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RESEARCH ARTICLE

Reduce Energy Consumption by Improving the LEACH Protocol

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Abstract —The wireless sensor networks suffer from the problem of energy consumption, so it has been used several protocols to avoid this problem, the best of these protocols is a LEACH protocol which works to reduce the energy consumption of the network. On the other hand, LEACH protocol suffers from the problems of accelerated the dead nodes as well as the short duration of the network lifetime. In the present work, an improvement is added to the original LEACH protocol via the use of the SPIN protocol idea. That result a new protocol call (S-LEACH). Since the protocol SPIN uses so-called meta-data (which is very small in size) before receiving packets full advantage of this feature so that there is no identical or similar packets. The improved LEACH protocol is simulated using matlab software. The simulation results shows that the improved protocol gives better performance than the original one in the following aspects:

1- ***Increasing the number of rounds.***
2- ***Delayed the first node dies.***
3- ***Deceleration in the death of nodes.***
4- ***More remaining nodes.***
5- ***Extended lifetime network.***

Keywords: sensor network; WSN; CH; lifetime; LEACH; S-LEACH; dead node.

I. INTRODUCTION

Recently Wireless sensor network (WSN) has attracted considerable attention, since it has a wide range of applications, such as security, environment monitoring and military systems [1]. Wireless sensor networks (WSNs) usually contain thousands or millions of sensors [2], [3]. Placement of a sensor network in these applications can be in arbitrary fashion (e.g., released from a helicopter) or can be fixed manually (e.g., fire alarm sensors in an office) [4]. Information about the environment is collected by the sensors and is provided to a central base station where the operator can extract the preferred data [4].

An important challenge in the design of these networks is that two key resources—communication bandwidth and energy—are significantly more limited than in a tethered network environment [2].

In wireless sensor network, the majority energy of nodes is used for data transmission and reception. To balance the node energy consumption and prolong network lifetime has become an important indicator of good or bad routing algorithm, so a good routing algorithm must balance the energy consumption of nodes to extend the network life without increasing computational complexity [5]. Since energy is the major constrain in WSNs, therefore, to solve the energy constraints problem of WSNs, various energy efficient routing protocols have already been proposed such as LEACH, PAMAS and HEED. The main objective of the routing protocols in wireless sensor networks is to find approach for improvement of energy efficiency and reliable transmission of sensed data to the base station [6].

Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular hierarchical routing protocols for wireless sensor networks. The idea is to form clusters of the sensor nodes based on the received signal strength and use local CHs (cluster heads) as routers to the sink (base station). This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes [7].

LEACH divides the whole network into several clusters, and the run time of network is broken into many rounds. In each round, the nodes in a cluster contend to be cluster head according to a predefined criterion [8], [9]. LEACH is a more mature clustering routing algorithm, but it still have defect of short survival time and is low degree of load-balancing. The cluster head is selected randomly in Leach, and this is likely to bring some of the inefficient subclustering schedules [10]. In this research, we provide the best solution in the energy consumption of the original protocol and thus the network will have a longer lifetime.

II. RELATED WORK

There are many researches focused on the energy and lifetime in sensor networks. In this section, a survey covers some previous researches related to our work are as follows:

C. Wang and J. Liu, proposes an improved LEACH protocol with a more reasonable set-up phase. The proposed protocol focuses on saving the energy cost induced due to redundant nodes (twin nodes) and balancing the energy consumption among sensor nodes by splitting large clusters into smaller ones [2].

W. Xiaoping, L. Hong and L. Gang, proposes an improved routing algorithm based on LEACH protocol, which involves cluster head choosing, multi-hop routing and the building of its path. An improved routing algorithm has higher energy utilizing rate, and it helps prolong network's lifetime [11].

W. Weichao, D. Fei and X. Qijian, proposes LEACH-TM protocol, where LEACH-TM introduces the concept of Trust, designs the cluster-head adjusting procedure and establishes multi-path with cluster-heads acting as routers. The simulation illustrates that LEACH-TM makes much progress in the reliability of data transmission, the distribution of cluster heads and the lifetime of networks [12].

