Reducing Energy Consumption in Wireless Sensor Networks using Ant Colony Algorithm and Autonomy Mechanisms

Javad Mozaffari
Department of Computer, Ardabil Science and Research Branch, Islamic Azad University, Ardabil, Iran
Department of Computer, Ardabil Branch, Islamic Azad University, Ardabil, Iran

Mehdi EffatParvar*
Department of Computer, Ardabil Branch, Islamic Azad University, Ardabil, Iran

***Abstract*—Wireless sensor network includes hundreds or thousands of nodes with limited energy. Since the lifetime of each sensor is as the battery life of the sensor, the energy issue is discussed as a fundamental challenge. In this article, parallel ant algorithm and exclusive territoriality algorithm have been used by providing the ability of nodes self-determination, in order to improve the parameters of energy consumption, extend the life and network coverage. For routing nodes also is used direct send method, sending by hierarchical clustering, along with carrier head cluster. This article is evaluated by focusing on network stability, based on two main factors: reduce energy consumption and extend the network life and increase network coverage. The simulated output in this paper represents an increase of energy consumption balance and network lifetime approach (the first death time) and network imperative life (the last death time), which represents network high-performance than latch, direct transmission and other methods. Therefore, also in this article the purpose is to provide a better way than previous methods based on developed ant algorithm to reduce energy consumption against hardware limitations.**

Keywords*—wireless sensor networks; ant algorithm; network stability; energy consumption reduction; network coverage; network lifetime

I. INTRODUCTION

Nowadays, wireless sensor networks are attractive for academic and industrial circles as a new and efficient technology in information collecting and mobile communication, as that is the one area that has seen the most development and this rapid development reveals some major problems that it has which include the hardware limitations and energy consumption. These two issues caused a lot of researches in the field of hardware, i.e. reducing the size and increasing energy efficiency and in the field of software, i.e. energy efficiency Sensor node includes a processing unit, transmission unit, the receiving unit and the unit positioning unit. Wireless sensor network includes relay typical nodes, head cluster and base station, which the requirement to all this equipment and facilities has caused that downsizing technology, fails to reach its ultimate goals, and, in fact, reduce energy consumption needs energy consumption management to increase these networks lifetimes by this way. Routing is the most important approach in energy consumption, because wireless networks generally varies inversely with distance, so, efforts to reduce energy consumption is often in terms of routing and reduce the mean distance, in which always the goal of algorithms, was routing parameters improvement, including routing algorithms we can refer to routing algorithms based on clustering However, the clustering will be useful in situations that the distance from the sink in the total of network be greater than base distance, if the distance average from sink be lower than or close to base distance, clustering will not be useful. But with increasing distance from the sink and distribution network area development, single step and multi steps clustering will have the highest efficiency in reducing energy consumption respectively.

Nodes in each cluster receive information from environment and send it to head cluster. Head cluster aggregate them after receiving. After integration, information is transmitted to the base station through the single step path or multi step path. Cluster size, number of node (head cluster) per cluster and selecting the head cluster are considered as important factors in clustering (7). On the other hand the head cluster position is considered as a major issue in clustering. As the energy model, energy consumption has a direct relationship with the square of the distance (8, 13). We used of ant colony optimization techniques in sizing Meso-Structures for in Non Pneumatic Tires (9), thus the head cluster inappropriate choice will increase gap and more energy consumption. Therefore, an approach that would take into account all aspects and give to network flexibility is often of interest.

In other words, an algorithm that can show flexibility in various conditions and by relying on the conditions (such as changing the size of the network, change the shape and dimensions of the network, etc.) uses a particular method in sending and receiving information, this algorithm would be appropriate. We also used of ant colony optimization Analysis of the graph complexity connectivity method for Procedia (15) Based on the above principles, the designed network in this paper is used the ant algorithm and exclusive territoriality and to choose the optimal head clusters and autonomy and to increase the flexibility it used of the autonomy ability and change the clustering type (directly and hierarchy transmission).

