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HYBRID APPROACH FOR OPTIMAL CLUSTER HEAD SELECTION IN WSN USING LEACH AND MONKEY SEARCH ALGORITHMS

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Abstract

Wireless Sensor Networks (WSNs) are being widely used with low-cost, low-power, multifunction sensors based on the development of wireless communication, which has enabled a wide variety of new applications. In WSN, the main concern is that it contains a limited power battery and is constrained in energy consumption hence energy and lifetime are of paramount importance. To achieve high energy efficiency and prolong network lifetime in WSNs, clustering techniques have been widely adopted. The proposed algorithm is hybridization of well-known Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm with a distinctive Monkey Search (MS) algorithm, which is an optimization algorithm used for optimal cluster head selection. The proposed hybrid algorithm exhibit high throughput, residual energy and improved lifetime. Comparison of the proposed hybrid algorithm is made with the well-known cluster-based protocols for WSNs, namely, LEACH and monkey search algorithm, individually.

Keywords: Wireless sensor networks, Clustering, LEACH, Monkey search algorithm, Hybrid algorithm.

1. Introduction

With the recent advancements in Wireless Sensor Networks (WSNs) it has been possible to create networks of various sizes that helped to develop numerous applications. In these systems, the sensor nodes organize themselves into a wireless network. Each node is having sensors and is battery operated [1 - 5]. The data from the nodes is to be transmitted to the Base Station (BS). But sending the data from each node to the base station can be a dreadful task as it leads to energy

Nomenclatures

D	Distance, m
E_{amp}	Transmit amplifier
E_{elec}	Radio dissipates to run the transmitter or receiver circuitry, nJ/bit
G	Set of nodes not been cluster-heads in the last $1/p$
I_n	distances from sensor nodes to cluster head
I_S	sum of the distances from all cluster heads to target node
N	Number of nodes
P	Cluster- head probability
S_i	Number of cluster heads
$T(n)$	Threshold energy, J

Abbreviations

BS	Base Station
CH	Cluster Head
CM	Cluster Member
EECS	Energy Efficient Clustering Scheme
EEDUC	Energy-Efficient Distributed Unequal Clustering
FLOC	Fast Local Clustering Service
HSA	Harmony Search Algorithm
HEED	Hybrid Energy Efficient Distributed
LEACH	Low Energy Adaptive Clustering Hierarchy
MS	Monkey Search
PEGASIS	Power- Efficient Gathering in Sensor Information Systems
PSO	Particle Swarm Optimization
SA	Simulated Annealing
TEEN	Threshold Sensitive Energy Efficient Sensor Network
WSN	Wireless Sensor Network

drain in sensor nodes. Instead of sending the data from the individual node, clustering is carried out by sending the data to a collection of nodes called as cluster heads, which then transmits it to the base station [6 - 9]. These cluster heads act as coordinators and they decide which node should send the data to them so that they can send it to base station effectively. These contribute to the overall system scalability, lifetime and energy efficiency [10 - 13].

The formation of clustering in nodes is based on energy based switching. Here, the energy of the current cluster head (CH) has been compared with the other nodes in the cluster. If the energy of a node is more than the current CH, then this node will be considered as new cluster head of this cluster. For example, in MS algorithm, such selection of cluster head is similar to the MS mechanism where the monkey changes their location when attracted towards best food source. After the node with higher energy is selected as new CH, clustering is repeated and the process continues till the maximum round.

As in Low-Energy Adaptive Clustering Hierarchy (LEACH) Algorithm [14], the role of cluster head is changing periodically in a probabilistic manner, which ensures that all nodes will lose energy and run out of battery at the same time. But this method has the disadvantage that it does not account the residual energy of the node, hence the node having lower residual energy is equally likely to be cluster head as the node with higher residual energy. Hence, a new algorithm called Monkey Search algorithm is used, which uses fitness function for optimum selection of cluster head that might result in better lifetime and efficiency. A new method is proposed which is the hybrid of LEACH and Monkey Search algorithm which minimizes the energy consumption and improves the lifetime of the network even more.