B. A. Bakr and L. Lilien, proposes the LEACH-SM protocol, which modifies the prominent LEACH protocol by enhancing it with an efficient management of spares. One of the spare management features in LEACH-SM is adding the spare selection phase to LEACH. During this phase, each node decides in parallel whether it should become an active primary node, or a passive spare node. The nodes that become spares go asleep, while the WSN as the whole maintains the required above-threshold target coverage. Identification of spares alone increases energy efficiency for WSNs, thus extending WSN lifetime [13].

III. LEACH PROTOCOL

LEACH is an adaptive clustering routing protocol proposed by Wendi B. Heinzelman, et al [8]. It is a kind of self-adaptive cluster-organized topological algorithm. Nodes organize themselves into clusters; one node in every cluster would acts as cluster head (CH) [11]. The operation of LEACH is broken up into rounds, where each round begins with a set-up phase when the clusters are organized followed by a steady state phase when data are transferred from the nodes to the cluster head and on to the BS, as shown in Fig. 1 [2], [12].

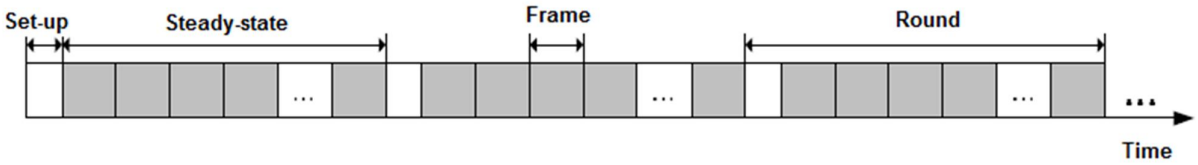

Fig.1: Time line showing operation of LEACH

The steady-state phase duration is usually much longer than set-up phase duration. However, the first phase is more important, in which sensor nodes are allowed to elect themselves as cluster-heads randomly, and then divided into clusters. Each node that becomes the cluster head (CH) will create a TDMA schedule for the sensor nodes within the cluster. That allows the radio components of each non-CH node to be turned off all times except during their transmit time Fig..2 shows the cluster formation algorithm of LEACH. [2].

