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ENERGY EFFICIENT CLUSTER FORMATION IN WIRELESS SENSOR NETWORKS BASED ON MULTI OBJECTIVE BAT ALGORITHM

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ABSTRACT

The most challenging task in the design of wireless sensor networks (WSN) is increasing the lifetime of sensor nodes. The most crucial factor to increase the lifetime of wireless sensor networks is to reduce the energy consumption. In this paper, a Multi Objective Bat algorithm is used to find the optimal cluster formation and routing model in wireless sensor networks. The proposed Energy Efficient Multi Objective Bat algorithm (EEMOB) optimizes the energy consumption in wireless sensor networks by selecting the best fittest node as cluster head and modeling of the communication distance by Bat's loudness parameter. The proposed method outperforms the LEACH clustering protocol. It also extends the lifetime of sensor networks and achieves good reliability. The experimental results show that this scheme achieves considerable improvement in accuracy and convergence when compared to LEACH.

Keywords: ***Wireless Sensor Networks, Multi Objective Bat Algorithm, Energy Aware, Cluster Formation.***

I INTRODUCTION

Wireless sensor network (WSN) is a spatially distributed, homogenous, self organized autonomous sensor to monitor the physical or environmental conditions such as pressure, temperature, humidity etc [1]. The most challenging tasks in WSN are network lifetime, coverage ratio, power consumption, storage capabilities [2]. The

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crucial challenge in the deployment of WSN is to preserve the energy with maximum allowable coverage. Furthermore the research community has been paid much attention in grouping of sensor nodes into clusters and to select leader for every cluster known as cluster-head (CH). Till now, many clustering algorithms for ad-hoc networks[3] have been proposed with a main objective to care about node reachability, generate stable clusters, route stability etc. but they have not provided much concern about design goals of WSN such as network lifetime, coverage.

In this paper, we propose an Energy aware multi objective Bat algorithm for cluster head selection and to increase the lifetime and coverage in WSN among participating nodes. The nodes inside the cluster can only send the data to the nearest cluster head thus reducing the communication cost. CH is identified by the sensor nodes that are richer in resources. The main objective of CH is to increase the network scalability, localize the route set up and reduce the size of routing table [4]. The scheduling activities inside the cluster are done by CH and it will also limit the scope of bandwidth consumption, inter cluster interaction to cluster heads etc. Sensors are arranged in round robin fashion and the time for transmission and reception of packets is determined so that redundant transmission can be avoided and collision of packets can be preserved. CH spends more energy while communicating with the sink node and rotation of CH in each node is determined by election process.

In this paper, a multi objective bat algorithm is used that can be applied to both equal and unequal clustering. Furthermore, it minimizes the communication distance, maximizes the energy, coverage and network lifetime.

II LEACH PROTOCOL

One of the mostly used clustering and routing protocol for WSN is Low Energy Adaptive Clustering Hierarchial Protocol. LEACH divides the network into number of clusters and optimally selects the cluster head thereby proving its efficiency. These cluster heads are selected based on the nodes having higher residual energy. The other nodes join to the cluster based on minimum distance to the cluster head. Each CH directly communicates with base station. This protocol operates in two phases; the first phase is “setup phase” in which clusters are formed and cluster head is selected based on CSMA advertisement messages. The second phase is “steady phase” in which the data packets are transferred from CH to base station. LEACH undergoes a number of rounds. Let us consider the percentage of CH selected will be “S” , and T(k) be the threshold value. If number of CH is less than T(k), then sensor k becomes CH of current round. The T(k) is given by

$$T(k) = \begin{cases} \frac{S}{1 - S * (c \bmod \frac{1}{S})} & k \in p \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

where p is the set of nodes, S is the desired percentage of CH, c is current round number.

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2.1 Disadvantages of LEACH Protocol

Although LEACH protocol increases the network lifetime, it still has some disadvantages. The three main disadvantages are discussed here:

1. In this protocol, CHs are selected randomly so there may be a possibility of two or more CHs formed close to each other. If more number of CHs are selected in a small area, huge amount of energy will be lost and it is proportional to the number of CHs present in that area. CH communicates with base station in a single hop count which causes LEACH protocol not applicable to large scale WSN.

2. The LEACH protocol gives homogeneous distribution of nodes, which is not very realistic since some scenario needs random deployment of nodes in the cluster.

3. The LEACH restricts the selection of CH that was not previously selected in the 1/S rounds. This causes the high energy nodes to lose their potential chances to select as cluster head.

