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Hybrid Approach for Energy Optimization in Wireless Sensor Networks

P.Leela , K.Yogitha
M.E - Network Engineering, Arunai Engineering College, Tiruvannamalai, Tamilnadu, India
Assistant professor of ECE Department, Arunai Engineering College, Tiruvannamalai, Tamilnadu, India

ABSTRACT: In wireless sensor network the main issue is power consumption and lifetime of network. This can be achieved by selection of proper cluster heads in a cluster based protocol. In cluster based networks, the selection of cluster heads and its members is an essential process which affects energy consumption. A hybrid clustering approach is proposes to minimize the energy of the network so the life time of WSN can be increase. The cluster based firefly and ABC algorithm are implemented for energy optimization. Then by combining the concept of both algorithm forms a hybrid algorithm. Using this hybrid algorithm the energy of network can be saved and hence the life of network increased.Performance and analysis results approve that the proposed hybrid algorithm presents promising solutions on WSN routings.

KEYWORDS: Wireless sensor networks, Cluster based routing, Artificial Bee Colony algorithm, Firefly Algorithm

I. INTRODUCTION

Wireless sensor network(WSN) have gained world-wide attention in recent years due to the advances made in wireless communication, information technologies and electronics field.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's why most of the research on WSNs has concentrated on the design of energy and computationally efficient algorithms and protocols. Wireless sensor networks consist of a number of sensor nodes. Sensor nodes are powered only by irreplaceable batteries with limited energy. Processor of sensor nodes has limited processing power and communication channels used for them are in low bandwidths. By considering these limitations of sensor nodes, efficient techniques are required for reliable communications. Not only the good communication is required but also the network life time should be long as much as possible in the applications of wireless sensor networks.

II. FIRST ORDER RADIO MODEL

Currently there is a great deal of research in the area of low energy radios. Different assumptions about the .radio characteristics [5], including energy dissipation in transmit and receive modes, will change the advantages of different protocols. In this work, it assume a simple model where the radio dissipates E_{elec}= 70 nJ/bit to run the transmitter or receiver circuitry and ϵ_{amp} = 120 $pJ/bit/m^2$ for the transmit amplifier to achieve an acceptable E_b/N_0 (See Figure 2.1 and table 2.1). These parameters are slightly better than the current state-of-the-art in radio design. It also assumes an r^2 energy loss due to channel transmission.Thus to transmit a k-bit message, a distance d using our radio model, the radio expends:

$$E_{Tx}(k,d) = E_{Tx\text{-}elec}(k) + E_{Tx\text{-}amp}(k,d)$$

$$E_{Tx}(k,d) = E_{elec} * k + \epsilon_{amp} * k * d^2 \quad (1)$$

And to receive this message, the radio expands:

$$E_{Rx}(k) = E_{Rx\text{-}elec}(k)$$

$E_{Rx}(k) = E_{elec}*k$

For these parameter values,receiving a message is not a low cost operation;the protocol thus should try to minimize not only thetransmit distances but also the number of transmit and receive operations for each message.

Table 2.1 Radio characteristics

Operation	Energy dissipated
Transmitter Electronics ($E_{Tx-elec}$) Receiver Electronics ($E_{Rx-elec}$) ($E_{Tx-elec} = E_{Rx-elec} = E_{elec}$)	70 nJ/bit
Transmit Amplifier(ϵ_{amp})	120 pJ/bit/ m^2

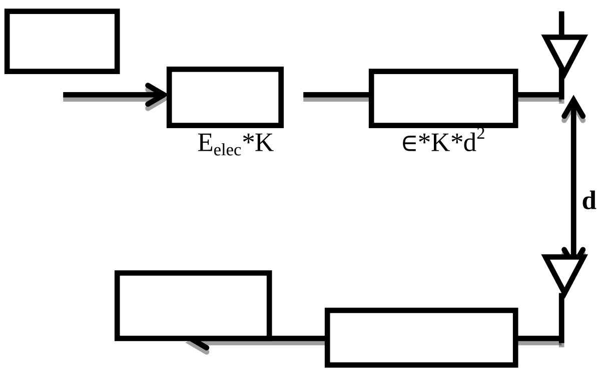

Fig.2.1. First order radio model

This paper makes the assumption that the radio channel is symmetric such that the energy required to transmit a message from node A to node B is the same as the energy required to transmit a message from node B to node A for a given SNR. It also assumes that all sensors are sensing the environment at a fixed rate and thus always have data to send to the end user. For future versions of these protocols, it will implement an "event-driven" simulation, where sensors only transmit data for some event occurs in the environment.