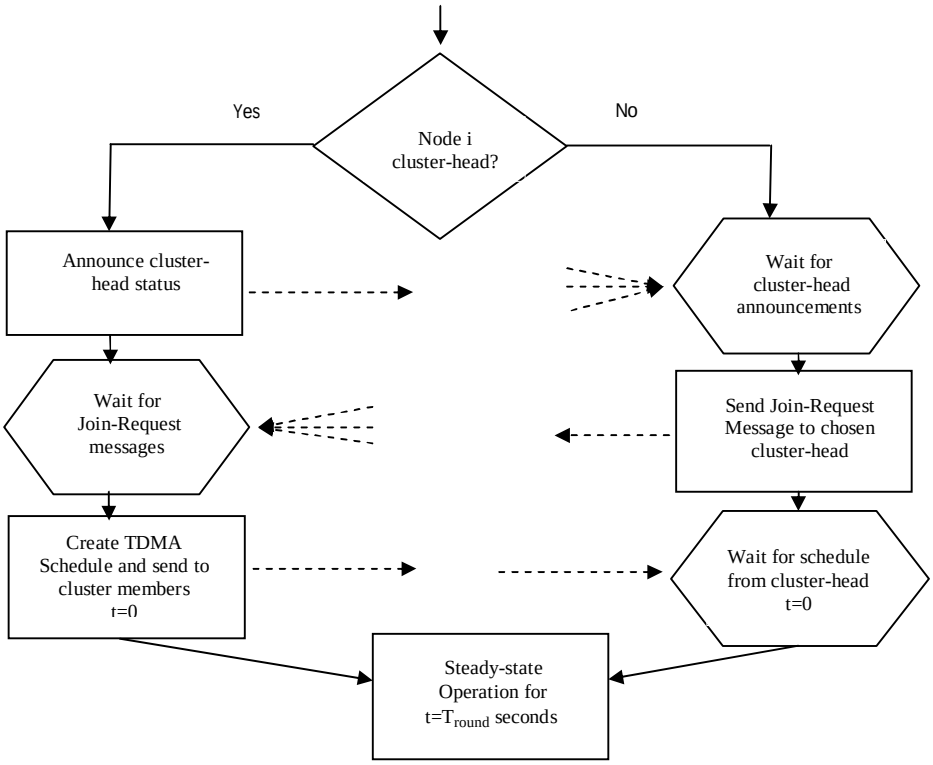

Fig.2. Cluster formation of LEACH protocol

The selection of CH depends on decision made by the node by choosing a random number between 0 and 1. If the number is less than a threshold), the node becomes a cluster-head for the current round. The threshold is set as [4]:

$$T(n) = \begin{cases} \dfrac{P}{1-P\times[r \bmod (1/p)]}, & n \in G \\ 0, & \text{otherwise} \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where P is the desired percentage of cluster heads (e.g. =0.05), r = the current round, and G is the set of nodes that have not been cluster-heads in the last 1/P rounds. Using this threshold, each node will be a cluster-head at some point within 1/P rounds. Nodes that have been cluster heads cannot become cluster heads for a second time for P rounds. After that, each node has a 1/p probability of becoming a cluster head in every round. At the end of every round, every node that is not a cluster head select the nearest cluster head and joins that cluster to transmit data. The cluster heads combine and compress the data and forward it to the base station, therefore it extends the life span of major nodes [8], [4], [14].

This protocol contains many problems and flaws are as follows:

1- In the original LEACH protocol distributed nodes on a specific area randomly and thus possible that the nodes are far from Cluster head, leading to an acceleration in the death of nodes.

2- Possible that there will be two nodes or more neighboring leading to send information identical to CH and this increases energy consumption and reduce the network lifetime.

IV. S-LEACH PROTOCOL

In this section, we explain the proposed protocol, this protocol addresses the problems of the original protocol, these problems is that the nodes die quickly in rounds and shortness of network lifetime. When we implement the original protocol the nodes are distributed randomly, as shown in Fig. 3:

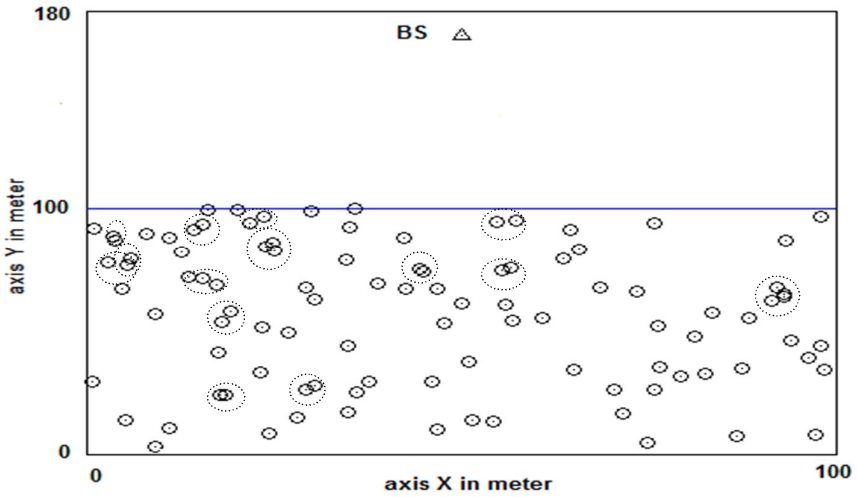

Fig. 3 100 nodes with BS in original LEACH protocol

Refer to Fig. 3, there are two nodes or neighboring more (the nodes of neighboring inside dashed circles), the neighboring nodes send identical packets. CH leading to the additional work for these identical packets, which increases the energy consumption, thus neighboring nodes dies early.

