Journal of Engineering Science and Technology
Vol. 9, No. 2 (2014) 246 - 260
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ENERGY OPTIMIZATION IN CLUSTER BASED WIRELESS SENSOR NETWORKS

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Abstract

Wireless sensor networks (WSN) are made up of sensor nodes which are usually battery-operated devices, and hence energy saving of sensor nodes is a major design issue. To prolong the networks lifetime, minimization of energy consumption should be implemented at all layers of the network protocol stack starting from the physical to the application layer including cross-layer optimization. Optimizing energy consumption is the main concern for designing and planning the operation of the WSN. Clustering technique is one of the methods utilized to extend lifetime of the network by applying data aggregation and balancing energy consumption among sensor nodes of the network. This paper proposed new version of Low Energy Adaptive Clustering Hierarchy (LEACH), protocols called Advanced Optimized Low Energy Adaptive Clustering Hierarchy (AOLEACH), Optimal Deterministic Low Energy Adaptive Clustering Hierarchy (ODLEACH), and Varying Probability Distance Low Energy Adaptive Clustering Hierarchy (VPDL) combination with Shuffled Frog Leap Algorithm (SFLA) that enables selecting best optimal adaptive cluster heads using improved threshold energy distribution compared to LEACH protocol and rotating cluster head position for uniform energy dissipation based on energy levels. The proposed algorithm optimizing the life time of the network by increasing the first node death (FND) time and number of alive nodes, thereby increasing the life time of the network.

Keywords: AOLEACH, ODLEACH, FND, Lifetime, SFLA.

1. Introduction

In recent years there have been a worldwide attention given to the field of wireless sensor network because of the development and advances in Wireless communication, information technologies and electronics field. The concept of

Nomenclatures

d	Distance, m
E_{amp}	Transmit amplifier, pJ/bit/m^2
E_{elec}	Radio dissipates to run the transmitter or receiver circuitry, nJ/bit
G	Set of nodes not been cluster-heads in the last $1/p$
n	Number of nodes
P	Cluster- head probability
$T(n)$	Threshold energy, J

Abbreviations

AOLEACH	Advanced Optimized Low Energy Adaptive Clustering Hierarchy
BS	Base Station
CH	Cluster Head
FND	First Node Death
LEACH	Low Energy Adaptive Clustering Hierarchy
ODLEACH	Optimal Deterministic Low Energy Adaptive Clustering Hierarchy
SFLA	Shuffled Frog Leap Algorithm
VPDL	Varying Probability Distance Low
WSN	Wireless Sensor Network

wireless sensor networks is based on a simple equation: Sensing + CPU + Radio = Thousands of potential applications [1]. Efficient design and implementation of wireless sensor networks has become a hot area of research in recent years, due to the vast potential of sensor networks to enable applications that connect the physical world to the virtual world. At present, most available wireless sensor devices are considerably constrained in terms of computational power, memory, efficiency and communication capabilities due to economic and technology reasons. That is why most of the research on wireless sensor network (WSN) has concentrated on the design of energy and computationally efficient algorithms and protocols, and the application domain has been confined to simple data-oriented monitoring and reporting applications [2]. WSNs nodes are battery powered which are deployed to perform a specific task for a long period of time, even years. If WSN nodes are more powerful or mains-powered devices in the vicinity, it is beneficial to utilize their computation and communication resources for complex algorithms and as gateways to other networks. New network architectures with heterogeneous devices and expected advances in technology are eliminating current limitations and expanding the spectrum of possible applications for WSNs considerably. Clustering, in general is defined as the grouping of similar objects or the process of finding a natural association among some specific objects or data. In sensor networks, clusters are used to transmit processed data to base stations. In cluster-based systems the network nodes are partitioned into several groups. In each group one node becomes the cluster-head and the rest of the nodes act as ordinary nodes. The process of cluster formation consists of two phases, cluster-head election and assignment of nodes to cluster-heads. The cluster-head needs to coordinate all transmissions within the cluster, so also it handles the inter-cluster traffic, delivers the packets destined for the cluster, etc. [3]. Hence these cluster-heads experience high-energy consumption and thereby exhaust their energy resources more quickly than the ordinary nodes.