The remainder of the paper is organized as follows: Section II gives an overview of related works in past. Section III contains some of the preliminary work. Section IV describes the proposed algorithm. Section V gives the simulation results and their analysis. Finally the paper is concluded in section VI.

2. Related Works

In literature, there has been a number of clustering protocols proposed for wireless sensor networks. LEACH [14] has been the most well-known algorithms that forms nodes based on received signal strength and random probabilistic distribution, Power- Efficient Gathering in Sensor Information Systems (PEGASIS) [15] is an enhancement over LEACH protocol. In this each node communicates only with the closest neighbour by adjusting its power signal to be only heard by this closest neighbour, Hybrid Energy Efficient Distributed (HEED) protocol is the clustering protocol. It uses residual energy as primary parameter and network topology features (e.g. node degree, distances to neighbours) are used as secondary parameters to break tie between candidate cluster heads, as a metric for cluster selection to achieve load balancing [16-18].

The Energy-Efficient Distributed Unequal Clustering (EEDUC) algorithm provides a new way of creating distributed clusters. Here, each sensor node sets the waiting time. This waiting time is considered as a function of residual energy, number of neighborhood nodes. It uses waiting time to distribute cluster heads and Fast Local Clustering Service (FLOC) produces non-overlapping and approximately equal-sized clusters. The clustering is carried out in such a way that all nodes within unit distance of a cluster-head belong to its cluster, and the node with *m* units away from the cluster-head may belong to its cluster.

Energy Efficient Clustering Scheme (EECS) is an improved clustering algorithm than LEACH that suits the periodical data gathering applications. Here, the network is partitioned into several clusters and communication between the CH and the base station is performed. In EECS, CH candidates compete for the ability to elevate to CH for a given round. This competition involves candidates broadcasting their residual energy to neighbouring candidates. If a given node does not find a node with more residual energy, it becomes a CH. Different from LEACH for cluster formation; EECS extends LEACH by dynamic sizing of clusters based on cluster distance from the base station.

In Threshold Sensitive Energy Efficient Sensor Network (TEEN) [19], a CH sends its members a hard threshold and a soft threshold. Thus the hard threshold tries to reduce data communications by allowing the nodes to transmit only when the sensed attribute is in the range of interest. The soft threshold further reduces data communications might have otherwise occurred when there is little or no change in the sensed attribute. At the expense of increased energy consumption, a smaller value of the soft threshold generates more accurate information of the network, thus users can control the trade-off between energy efficiency and data accuracy by the parameters adjustment. Moreover, the soft threshold can be varied and the users can change the fresh parameters as required at every cluster change time.

In [20-22], the energy efficient for optimal selection of cluster head using various hybrid meta-heuristic algorithms is discussed. For meta-heuristic algorithms to be efficient, it has to be able to cover the solution space where the global optimum may lie and also generate new, improved solutions [23]. Also, the meta-heuristic algorithm must be able to escape the local optimum. On the other hand, there are meta-heuristic algorithms like Particle Swarm Optimization (PSO) and Cuckoo Search which aim at global optimization (exploration). Alternatively, there are algorithms like Simulated Annealing (SA) and Harmony Search Algorithm (HSA) which get confined in the local optima (exploitation). Exploration is the ability to test various regions in the problem space in order to locate a good optimum, hopefully the global one [22, 24-31]. Exploitation is the ability to concentrate the search around a promising candidate solution in order to locate the optimum precisely.

3. Protocols Description

3.1. Leach protocol

LEACH is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensors in the network [14].The operation of LEACH is broken up into rounds, namely, set-up phase in first round, when the clusters are organized, second is steady-state phase, where data transfers to the base station as the clusters are being created. Each node decides whether or not to become a cluster-head for the current round based on the percentage of cluster heads for the network and the number of times the node has been a cluster-head so far. Here we choose a random number between 0 and 1 for every node n. If the number is less than a threshold 'T(n)', the node becomes a cluster-head for the current round.

