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Improving LEACH Protocol Using SFLA Algorithm to Reduce the Energy Consumption of Wireless Sensor Networks

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Abstract : Changing and charging the battery is not possible in wireless sensor network due to the large number of sensors. The main issue in designing the network is the inadequacy of sensors energy resources. One of the most common protocols for reducing energy consumption of wireless sensors is LEACH protocol. Controlling the number and position of cluster head in protocol is considered as a challenge. This article propose SFLA – LEACH protocol. Finally this protocol compared with LEACH, LEACH-C, WEEC, BN-LEACH and GA-LEACH. The results show that this protocol comparing to other mentioned ones increase the wireless sensor longevity and also moderate energy consumption.

Key words: wireless sensor network, clustering sensors, LEACH algorithm, SFLA algorithm, Energy, fitness.

1-Introduction

By recent development in electronic and wireless telecommunication, the ability of designing and manufacturing sensors with low power consumption, small size, suitable price and different application have improved. In suggested protocol of this article which is called SFLA-LEACH, the possibility of cluster head selection in each round is determined by SFLA algorithm. In this method, also, the network longevity is more than LEACH, LEACH-C, WEEC, BN-LEACH and GA-LEACH protocols and the death of first node comparing to LEACH, LEACH-C, WEEC and GA-LEACH protocols is improved. The study first considers the protocols related to cluster head election and then describes SFLA-LEACH protocol. After that the stimulation and results are mentioned. At the end the conclusion and suggestion for future worksare stated.

1-1- LEACH[1]algorithm

The base of this algorithm is clustering. In this protocol, the

time is divided to equal intervals which are called rounds. Each round includes two steps.In the first, the clustering is done according to equation (1). A random number between zero and one is attributed to each sensor. If the number is smaller than the threshold, that node will become the head cluster. In this equation p is the number of head clusters in the network which are defined previously. r is the number of current round and ci(t) is a function which shows that the node i has been head cluster

$$T(n) = \begin{cases} \dfrac{P}{1 - P(r \bmod \frac{1}{P})} & C_i(t) = 1 \\ 0 & C_i(t) = 0 \end{cases} \quad (1)$$

in p(r mod 1/p) period of time.

The second step is data transferring. It includes some time frame. In each of them, all nodes of one cluster send data to head cluster and then at the end of frame, head clusters send their data to central base station[ii].

1-2- LEACH-C[2]algorithm

The use of leach doesn't guarantee the number and place of head clusters. So, using a central control algorithm in clustering can help the formation of head clusters. This data is used in another protocol called LEACH-C. Despite of LEACH, it uses a central clustering algorithm and its stability phase is similar to LEACH. In startup phase of LEACH-C, each node send data about its current position and energy level to base station[iii].

1-3- WEEC[3]algorithm

Another improved protocol is WEEC. It is a weighted energy efficient clustering protocol which use the position of each node for clustering. The possibility that each node can become the head cluster is the function of the distance of that node and the sum of the distances of all nodes to base station (BS)[iv].

1-4- BN-LEACH[4]algorithm

BN-LEACH algorithm for selecting the optimized cluster head, use a Bayesian network model. The main parameters in this model are the probability of distance from main station, density and sensor node energy [v].

1-5-GA-LEACH[5] algorithm By using genetic algorithm, the position of cluster head is determined in a way that network consume the minimum of energy. The fitness value is

[1] Low-Energy Adaptive Clustering hierarchy

[2] LEACH-Centralized
[3]Weighted Energy Efficient Clustering
[4] Bayesian Network-LEACH
[5] Genetic Algorithm-LEACH