III BAT SWARM ALGORITHM

In 2010, Yang proposed a bat algorithm based on Swarm intelligence known as Bat Swarm Optimization (BSO) algorithm. It can be applied to non linear global optimization problems. The basic idea behind this is inspired from bat's natural behavior. Bats have a well defined echolocation system that is used for identifying the bat's prey, avoiding obstacles and sense the distance in darkness. It emits a sound called echolocation and waits for reply back from the surrounding objects. The steps involved in the BSO are as follows:

Step 1: Initialization

Initialize the generation counter c=1

Initialize the population of n bats as p

Define the loudness ai , pulse rate R

Set the initial velocities V(j=1,2,..n)

Set the pulse rate as R

Step 2: Determine the location of bats and update the velocities

Until termination criteria satisfied, generate new solutions by adjusting the frequency

Update the velocities, locations

Step 3: Rank the bats and find the current Xc*=c=1;

Step 4: Post processing and result visualization.

Let us consider jth bat moves randomly with fixed frequency f and with velocity vj.The movement of virtual bat is simulated by the following equations:

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$$fj = fmin + (fmin - fmax) * \alpha \quad (2)$$

$$v_j^c = v_j^c - 1 + (X_j^c - X^*) \quad (3)$$

$$X_j^c = X_j^{c-1} + v_j^c \quad (4)$$

where α is the random vector drawn from uniform distribution α∈[0,1], X* is the current best solution, it is located after comparing all the location among all bats and fj is the frequency drawn from[0,1]. The local search to identify the current location is given by

$$X_{new} = X_{old} + \Delta a^c \quad (5)$$

Where Δ is the random number ∈[-1,1] and a^c is the loudness at this step. When a bat identifies its prey it will increases its pulse emission rate and decrease its loudness. It is expressed mathematically as follows:

$$a_j^{c+1} = \beta a_j^c \quad (6)$$

$$R_j^{c+1} = R_j^0[1-\exp(-\gamma c)] \quad (7)$$

$$a_j^c \rightarrow 0 \text{ and } R_j^c \rightarrow 0 \text{ as } t \rightarrow \infty \quad (8)$$

β is a constant factor and γ is also a constant factor where γ>0.

IV ENERGY EFFICIENT MULTIOBJECTIVE BAT ALGORITHM

The idea behind the multi objective bat algorithm is to increase the coverage ratio and minimize the energy consumption for both nodes and CH. In this model all nodes are elected as CH depending on the confidence level of the node. The efficiency of the proposed model depends upon the nodes sensing range. The cluster formation depends upon the distance between the nodes and it should be less than bat's sensing range. The cluster head is nominated as the best when it consumes minimum energy, has minimum distance as well as effectively met the threshold of sensing range. The multi objective function either has to minimize or maximize the objective function given by Minimize or Maximize F(x)=(F_1(x),…., F_k(x)). The two main objective functions of the proposed model are as follows:

Maximize the total coverage of sensor network, F_1

Minimize the amount of energy consumed, F_2

Objective 1: F_1(x)=max(coverage)

If the sensor node lies within the sensing range of the cluster, then the coverage probability will be 1 else it will be zero. The Euclidean distance is used to calculate the distance between CH and sensor node. It is given by

$$D = \sqrt{(x1 - x2)^2 + (y1 - y2)^2} \quad (9)$$

where x and y are coordinates of node j. Coverage area of network in the sensor network is identified by the union of sensing areas. It can be expressed as follows:

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$$C(x,y)=\begin{cases}1, \text{if } D \leq R\\ 0, \text{if } D \geq R\end{cases} \quad (10)$$

where C(x,y) is the coverage, D is the Euclidean distance and R is the sensing range. The first objective of maximum coverage is called by following expression:

$$F_1(x)=\max\left(\frac{k(j=1,2,..n)}{a}Aj\right) \quad (11)$$

where Aj is the area covered by j th cluster head node, n is the total number of nodes and a is the WSN area.

Objective 2: $F_2(x)$=max(Residual energy)

This is based on first order radio frequency energy model [5]. It is divided into two parts,

Initialize all the nodes based on first order radio energy model.

The messages with l bits are transmitted from the node at a distance d1 hence the energy consumed is given by E_t(l,d1) calculated based on first order energy model.

