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Cluster Based and Energy Efficient Coverage Protocol for Wireless Sensor Networks

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Abstract

One of the most important problems in the wireless sensor networks is the detection of events in a certain area (target area). This challenge is an important case in the wireless sensor network research and it is named the coverage problem. Regarding the sensors redundancy, we can improve the network lifetime by activating enough number of nodes and making the others sleep. Also, proposing a method that uses the nodes energy equally can prolong the network lifetime. In this paper, we propose a new Energy Based Coverage Method (EBCM). The proposed method decreases the energy consumption and prolongs the network lifetime. The effectiveness of the proposed method is evaluated using NS2 simulator.

Keywords: *Wireless Sensor Network, Scheduling, Energy consumption, Network lifetime, Area Coverage*

1. Introduction

The wireless sensor network (WSN) has emerged as a promising tool for monitoring the physical world. This kind of networks consists of sensors that can sense, process and communicate. Sensors can be deployed rapidly and cheaply, thereby enabling large-scale, on-demands monitoring and tracking over a wide range of applications such as danger alarm, vehicle tracking, battle field surveillance, habitat monitoring, *etc.*, [1-3]. Due to their portability and deployment, nodes are usually powered by batteries with finite capacity. Although the energy of sensor networks is scarce, it is always inconvenient or even impossible to replenish the power. Thus, one design challenge in sensor networks is to save limited energy resources to prolong the lifetime of the WSN [4, 5]. A number of studies for reducing the power consumption of sensor networks have been performed in recent years. These studies mainly focused on energy efficient MAC protocols, data aggregated routing algorithms, and the applications of level transmission control. Power saving techniques can generally be classified in two categories: scheduling the sensor nodes to alternate between active and sleep mode, and adjusting the transmission or sensing range of the wireless nodes [5]. In this paper, we use the number of active nodes as a metric to evaluate the quality of service. We try to decrease the energy consumption by changing the node mode to active and passive.

Due to the importance of wireless sensor networks, there are a large number of studies in the field of network architecture, the design of communicating protocol and the way of decreasing energy consumption. But there is not so very notice to the quality of service in these networks since the quality of service in various applications in wireless sensor networks is different. In spite of traditional networks, there is not the same metrics for evaluating

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quality of service in these networks and regarding the application, the essential of quality of service is different. The quality of service can be evaluated in two aspects such as application and network. In the field of application, different essentials are considered in the network quality of service. In this field, event detection [6], network coverage [7] and the number of active sensors [8] are considered. From the network aspect, the quality of service depends on data delivering model, *i.e.*, regarding the model in which the network provides data, different essentials are defined for quality of service. There are three main models for delivering data consist of event driven, query driven and continuous delivery models. In event driven model, the network begins to collect and deliver data after happening an event. For example, a network designed to recognize an animal crossing in a part of jungle, uses this kind of data model. In this model, the truth of recognition and delay of its report are the metrics of evaluating quality of service. In the query driven model, the query is prepared from central node and network responses by collecting proper data. In this model, the response time to query and response accuracy are the metrics of quality of service. In continuous deliver model, the nodes send information to the central node continuously in certain time periods. Network coverage is the main metric of quality of service in this model.

In our previous work [9], we propose a scheduling method based on virtual clustering and boundary energy called *VCBE*. The *VCBE* method tries to decrease the energy consumption by changing the node mode to active and passive. In this paper, we propose a new Energy Based Coverage Method (*EBCM*). The proposed method presents the acceptable coverage rate and decreases the energy consumption. Thus proposed method can prolong the network lifetime. The remaining of this paper is organized as follow: related works are explained in Section 2. The network model is explained in Section 3. Proposed method is explained in Section 4. Simulation results are shown in Section 5. Section 6 is the conclusion.

2. Related Works

2.1. Gur Game Method

In *Gur Game*, some of players select an option between "1" and "0" in each round without knowing other player's decision. At the end of each period, the number of "1" (k) is counted and the amount of reward is calculated based on one reward function ($r = f(k)$). Based on this amount of reward, it is cleared that how possible it is to give the players reward in this period. The purpose of this game is to have optimum number of selection "1". This optimum number is shown with parameter $k*$. The value of reward function is between "0" and "1". The more k value nears $k*$ the nearer to "1". Each player decides by a state machine with $2\times n$ states. It is shown in Figure 1. This state machine has n conditions with positive label and n conditions with negative label as shown in Figure 1. If the players are in positive condition, they will select "1"; otherwise they'll select "0". After getting r value, the nodes change to the condition with larger label with possibility r and change to the condition with lower label with possibility $1-r$. As shown in paper [10], playing this game and after enough period, the number of players who select "1" converge to $k*$.

Paper [8] uses *Gur Game* in order to control the number of sensor nodes. In this method, each node has a state machine and based on it the node becomes active or passive. The central node sends the control signal to nodes by a direct channel and controls the quality of service by changing the condition of the nodes state machine. In this method, the receiver of all nodes should wait for winning the reward amount until the end of period. This will decrease the network lifetime.