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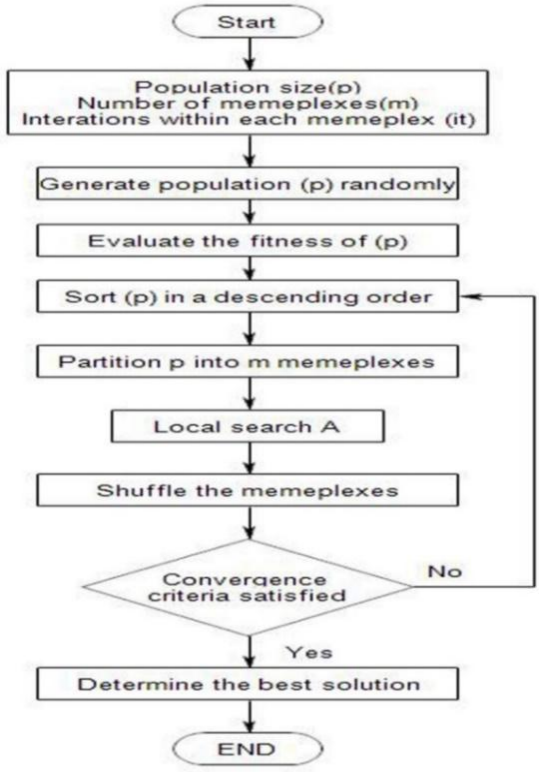
determined according to the minimum of energy consumption of network nodes during each data sending operation. In fact, the selection of new generation population is done by the fitness value of minimum difference of network energy comparing to previous round [i].

1-6- SFLA[6] protocol

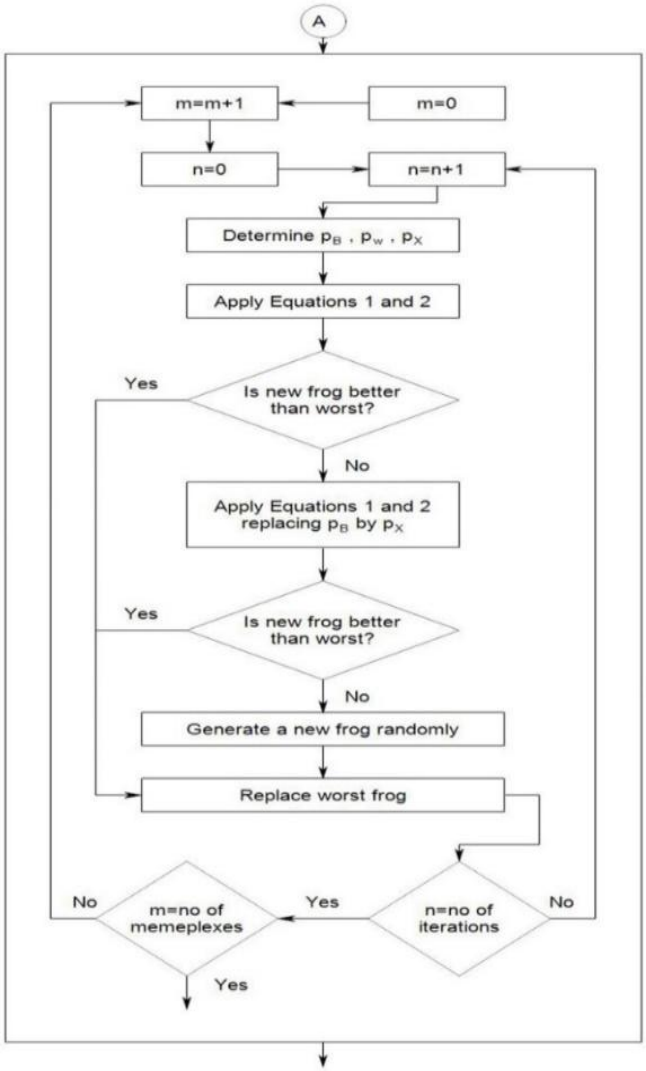
In this algorithm each frog has information of one issue. Thealgorithm start by the random election of frogs as a group which is called memeplex. Each memeplex divided into several sub-memeplex and each sub-memeplex can start local search independently and with different method. The frog of each sub-memeplex can effect on the other frogs. By this, thefrogs of the subgroup can develop. After the development of some memeplex, sub-memplexes are combined with each other.The global zone optimized. SFLA algorithm has two steps.Local and global. The chart (1) show the global search andchart (2) show the local search [vii- ix-x].