As mentioned previously, the use of the idea of SPIN protocol in which the nodes send metadata (which is very small in size) to the so-called resource manager (which is similar to CH), If the information in the metadata is not identical with the data packets that belong to other nodes, the resource manager asks the node to send full packet; otherwise there is no need for that packet.

We apply the principle of SPIN in the S-LEACH protocol (As shown in Fig. 4), Where we noticed that the nodes that is less than 3 meters far from the location of node sends the same data, thus no need for more than one node to send the same data packet. The neighboring nodes are forced to be in a state of sleep until the death of the first node.

All nodes send metadata to the CH, and CH is determined neighboring nodes. We found through the implementation of the program as possible that there will be two nodes neighboring, three or four by spreading the nodes randomly as shown in Fig. 3.

By incorporating the idea of SPIN in LEACH got good results in increasing the number of rounds, delayed the first node dies and prolongs the largest network lifetime. These results will be discussed in the next section.

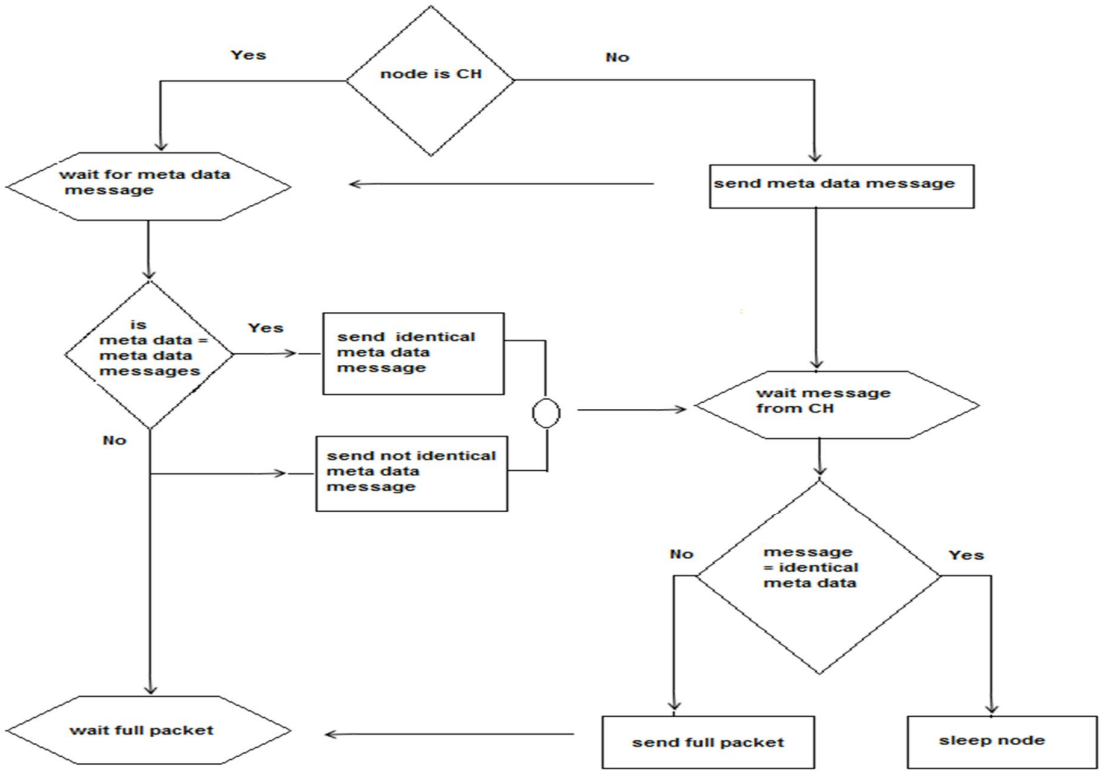

Fig. 4: CH determines the status of nodes (sleep or active)