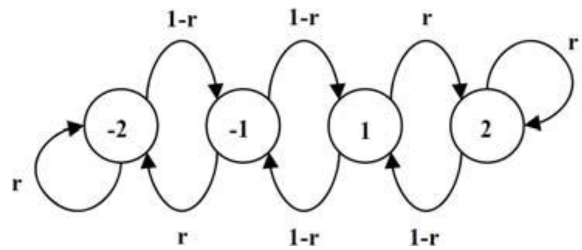


Figure 1. State Machine with *2×n* States

2.2. Ack Automata

Paper [11] uses *Ack Automata*. The nodes send based on the possibility determined by their state machine condition. Figure 2 shows the example of *Ack Automata*. As *Gur Game* method, in *Ack Automata* the central node controls the number of sender nodes by sending control signal to the sensors and changes their condition. In this method, the central node sends the proper control signal immediately after receiving each packet and evaluating the number of received packet. So, the sensor receives the control signal from central node immediately after sending the package. As a result, sensor's sender-receiver is passive in most of the time and this leads to decrease energy consumption in comparison with *Gur Game* method. But in this method, as in *Gur Game* method, regarding the nodes decision to send alternately, those which send earlier than others, will win a reward and resend in next periods, so other nodes will not win the reward even they sends packet and their states change to the states with lower possibility. This mechanism causes the $k*$ first node resend packet in the next periods. This process continues until the energy of these nodes finish while other nodes have still consumed a little energy.

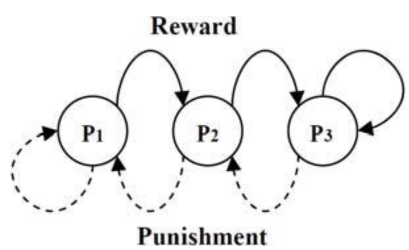


Figure 2. Example of *Ack Automata*

This unbalance energy consumption and early death of sender nodes cause the network not to be able to prepare the required quality of service. Making the nodes energy consumption equal can lead to increase network lifetime. For example suppose a sensor network with 100 nodes and the central node need $k*$ =70 in each period. So, 70 nodes send continuously in all periods. Therefore the quality of service is prepared ideally in these periods. But immediately after emptying the energy of these 70 nodes and going out of the network, remaining 30 nodes will not be able to prepare the quality of service and it is the end of network lifetime while these 35 nodes have not still consumed most of their energy.

2.3. NSGA

In [5], the problem of maintaining sensing coverage by keeping a small number of active sensor nodes and a small amount of energy consumption is studied and proposed NSGA algorithm. NSGA uses a cluster-based coverage control scheme. The cluster-head will choose a set of nodes to do the sensing job and assign each working node with a different sensing radius. But, decreasing nodes density causes efficiency of NSGA algorithm to decrease. Also, NSGA keeps a small number in active mode. Thus, it can't maintain balance in using nodes energy so that it causes the network lifetime to decrease.

3. The Network Model

3.1. The Event based Method

Regarding that it is impossible to evaluate the coverage of all network points, we use the event based method for calculating the coverage rate. In this method, the coverage is done according to nodes location and sensing radius (see Figure 3).

The event is covered if it is within the sensing area of a sensor node:

$$Coverage\ (C_i) = \begin{cases} Yes & if\ C_i\ is\ within\ the\ sensing\ area\ of\ a\ sensor\ node \\ No & else \end{cases} \quad (1)$$

As a result, one cell is covered if it is within the calculated sensing radius of an active sensor node as shown in Figure 3.

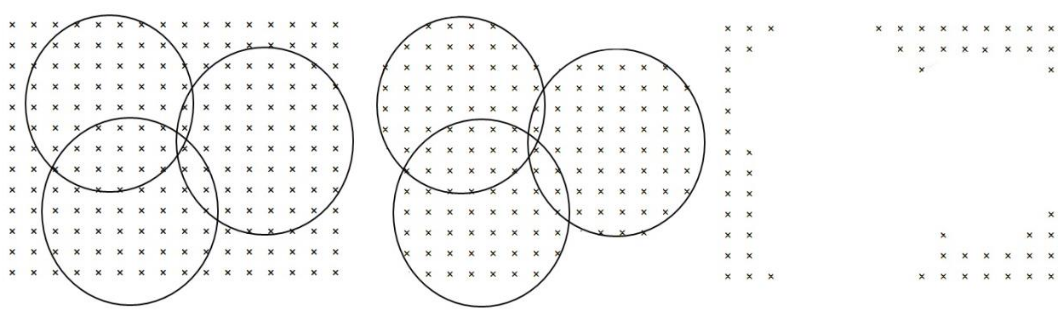


Figure 3. The Covered Enevts in the Event based Method

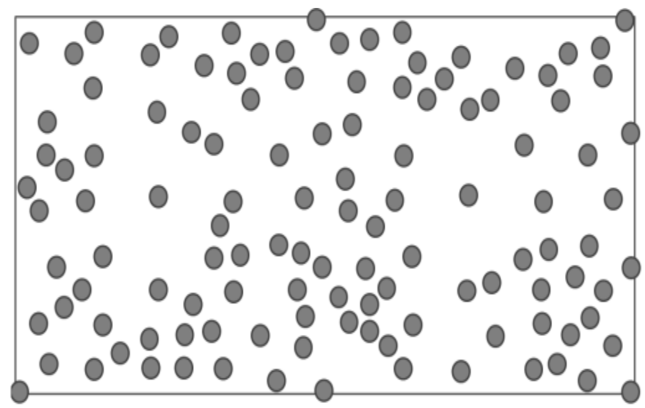
3.2. Coverage Rate of Sensor Network

As mentioned before, we assume the event x is covered by the sensor network if any node covers it. Therefore the coverage rate of the sensor network is calculated as (2):