It is therefore required that the cluster-head's energy consumption be minimized (optimal) thus maximizing the network lifetime**.** The rest of the paper is organized as follows. In Section 2, the current studies on choosing cluster head are briefly reviewed. The new versions of Low Energy Adaptive Clustering Hierarchy (LEACH) called Advanced Optimized Low Energy Adaptive Clustering Hierarchy (AOLEACH), Optimal Deterministic Low Energy Adaptive Clustering Hierarchy (ODLEACH), and Varying Probability Distance Low (VPDL) combine with Shuffled Frog Leap Algorithm (SFLA) are described in detail in Section 3. In Section 4, the experimental results are shown. Finally, a conclusion is given in Section 5.

2. Network and Radio Models

In this paper, it is assumed that a network sensor model with the following properties:

- All sensor nodes are immobile and Fixed base station
- Power varying capabilities of the sensor nodes
- Each node senses the environment and always has the data to send.

Currently, there is a great deal of research in the area of low-energy radios. Different assumptions about the radio characteristics, including energy dissipation in transmit and receive modes, will change the advantages of different protocols. In Fig. 1 simple model is taken where the radio dissipates E_{elec} = 70 nJ/bit to run the transmitter or receiver circuitry and E_{amp} = 120 pJ/bit/m^2 for the transmit amplifier to achieve an acceptable E_b/N_0. These parameters are slightly better than the current state-of-the-art in radio design. Assume an d^2 energy loss due to channel transmission. Thus, transmit a '*k*' bit to a distance '*d*' using first order radio model.

$$E_{tx}(k, d) = E_{elec}\, k + E_{amp}\, k\, d^2 \tag{1}$$

$$E_{rx}(k) = E_{elec}\, k \tag{2}$$

For these parameter values, receiving a message is not a low cost operation; the protocols should thus try to minimize not only the transmit distances but also the number of transmit and receive operations for each message. Assumption is made that the radio channel is symmetric such that the energy required transmitting a message from node A to node B is the same as the energy required transmitting a message from node B to node A for a given SNR.

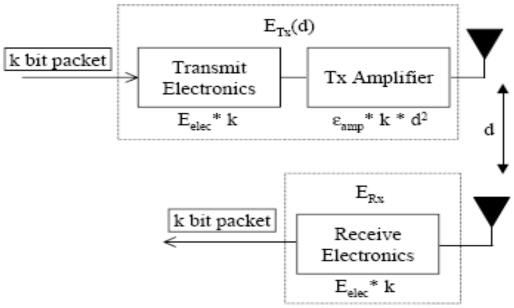

Fig. 1. First Order Radio Model.

2.1. Cluster head selection in low-energy adaptive clustering hierarchy (LEACH)

LEACH is a clustering-based protocol that minimizes energy dissipation in sensor networks. LEACH randomly selects nodes as cluster-heads and performs periodic re-election, so that the high-energy dissipation experienced by the cluster-heads in communicating with Base Station (BS) is spread across all nodes of the network. Each iteration selection of cluster-heads is called a round. The operation of LEACH is broken up into two phases: set-up and steady. Where each round begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase [4, 5]. Since data transfers to the base station dissipate much energy, the nodes take turns with the transmission the cluster-heads "rotate". This rotation of cluster-heads leads to a balanced energy consumption of all nodes and hence to a longer lifetime of the network. LEACH algorithm randomly selects cluster heads and rotates the role to distribute the consumption of energy.

All the data processing such as data fusion and aggregation are local to the cluster. Initially a node decides to be a Cluster Head (CH) with a probability P and broadcasts its decision. Each non-CH node determines its cluster by choosing the CH that can be reached using the least communication energy. The role of being a CH is rotated periodically among the nodes of the cluster in order to balance the load [6]. During the set-up phases, each sensor node chooses a random number between 0 and 1. If this is lower than the threshold for node n, $T(n)$, the sensor node becomes a cluster-head. The threshold $T(n)$ is calculated as

$$T(n) = \begin{cases} \frac{p}{1-p*(r mod \frac{1}{p})} & if\ n \in G \\ 0 & otherwise \end{cases} \tag{3}$$

where $T(n)$ denotes threshold value, n is the number of nodes, p is the cluster-head probability, r is the number of the current Round, and G is the set of nodes not been cluster-heads in the last $1/p$.