III. RELATED WORK

A. Direct Communication

In wireless sensor network the most conventional approach for data communication was direct transmission protocol [3]. In direct transmission approach all the nodes sends data directly to base station. There are no intermediate nodes for data reception, data aggregation and then sending data to the base station. So if the base station is very far away from the sensor nodes then it will require more energy to send data to the base station (because d will be more in equation 1). This large amount of energy consumption will cause early die of battery and hence reduces the system lifetime.

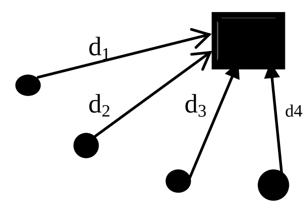

Fig.3.1. Direct communication

Energy is proportional to the square of the distance in transmitting according to first order radio model:

$$E_{Tx} \propto d^2 \qquad (2)$$

B.LEACH Protocol

LEACH (Low energy Adaptive clustering hierarchy) is a cluster based protocol. It uses randomization to distribute energy load evenly among the sensors in the network[3]. In LEACH, the nodes arrange themselves into local clusters where one nodes in each cluster behaves as cluster head or local base station [5,6]. In this approach all the nodes in the clusters sends data only to their respective cluster head and these cluster head collects data from their member nodes, aggregates data and then sends these data to the base station which is far away from the sensor network.

Being cluster head drains the battery of that node, this is because according to the first order radio model in each round cluster head gets data from their member nodes which causes dissipation of energy while receiving data(E_{Rx})and also these cluster head have to send data to the base station which is very far away from the network in each round causes more energy dissipation because greater value of d in equation 1. So LEACH introduces the concept of randomization rotation of cluster head position so that energy consumption of particular nodes

(CHs) will reduces and the system life time increases significantly. This concept will not drain the battery of single nodes earlier.

Sensor nodes find themselves as cluster heads in given round depends on the cluster probability. So cluster head selection in LEACH is probabilistic which is depends on the following equation:

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

Where T(n) denotes threshold value, n – no. of nodes

P denotes clustering probability

R denotes current round

G is the set of nodes that have not been cluster head in the last $\frac{1}{p}$ rounds.

Based on this threshold value few nodes will be selected as cluster head. After formation of cluster all member nodes send data to the cluster head and cluster head gets data, aggregates data and send these data to the base station which is far away from the sensor network.

C.Firefly Algorithm

Firefly algorithm is a nature inspired algorithm means inspired from the social behavior of fireflies that how they use their flashing light characteristics for the communication among each other. The flashing light can be formulated in such a way that it is associated with the objective function to be optimized, which makes it possible to formulate new optimization algorithms [1, 2].

For describing the firefly algorithms we can use these three idealized rule: (i). All fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex. (ii). other feature of fireflies is to glow brighter and brighter to attract potential prey and share food with other fireflies and these brightness is determined by the objective function. (iii). Attractiveness is proportional to their brightness so fireflies which are less bright will move towards the more brighter fireflies. Attractiveness and brightness of fireflies will decreases as the distance increases. But if there is no brighter fireflies than a particular fireflies then that fireflies will move randomly in the environment. Based on these three idealized rules pseudo code of fireflies algorithm is generated.

D.Artificial Bee Colony (ABC) algorithm

Artificial bee colony algorithm is a swarm-based artificial intelligence algorithm which is inspired by intelligent foraging behavior of honey bees [9, 10]. In the ABC algorithm, there are three bee groups: onlookers, scouts, and employed bees where each bee represents a position in the search space. When the network consists of n cluster-head sensors, the bees fly in the search space with n dimensions. The ABC employs a population of bees to find the cluster-heads. The position of a food source represents a possible solution to the optimization problem and the nectar amount of a food source corresponds to the quality (fitness) of the associated solution.

