A Modified Approach of I-LEACH Algorithm for Cluster-h Head Selection in Wireless Sensor Networks

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Although Wireless Microsensor Networks have been widely employed for numerous security related applications, the lifespan of microsensor nodes and energy efficiency have always been a challenge. LEACH protocol has proved to be a milestone in this field by providing the methodology of forming clusters of sensor nodes in the network. Moreover, each cluster has a cluster head (CH) node which needs to be selected strategically for desirable network performance. This paper presents a variant of the LEACH protocol for CH selection by using an optimization technique called the Simulated Raindrop algorithm that ameliorates the lifespan of microsensor nodes, throughput and energy efficacy in the network. The CH nodes are well-dispersed in the network to reduce the energy loss of microsensor nodes for data transmission as well as reception and successful data packet delivery to base station. The results are analyzed and compared to LEACH-C, LEACH-GA and I-LEACH protocol on the basis of network lifetime, throughput and remaining energy in the network have surpassed them.

Keywords: LEACH; LEACH-C; LEACH-GA; I-LEACH; Simulated Raindrop algorithm; Wireless microsensor networks; cluster head; throughput.

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1 Introduction

Wireless sensor network (WSN) is one of the most explored fields of computer science due to its vast applicability. It is a collection of sensor nodes deployed over a region to gather information about the events taking place in that environment or surroundings. The applicability of WSN ranges from security-based military applications [11] to usual applications for gathering data related to physical parameters of the area like temperature, pressure, sounds and many more. Sensors are capable of working remotely and do not have any physical connections with each other within the network. Each sensor works independently to collect data from its surroundings. Sensors have gone through enormous enhancements, which results into the invention of microsensors. Microsensors also perform the same functions as that of sensors, but they differ in terms of cost and applicability. Microsensors have low cost, more exploitation of IC technology, wider applicability to sensor arrays and lesser weight. But the design of network varies according to the application for which it is being used.

One of the benchmark set up in the field of WSN is LEACH protocol [4], that form clusters of the sensor nodes deployed in the network. This protocol was put forward with the ambition of data transmission at lower costs, in terms of energy dissipation and latency. Here, each cluster of sensor node has a CH sensor node which aggregates the data transmitted by sensor nodes in their respective cluster. This aggregated data is further sent to base station in the network. A number of LEACH variants are presented that ameliorates network performance in numerous ways. LEACH protocol is modified on the basis of three wider fields, namely, cluster formation, CH selection and data transmission. These fields can be further divided into many categories which forms the basis for variations. The variant of LEACH, i.e. LEACH-C [6] protocol make use of optimization method Simulated Annealing [1] for forming clusters and selecting CH for each cluster formed in the network. In this paper, we proposed a new method for CH selection which makes use of an optimization technique called Simulated Raindrop Algorithm [21].

Optimization is the term used in computer science, which means to select the best and most appropriate solution for a problem from given set of possible solutions. Most of the optimization techniques are bio-inspired [16]. Simulated Raindrop is a single solution based [10] global optimization technique which utilizes the concept of the raindrops falling on the land to find optimal solution from a set of available possible solutions. Initially, Simulated Raindrop algorithm picks a random candidate solution from a defined set of possible solutions. The best solution is determined from the given set of possible solutions in a number of successive iterations. According to natural phenomenon, a raindrop fallen on land tries to reach the lowest point of the terrain which is optimal solution. The same procedure is followed in this algorithm to achieve the best solution for a problem. In Simulated Raindrop algorithm, the terrain is represented by the objective function, the flow of raindrop from a higher point in terrain to the lower point is represented by the local search among the raindrop splashes and the lowest point in that terrain is represented as the optimal solution [21]. Simulated Raindrop algorithm for optimization claims to provide better results compared to the Simulated Annealing Algorithm which is used in the Centralized LEACH [6] protocol.

The remaining paper is organised as follows: Section 2 discusses the previous work in this field, Section 3 elaborates the proposed technique for CH selection using Simulated Raindrop algorithm and implementation of proposed protocol, Section 4 explains the energy model used for implementing proposed protocol, and Section 5 presents simulation and results of the work which is followed by Conclusion and Future work in section 6.