During the steady phase, data transmission takes place based on the TDMA schedule and the CH perform data aggregation/fusion through local computation. The BS receives only aggregated data from cluster-heads (CHs), leading to energy conservation. After a certain period of time in the steady phase, CHs are selected again through the set-up phase. Since the decision to change the CH is probabilistic, there is a good chance that a node with very low energy gets selected as a CH. When this node dies, the whole cell becomes dysfunctional. Also, the CH is assumed to have a long communication range so that the data can reach the base-station from the CH directly. Disadvantages of this method are CH selection is randomly, that doesn't take into account present energy state of the nodes.

2.2. Advance leach (ALEACH)

ALEACH algorithm [7] selects a certain number of clusters during each round using distribute algorithm without central intervention. The threshold value depends on the round but does not depend on its current energy which represents its present condition. In ALEACH, improve the threshold equation by introducing two terms: General probability (G_p) and Current State probability (CS_p). The threshold equation of a node for the current round depends on both terms.

$$T(n) = G_P + CS_P \tag{4}$$

$$CS_P = \frac{E_{n\_current}}{E_{n\_max}} \cdot \frac{k}{N} \tag{5}$$

$$G_P = \frac{k}{N - k\left(r \bmod \frac{N}{k}\right)} \tag{6}$$

$$k = Np \tag{7}$$

where p is the cluster-head probability.

If the nodes in a cluster are having different amount of energy at the same time, then the node with the highest energy should be cluster-head to ensure that all nodes die at approximately the same time. This can be achieved by setting the probability as a function of node's current Energy $E_{n\_current}$ relative to the initial energy E_{n_max} in the networks, multiplying by the percentage of cluster (k/N) in the network. Therefore, the final threshold equation becomes

$$T(n) = \frac{p}{1 - p\left(r \bmod \frac{1}{p}\right)} + \frac{E_{n\_current}}{E_{n\_max}} \cdot \frac{k}{N} \tag{8}$$

The cluster-heads in ALEACH act as local control centres to coordinate the data transmissions in their cluster. The cluster-head node sets up a TDMA schedule and transmits this schedule to the nodes in the cluster. This ensures that there are no collisions among data messages and also allows the radio components of each non-cluster-head node to be turned off at all times except during their transmit time, thus minimizing the energy dissipated by the individual sensors. After the TDMA schedule is known by all nodes in the cluster, the set-up phase is complete and the steady-state operation (data transmission) can begin. The cluster-head must be awake to receive all the data from the nodes in the cluster. Once the cluster head receives all the data, it performs data aggregation to enhance the common signal and reduce the uncorrelated noise among the signals. Assuming, perfect correlation, such that all individual signals can be combined into a single representative signal. The resultant data are sent from the cluster-head to the Base Station (BS). Since the BS may be far away and the data messages are large, this is a high energy transmission.

3. Proposed Techniques

The proposed method new version of LEACH protocols called ODLEACH, AOLEACH and VPDL combine with SFLA algorithm in detail.

3.1. Optimal deterministic low energy adaptive clustering hierarchy (ODLEACH)

In LEACH, as cluster heads spend more energy than leaf nodes, it is quite important to reselect cluster heads periodically. If this probability is set high, more nodes will become cluster heads and the rate of energy consumption becomes high; If this probability is low, the size of each cluster becomes larger and the average distance between leaf nodes and their cluster head increases, and the rate of energy consumption in the network also increases since the energy consumption is related to the square of distance from leaf nodes from the cluster. The optimal value of this probability for selecting cluster head is defined by the various electrical parameters and data length and is given by as the optimal value of 'p'. The operation of ODLEACH is almost similar to that of LEACH protocol except in selection of cluster heads in the network. In LEACH the value of probability is random chosen. But in ODLEACH, 'p' is the optimal probability of determining cluster head, determined from optimal CH selection algorithm [8].

$$p = \sqrt{\frac{E_{amp}k_{data}L^2}{M(3E_{elec}k_{inter}+2E_{amp}k_{data}L^2)}} \tag{9}$$

where M is the total number of nodes in a network, E_{elec} is energy consumption for the electrical components during its active mode, E_{amp} is the energy consumption due to amplification, K is the number of bits in a transmission, and L is the size of the network.