Let us consider the first order radio model dissipates energy as E, E_{aml} is the total energy needed for amplifier, $E_{tl}(l)$ is the running energy for transmitter circuitry, $E_{tamp}(l)$ is the transmitter amplifier energy. The energy can be mathematically expressed as follows:

$$E_t(l,d1)= E_{tl}(l)+ E_{tamp}(l, d1) \quad (12)$$

$$E_t(l,d1)=\begin{cases}E * l + E_{amlf} * l * d1^2\\ E * l + E_{amlm} * l * d1^4\end{cases} \quad (13)$$

$$d2=\sqrt{\frac{E_{amlf}}{E_{amlm}}} \quad (14)$$

where E is the dissipated energy to run the transmitter/ receiver E_{amlf} is the transmission in free space of amplifier and E_{amlm} is the amplifier parameter of transmission, d2 is the threshold value of transmission distance. Similarly the reception dissipation energy for l bits of message is given by $E_r(l)$. $E_{rl}(l)$ is the energy needed for transmitter circuitry. $E_r(l)$ is calculated as follows:

$$E_r(l)= E_{rl}(l)=E* l \quad (15)$$

Finally the total amount of energy consumed for wireless network is calculated as follows:

$$E_{tt}= E_{CH}+ E_{nCH} \quad (16)$$

$$E_{tt}=(E_{rCH}+E_{tt}= E_{CH}+ E_{CHbs} + E_{tt}= E_{CH}+ E_{CHfu})+ E_{nCH} \quad (17)$$

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E_{rCH} is the total amount of energy needed for CH to receive data from sensors, E_{CHbs} is the total amount of energy needed for CH to base station, $E_{CHfu}$is the total energy needed for data diffusion CH and E_{nCH} is the total energy needed for all sensors to send data to CH.

In WSN deployment, there are totally n nodes distributed in m*m region, suppose there are C clusters then average of n/C nodes per cluster will be present. Each CH distributes its energy signals to the base station. The energy dissipated in CH during a single frame is given as follows:

$$E_{CH} = [l * E * \frac{n}{c}] + [l * E + l * E_{mp} * d1^{4}_{tbs}] + [l * E_{da} * \frac{n}{c}] \quad (18)$$

where $[l * E * \frac{n}{c}]$ is the total energy consumed by CH to receive l bits from the sensor nodes, E_{da} is the data aggregation cost per signal where as energy consumed by non cluster head is given as follows:

$$E_{nCH} = l * E + l * E_{fs} * d1^{2}_{tCH} \quad (19)$$

where $d1^{2}_{tCH}$ is the distance from node to CH, the energy dissipated in cluster per round is given as follows:

$$E_{C} = E_{CH} + \frac{n}{c} E_{nCH} \quad (20)$$

For each round the network total residual energy E_{tt} is calculated as follows:

$$E_{tt} = C * E_{C} \quad (21)$$

where C is number of clusters used in each round and the second objective can be calculated using the formula

$$F_{2}(x) = \max(E_{tt}) \quad (22)$$

V SIMULATION

The Energy Efficient Multi Objective Bat algorithm is simulated using MATLAB. The network model is deployed in 200*200 m^2, the base station is fixed, motionless device that is located in the region of (100,200). The CH is selected based on the node with maximum remaining energy and the cluster formation is based on multi objective bat algorithm. The simulation parameters of multi objective bat algorithm are given in table 1.

Table1 Multi objective bat algorithm parameters

Parameters	Value
No of nodes	200
Number of generations	100
Loudness ai	0.8
Packet size(sensor-CH)	300 bits
Packet size(CH-BS)	7200 bits
Pulse emission rate R	0.7
Maximum frequency	1

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Performance Analysis

The proposed multi objective bat algorithm (MOB) is compared with LEACH protocol and the metrics such as sensor networks lifetime, coverage, residual energy and throughput are analyzed and described in the following section. The result analysis shows that the proposed scheme provides better optimization compared to LEACH clustering protocol.

(a) Sensor Networks Lifetime

The proposed model analyze the network life time by considering the number of iterations against death of first nodes, 50% of nodes and last nodes. It is compared with the LEACH protocol and identified that MOB provides better optimization than the LEACH protocol. The figure 1 depicts the sensor network's life time of proposed scheme and LEACH protocol.

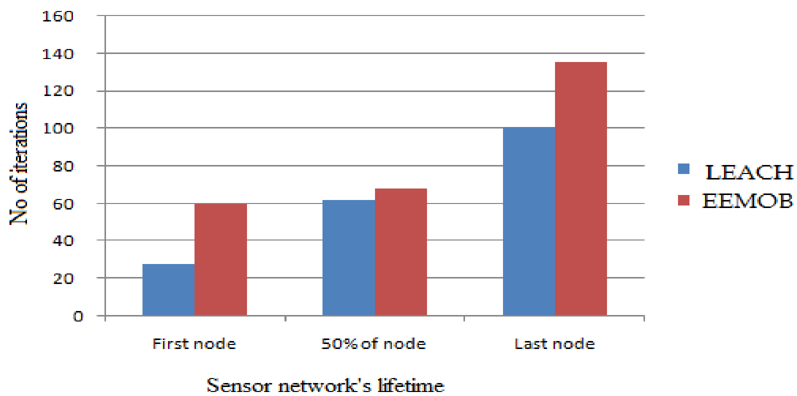

Figure 1. Sensor network's lifetime

(b)Coverage Ratio:

The most prominent challenge in some critical applications is coverage ratio. Increasing the coverage ratio is much important than increasing the life time of sensor network.