Corresponding author: Mehdi Effatparvar

A. Ant colony optimization algorithm

Ant colony optimization algorithm is also one of the methods based on the behaviour of ants to find food. Ants create a route with the shortest length between their nest and the food source to prepare food. This algorithm is presented as the standard mode for discrete optimization problems. In fact, the ants' way in reality is that they initially look for food randomly. Once they find a source of food, they return some food with themselves to the colony. Along the way, ants leave a chemical substance called pheromones. This chemical substance does somehow related to the information exchange of bees dancing act. Pheromone is a volatile substance that evaporates over time. Consequently, if the ants in their various searches find many sources, most favourable (closest) food sources have been accessed by more ants and in turn, the path that supreme from colony to that resource containing greater amounts of pheromones it should be noted that the process of evaporation would be to avoid getting stuck in local optimum. Pheromones values in this algorithm update as follows in each iteration:

$$P_{ij}^{k} = \begin{cases} \dfrac{(\tau_{ij})^{\alpha}(\eta_{ij})^{\beta}}{\sum_{m \in N_i^k} (\tau_{im})^{\alpha}(\eta_{im})^{\beta}} & j \in N_i^k \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

According to equation (1) p^{k}_{U} is the probability that ant k chooses to go from node i to node j, N^{k}_{i} is a set of all the probable neighbours that have still not met by ant k، η_{ij} is heuristic function, t_v is the pheromone on edge i to j, α and β are parameters that determine heuristic information importance or relative weight and pheromone scale.

Pheromone update is done through the following formula:

$$\tau_{ij} = \tau_{ij} + \Delta\tau_{ij}^{k}$$

$$\Delta\tau_{ij}^{k} = \begin{cases} \dfrac{Q}{f(\psi^{k})} & l_{ij} \in \psi^{k} \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

Evaporation is updated through the following formula:

$$\tau_{ij} = (1-\rho)\tau_{ij} \quad (3)$$

Where ρ is pheromones reduction constant coefficient, $f(\psi^{k})$ is cost solution made by ant k, and Q is a constant value. This process is repeated until to get a certain number (7), (10, 18). Presented Second Edition Leach algorithm and selecting the number of head clusters is central station responsibility. In the preparation phase, each node sends location information and its residual energy to the central station. Base station computes the average value of the energy network. It do not let to those nodes that their energy levels are lower than the mean value to be head cluster, Its function T (n) is calculated in the form below.

$$T(x)\begin{cases} \dfrac{p*\lambda}{1-p\left[r \bmod\left(\frac{1}{p}\right)\right]*} & if\ n \in G \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

$$\lambda = \frac{\text{resudal energy}}{primal\ energy}$$

The disadvantage of this version is wasting energy when it occurs in notice of the location situation and its residual energy (7). (11,14).present an performed model of leach using the **PSO** algorithm, the assumptions used in this algorithm are higher energy of head cluster and head cluster closer distance to the main station, to achieve this assumption the following equations is used.

$$fi = \propto 1.f1 + \propto 2.f2 \quad (5)$$

$$f1 = \sum_{i=1}^{n} qi / \sum_{i=1}^{k} qk \quad (6)$$

$$f2 = \sum_{i=1}^{n} li / \sum_{i=1}^{k} lk \quad (7)$$

According to the above equations f1 is to achieve higher energy and f2 is for closer head cluster to the main station and the sum of the coefficients equal to 1, the effectiveness of any of the above functions is done by setting the alpha 1 and alpha 2 parameters, in the first run of leach, due to the amount of energy equality we just consider parameter P, so P value is calculated as follows. (12, 16)

$$p = \sqrt{\frac{n}{2\pi}} \frac{D\sqrt{\varepsilon fs}}{\sqrt{Eelect(N+1) + \varepsilon mpl4}} \quad (8)$$

By doing this, it reached to the longer life and more equitable use of energy, due to the use of energy level and distance, but despite this, optimization has been done to clustering step. (17)

Now, a lot of research have been done about reduce energy consumption, routing optimization and increase reliability of wireless networks, and each of them used the specific methods and procedures to improve the situation,

But in general, data processing for routing and network stability increasing stability is significantly high in them, and in a few of them is emphasized about appropriate and essential use of nodes, that in this study this goal is noticed by the use of a particular type of ant algorithm and disable unnecessary nodes.

B. Suggested method

For a better visual understanding of an issue that is considered to be established, with a few examples, challenging initial deployment of sensors in a wireless sensor network is explained. The goal here is to test the clustering effect in different situations. It is assumed that to select the 9 point on the coordinates screen, and this 9 point be placed in a

symmetrical situation, so that all states, including the points with greatest distance from the sink, points with the shortest distance from the sink and the points with medium distance from the sink could be selected as a head cluster.