2- Suggested protocol SFLA-LEACH

Like the algorithm LEACH, SFLA-LEACH has startup and stable phase. In startup phase, shuffle frog leaping algorithm is used for head cluster selection. It is supposed that the clustering is done in base station and then its result will be sent to the whole network. The steps of suggested algorithm SFLA-LEACH is as follows.



Chart(1). Shuffled frog leaping algorithm flowchart [vi].



Chart(2). Local search algorithm [viii].

The first step is providing a single frog position in which each frog is considered as an array of head node candidate. Each elements of this array as an ID if network node which is selected on the base of three conditions.

1) Id shouldn't be repeated. 2) At maximum level, it shouldn't be head cluster in 20 rounds before. 3) It should be alive.

Here, an array with 5 elements is defined for each frog. The primary four elements are ID of candidate nodes and the last element is fitness function.

The second step is the calculation of fitness function.Consumed energy for head cluster candidate node in each frog during current process. Its nodes will be presented to network as head cluster. The current level of energy in k round is shown as $E_{Network}^{K}$ and the network energy for next round for each frog is shown as $E_{Network}^{k+1}$.Fitness function is calculated according to equation (2).

[6] Shuffled Frog Leaping Algorithm

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$$fitness = \left| E^{K}_{Network} - E^{k+1}_{Network} \right| \quad (2)$$

Then the frogs will be arranged in ascending order according to the value of fitness and save the first frog in p_x variable as the best position of frog.
The third step is making a memplex in which the frogs are distributed to m groups in a way that each group has n fogs or in other words F = m×n. this should be in such a way that the first n frog of the arrangement allocate to first group, the second one to the second group and the allocation process will be continued in this way until n frogs allocate to each m group. The members of submemplex are the same as memplex. Then the frogs will be arranged in ascending order in memplex and the position of the best and worst frog in submemplex will be shown by P_b and P_w respectively.

The forth step is the amendment of worst frog position, so that the worst frog in each submemplex will update. By random selection in p_B subsequence, q frog in submemeplex (U (q)) will be achieved and replace with its corresponding in P_w. the other position in P_w won't change. After substitution, if two equal number is achieved, then a frog will be made randomly. The process is shown in figure (1).
If fitness of U (q) is better than Pw, then Pw will be replaced by U (q); if not P_B will be substituted by P_x and a process like above mentioned process will operated until the production of another new U (q). If it is not improved, the frog will be made randomly from possible area.
Finally if convergence condition (the decrease of network energy consumption rate) is existed, it will be stopped. If not, the above mentioned process will be repeated after the selection of proper frog by shuffle frog leaping algorithm, the rest of process will continue including clustering, data sent schedule according to LEACH algorithm.

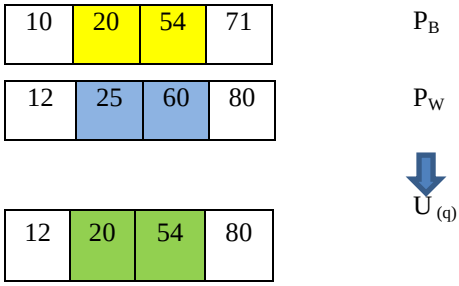

Figure (1).UpdatingU (q)

3. Stimulation and analysis of results

For stimulating and evaluating LEACH, LEACH-C, WEEC, BN-LEACH, GA-LEACH protocols and also suggested protocol SFLA-LEACH Matlab software has been used. The aim of SFLA-LEACH protocol is the delay of first node death and increase of network longevity. So this protocol will be analyzed from two points of viewlongevity and network energy consumption.

3-1- stimulation parameters of SFLA-LEACH

The value of stimulated parameters for wireless sensor network are shown in table (1).