V. RESULTS AND DISCUSSION

In this section, presents the results obtained from the S-LEACH protocol, usually, the nodes of WSN are distributed randomly by helicopter (for example for different reasons), so the sensor networks are spread randomly. Suppose also that all nodes are consumes equal energy and the base station is static and positioned distant from the sensors. The CHs numbers are left as in the original LEACH protocol. The table I shows the parameters used in the original LEACH protocol and the S-LEACH protocol simulations:

Table I
Simulation parameters

Parameter	Values
Nodes	100
Simulation area	100×100 m^2
Base station location	(50,170)
Node energy	0.5J
Rounds	800
Size of Packet	6400 byte
Meta-data	200 byte

After the implementation of the program by using the previous parameters we got the result that the nodes of the dead in the original protocol more than the proposed protocol as in Fig. 5:

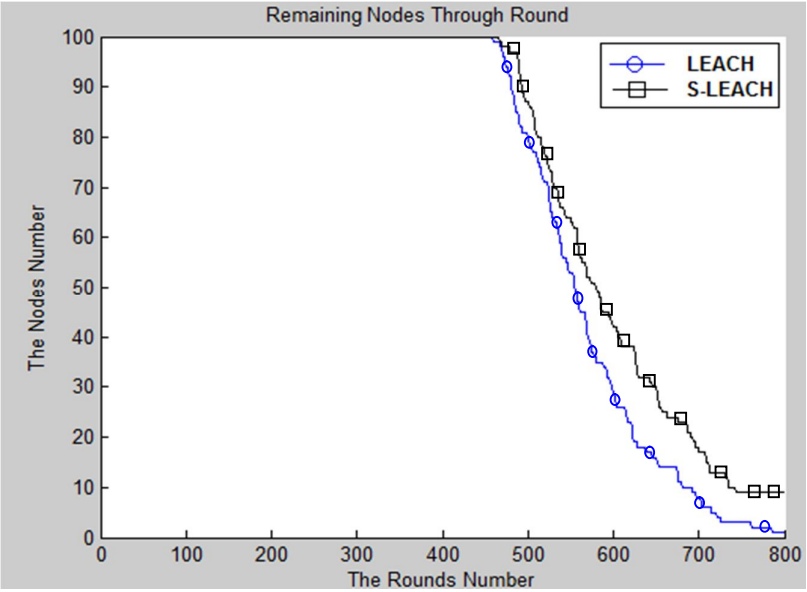

Fig. 5: Remaining nodes in both original LEACH and S-LEACH protocol through rounds

Thus, the remaining nodes in the original protocol and the proposed protocol are shown in Fig. (6 and 7):