2 Related Work

A number of LEACH variants are proposed which tend to provide better results, which provided different concepts on chain-based procedure [8], deterministic CH selection [7], centralized [23], distributed [23], semi-distributed [15], heterogeneous networks [17] or homogeneous networks, mobility, security [17], cluster radius fixation [18] and many more.

LEACH-C (Centralised Low Energy Adaptive Clustering Hierarchy) is a protocol architecture developed by Wendi Heinzelman, Anantha Chandrakasan and Hari Balakrishnan in 2002 [6]. It is an improved version of LEACH protocol architecture. It is application specific protocol architecture for Wireless Microsensor networks. [12] It is quite similar to LEACH and the variation occurs in the set-up phase to form clusters.

The major difference between LEACH and LEACH-C protocol architecture is the method used for forming clusters. In LEACH, distributed algorithm is used for this purpose while LEACH-C makes use of simulated annealing algorithm. This central clustering technique gives better results due to formation of better clusters and CH nodes are dispersed throughout the network. Moreover, in LEACH there is no guarantee of the placement or number of CHs in the network. CHs may be close to each other, which limits the quality of the results. LEACH-C also performs its functions in the set of rounds, like LEACH. Each round contains two phases, namely, set- up phase and steady-state phase.

In the set up phase of LEACH-C, each node needs to transmit information about their location to the BS of the network. The information about the location of node is determined by using Global positioning system (GPS) receiver in each round. Next step is to form the clusters of these nodes, which is referred to as a NP-hard problem. The most reliable method of solving NP-hard problems is to use approximation algorithms to determine optimal solution of the problem in polynomial time [5]. The simulated annealing algorithm [1] is used, which is based on the principle of thermodynamics. This algorithm will form clusters by determining whether a node will belong to the current cluster being formed or not. This algorithm makes use of probabilistic functions to determine the optimal result for NP-hard problem. The first step is to ensure that all the nodes in the network have approximate equal energy. In case, any node have lesser energy than the average it cannot be the CH in the present round. Now simulated annealing algorithm will determine the best possible CHs in the network and then associates them to their respective clusters. CHs are selected such that they are dispersed in the network and the nodes in the cluster are too close to them. Thus, the squared distance between CHs and sensor nodes is kept minimum which also results in the lesser energy consumption of the non CH nodes to transmit collected data to the CHs. The information regarding CH nodes and clusters is broadcast to all the nodes by the BS using a message consisting of the CH ID. Each node checks this ID and compares with their own ID to check whether it is CH. Each CH node sends a signal of same strength to all other nodes using CSMA MAC [3] protocol, so that sensor nodes can join suitable cluster whose CH node is least distant. All non CH nodes determine their TDMA schedule to transmit data to CH and goes to the sleep state to prevent unnecessary loss of energy.

The steady-state phase of LEACH-C is identical to that of LEACH protocol. All the nodes in the network sense their environment and record various events taking place. The nodes transmit collected data to associated CH in the assigned TDMA slot. After receiving the data, the CH evaluates it and determine the required information which is to be sent to the BS by compressing into a single signal. This prevents unnecessary traffic in the network as only few nodes have to send data to the BS.

I-LEACH [19] is used to improve network performance and energy consumption of the nodes in WSN. It takes into account the various features of sensor node for selecting it as a CH, namely, distance to BS, energy, location and number of neighbours of the sensor node. This algorithm works under the three phases. First, CH node selection phase takes into account the various factors like residual energy, position and neighbours of sensor nodes for selecting the CH in the network. Second, Cluster formation phase checks the distance between CH node and the BS as well as the distance between CH nodes and the other sensor nodes in the network. Third, Data transmission phase is responsible for the data transmission from sensor nodes to their respective CH nodes in the network. These CH nodes integrate the data and further transmit it to the base station.