The above P substitute in ALEACH final Eq. (8) and get optimal selection of CH. Cluster-heads communicate to the intra cluster nodes and BS similar method as described in ALEACH.

3.2. Advanced optimized low energy adaptive clustering hierarchy (AOLEACH)

AOLEACH forms clusters by using a distributed algorithm. The nodes themselves determine whether they become cluster-heads. A communication with the base station or an arbiter-node is not necessary. The operation of AOLEACH is almost similar to that of LEACH protocol except in selection of cluster heads (CH) are randomly selected on a probability basis. The cluster head determination is crucial in deciding the network life time and thereby residual energy of the network. The proposed AOLEACH algorithm selects certain number of cluster heads in every round without any central intervention. Therefore, apt cluster head determination algorithm should be designed such that nodes are cluster heads approximately the same amount of time, and in a cluster, a node having much energy compared with the other nodes should be cluster head for that round, assuming all nodes start with the same amount of energy. Still improving the threshold for appropriate determination of cluster head, we take into account the Current State Probability term from ALEACH, that if the nodes in a cluster having different amount of energy at the same time, then the node with the highest energy should be cluster-head to ensure that all nodes dies at approximately the same time. Since every sensor node has the same probability 'p'. To become cluster head, the expected number of cluster heads in the network is $k= Np$, Substituting in the threshold equation, we get the AOLEACH threshold equation as

$$T(n) = \frac{p}{1-p\left(r \bmod \frac{1}{p}\right)} * \frac{E_{cur}}{Eo} + \frac{E_{cur}}{Eo} * p \tag{10}$$

But in LEACH, ALEACH the value of probability is random chosen. But in AOLEACH, 'p' is the optimal probability of determining cluster head, determined from optimal CH selection algorithm Eq. (9).

3.3. Varying probability distance low energy adaptive clustering hierarchy (VPDL)

VPDL forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control. The advantages of this approach are that no long-distance communication with the base station is required and distributed cluster formation can be done without knowing the exact location of any of the nodes in the network. In addition, no global communication is needed to set up the clusters and nothing is assumed about the current state of any other node during cluster formation. The operation VPDL is divided into rounds. 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 BS via through their respective cluster-head.

The cluster head determination is crucial in deciding the network life time and thereby residual energy of the network. This proposed VPDL algorithm selects certain number of cluster heads in every round without any central intervention. Therefore, suitable cluster head determination algorithm should be designed such that nodes are cluster heads approximately the same amount of time, and in a cluster, a node having much energy compared with the other nodes should be cluster head for that round, assuming all nodes start with the same amount of energy. It can be seen from Eq. (3) the improved expression of $T(n)$ that the formula directly correlates to the energy of the nodes. If the random number $Random(n)$ is smaller than the threshold $T(n)$ and the distance d_{dist} between the node and the current cluster head is greater than D_d, the node can become a cluster head. With the application of the distance constraint condition, cluster heads can be distributed uniformly in actual limited regions; the improved $T(n)$ can make each node act as a cluster head in more balance, thus utilizing energy in the network effectively and prolonging survival time of the network to a certain extent. Now, still improving the optimal cluster head selection algorithm process, we consider the distance factor as an important metric. Network life time of the network depends on the number of alive nodes of the network. The death of nodes is due to

- Node being selected as a CH comparatively more time than other nodes.
- More energy dissipation due to far position from base station.

Therefore, the proposed algorithm we define nodes present far from base station as advanced nodes and we provide them with an extra amount of energy. Now, in each cluster therefore the nodes present at the corners have more energy levels compared to inner nodes. For equal energy dissipation the nodes in every cluster should be equal probabilistic. Therefore, number of cluster heads of normal nodes must be equal to that of advanced nodes.

Let

$$\mathrm{p_0} \times \mathrm{n_0} = \mathrm{p_a} \times \mathrm{n_a} \tag{11}$$

where $p_0$is the probability of normal nodes of becoming cluster head, p_a is the probability of advanced nodes of becoming cluster head, n_o is the number of normal nodes, and n_a is the number of advanced nodes.