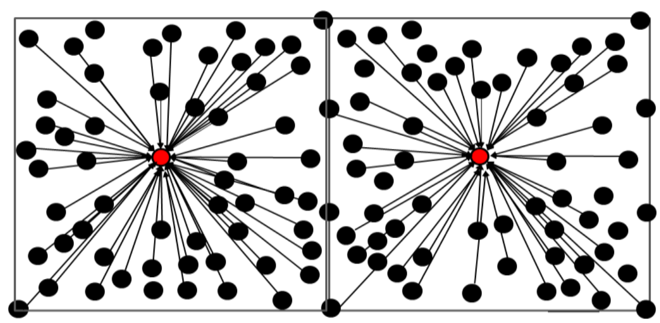
$$Coverage_{rate} = Covered\ events\ /\ All\ events \quad (2)$$

3.3. The Cluster-based Architecture

Our energy efficient coverage protocol uses a cluster-based coverage control architecture, which is scheduled into rounds. The target area is divided into several equal squares. Then the sensor node in each square having the largest energy will be chosen as the cluster head. The procedure of selecting the cluster head is the same works by Jia and Chena in 2006 and 2009 [5, 12]. This cluster based architecture is shown in Figure 4. The red nodes are cluster-heads. The cluster head will choose a set of sensor node to do the monitoring job [5].



(a)



(b)

Figure 4. (a) The Wireless Sensor Network before Clustering (b)The Cluster-based Coverage Control Architecture

3.4. The Sensing Model

The sensor set is $s=\{s_1, s_2, \dots, s_n\}$. The coverage model of the sensor node is supposed as a circle centered at its coordinates (x_{node}, y_{node}) with radius r.

$$Node\ N\ covers\ event\ C = \begin{cases} Yes & if\ (x_{event} - x_{node})^2 + (y_{event} - y_{node})^2 \le r_i^2 \\ No & else \end{cases} \quad (3)$$

3.5. Energy Consumption Analysis

The energy consumed by an active sensor node is proportional to r^2, where r is the sensing radius of the sensor node [3, 5, 12]. Thus, the coverage energy consumption of the sensor set, which is related to the sum of the sensor's sensing radius squared, is defined as:

$$Energy\ Consumption = number\ of\ active\ nodes \times r^2 \quad (4)$$

4. Proposed Method

Gur Game and *Ack Automata* method guarantee the quality of service by activating the k^* node and sleeping other nodes in order to reduce energy consumption and prolong the network lifetime. These methods have two weaknesses. The first one is that they select k^* node regardless of energy of nodes, but it will be better that the nodes with more energy be selected. The second weakness is the possibility of improper distribution of the active k^* nodes. It means that the active nodes compression is more or less than required value at some locations. In this paper, we propose an energy efficient coverage method with rapid convergence towards activating k^* nodes. Our proposed method is able to remove both weaknesses mentioned above.

The proposed coverage control method is scheduled into periods. In each period, the nodes send its remained energy together with their data to cluster head. The cluster head creates a list of the sensor nodes. The cluster head sorts its list descending based on the remaining energy of the member nodes. The energy of k^* th node is called E_{bound}. Then the cluster head broadcasts this energy value to sensor nodes.

The member nodes will send data at next period with probability α (α is a number near to 1), if their remaining energy is equal to or more than E_{bound}. But, the nodes which their remaining energy is less than the E_{bound} will send data at next period with probability β. If the member node do not send until next period, it will become inactive (the receiver of node will be inactive until the end of period) and in the next period will decide according to the same probability. As a result, there will be no waste of energy as *Ack Automata* and unlike *Gur Game* method. As mentioned before, in *Gur Game*, the receiver of all nodes should wait for receiving the reward amount until the end of period. This will decrease the network lifetime. The relationship between the number of nodes and k^* is shown in (5):

$$\alpha k^* + \beta (N - k^*) = k^* \quad (5)$$

Where N is the number of nodes and α is a value near 1 (e.g. α=0.9). Therefore the optimum probability β is calculated as (6):

$$\beta = ((1-\alpha)\, k^*) / (N-k^*) \quad (6)$$

It is considerable that sending is based on probability. If some node which don't send data and don't receive new E_{bound} value, send once only, regarding its energy which is more than E_{bound}, it will become a constant sender at next periods. It means that regarding its more energy in comparison with E_{bound}, it will send data in probability α (α is a number near 1).

We give the follow chart for proposed method as follows:

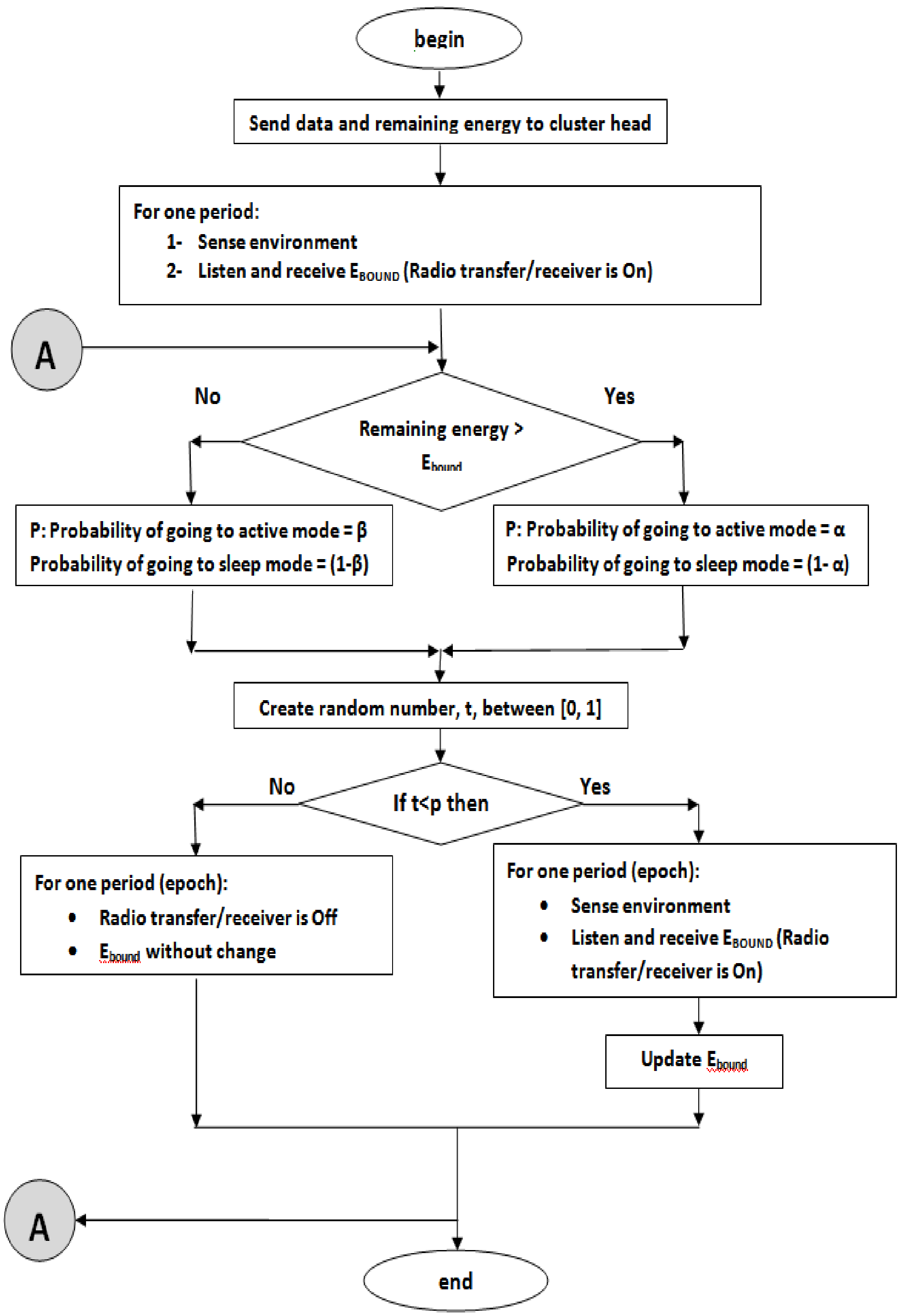


Figure 5. The Follow Chart for Proposed Method (for each Member Node)

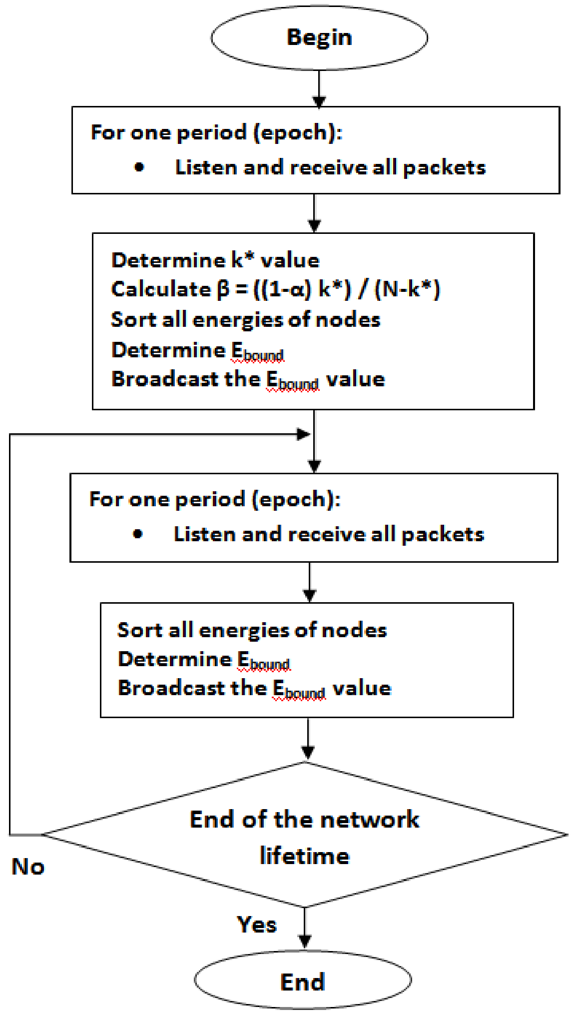


Figure 6. The Follow Chart for Proposed Method (for Cluster Head)

5. Experiment Results

In this section, our proposed method is simulated and compared to *NSGA*, *Gur Game* and *Ack Automata* methods using NS2 simulator. We use the discussed scenario in papers [8] and [11] in order to compare the proposed method to *Gur Game*, *Ack Automata* and *NSGA* methods. It is supposed that sensor nodes are distributed in the environment randomly. The cluster head receives packets from nodes in a single-hop manner. Suppose that the cluster head needs a receiving rate equal to k^* packets in each epoch (period). These experiments are done in 1000 epoch. In each epoch, the nodes send environmental data to the cluster head and then regarding the number of sender nodes and required quality of service, the cluster head broadcasts the energy boundary value (in *EBCM* methods) and control signal (in *Ack Automata* and *Gur Game* methods). Also, we supposed that α =0.9. The Fig. 7 and Table 1 show the coverage rage for different sensing radius in different configuration of the sensor networks.