And each time the remaining energy to be considered for a round, i.e. each time a node is selected as head cluster and once send and receive act is done and then the network residual energy is done and then the remaining energy to be reviewed. As shown in Figure 1, all nodes are distributed symmetrically around a point and in symmetrical form and also a sink is located in zero point with red color and solid in the figure below, the node in points 40 and 25, or start node, is selected as head cluster for the first time and then in counter-clockwise in the other nodes is selected as head cluster and finally central node is selected as a head cluster and each time entire network consumed energy is tested, according to Table 1, nodes distances from the sink nodes is calculated respectively as shown below.

TABLE I. NODES DISTANCES FROM THE SINK

47.1699	42.4264	47.1699	58.3095	68.0074	70.7107	68.0074	58.3095	56.5685

That their average from base distance about (87), is less

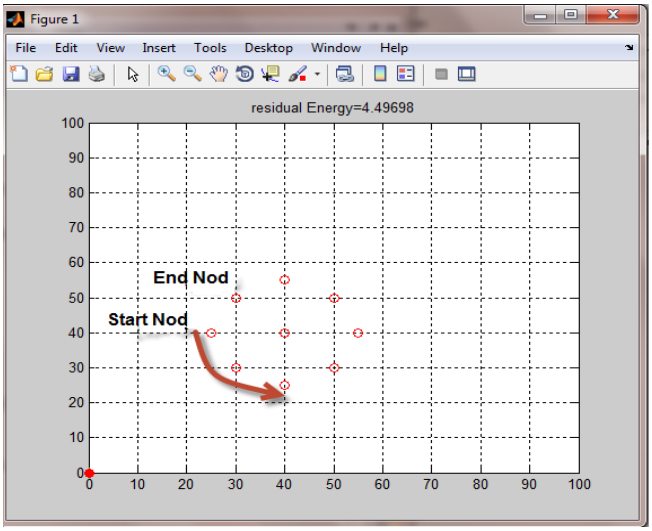

Fig. 1. The positioning graph of the nodes in a page

II. HOW TO CHOOSE THE HEAD CLUSTER

Most of the residual energy occurs when nodes send information directly; it means that, when an average distance of nodes is less than the base distance, clustering is not considered as a good strategy for reducing energy consumption. So we should withdraw from that, i.e., when the sizes of the area is close to the base distance, direct transmission is considered as the best method of sending information and any other method, including single-step head clustering such as latch and multi-step head clustering such as hierarchical clustering is rejected, also, if the optimal mode of clustering be done, for example, in an area with dimensions of 100 * 100 or 87 * 87, direct transmission even is better than single step clustering and also from multi steps clustering. But it seems that when the average distance from the sink, is greater than base distance, send data directly is costly and clustering is needed in such circumstances very much Then the network is going to set that, the nodes average distance from the sink be greater the distance of the base.

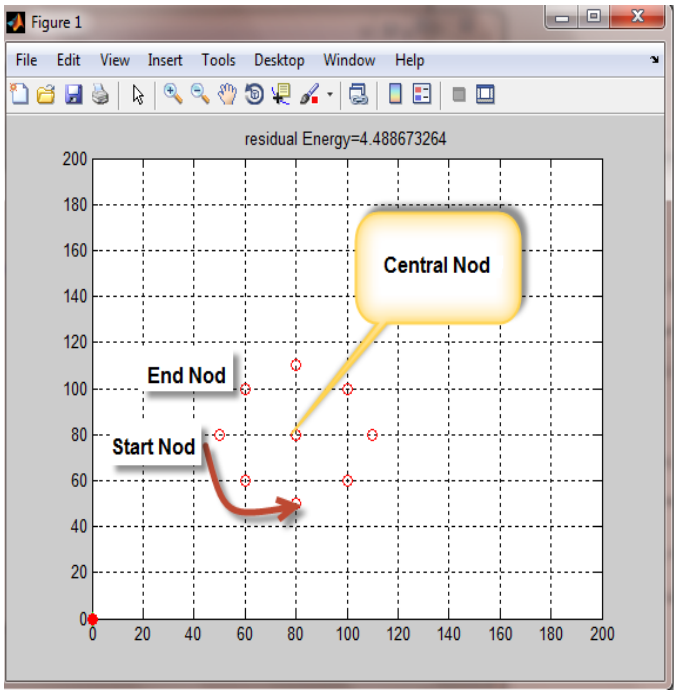

Fig. 2. Nodes placement graph in a page, with the distance more than base distance