For equal balance of energy dissipation, but $n_o/n_a >> 1$. Since number of normal nodes are greater than advanced node. Therefore, $p_o >> p_a$ and we define two different probabilities of various nodes in the WSN. So, the p value in the threshold function is substituted with p_a or p_o based on the type of node. Therefore, the final threshold equation in choosing the CH is

$$T(n) = \frac{p}{1-p\left(r \bmod \frac{1}{p}\right)} \cdot \frac{E_{cur}}{E_o} + \frac{E_{cur}}{E_o} \cdot p \qquad (11)$$

where $p = p_a$ or p_o.

3.4. Shuffled frog leap algorithm (SFLA)

SFLA forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control [9, 10]. The advantages of this approach are that no long-distance communication with the base station is required and distributed cluster formation can be done without knowing the exact location of any of the nodes in the network. In addition, no global communication is needed to set up the clusters and nothing is assumed about the current state of any other node during cluster formation. The goal is to achieve the global result of forming good clusters out of the nodes, purely via local decisions made autonomously by each node [11-13]. The operation SFLA is divided into rounds. 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 BS via through their respective cluster-head.

In SFLA, there is a population of possible solutions defined by a set of virtual frogs partitioned into different groups which are described as memeplexes, each performing a local search. Within each memeplex, the individual frogs hold ideas, which can be infected by the ideas of other frogs. After a defined number of memetic evolution steps, ideas are passed between memeplexes in a shuffling process. The local search and the shuffling process continue until the defined convergence criteria are satisfied. The SFLA is a heuristic search algorithm [14]. It attempts to balance between a wide scan of a large solution space and also a deep search of promising locations for a global optimum. As such, in the SFLA, the population consists of a set of frogs (solutions) each having the same solution structure. A solution to a given problem is represented in the form of a string called “frog”, consisting of a set of elements, which hold a set of values for the optimization variables.

Figure 2 shows whole population of frogs, which is then partitioned into subsets referred to as memeplexes. The different memeplexes are considered as different cultures of frogs that are located at different places in the solution space (i.e., global search). Each culture of frogs performs a deep local search. Within each memeplex, the individual frogs hold information, that can be influenced by the information of their frogs within their memeplex, and evolve through a process of change of information among frogs from different memeplexes. After defined number of evolution steps, information is passed among memeplexes in a shuffling process .The local search and the shuffling processes (global relocation) continue until a defined convergence criterion is satisfied. As explained, the SFL formulation places emphasis on both global and local search strategies, which is one of its major advantages. SFL algorithm starts with an initial population of “P” frogs created randomly. Frog i is represented as $X_i = (xi_1, xi_2, ..., xi_S)$; where S represents the number of variables. Afterwards, the frogs are sorted in a descending order according to their fitness. Then, the entire population is divided into m memeplexes, each contains n frogs (i.e., $P=m.n$)[15,16].

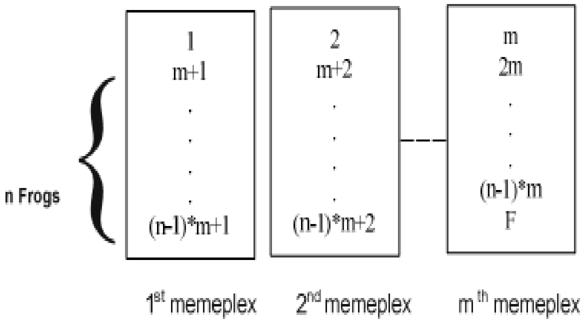

Fig. 2. Memeplex Formation according to Frog Fitness.