The threshold is set as:

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

where p is the desired percentage of cluster head, r is the current round, G is the set of nodes that has 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. After each node has decided to which cluster it belongs, it informs the cluster-head node that it will be a member of the cluster. Now, data transmission from cluster heads to base station happens. Assuming nodes always have data to send, they send it during their allocated transmission time to the cluster head. Every transmission uses a minimal amount of energy calculated using first order radio energy model. When the transmission is going on for that time each non-cluster-head node can be turned off until the node's allocated transmission time, thus minimizing energy dissipation in these nodes.

3.2. Monkey search algorithm

This algorithm is inspired by the tree climbing process of monkeys. It is a meta-heuristic approach for global optimization [20, 22] invented by Mucherino and Seref in 2008. It is based on how monkeys climb the trees in their search for food. Here it is assumed that monkey can survive in a jungle full of trees because it can remember on which tree the quality of food is best. The main assumption in this approach is that a monkey is able to survive in a jungle of trees because it is able to remember which tree has the most food when it climbed the same tree before. It marks the same and remembers it for future reference when it needs food again. Although, during the initially stage it may not have any knowledge about the quality of food available, it chooses randomly any tree and from then on starts marking the food sources. The main components of the algorithm are Representation of Solution, Fitness Function, Initialization, Exploring, Climb Process, Watch-Jump Process and Termination. We use this behaviour of monkey for clustering process. Here the nodes having residual energy higher than the average level are eligible to be a cluster head candidate for the current round. Monkey Search is used to find optimal cluster heads for '*k*' packet length, the fitness function in [20] is used to compute the optimum, as shown below:

$$\text{Fitness} = (w\times (D-I) + (1-w) \times (N- Si)) / 100, \quad I = In + Is \tag{2}$$

where, D is the total distance of all nodes to the target node, N is the total number of nodes, w is a weight defined previously, I_n gives the distances from sensor nodes to cluster head, I_S gives the sum of the distances from all cluster heads to target node and S_i is the number of cluster heads. After the creation of cluster, the non-cluster head nodes send data to cluster heads which in turn send it to the base station [21]. The process of selecting clusters is repeated every round of exchanging data among sensor nodes. During the transmission process from the sensor nodes to CH residual energy of each node is taken care of as it assists the BS to select the best cluster head and cluster at the next round. This is done based on the fitness function above. Fitness function is the representation of Monkey climbing process in WSN terms.

Network Model: The following assumptions are made in the presented work:

- BS is fixed and is located outside the region in which sensor nodes are distributed.
- All sensor nodes are having the same energy initially i.e. homogenous and are energy constrained.
- All links are symmetric.
- Each node is assigned a unique identifier.
- For energy analysis, first order radio model is used.
- The nodes always have data to send to the BS and nodes located close to each other have correlated data.

First order radio model

First order radio model [20] is used for energy analysis of nodes. Here, during every round, each node tends to lose its energy. As shown in Fig. 1, a simple first order model is assumed 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. It also assumes a d^2 energy loss due to channel transmission. Thus to transmit a k-bit message a distance d using our radio model, the radio expends:

$$E_{TX}(k,d) = E_{elec} \times k + E_{amp} \times k \times d^2 \tag{3}$$

and to receive this message, the radio expends:

$$E_{RX}(k) = E_{elec} \times k \tag{4}$$

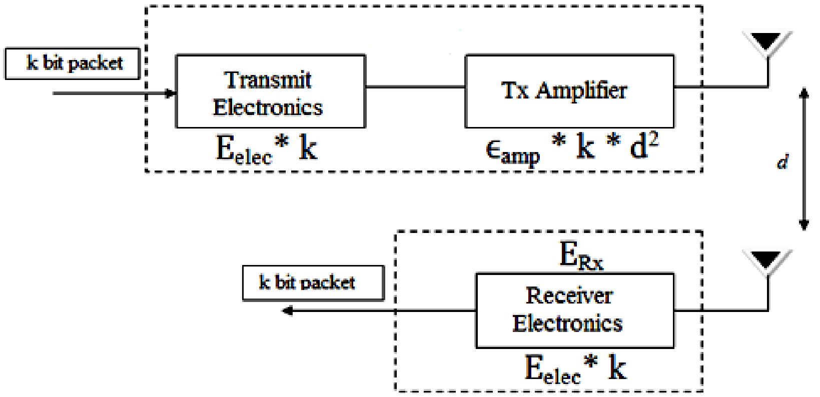

Fig. 1. Schematic of first order radio model [2].