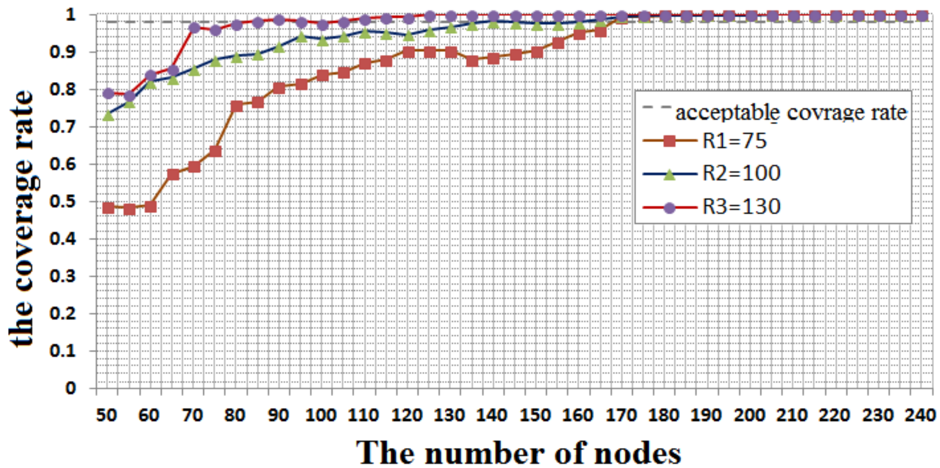


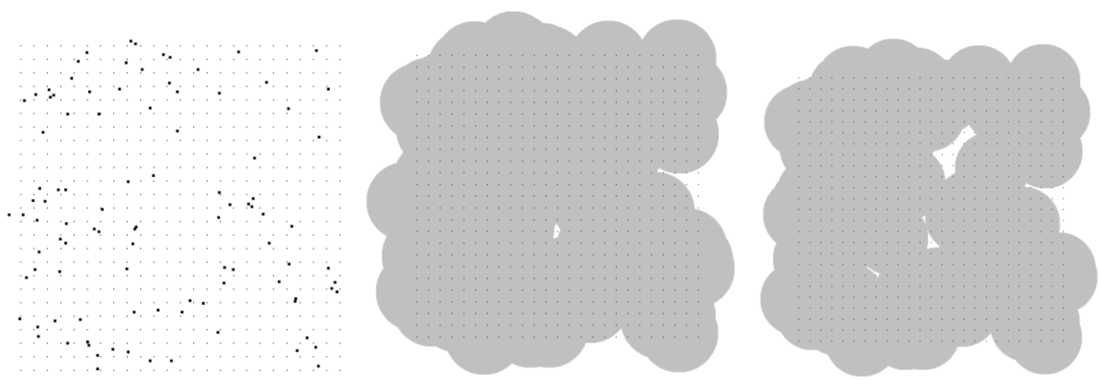
Figure 7. Verifying the Coverage Rate for Different Sensing Radius

Table 1. Verifying the Coverage Rate for Different Sensing Radius

Epoch (period)	R_1=75	R_2=100	R_3=130
50	(303/625) %48.40	(460/625) %73.60	(492/625) %78.72
55	(305/625) %48.80	(480/625) %76.80	(495/625) %79.20
60	(307/625) %49.10	(514/625) %82.24	(525/625) %84.00
65	(360/625) %57.60	(520/625) %83.20	(535/625) %85.60
70	(373/625) %59.68	(535/625) %85.60	(601/625) %96.16
75	(400/625) %64.00	(550/625) %88.00	(605/625) %96.80
80	(475/625) %76.00	(557/625) %89.12	(610/625) %97.60
85	(480/625) %76.80	(560/625) %89.60	(615/625) %98.40
90	(505/625) %80.80	(573/625) %91.68	(618/625) %98.88
95	(510/625) %81.60	(585/625) %93.60	(618/625) %98.88
100	(525/625) %84.00	(590/625) %94.40	(618/625) %98.88
105	(530/625) %84.80	(590/625) %94.40	(618/625) %98.88
110	(545/625) %87.20	(595/625) %95.20	(619/625) %99.04
115	(550/625) %88.00	(598/625) %95.68	(620/625) %99.20
120	(565/625) %90.40	(598/625) %95.68	(621/625) %99.36
125	(565/625) %90.40	(600/625) %96.00	(623/625) %99.68
130	(565/625) %90.40	(605/625) %96.80	(625/625) %100.0
135	(565/625) %90.40	(610/625) %96.60	(625/625) %100.0
140	(565/625) %90.40	(615/625) %98.40	(625/625) %100.0
145	(565/625) %90.40	(615/625) %98.40	(625/625) %100.0
150	(565/625) %90.40	(615/625) %98.40	(625/625) %100.0
155	(580/625) %92.80	(615/625) %98.40	(625/625) %100.0
160	(595/625) %95.20	(617/625) %98.72	(625/625) %100.0
165	(600/625) %96.00	(617/625) %98.72	(625/625) %100.0
170	(621/625) %99.36	(617/625) %98.72	(625/625) %100.0

175	(622/625) %99.52	(617/625) %98.72	(625/625) %100.0
180	(624/625) %99.84	(624/625) %99.84	(625/625) %100.0
185	(624/625) %99.84	(625/625) %100.0	(625/625) %100.0
190	(624/625) %99.84	(625/625) %100.0	(625/625) %100.0
195	(624/625) %99.84	(625/625) %100.0	(625/625) %100.0
200	(624/625) %99.84	(625/625) %100.0	(625/625) %100.0
205	(624/625) %99.84	(625/625) %100.0	(625/625) %100.0
210	(625/625) %100.0	(625/625) %100.0	(625/625) %100.0
215	(625/625) %100.0	(625/625) %100.0	(625/625) %100.0
220	(625/625) %100.0	(625/625) %100.0	(625/625) %100.0
225	(625/625) %100.0	(625/625) %100.0	(625/625) %100.0
230	(625/625) %100.0	(625/625) %100.0	(625/625) %100.0
235	(625/625) %100.0	(625/625) %100.0	(625/625) %100.0
240	(625/625) %100.0	(625/625) %100.0	(625/625) %100.0
245	(625/625) %100.0	(625/625) %100.0	(625/625) %100.0
250	(625/625) %100.0	(625/625) %100.0	(625/625) %100.0

We suppose that 100 nodes are distributed in the environment randomly and the sensing radius is equal to 130. Also the k^* parameter is equal to 70 (see Figure 8).