In this process, the first frog goes to the first memeplex, the second frog goes to the second memeplex, frog m goes to the *m* memeplex, and frog m+1 goes to the first memeplex, etc. Within each local memeplex, the frogs with the best and the worst fitness are identified as X_b and X_w, respectively. Also, the frog with the global best fitness (the overall best frog) is identified as X_g. Then, an evolutionary process is applied to improve only the frog with the worst fitness (not all frogs) in each cycle. Accordingly, each frog updates its position to catch up with the best frog as follows: Change in frog position (D_i)

$$D_i = \text{rand}() \times (X_b - X_W) \tag{13}$$

New position X_W

$$X_W = \text{current position } X_W + D_i \qquad (D_{max} \geq D_i \geq -D_{max}) \tag{14}$$

where rand() is a random number between 0 and 1 and D_{max} is the maximum allowed change in a frog's position. The proposed algorithm selects certain number of cluster heads in every round without any central intervention. Therefore, apt cluster head determination algorithm should be designed such that nodes are cluster heads approximately the same amount of time, and in a cluster, a node having much energy compared with the other nodes should be cluster head for that round, assuming all nodes start with the same amount of energy. The initial iterations, i.e., for nearly 250 rounds we perform the functioning of CH selection using above threshold equation. After 250 rounds, we optimize the energy by implementing SFLA algorithm. After 250 rounds [11-13] the energy of the nodes are sorted out in descending order and is distributed to various memeplexes (clusters) and local search and shuffling is performed by using Eqs. (13) and (14). The SFLA setup phase and steady-state operation is similar to VPDL setup and steady-state phase operation.

4. Simulation and Results

4.1. Simulation environment

The Hundred WSN nodes are randomly distributed in a spatial region of 100mx100m network area. The simulation is carried for 1500 rounds of operation. The simulation parameters are listed in the Table 1.

Table 1. Simulation Parameters.

Name	Value
Region	100 m×100 m
No. of nodes	100
Nodes sensing range	15 m
Initial Energy per node	0.5 J
Size of a Packet	4096 bits
1 Round (1 TDMA frame)	0.2 s
Location of base station	50, 50
Advanced nodes energy	1 J

In order to analyse the performance of the proposed algorithm, we run the simulation under the MATLAB simulator.

Simulation Metrics

To compare the performance of the proposed algorithm with the prevalent ones we measure the following metrics:

Number of dead nodes: The performance of a network depends on the lifetime of its nodes. If the lifetime of the nodes is high then the network performs well and also transmits more data to the base station.

Energy: The residual energy of the network with respect to number of rounds is analysed. The greater the residual energy of the network, the better is the algorithm.

4.2. Results and analysis

LEACH Approach

Figure 3 shows the initial sensor nodes distribution in LEACH. Advanced nodes are represented by + sign having more energy initially. Base station is in the centre of the area. All the nodes have equal amount of energy of 0.5 J. Figure 4 shows the scenario after 1500 rounds. Dead sensor nodes are shown by red dots and alive one by blue holes. Due to energy consumption of nodes in sensing the environment and CH operation, the nodes energy drains out and goes below the threshold level and dies out. These nodes are dead nodes and cannot be used for transmission.

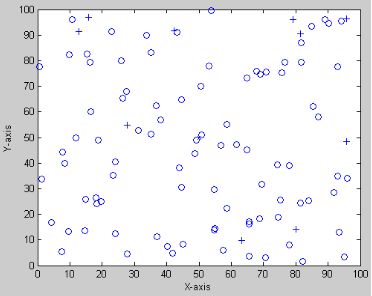

Fig. 3. Initial Scenario of

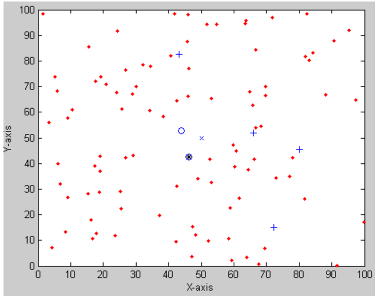

Fig. 4. Scenario after 1500 Rounds.

Figure 5 shows the number of dead sensor nodes after each round. When the sensor nodes transmit the data there energy will be depleted. Figure 6 shows when their residual energy falls below the threshold energy level the node will be considered as the dead node. Thus, after particular rounds the nodes drain out of energy and is plotted for the corresponding rounds.

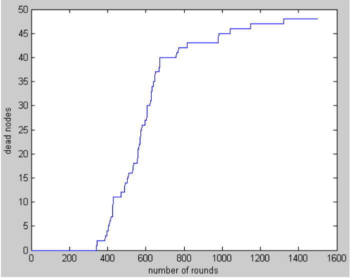

Fig. 5. Number of Dead Sensor Nodes

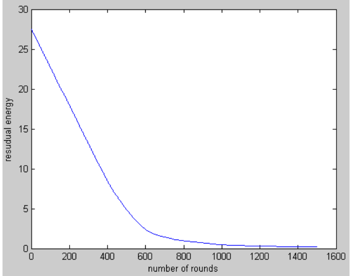

Fig. 6. Total Residual Energy of the Network Nodes.