3.3. Proposed algorithm

Proposed algorithm is Hybrid of LEACH and Monkey Search Algorithm. The proposed scheme is based on the common characteristics of both LEACH and MS algorithms. From the simulation results it was noticed that LEACH algorithm performs better in the initial stages of the process as it had a higher value of first node death but MS algorithm performs better overall as it gives optimal cluster head selection. Hence, in the hybrid scheme, LEACH algorithm runs initially for few duration, which is followed by MS algorithm for the remaining duration so that lifetime of network is improved. The time for which each algorithm should be run was determined by repeated simulations so that optimum time should be determined. The advantage of this method is that it has delayed First node death capability of LEACH algorithm and improved lifetime and throughput capability using optimal cluster head selection of MS algorithm. Hence this algorithm gives the best results in terms of lifetime, throughput and residual energy. The flowchart of the proposed hybrid algorithm is shown in Fig. 2.

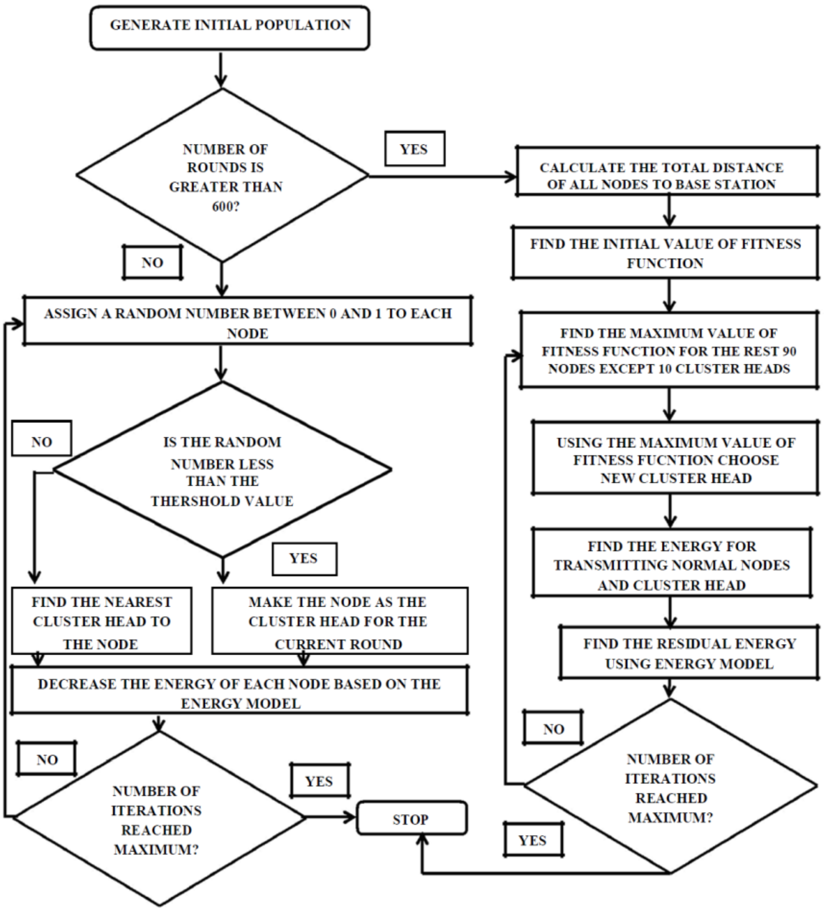

Fig. 2. Flowchart of the proposed hybrid algorithm.

4. Simulation Results

In this section the performance of the network is measured on the following metrics: Residual energy of the network, Number of Nodes alive, Number of Dead nodes and Throughput of the network. The simulation is done for 100 nodes spread over and area of 100×100 m^2, the base station is located at the position (50,150). The initial energy to every node is assigned as 0.5 J. Every node transmits a 2048 bit message. The probability to be a cluster head is taken as 0.1.