(a) **(b)** **(c)**

Figure 8. (a) 100 Sensor Nodes are Distributed in the Environment Randomly (b) The Coverage Rate for all Nodes is 99.2% (c) The Coverage Rate for *k=70 Node is 98.5%**

Figure 9 and Table 2 show the number of active nodes (received packets) in each epoch. The results show that in about 900 epochs, the *EBCM* method receives 70 packets. But, due to death of many sensors, *Gur Game*, *Ack Automata* and *NSGA* methods are not able to send the required numbers of packets. The *EBCM* uses the nodes energy equally and prolongs the network lifetime.

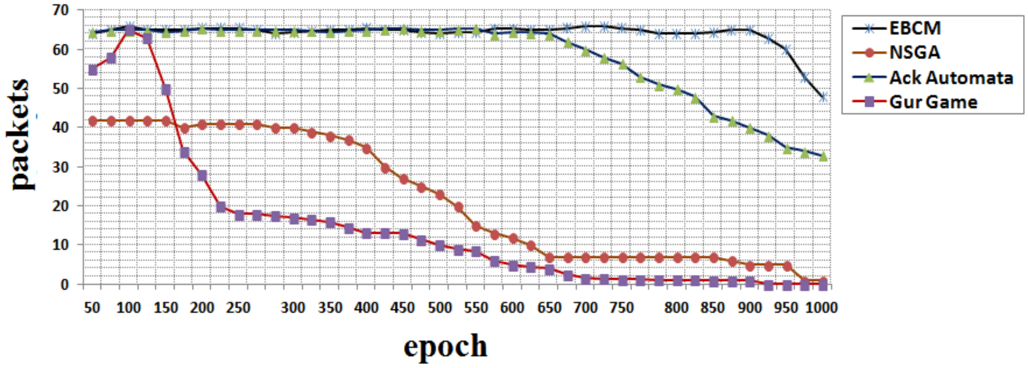


Figure 9. The Number of Active Nodes (Received Packet) in each Epoch

Table 2. The Number of Active Nodes (Received Packet) in each Epoch

Epoch	*EBCM*	*Ack Automata*	*Gur Game*	*NSGA*
50	67.0	67.5	58.0	42.0
100	69.0	68.0	68.2	42.0
150	68.0	67.5	53.0	42.0
200	68.5	68.5	31.0	41.0
250	68.5	68.0	21.0	41.0
300	67.5	68.0	20.0	40.0
350	68.0	67.5	19.0	38.0
400	68.5	68.0	16.2	35.0
450	68.0	68.5	16.0	27.0
500	67.0	68.0	13.0	23.0
550	67.5	68.5	11.5	15.0
600	68.0	67.5	8.0	12.0
650	69.0	67.0	7.0	8.0
700	68.5	63.0	4.5	7.0
750	68.0	59.5	4.3	7.0
800	67.0	53.0	4.1	7.0
850	67.5	46.0	4.0	7.0
900	68.0	43.0	4.0	5.0
950	63.0	38.0	3.0	5.0
1000	51.0	36.0	3.0	5.0

In Figure 10 and Table 3, we compared the number of nodes going out of the network. The important point of this diagram is the difference between the numbers of died nodes in our both proposed method, *NSGA*, *Gur Game* and *Ack Automata* methods. In *Ack Automata* method, when the energy of the first node depletes, the number of nodes going out of the network increases at almost a constant slope. While in the proposed methods, at first, the number of died nodes increase slowly but increase suddenly at the last epochs. Thus, in the proposed methods, the node's energy depletes almost simultaneously and the energy consumption of the sensor nodes is balanced. This can be evaluated in details in Figures 11 and Tables 4. These figures show the minimum, maximum and average of node's energy in different epochs. The noticeable point is that the minimum and maximum energy values are nearer to the average value in the proposed method. It means that in the proposed method, the nodes participation for sending data is equal and so, the energy of all nodes is consumed equally.