AOLEACH Approach

Figure 7 when the sensor nodes transmit the data there energy will be depleted. When their residual energy falls below the threshold energy level the node will be considered as the dead node. Thus, after particular rounds the nodes drain out of energy and is plotted for the corresponding rounds. Figure 8 shows the total amount of residual energy left in the sensor nodes of the network.

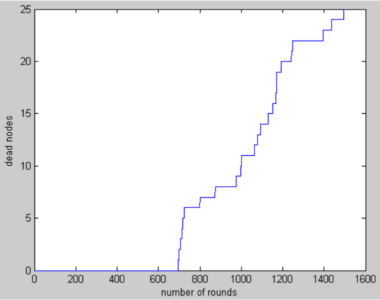

Fig. 7. Number of Dead Nodes.

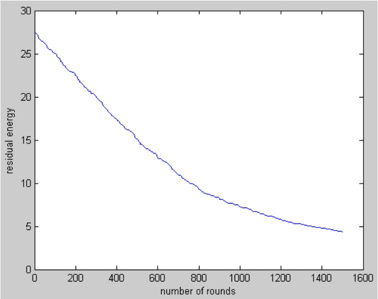

Fig. 8. Total Residual Energy of the Network Nodes.

Figures 9, 11 and 13 shows the energy will be depleted. After particular rounds the nodes drain out their energy and are plotted for the corresponding rounds. Figures 10, 12, and 14 shows the total amount of residual energy left in the sensor nodes of the network.

Figure 15 provides information about SFLA with VPDL number of dead nodes, while Fig. 16 provides the information about total residual energy of the SFLA with VPDL WSN network nodes.

VPDL Approach

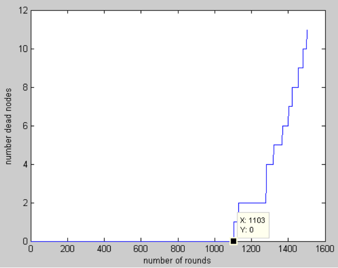

Fig. 9. Number of Dead Nodes.

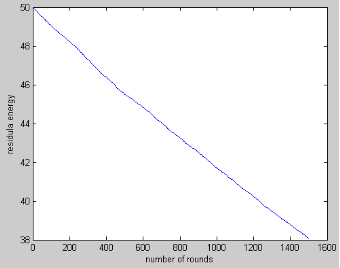

Fig. 10. Total Residual Energy of the Network Nodes.

SFLA with AOLEACH Approach

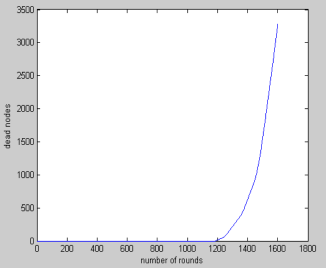

Fig. 11. Number of Dead Nodes.

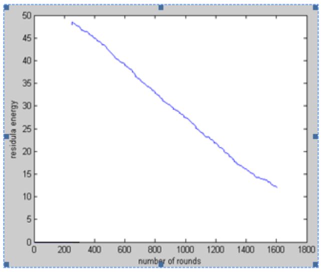

Fig. 12. Total Residual Energy of the Network Nodes.

SFLA with ODLEACH

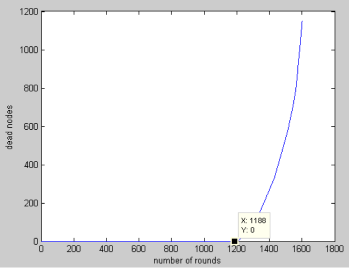

Fig. 13. Number of Dead Nodes.

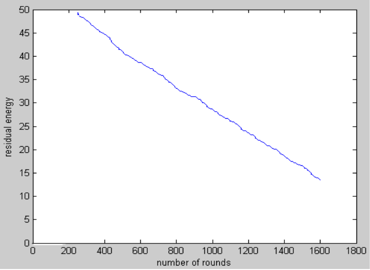

Fig. 14. Total Residual Energy of the Network Nodes.