In the network nodes head clustering does not occur any difference and sinusoidal modes is repeated between beside nodes and when the central node is selected as the head cluster, the highest efficiency in energy consumption occurs too, but when none of the nodes in accordance with the 10th stage isn't selected as head cluster, the residual energy unlike the previous case decreases than clustering and if this conditions is maintained for the case that 50 precent of nodes are in less distance and 50 precent of node are in greater distance, then energy consumption in direct transmission also will be greater because of more efficacy of large numbers power (large distances). That is, if the node average distance from the sink be more than base distance, is greater than first, latch single-stage method and then multi-stage method can be useful, in other words, each of the routing algorithms, in a certain range, has an advantage. Now, to improve the conditions so that the network can be balanced in terms of energy consumption it is necessary to: First, clustering is specific for areas that are at a greater distance from the base distance. Second, the nodes around head cluster must be placed on its base distances; otherwise it should be prevented receiving data from beyond nodes or be created a new head cluster for nodes on the outskirt. Thirdly, in areas less than from the base distance, there should be connecting rings to connect beyond head clusters to sink, that this nodes in this article introduced as carrier nodes.

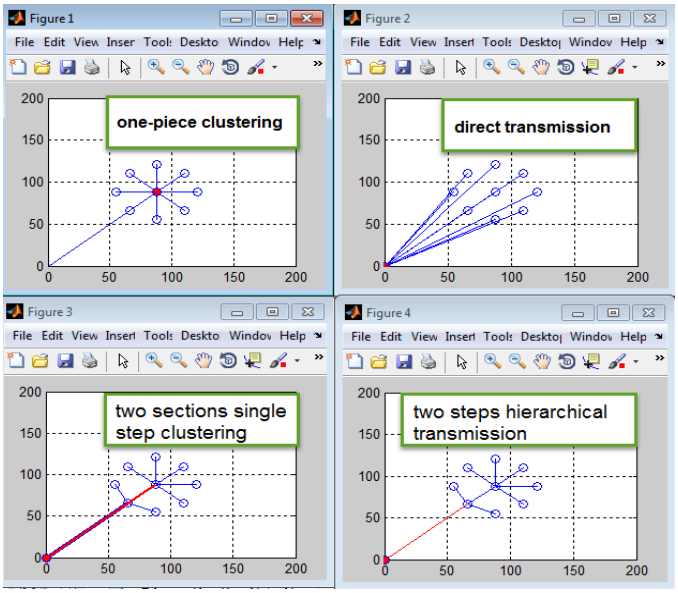

Fig. 3. Different routing algorithms

In the distance between the base distance near the 100 meters, two sections single step clustering algorithms (Figure 3) has the best performance. But then, this average distance is increased gradually and when the distance is going to be more than 130 meters, two steps hierarchical transmission is presented as the best performance and transmission with single step clustering (leach) is presented as the second useful transmission method in energy consumption and direct transmission is the worst way at such distances and this rating is always maintained. Therefore, we can say that direct transmission, at least from the base, single step and multi-step hierarchical transmission at distances greater than 130 meters and two-pieces single step and one-piece single step transmission in the middle distance have the best usage.