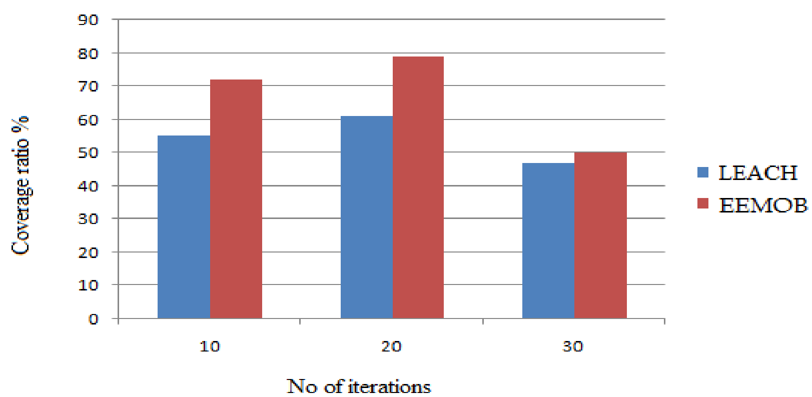

Figure 2. Coverage ratio

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The proposed scheme provides an optimized CH selection where as in LEACH protocol the CH selection is not uniform and suffers from drastic loss of energy. The figure 2 depicts the coverage ratio of LEACH and MOB against number of iterations.

(c) Residual Energy:

Residual energy is defined as total sum of available energy in the sensor network against the networks lifetime[6]. From the proposed result it has been verified that MOB provides stable, energy efficient clustering model for sensor network. It selects the optimum number of cluster and CH that have maximum residual energy. The following figure 3 depicts the residual energy comparison of proposed scheme with LEACH protocol.

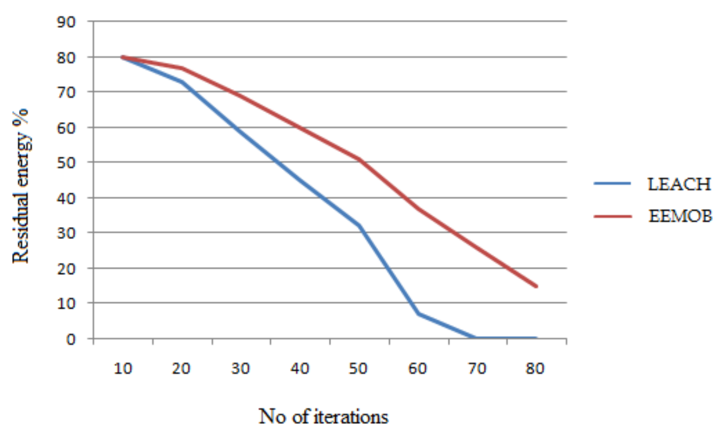

Figure 3. Residual energy against number of iterations

(d) Throughput:

The CH collects the information from sensor nodes and transfer those information to BS(Base Station). This ensures success rate of packet transmission across the network. From the result it has been identified that proposed system outperforms the LEACH protocol and it provides stable and efficient throughput thus it optimally increases the cluster formation. The figure 4 depicts the throughput analysis on MOB and LEACH protocol.

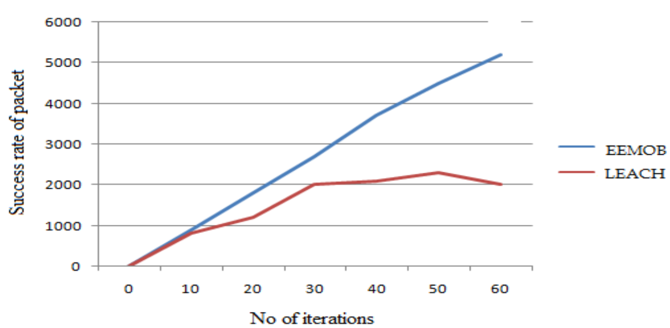

Figure 4. Throughput analysis

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VI CONCLUSION

In this paper, the Energy Efficient Multi Objective Bat optimization algorithm has been discussed. The parameters taken into account for performance analysis are sensor networks' life time, coverage, residual energy and throughput. The proposed model selects the best nodes as cluster heads thereby it optimizes the sensor network by reducing the energy consumption and increasing the coverage, throughput and networks' lifetime. Thus it provides the energy efficient cluster modeling scheme for WSN. Hence the proposed scheme outperforms the existing LEACH clustering protocol and it can have significant applications in the real life scenarios.

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