Table (1).Stimulation parameter values

parameter	Description	Value
M * M	Two dimensional space area	100 ×100 m^2
N	The number of sensor nodes	100
BS (x, y)	Main station coordinate	(175,50)
E_0	The initial energy of each sensor node	0.5 J
E_{TX}	The necessary energy in transmitter electric circuit for sending 1 bit	50 NJ/bit
E_{RX}	The necessary energy in receiver electric circuit for receiving 1 bit	50 NJ/bit
E_{fs}	Energy consumption in sensor RF amplifier for sending a bit in the distances lower than threshold distance	10 PJ/b/m2
E_{mp}	Energy consumption in sensor RF amplifier for sending a bit in the distances more than threshold distance	0/0013PJ/bit/m 4
E_{DA}	The necessary energy for collecting and combining data	5NJ/bit/signal
Packet Size	the packet size of data sent	2000 bit

Table (2) shows the parameters of shuffle frog leaping algorithm. The best values for SFLA-LEACH are presented here according toconsecutive experiments.

Table (2).Stimulation parameter values of shuffle frog leaping algorithm

parameter	Description	Value
Number of cluster	The number of clusters in each round	$\left\lceil \frac{Number\ of\ Alive\ Nodes}{25} \right\rceil$
Number of G	The number of candidate node	Sum of nodes which don't become headcluster in recent round
Number of frogs	The number of frogs	$\left\lceil \frac{Number\ of\ G}{Number\ of\ cluster} \right\rceil$
M	The number of memplex	$\left\lceil \frac{Number\ of\ Frogs}{5} \right\rceil$
N	The number of memplex members	$\left\lceil \frac{Number\ of\ Frogs}{m} \right\rceil$
q	The number of submemplex	n
Nt	The number of local search iteration	3
Ns	The number of globalsearch iteration	1
Niter	The number of SFLA iteration	4

In figure (2), the number of alive nodes in SFLA-LEACH is compared to LEACH, LEACH-C, WEEC, and BN-LEACH during 2500 round of data sending and receiving. Alsocan comparenetwork longevity.All nodes of LEACH, LEACH-C, WEEC, BN-LEACH and SFLA-LEACH will die in 1292, 1450, 1487, 1593 and 2235 round respectively. By comparing the suggested algorithm SFLA-LEACH to other algorithm it can be found that the suggested algorithm increase the longevity of

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network. Considering the first node death in LEACH, LEACH-C,WEEC,BN-LEACH,SFLA-LEACH it die in 835, 1066,824, 1218 and 1094 round, respectively. According to these results, the death of the first node and network longevity of the suggested algorithm is improved comparing to the first three algorithms.

Figure (3) represent the energy consumption of SFLA-LEACH and LEACH, LEACH-C, WEEC and BN-LEACH. Energy consumption of suggested algorithm is improved comparing to WEEC and LEACH algorithm in all rounds. But in the case of LEACH-C and BN-LEACH algorithm, it is improved from 1300 and 1500 round, respectively. Since some nodes die in upper rounds, so a lower number of frogs can be made from nodes. By iterating the loop, the possibility of finding a better frog is less comparing to lower rounds in which there are more alive nodes. In suggested algorithm, SFLA is an exponential algorithm. so it's operational time is high. The more loop iterate, the higher operational time need. By doing consecutive experiments, the number of iteration is considered in which the operational time is not high and an acceptable response can be achieved comparing to other algorithms. If a large number of loop iteration is considered, the result in all rounds will be better than all mentioned algorithm.