III. Routing Model Influenced by Territory

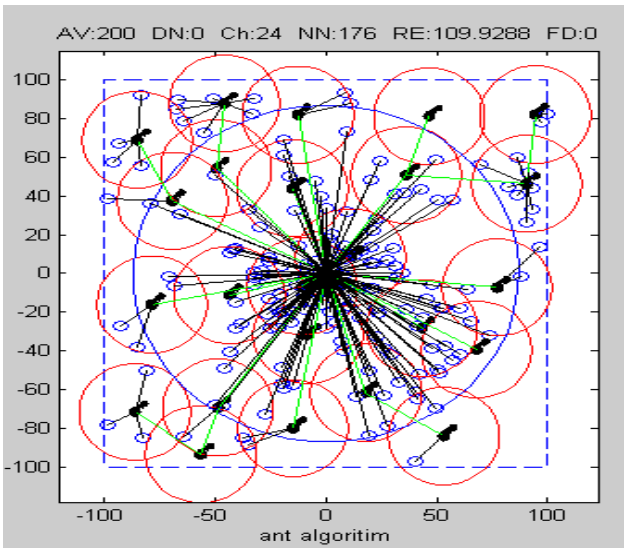

Fig. 4. Routing model affected by territory

IV. Results Simulation and Evaluation

The idea Experimental evaluation proved that when the size of network area is larger than the base area, hierarchical clustering is the best mode for routing head clusters, but with increasing the number of nodes or the size of the network, this performance is better for single step transmission, for example, at a time when network is 200*200 and the number of nodes increased from 100 to 200 or more, the results of latch will be better therefore, it is necessary to increase network capabilities, appropriate control parameters to be created in accordance with changing network conditions and always maintain network functionality. Experimental evaluation showed that the single step routing length between the head clusters should be decreased by increasing the number of nodes and by increasing the size of the simulation it should be increased, in the other words, with increasing the number of nodes, the layers radius between head clusters must be reduced and by increasing the size of the simulation area, the radius should be increased.

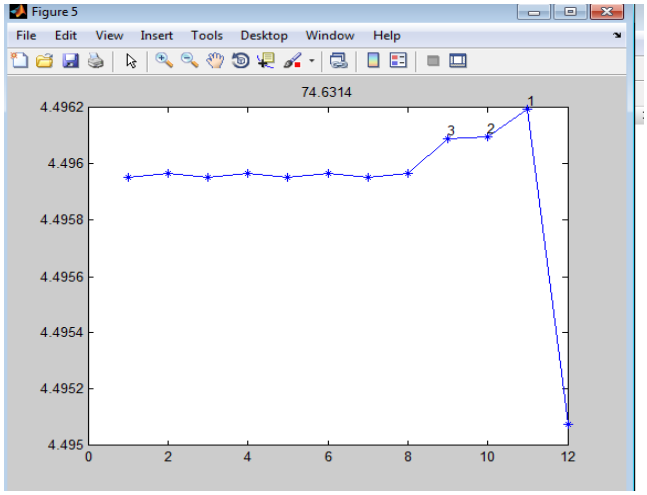

Fig. 5. The energy consumption graph based on head cluster point

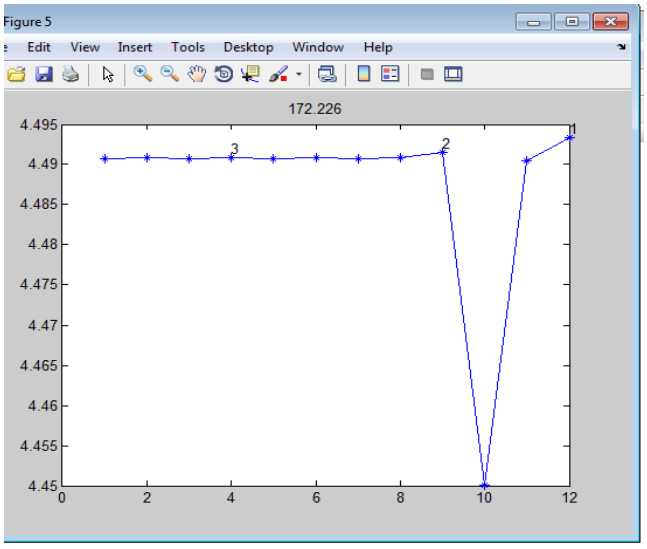

Fig. 6. Energy consumption diagram according to the head cluster point

TABLE II. SIMULATION PARAMETERS

parameter	parameters	
area	area	1000, 500, 200, 100, 70
Number of nodes	N	400, 100, 70
Sink location	BS location	0 and 0
Base distance	d0	87 m
Primary energy	E0	0.5 J
Near distance supportive energy	EFS	10 pj/bit
Near distance supportive energy	EMP	0.0013 pj/bit
Collecting energy	EDA	5 nj/bit
Pocket size	Packet size	4000 bit

V. SIMULATION SCENARIOS AND ANALYSIS OF RESULTS

To show the proposed algorithm ability, various scenarios were considered with two important variables, area size and number of nodes. The results in Table 3 indicate the increasing network longevity in proposed algorithm than other algorithms in large areas and by decreasing the simulation area, the longevity distance of proposed method will decrease than other methods that this agent is because of the nature of energy consumption in the base and limited areas and also observed that the lifetime of the network in networks with several nodes often is more than networks with fewer nodes.