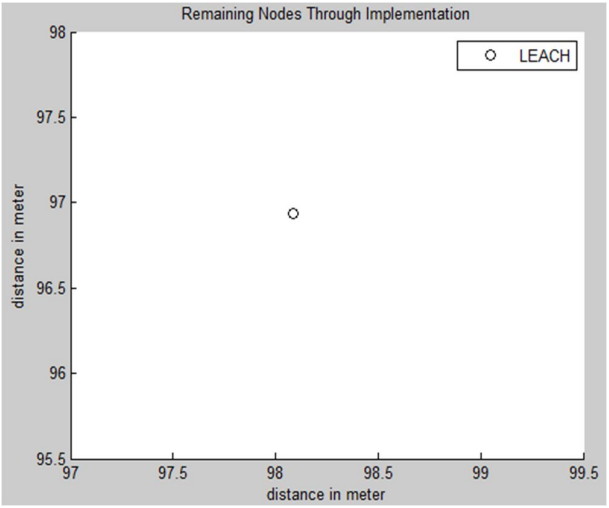

Fig. 6: Remaining nodes in LEACH

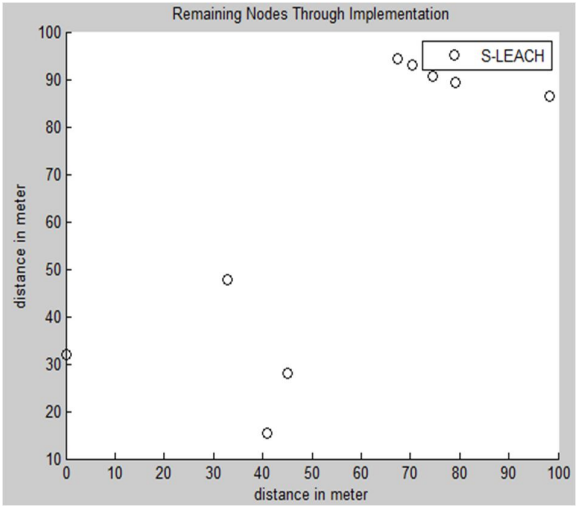

Fig. 7: Remaining nodes in new LEACH

It is clear from earlier figures that the remaining nodes in the original protocol is a single node, while in the new protocol there are 9 nodes This reflects the efficiency of the S-LEACH protocol.

That is, through the S-LEACH protocol can increase the number of rounds to more than 800 round because of extended in lifetime the network, Also in the S-LEACH protocol has been noticed that there is delayed in the death of nodes and that there is a delay in the death of the first node. 1000 experiment was performed on both the protocols and the results are shown in table II which gives sample of results:

Table II
Results 1000 experiment for both protocols

Original LEACH Protocol					New LEACH Protocol				
No.	Remaining Nodes	First Dead Node	Dead Nodes in 500 round	Dead Nodes in 700 round	NO.	Remaining Nodes	First Dead Node	Dead Nodes in 500 round	Dead Nodes in 700 round
1	1	390	38	90	1	6	410	26	86
2	1	458	20	92	2	9	466	13	83
3	3	434	39	94	3	12	454	10	74
4	4	413	28	93	4	5	397	20	86
5	1	423	31	90	5	5	447	20	86
6	2	419	35	91	6	10	462	13	82
7	3	438	33	91	7	8	459	23	79
8	5	427	35	91	8	14	449	6	74
9	2	432	32	91	9	5	451	14	85
10	2	417	32	90	10	7	453	13	84
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
990	3	405	35	96	990	12	475	5	75
991	4	410	33	93	991	14	432	15	72
992	4	400	43	94	992	7	408	24	87
993	2	414	30	92	993	7	432	24	87
994	4	419	34	93	994	7	479	11	82
995	4	427	31	95	995	7	436	11	87
996	1	434	34	93	996	12	461	7	78
997	4	422	37	93	997	9	481	8	81
998	4	427	25	90	998	5	481	14	83
999	4	411	42	90	999	5	434	15	89
1000	1	409	27	92	1000	6	448	21	82

Through the above table we reviewed Dead Nodes in 500 or 700 round even show acceleration and deceleration in the death of nodes for both Protocols. Fig. 8 and Fig. 9 show the death of the first node for both protocols and 1000 experiment while the Fig. 10 and Fig. 11 show the remaining nodes to both protocols and 1000 experiment.