In Fig. 3, it can be seen that hybrid scheme designed using LEACH and MS algorithm is performing best for energy optimization in clustered WSN. The reason for this Hybrid algorithm performing much better than other algorithms is that it combines the searching capability of MS with the power of LEACH to delay the first node death. As shown in Fig.4, it is clear that the number of nodes alive is highest in hybrid scheme when compared to all other algorithms LEACH and Monkey Search. This implicates the lifetime of the network is increased as long as more number of the nodes are alive. Alive nodes directly indicate the lifespan of network. Thus maximum lifetime is achieved in the Hybrid scheme.

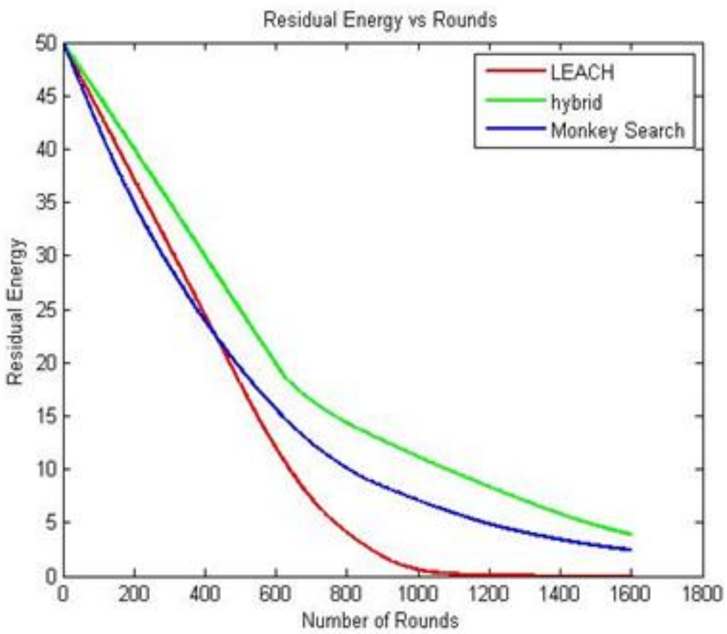

Fig. 3. Residual energy vs. number of rounds.

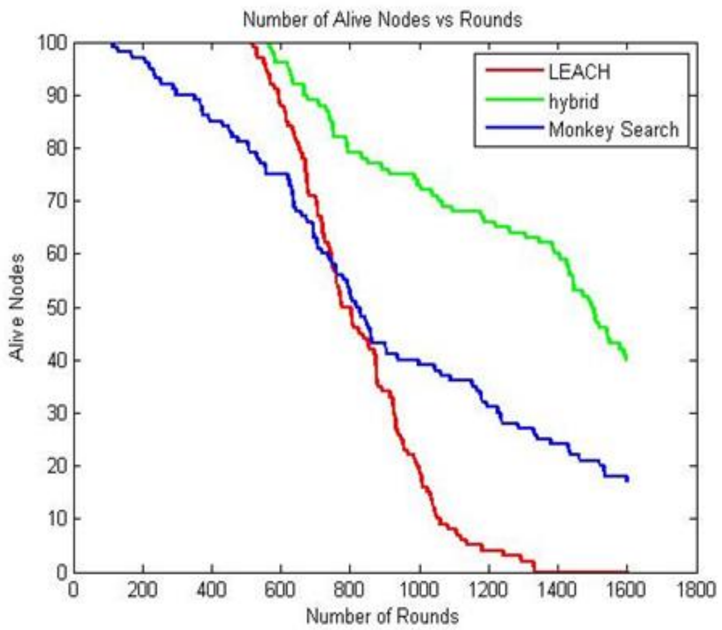

Fig. 4. Alive nodes versus number of rounds.

As shown in Fig. 5, the number of dead nodes is minimum in hybrid scheme and maximum in residual energy based scheme. Number of dead nodes is inversely proportional to lifetime of the network hence dead nodes should be minimum for the lifetime of the network to be high. Hence, hybrid scheme gives the highest lifetime and is preferred. As shown in Fig. 6, it is clearly visible that the throughput of the network is highest in the case of hybrid scheme designed using hybrid algorithm majorly due to the combination of best possible features from both algorithms. The reason is the throughput is directly proportional to the number of alive nodes.