LEACH-GA [14] makes use of optimization based Genetic Algorithm [2] for CH selection in the network. It starts with an additional preparation phase with commencement of rounds. Further, every round contains two phases, namely, set-up phase and steady-state phase. Initially, each node in the network evaluates itself to be possible CH node or not by performing a CH selection process defined in this protocol. The node sends the respective message to the BS along with node ID and location details. The BS than performs an optimization to evaluate probability of node to become CH by Genetic Algorithm method. It aims to reduce energy consumption of SNs via this process. The BS in return broadcast an advertisement message to all the nodes [22] along with their probability so that they can form the clusters. The other two phases are performed in the same way as that in LEACH protocol.

3 Proposed Routing Protocol

The location of CH nodes is one of the major issues in LEACH protocol which needs to be solved. LEACH-C protocol makes use of Simulated Annealing algorithm for this purpose. Recently, a new optimization technique called Simulated Raindrop Algorithm is proposed provides better optimization in comparison to the Simulated Annealing algorithm. This technique can be used in collaboration with the LEACH protocol architecture. Simulated Raindrop algorithm can be used to find optimized location for CH nodes to improve their lifetime and lesser energy consumption. This may help to determine ideal location for the CH nodes based on their distance and residual energy of the node. This technique may provide better results as compared to the LEACH in terms of lifetime of the network.

We have put forward a new application of Simulated Raindrop Algorithm for CH selection, to improve the network performance and energy efficiency.

3.1 CH selection based Simulated Raindrop Algorithm

Initially, CH nodes in the network are selected randomly. It is assumed that all the sensor nodes in the network act as possible solutions for becoming the CH node. So, present CH node act as raindrop and its neighbouring nodes act as splashes from which some nodes are selected and are referred to as splash nodes. Number of splash nodes (N_s) is computed using Equation 1.

$$N_s = \lfloor \frac{Number of nodes \in problem area}{a} \rfloor + b \qquad (1)$$

Where a and b are control parameters and problem area is evaluated by Equation 5.

The location of CH node is taken as s_{min} and s_{max} be the position of farthest node among the set of sensor nodes. Firstly, few random nodes (s_i) are selected between s_{min} and s_{max} as mentioned in Equation 2 provided its energy is non-zero and act as splashes, so they are called splash node.

$$s_i = rand(s_{min}, s_{max}) \qquad (2)$$

Calculate the value of p(i) for each splash node, that is, probability of splash node to become CH node using Equation 8. The splash node with highest probability is compared to the probability of existing CH node, select it as candidate CH node. Otherwise new splash nodes are generated until all the sensor nodes in the given area are checked. Assuming this node as raindrop, the value of s_{min} is updated by position of s_i using Equation 3 and a new sensor node from the set is selected and its probability is compared to that of s_i. This process continues in successive iterations until all active nodes in the given area are evaluated.

$$s_i = rand\left(\frac{s_{min}}{iCount}, \frac{s_{max}}{iCount}\right) \quad (3)$$

Where iCount is the difference between non-improving and improving moves [21] and its value varies as shown in Equation 4.

$$iCount = \{iCount + +ifsolutionimprovediCount - -otherwise \quad (4)$$

This way, Simulated Raindrop algorithm can be used to determine the optimal CH nodes in the network, which will ultimately result into prolonged network lifetime, improved throughput and energy efficiency.

3.2 Implementation

The implementation of proposed protocol is split into two phases, namely, setup phase and steady state phase. Setup phase includes CH selection and cluster formation in the network whereas steady state phase deals with network transmission.

(i) Setup phase: Once the network is deployed by providing random positions to the sensor nodes, CH nodes are selected randomly and clusters are formed in the network according to LEACH [4]. Then, by taking CH node as centre radius R_{CH} is calculated using Equation 5 and number of sensor nodes present within this radius are figured out to calculate number of splash nodes in cluster based Simulated Raindrop algorithm.

$$R_{CH} = \sqrt{\quad} \quad (5)$$

Where M*M is the area of the network, k is the optimal number of clusters which is calculated as mentioned in Equation 6.

$$k = \left(\sqrt{\quad}\right) \quad (6)$$

Where N is the number of sensor nodes in the network and d_o and $d_{to\ BS}$ are determined using Equation 7.

$$do = \sqrt{\quad} \quad \text{and} \quad d_{BS} = 0.765\left(\frac{M}{2}\right) \quad (7)$$

R_{CH} is considered as the problem area for applying cluster based Simulated Raindrop Algorithm mentioned in Section 3.1 and optimal CH node is selected from a cluster.