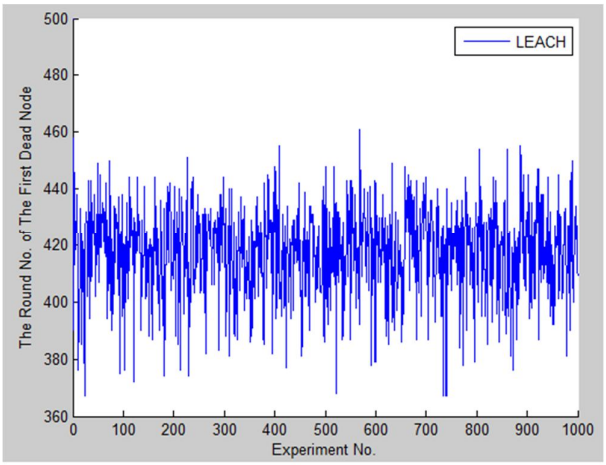

Fig.8: LEACH First dead node through 1000 experiment

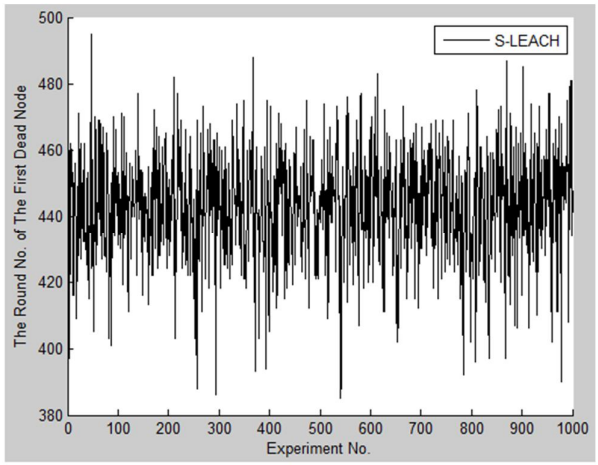

Fig.9: S-LEACH First dead node through 1000 experiment

The average of both results in Fig. 8 and Fig. 9 for LEACH = 417.379 and for S-LEACH = 442.707

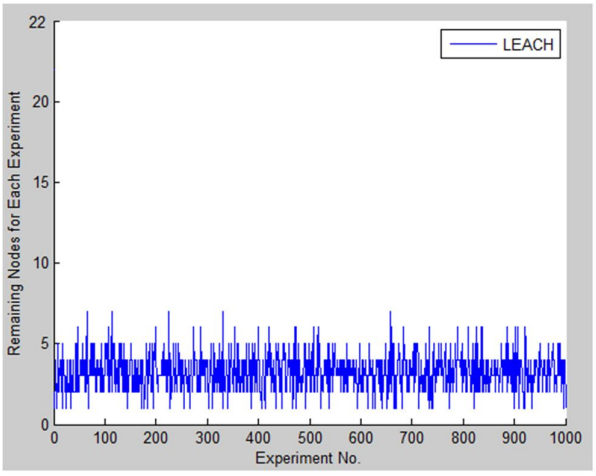

Fig. 10: LEACH remaining nodes through 1000 experiment

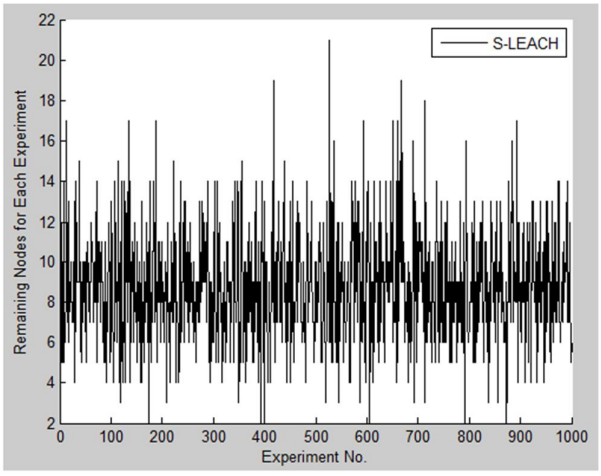

Fig.11: S-LEACH remaining nodes through 1000 experiment

VI. CONCLUSION

After the implementation of both protocols on the same parameters listed in Table I we conclude that the S-LEACH protocol gives better results than the original protocol. But we noticed that the remaining nodes in the S-LEACH protocol vary from implementation to another, as in Table II, Due to the spread of nodes (the area of 100 × 100 m) randomly, as the CH selected randomly depending on the threshold, This means that the location neighboring nodes differ from experiment to another. Distance from the nodes to the CH or to Base Station possible to affect the results. We conclude that the overall results of the S-LEACH protocol are more efficient and more ideal in reducing energy consumption (i.e., an increase in network lifetime) of the original LEACH prol.

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