Fitness function for ABC:

The fitness of cluster heads selection is stated as a fitness value, which is in inverse proportion to the amount of energy consumption for a tour. Energy consumption is calculated by multiplying transmitting power (Ps) and the transfer time (t) using equations (4) and (5).In the equations, m is the number of nodes, i is the node index, d_i is the distance between i^{th} node and clusterhead, b is the distance between cluster-head and the base, and E is the transfer energy of the cluster. Considering multiple clusters, the calculation of minimum energy consumption emphasizing the effect of distances will be as in Eq. (6) expressing sum of the energy consumptions of clusters. In the equation, j is the cluster index, d_{ij} is the distance between i^{th} node and j^{th} cluster-head, and b_j is the distance between j^{th} cluster-head and the base.

$$E = \sum_i^m (P_i^s)\ .\ t \geq \alpha\ .(\sum_i^m d_i^2 + b^2).t \quad (4)$$

$$E \geq w.\sum_i^m d_i^2 + b^2 \quad (5)$$

Since there are multiple clusters, so the calculation of minimum energy consumption is emphasizing the effect of distances.

$$\sum_{j=1}^n E \geq w.\sum_j^n (\sum_i^{mj} d_{ij}^2 + b_j^2) \quad (6)$$

According to these considerations, fitness function (f^{dist}) is expressed by Eq. (7) (simply inverse of the energy consumption) and the constraints given in Eq. (8).

$$f^{CWA} = f^{dist} = \left[w.\sum_j^n (\sum_i^{mj} d_{ij}^2 + b_j^2)\right]^{-1} \quad (7)$$

$$E_j \geq \left(m_{j.\ E^{RX}} + E^{TX}\right) \quad (8)$$

IV PROPOSED HYBRID ALGORITHM

In wireless sensor network all the sensors have limited energy. So our main objective is to implement such algorithm for which the lifetime of the network increases significantly. This paper implements hybrid approach for increasing the lifetime of the network. Here proposed hybrid approach will take the advantage of firefly and ABC algorithm to improve the lifetime of the network. Here in cluster head selection we introduces a concept through which if a cluster head current energy is greater than the energy required for cluster head in that round then only that node will be eligible for cluster head otherwise that node will not be cluster head in that round. Here the steps of proposed hybrid algorithm:

Step 1: Initialization

Initially provide all the constant value which is used in the matlab code. i.e., network area, base station location, number of nodes in the network, initial energy provided to each nodes, data aggregation energy required in each round, transmitter and receiver electronics (E_{elec}) and transmitter amplifier (ϵ_{amp}), number of rounds (R_{max}), clustering probability and number of bits transferred (Kb).

Step 2: Generation of sensor network

Now network will be generated with the given number of nodes. Each node gets their position based on the random location generated by **rand** command.

Step 3: round begins

In this step we first initialize the value of dead is equal to zero and then check the energy of each node, if energy of node is equal to zero then we increment dead value by one. Then randomly generate the total number of clusters and CH based on the given probability value and save the result in a structure. After formation of cluster find the distance of each node with each CH and join the cluster in which cluster head is nearest than other CH. Then find whether first node is dead or not if first node dead then go to step 5 else go to step 4.

Step 4: Energy based switching

Now in this step first initialize the value of optimization round. Now compare the energy of the current CH with the other nodes in the cluster, if the energy of the node is more than the CH then that node will be eligible for the CH means location of cluster head changed as like firefly change their location if attracted towards more brighter firefly. After becoming new CH again clustering done, and comparison process runs till the given optimization round value in that current round.

While comparing if the energy of the CH is more than the node then the CH will not be changed in that optimization round. Now go to step 6

Step 5: Random selection of cluster head

Here we randomly select cluster head in each optimization iteration based on the given clustering probability and get the fitness value. Here we are not doing energy based switching for getting cluster head; cluster head selection is random in this step.

Step 6: Fitness value calculation

Now we find the fitness value in that optimization rounds for that the clusters.

$$CH\ (k).fit=\frac{CH(k).E}{M(k)} \quad (9)$$

Where CH(k).fit gives the fitness value and CH(k).E gives the energy of the current CH whereas M(k) is given as the sum of square of distances of all the nodes with their corresponding CH in addition with distance of CH with the base-station.