The probability of a sensor node to become CH node is determined using Equation 8, which takes into account the residual energy of the node, average distance of node from other nodes in the cluster and its position in the network with respect to base station.

$$p(i) = \frac{D_i*a+v_i*b+E_r*c}{\sum_{i=0}^{n} D_i*a+v_i*b+E_r*c} \quad (8)$$

Where p(i) is the probability of node i to become candidate CH node, Di is the average distance of sensor node from other nodes in network, vi is the distance between sensor node and base station, E_r is the residual energy of the node and a,b,c are the control parameters.

This value of p(i) is used to determine the threshold function using Equation 9 which is further compared to the random value generated by candidate CH nodes within the range [0,1]. If this randomly generated value is less than or equal to T(n), then the particular sensor node is selected as CH node.

$$T(n) = \frac{p(i)}{1-p(i)} \qquad (10)$$

Once the CH nodes are elected, clusters are formed in the network, by determining the closest CH node for each sensor node and joining its cluster.

(ii)Steady state phase: This phase performs inter-cluster as well as intra-cluster data transmission in the same way as performed in LEACH. Data transmission takes place from sensor nodes to the CH node. CH node aggregates the received data and transmits it further to the base station in the network. The energy of sensor nodes dissipates while transmitting and receiving the data packets. We have followed single hop [9] data transmission method.

4 Energy model

The proposed protocol is evaluated using the first order radio model. Transmitter energy gets consumed up for running radio electronics as well as power amplifier whereas Receiver energy get dissipated only for running the radio electronics. Moreover, channel model (that is, either free space model or multipath fading) to be used for data packet transmission depends upon the distance between transmitting and the receiving sensor node as mentioned in Equation 10. Multipath propagation occurs because of the presence of physical objects that lead signals to be reflected and scattered [20]. The amount of energy dissipated for receiving data packet is illustrated in Equation 11.

$$Et = \{kEtx + kE_{fs}d^2 kEtx + kE_{mp}d^4 d < d_0 d \geq d_0 \qquad (10)$$

$$Er = kErx \qquad (11)$$

Where Et is the total energy consumed while transmitting data packet, Etx is the transmitter energy, k is the data packet size, d_o is calculated as mentioned in Equation 7, Er is the total energy consumed for receiving data packet of size k bits, Erx is the receiver energy. If $d<d_o$, then free-space model is used. Otherwise, multipath fading model is used.

5 Simulation and Results

To evaluate the performance of the proposed protocol, MATLAB simulator is used. The parameters are setup as mentioned in Table 1. The probability to become CH node for each sensor node is 0.1, which means only 10% of sensor nodes in the network can become CH nodes in a round. These values of parameters are analyzed in [13].

Table 1. Parameters used for radio model

Parameters	**Value**
No. of nodes	100
Area	100*100
Initial Energy of nodes	0.5J
Transmitter Electronics (Etx)	50nJ/bit
Receiver Electronics (Erx)	50nJ/bit
Free space (E_{fs})	10pJ/bit/m2
Multipath Fading (E_{mp})	0.0013pJ/bit/m2
Data Aggregation Energy (E_{DA})	5nJ/bit
Cluster head Probability	0.1
Data Packet size	4000 bits
Location of BS	(100,100)

The results of the proposed protocol are compared to LEACH-C, LEACH-GA and I-LEACH protocol, in terms of network lifetime, throughput and remaining energy in the network with respect to rounds and results are presented in the graphs.