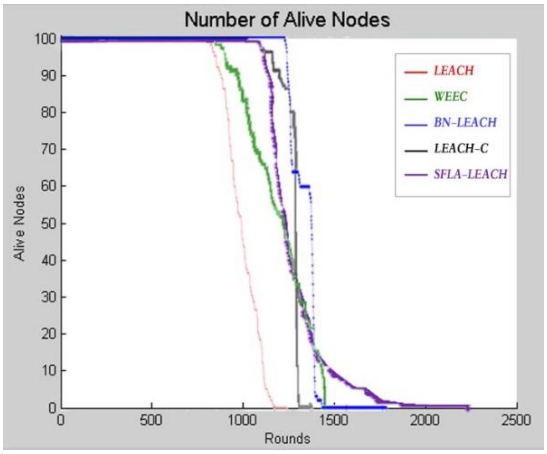

Figure (2). Number of alive nodes in each round

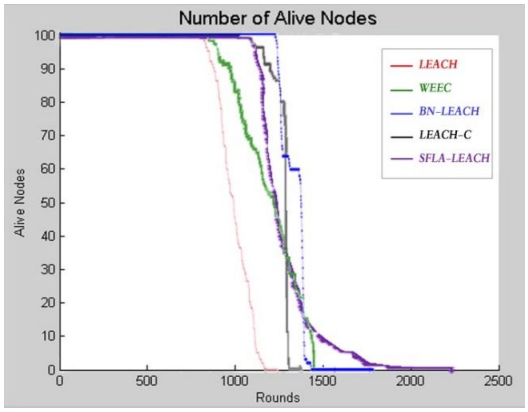

Figure (3).Network energy consumption in each round

3-2- Comparison of Genetic and suggested algorithms

The Genetic algorithm is used for the selected of LEACH algorithm cluster head. All the network parameters are the same as the suggested algorithm except the initial energy of each sensor (E_0) which equal to 0.1. Both algorithm are tested with this energy and compared with each other. The parameters of Genetic algorithm are in accordance of reference [i].

Figure (4) compares the number of a live nodes in suggested algorithm, SFLA-LEACH, and Genetic algorithm, GE-LEACH. The GE-LEACH algorithm in round 150 and SFLA-LEACH in round 228 lose all their nodes. In GE-LEACH, the death of first node occurs in round 70 but in SFLA-LEACH in round 129. The results show the improvement of network longevity in the suggested algorithm comparing to Genetic algorithm.

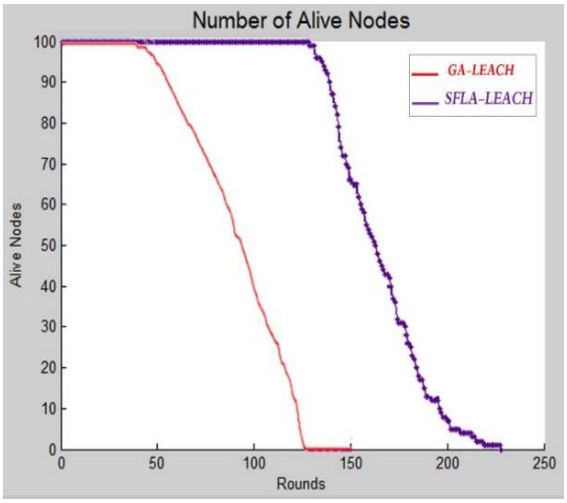

Figure (4). The number of alive nodes in each round with E0 = 0.1

Figure (5) compare the network energy consumption of these two algorithms. As the results show, the energy consumption of suggested algorithm was lower in all rounds comparing to Genetic algorithm.

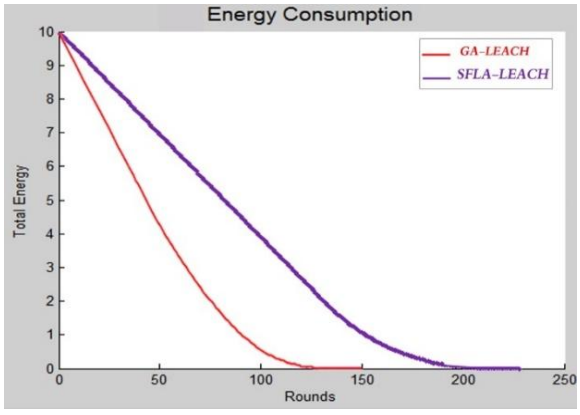

Figure (5). The network energy consumption in each round with E_0 = 0.1

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4. Conclusion and future work

In this article LEACH algorithm is modeling by SFLA algorithm. The practical results show that the suggested protocol increases the network longevity comparing to LEACH, LEACH-C, WEEC, BN-LEACH and GA-LEACH. The death of first node also improved. For further works can suggest a new fitness function with more efficiency.

Resource

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