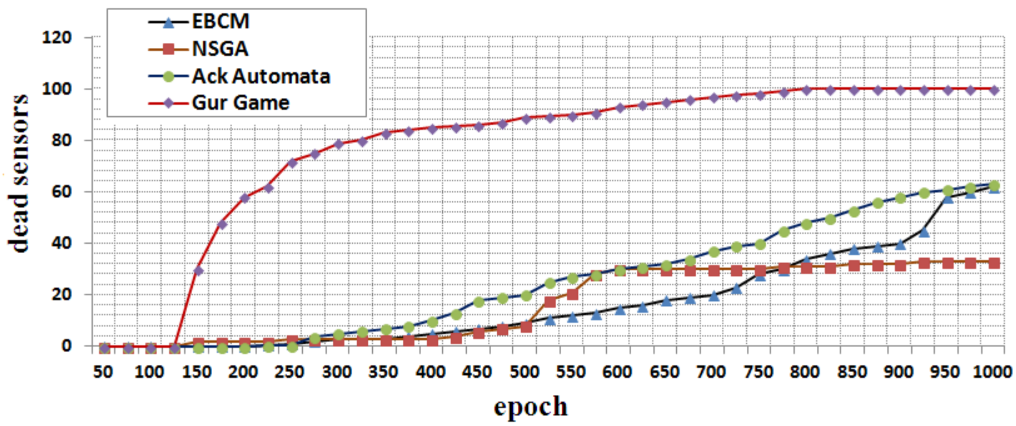


Figure 10. Number of Nodes Going Out of the Sensor Network

Table 3. Number of Nodes Going Out of the Sensor Network

Epoch	*EBCM*	*Ack Automata*	*Gur Game*	*NSGA*
50	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00
150	0.00	0.00	30.00	2.00
200	1.00	0.00	58.00	2.50
250	1.00	0.50	72.00	3.00
300	4.00	5.00	79.00	3.50
350	4.00	7.00	83.00	3.50
400	6.00	10.00	85.00	3.50
450	8.00	18.00	86.00	4.00
500	10.00	20.00	89.00	8.00
550	12.00	27.00	90.00	21.00
600	18.00	30.00	93.00	30.00
650	23.00	32.00	95.00	30.00
700	24.00	37.00	97.00	30.00
750	30.00	40.00	98.00	31.00
800	37.00	48.00	100.00	31.00
850	44.00	53.00	100.00	32.00
900	48.00	58.00	100.00	33.00
950	64.00	61.00	100.00	33.00
1000	68.00	63.00	100.00	33.00

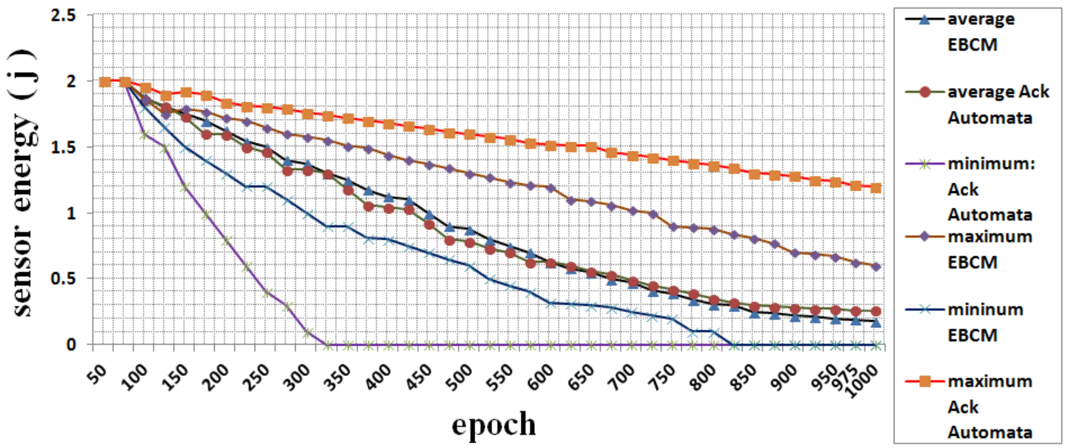


Figure 11. The Minimum, Maximum and Average of Node's Energy in Different Epochs for *EBCM* and *Ack Automata* Methods

Table 4. The Minimum, Maximum and Average of Node's Energy in Different Epochs for *EBCM* and *Ack Automata* Methods

Epoch	*EBCM*			*Ack Automata*		
	Min	Ave.	Max	Min	Avg.	Max
50	2.00	2.00	2.00	2.00	2.00	2.00
100	1.80	1.87	1.86	1.60	1.86	1.96
150	1.50	1.75	1.79	1.20	1.73	1.92
200	1.30	1.62	1.72	0.80	1.59	1.84
250	1.20	1.50	1.65	0.40	1.46	1.80
300	1.00	1.37	1.58	0.10	1.32	1.76
350	0.90	1.25	1.51	0.00	1.18	1.72
400	0.80	1.12	1.44	0.00	1.04	1.68
450	0.70	1.00	1.37	0.00	0.92	1.64
500	0.60	0.87	1.30	0.00	0.78	1.60
550	0.45	0.75	1.23	0.00	0.70	1.58
600	0.32	0.62	1.20	0.00	0.62	1.52
650	0.30	0.55	1.09	0.00	0.56	1.51
700	0.25	0.47	1.02	0.00	0.49	1.44
750	0.10	0.39	0.90	0.00	0.42	1.40
800	0.00	0.31	0.88	0.00	0.35	1.36
850	0.00	0.25	0.81	0.00	0.30	1.30
900	0.00	0.22	0.70	0.00	0.28	1.28
950	0.00	0.20	0.67	0.00	0.27	1.24
1000	0.00	0.18	0.60	0.00	0.26	1.20

Figure 12 and Table 5 show the coverage rate in each epoch. The results of experiment show the coverage rate is higher than other methods. The experiments results show that the proposed method can lead to increase network lifetime in comparison with other methods, because the energy consumption in the proposed methods is balanced.