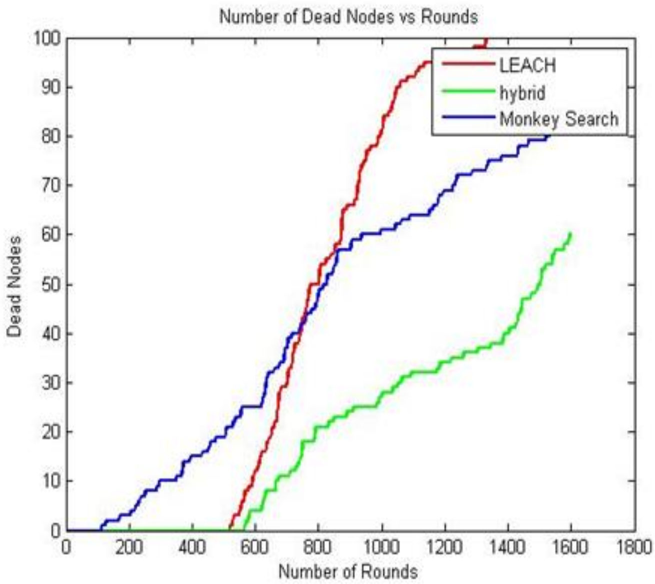

Fig. 5. Dead nodes versus number of round.

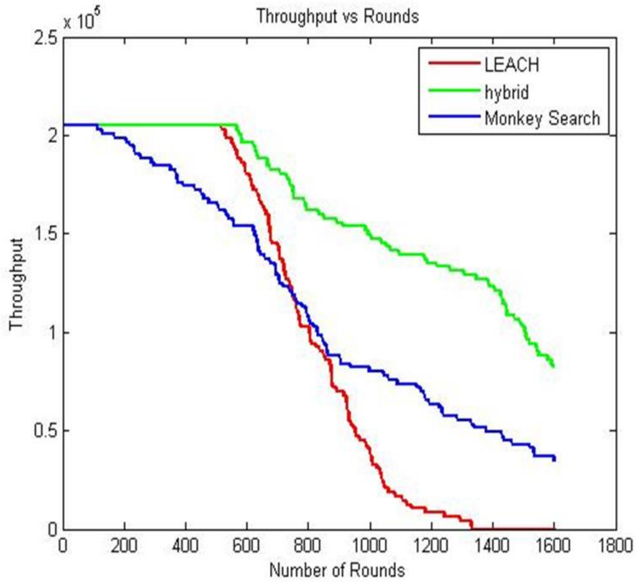

Fig. 6. Throughput versus number of rounds.

The comparison is made among the algorithms on the basis of first node death, residual energy, and number of alive nodes and throughput of the network. From Table 1 it can be seen that number of dead nodes is minimum with improved residual energy and throughput for the proposed hybrid algorithm. Hence, the hybrid algorithm is most preferred for clustering in wireless sensor networks.

Table 1. Comparison of the proposed and existing algorithms.

Algorithms	First Node Death(Rounds)	Number of Dead Nodes(Rounds)	Residual Energy (J)	Throughput (bits/round)
LEACH	463	97	0.0408	6144
Monkey Search	82	78	2.1794	45056
Hybrid	531	32	5.8551	139264

5. Conclusion and Future Work

In this paper, cluster head algorithms such as LEACH, Monkey Search Algorithm (MS) and proposed hybrid scheme designed using LEACH and MS has been analyzed and implemented for energy optimization in WSN. The simulation results display that the proposed hybrid algorithm can give more lifetime of the node and achieve higher throughput than other well-known algorithms. In future, other bio-inspired algorithms like K-Means, ant colony optimization, artificial immune system, and genetic algorithm can also be combined to design an energy efficient hybrid scheme. As each algorithm has its own advantage and disadvantage, they are combined to design an energy efficient hybrid protocol.

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