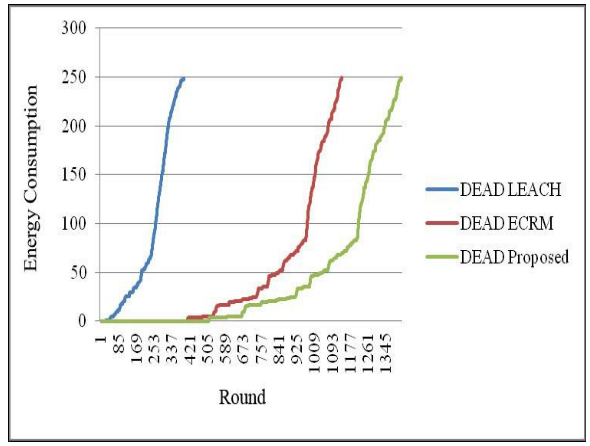

Figure 20. Died nodes in fourth scenario

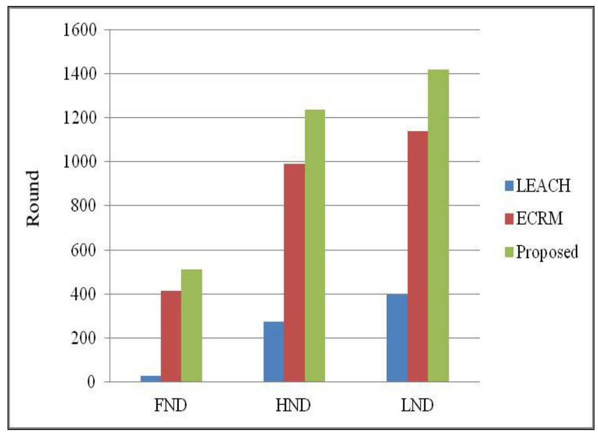

Figure 21. FND, HND and LND in fourth scenario

According to the results obtained from simulation in different condition and changing basic parameters of network such as primary energy and number of nodes, we conclude that proposed method consumes less energy compared to LEACH and ECRM methods and provides longer lifetime for network. ECRM is one of the strongest methods in the field of wireless sensor network coverage, thus by proving superiority of proposed method compared to ECRM method, proposed method potency will be indicated. The main reason for effectiveness of proposed method is using ordinary uniform distribution in environment, multi-step routing, tasks cycle, etc.

5. Conclusion

This study is aimed to using a technique to improve coverage and decrease energy consumption in wireless sensor networks. In order to cover the entire network, environment is divided to specific areas and nodes within each area are responsible for that area of network coverage. If there is more than one node in an area, the node with most remaining energy and centrality is in active mode and other nodes are in sleep mode. Selection of active node is one the innovative aspects in this study. Division of areas through sending messages by base station with appropriate distance and angle is conducted based on suitable division of network. Hence, division of node to different areas can also be considered as one of the innovations in this study. In general, division of network to different areas and finding sleep and active nodes setting using defined mechanism can be considered as innovative aspects of this study. In addition, using consensus estimate in coverage of empty area can be considered as an innovative idea in this paper.

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