The numbers of alive nodes in the network with respect to the rounds for all the four protocols are compared in Figure 1. The proposed protocol LEACH-SRD gives the best results due to the use of an effective optimization technique for selection of CH nodes in the network. I-LEACH provides better network lifetime than both LEACH-GA and LEACH-C. Figure 3 represents the successful delivery of the data packets to the base station for all the four variants of LEACH. It improves due to optimal location of the CH nodes in the network. Figure 4 shows the remaining energy in the network with respect to the rounds. The order of performance again remains the same in case of energy consumption.

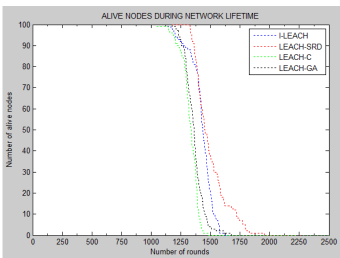

Fig. 1: Comparison of number of alive nodes in the network with respect to rounds

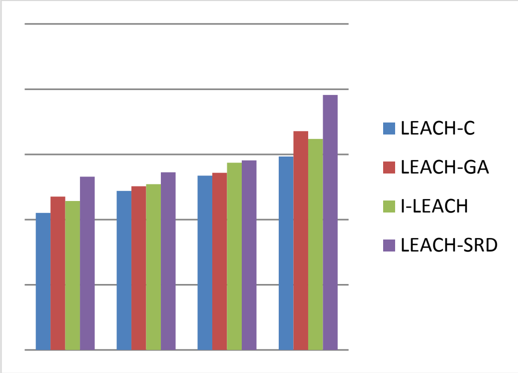

Fig. 2:.Network lifetime: Comparison of rounds when first node dies, 10% nodes die, half nodes die and last node dies

Table 2 makes comparison of the network lifetime at four points, that are, when first node dies, 10% nodes die in the network, 50% nodes die and all the nodes die in the network.

Table 2. Comparison of network lifetime

Protocol	**Count of round when**			
	First node dies	10% nodes dies	Half nodes Dies	Last node dies
LEACH-C	1050	1220	1336	1483
LEACH-GA	1176	1256	1358	1677
I-LEACH	1142	1271	1435	1619
LEACH-SRD	1329	1362	1453	1956

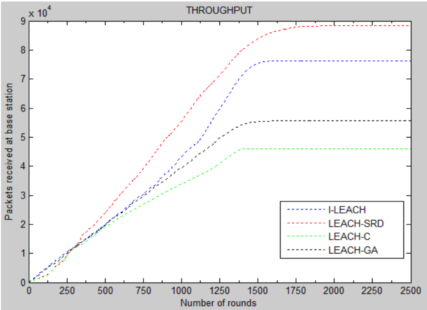

Fig. 3: Comparison of number of packets received successfully at the Base station

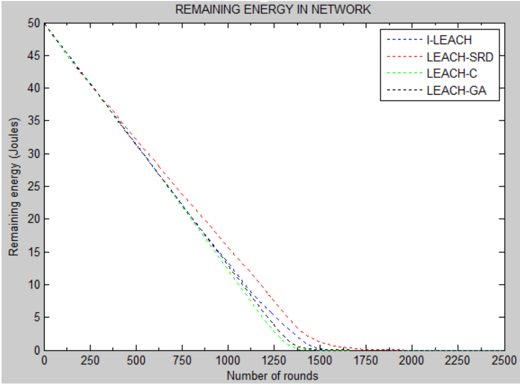

Fig. 4: Comparison of energy consumption among the protocols

6 Conclusion and future work

LEACH-SRD performed better than former LEACH variants. The results have proved that the proposed protocol not only improved network lifetime and stability period, but also successful delivery of data packets to base station and prevents the loss of data. The network lifetime improved by 29% and throughput by 16% in comparison to I-LEACH. The performance of LEACH-SRD improves with increasing number of rounds and does not deteriorate as seen in former variants. It also proved to be better in terms of energy consumption in the network due to optimal location of CH nodes that ensure consumption of lesser energy for data transmission either from sensor nodes to CH node or CH node to base station in the deployed network.

Simulated Raindrop Algorithm is a single solution based meta-heuristic, which can be updated to population based optimization technique. This further upgradation of algorithm when applied to get a LEACH protocol, may provide much better results.

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