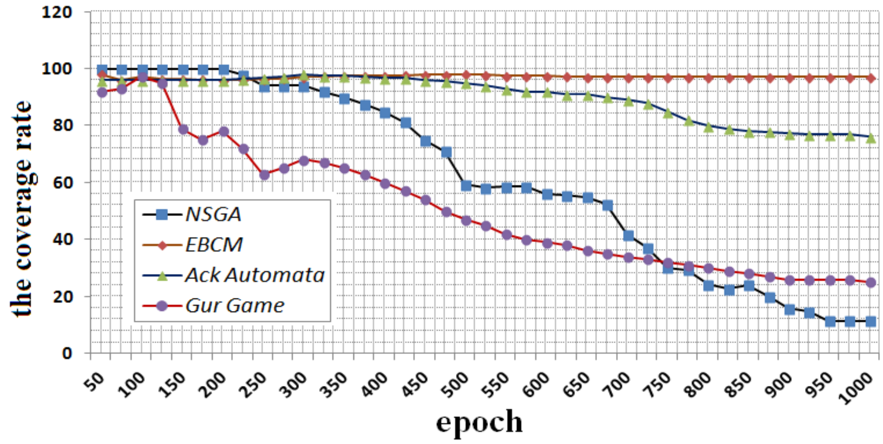


Figure 12. The Coverage Rate in each Epoch

Table 5. The Coverage Rate in Each Epoch

Epoch	*EBCM*	*Ack Automata*	*Gur Game*	*NSGA*
50	(613/625) %98.08	(608/625) %97.28	(584/625) %93.44	(624/625) %99.84
75	(615/625) %98.40	(612/625) %97.92	(596/625) %95.36	(624/625) %99.84
100	(619/625) %99.04	(618/625) %98.88	(610/625) %97.60	(624/625) %99.84
125	(612/625) %97.92	(600/625) %96.00	(610/625) %97.60	(624/625) %99.84
150	(608/625) %97.28	(607/625) %97.12	(610/625) %97.60	(624/625) %99.84
175	(614/625) %98.24	(611/625) %97.76	(609/625) %97.44	(624/625) %99.84
200	(617/625) %98.72	(615/625) %98.40	(608/625) %97.28	(624/625) %99.84
225	(618/625) %98.88	(609/625) %97.44	(605/625) %96.80	(592/625) %94.72
250	(619/625) %99.04	(605/625) %96.80	(603/625) %96.48	(588/625) %94.08
275	(616/625) %98.56	(599/625) %95.84	(592/625) %94.72	(588/625) %94.08
300	(609/625) %97.44	(591/625) %94.56	(571/625) %91.36	(587/625) %93.92
325	(612/625) %97.92	(606/625) %96.96	(542/625) %86.72	(571/625) %91.36
350	(615/625) %98.40	(618/625) %98.88	(525/625) %84.00	(562/625) %89.92
375	(600/625) %96.00	(618/625) %98.88	(489/625) %78.24	(534/625) %85.44
400	(596/625) %95.36	(617/625) %98.72	(473/625) %75.68	(511/625) %81.76
425	(610/625) %97.60	(612/625) %97.92	(484/625) %77.44	(491/625) %78.56
450	(619/625) %99.04	(605/625) %96.80	(525/625) %84.00	(468/625) %74.88
475	(615/625) %98.40	(608/625) %97.28	(521/625) %83.36	(410/625) %65.60
500	(609625) %97.44	(614/625) %98.24	(515/625) %82.40	(371/625) %59.36
525	(609/625) %97.44	(613/625) %98.08	(471/625) %75.36	(368/625) %58.88
550	(610/625) %97.60	(613/625) %98.08	(452/625) %72.32	(366/625) %58.56
575	(605/625) %96.80	(607/625) %97.12	(432/625) %69.12	(367/625) %58.72
600	(598/625) %95.68	(602/625) %96.32	(402/625) %64.32	(369/625) %59.04
625	(607/625) %97.12	(610/625) %97.60	(373/625) %59.68	(351/625) %56.16

650	(615/625) %98.40	(611/625) %97.76	(357/625) %57.12	(343/625) %54.88
675	(609/625) %97.44	(598/625) %95.68	(324/625) %51.84	(294/625) %47.04
700	(607/625) %97.12	(590/625) %94.40	(225/625) %36.00	(261/625) %41.76
725	(608/625) %97.28	(571/625) %91.36	(247/625) %39.52	(210/625) %33.60
750	(609/625) %97.44	(563/625) %90.08	(310/625) %49.60	(188/625) %30.08
775	(613/625) %98.08	(570/625) %91.20	(315/625) %50.40	(124/625) %19.84
800	(616/625) %98.56	(572/625) %91.52	(324/625) %51.84	(151/625) %24.16
825	(614/625) %98.24	(574/625) %91.84	(281/625) %44.96	(151/625) %24.16
850	(608/625) %97.28	(579/625) %92.64	(273/625) %43.68	(150/625) %24.00
875	(602/625) %96.32	(534/625) %85.44	(242/625) %38.72	(115/625) %18.40
900	(597/625) %95.52	(505/625) %80.80	(200/625) %32.00	(99/625) %15.84
925	(599/625) %95.84	(510/625) %81.60	(192/625) %30.72	(81/625) %12.96
950	(581/625) %92.96	(515/625) %82.40	(180/625) %28.80	(72/625) %11.52
975	(577/625) %92.32	(461/625) %73.76	(140/625) %22.40	(72/625) %11.52
1000	(572/625) %91.52	(459/625) %73.44	(126/625) %20.16	(72/625) %11.52

6. Conclusion

Regarding the sensors redundancy, we can improve the network lifetime by activating enough number of nodes and making the others sleep. Also, proposing a method that uses the nodes energy equally can prolong the network lifetime. In this paper, we proposed a new Energy Based Coverage Method (*EBCM*). The proposed method decreases the energy consumption and prolongs the network lifetime. The effectiveness of the proposed method is evaluated using NS2 simulator. Experiments results show that the *EBCM* method can decrease the energy consumption and prolong the network life time.

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