TABLE III. SIX ALGORITHM LONGEVITY RESULTS COMPARING

		area space 1000*1000 Number of nodes		area space 500*500 Number of nodes		area space 200*200 Number of nodes		area space 100*100 Number of nodes		Death of the last node Number of nodes	
		100	400	100	400	100	400	100	400	100	400
Longevity	LEACH_D	2	2	28	63	835	900	10101	1065	2500	2500
	LEACH_A	-	-	-	-	-	-	567	713	1857	2184
	LEACH_C	-	-	-	-	-	-	626	867	987	1087
	EBCS	-	-	-	-	-	-	785	879	992	1104
	DIs	2	2	10	10	337	274	1405	1505	2500	2500
	E_ANT	89	150	668	923	878	980	1714	1585	2500	2500

The lifetime of the network in 1000*1000, with the proposed algorithm, is much more compared to networks with typical latch algorithms and direct transmission diversely, but the network coverage is very limited than its life.

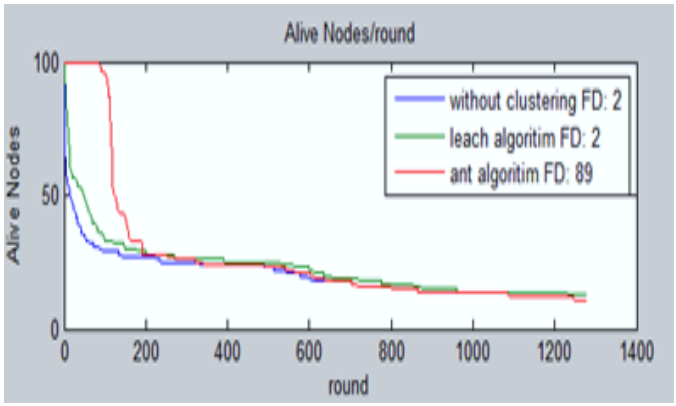

Fig. 7. Output charts in 1000*1000 areas with 100 nodes

As figure 7, the head cluster selecting chart patterns, the number of ordinary nodes, the number of live nodes, the number of dead nodes and energy consumption scale has been shown, that the proposed algorithm is shown in red.

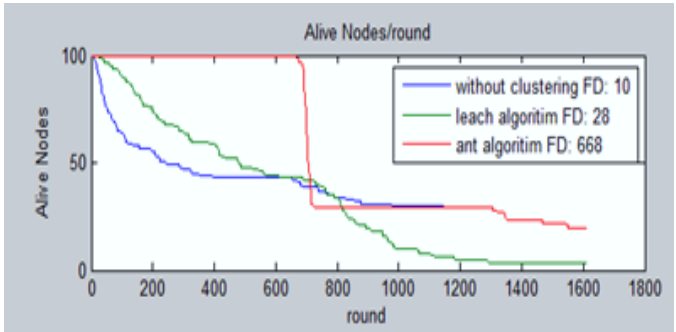

Fig. 8. Output charts in the 500*500 with 100 nodes

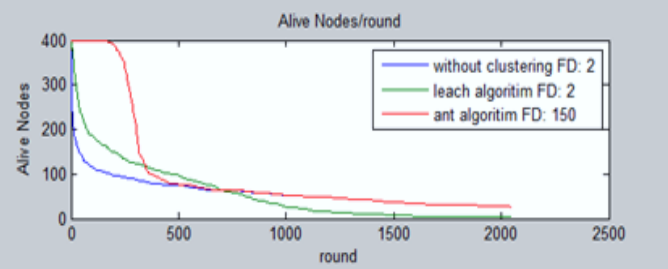

Fig. 9. Output charts in 1000*1000 area with 400 nodes

VI. Conclusion and Future Work

The goal of this article is modifying the conditions for extensive use of wireless networks. This means that the network aims a kind of broad intelligence so it can manage network in terms of longevity, energy consumption and network coverage under different conditions. The output of the simulation and results graphs shows that network can work under different conditions and shows high flexibility in different areas and develops this intelligence by reducing or increasing the size of the territory of each node, reducing or increasing the single step and multi steps length of routes and the number of head cluster nodes and finally the use of self-determination property outside of the realm confine. Also in this article we try to present comparable useful features with innovative methods of proposed algorithm as an important factor in maintaining the superiority of the proposed algorithm by identifying useful work area for various algorithms and compared in this article and using the method of them in the form combination. The proposed algorithm, working in all areas except the work area that only features in its self-determination was important, and we could improve the situation by changing some parameters. Therefore it is recommended that routing methods be balanced at the base areas that include have about 1 x 87 m with an average sink position. In other words, if there is a significant method of routing or clustering in base area that can perform better than direct transmission, an critical event will occur in the field of wireless networks energy consumption.

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