Step 7: Getting best CHs

Now in this step we first store the fitness value for the clusters of previous optimization round along with the fitness value for the clusters of the current optimization round. After storing the values get the fitness values in descending order and choose top k cluster-head for the further process and this step goes on and finally we will get the best possible set of CHs.

Step 8: Ratio calculation

Here after getting the best cluster head we need to find the ratio of the current energy of that cluster head to the energy required for a cluster head for thetransmitting and receiving process in that round. If the ratio is more than one or present energy is more than energy required then that nodes are eligible for cluster head and further process continues otherwise that nodes are not eligible for cluster head and go back to step 4 for further getting best cluster head.

Step 9: Energy consumption

After getting best possible CHs, all the nodes starts sending data to their respective CHs. Cluster-head collects these data and aggregate these data and sends it to the Base-station. All nodes update their energy and then algorithm goes back for the next round. Energy consumption is calculated as:
For transmitting data

$$E_{T\text{-}x}=E_{elec}*Kb + \in_{amp} *d^2 *Kb \qquad (10)$$

Where Kb is the number of bits sent and d is the distance between CH and node. For receiving data

$$E_{R\text{-}x}=E_{elec}*Kb \quad (11)$$

V.RESULTS AND ANALYSIS

In designing the wireless sensor network in all the protocols, the following assumptions are made

- The destination i.e., base station is located far away from the sensing field.
- Sensors and the base station are all stationary after deployment.
- Every node in the field has the initial energy of 0.5Jouls.
- All nodes are homogeneous and each node is assigned an unique identifier.
- All links are symmetric.

Rmax(no. of rounds taken)= 1200.Evaluation is made based on the following three metrics: Number of nodes alive, Residual energy of the network , Throughput of the network

Graphical analysis**:**

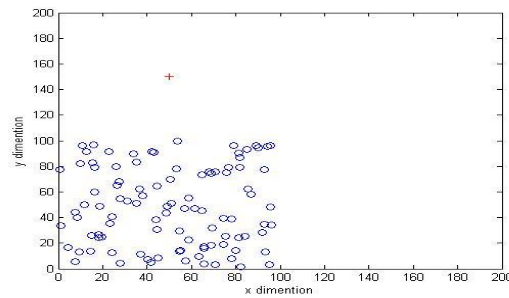

Fig.51. Sensor network

Fig.5.1 shows the random distribution of the 100 nodes in the given sensing area. Nodes are randomly distributed in the given 100*100 network whereas base station is placed at (50,150) location.

Alive nodes comparison

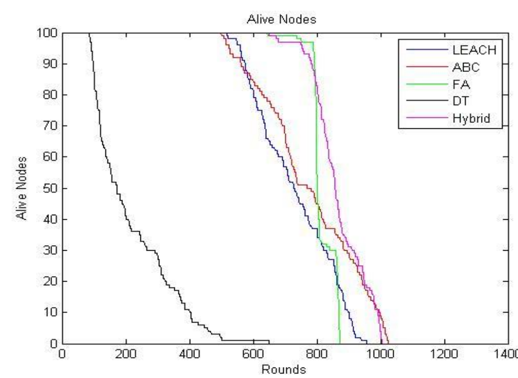

Fig.5.1 Alive nodes comparison

Fig.5.1shows the comparison of alive nodes of hybrid algorithm along with all the conventional algorithms. From the above fig. one can conclude that more number of nodes alive for longer duration in the case of hybrid algorithm. So hybrid algorithm is better than all the algorithms discussed here increases the lifetime of the network.

VI CONCLUSION

This paper discusses the proposed hybrid algorithm with algorithms like Leach, ABC and firefly. Now with taking advantages of ABC and Firefly algorithm along with adding one more parameter i.e., the ratio of Energy required in current round to the energy available to the CHs in that round should be greater than one, then only that node will be eligible for the Cluster-head, with such concepts Hybrid Algorithm proposed. This hybrid approach increased the life-time of the network. First node dies slightly later than firefly in hybrid. Hybrid algorithm also sends more bits of data than any other algorithms because more number of nodes alive in the case of hybrid algorithm for longer duration.

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