SFLA with VPDL

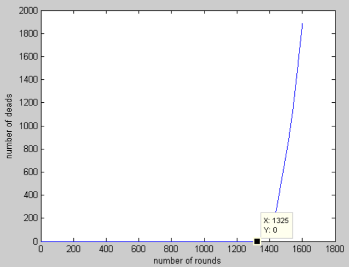

Fig. 15. Number of Dead Nodes.

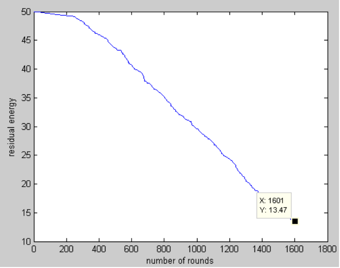

Fig. 16. Total Residual Energy of the Network Nodes.

The comparisons in Table 2, bar comparison Figs. 17 and 18 give the proposed SFLA combine with VPDL technique in wireless sensor networks is the best energy efficient protocol compared to LEACH and other improvements of LEACH protocol. Proposed algorithm increases the time first node drains out of energy (FND). Therefore, the time for the first node increases and thereby number of alive nodes for respective rounds is increased, also increasing the residual energy of the network. SFLA increases the alive nodes number by implementing the local search and shuffling process of the nodes.

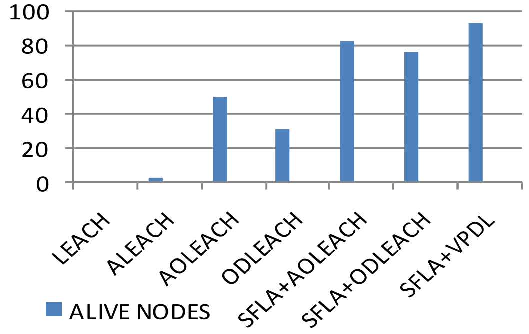

Fig. 17. Alive Nodes Comparison of Various Protocols.

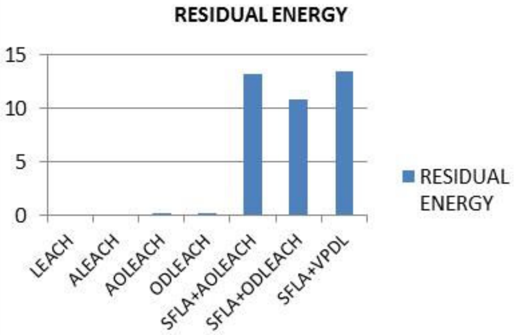

Fig. 18. Residual Energy Comparison of Various Protocols.

Table 2. Comparison of Results.

Protocol	FND	Number of alive nodes (After 1500 rounds)	Residual energy (After 1500 rounds)
LEACH	361	0	0.011
ALEACH	430	2	0.020
AOLEACH	730	50	0.235
ODLEACH	400	31	0.201
VPDL	1031	88	37.26
SFLA WITH AO LEACH	1130	82	13.2
SFLA WITH OD LEACH	858	76	10.8
VPDL with SFLA	1325	93	13.47

Initial energy = 0.5 J per normal node, 1 J per advanced node, rounds=1500

5. Conclusions

LEACH protocol is an effective cluster based protocol deployed in wireless sensor networks. However, the LEACH protocols CH selection is stochastic and the current state energy of the nodes is not included. But in ALEACH protocol current state energy of the nodes is taken into account with random probability. The proposed protocols consider the current state probability and optimal probability for selecting the CH, so energy will be optimized. This paper proposed AOLEACH, ODLEACH, and VPDL combination with Shuffled Frog Leap Algorithm (SFLA) that enables selecting best optimal adaptive cluster heads using improved threshold energy distribution compared to LEACH protocol and rotating cluster head position for uniform energy dissipation based on energy levels. The proposed algorithm results show that optimizing the life time of the network by increasing the first node death (FND) time, residual energy and number of alive nodes, thereby increasing the life time of the network compare to LEACH and ALEACH Protocols.

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