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Heuristic-based LEACH protocol: An improvement in total lifespan of the wireless sensor network using LEACH and TOPSIS-based heuristic algorithm

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ABSTRACT: The wireless sensor network is a promising domain of research due to its number of applications in the diverse area of technologies ranging from civil to the military domain. During the previous two decades, a number of efforts have been made to improve the efficiency of the wireless sensor network under several applications. This paper presents investigations on the Balanced LEACH algorithm. The investigations are reported for two cases such as inter-cluster and intra-cluster in order to estimate the throughput and energy efficiency. The simulation-based experiment on the proposed method reveals that the proposed approach is more efficient in terms of energy consumption compared to the previous routing algorithm.

Keywords: Energy efficiency, clustering, LEACH, throughput

I. INTRODUCTION

The wireless sensor network is a network of sensor nodes connected wirelessly with each other and considered an autonomous network. The main revolution is observed during the 21st century due to the development of an electro-mechanical system. The main component of a sensor node is a microcontroller, transmitter and receiver, power unit, small memory unit and battery. The major constraint of the wireless sensor network is energy consumption as there is no option to replace the battery [1-4]. As the network lifetime depends on the sensor battery, therefore it is the major concern of many researchers working in the domain of wireless sensor network technology. Therefore, many efforts have been made to reduce energy consumption. Due to this a number of routing algorithms are developed to overcome the challenge of energy consumption in order to improve the network lifetime [5-7].

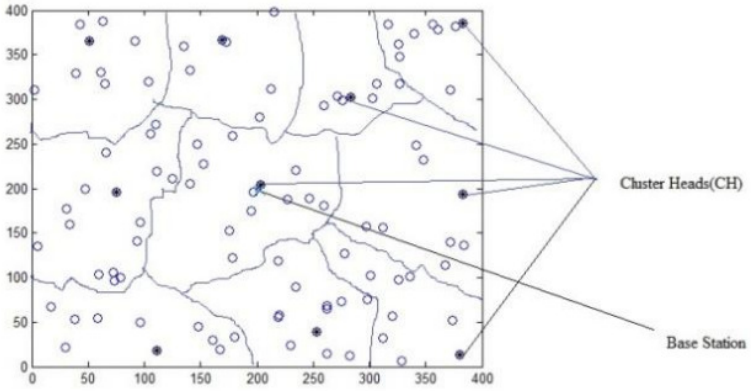

Fig. 1. Clustering of wireless sensor network.

Therefore, in order to reduce the network lifetime single level to multi-level hierarchy approach is used by many researchers. In the case of a two-level hierarchy, the system is one of the best clustering hierarchy approaches used by researchers [8-9]. For one level the sensor nodes are close to each other and create a group of sensor nodes. These sensor nodes collect the data and transfer it to the cluster head again a sensor to collect the information from all the nearby nodes. In the next level i.e. level two the cluster head collects the information from the other node, compresses the received information and forward that information to the

base station. The base station is known as a sink node that can be placed at any position within the network even this node can be placed outside the network as per the application of a wireless sensor network [10-12]. This node decompresses the received signal and retrieves the information. This sink node can be a simple computer or a high-speed server connected with various advanced equipment with an uninterrupted power supply. Therefore, it is important to take care while choosing the cluster head node and the sink node. The clustering problem is a case of an NP-hard problem. Figure 1 shows the clustering of the wireless sensor network.

LEACH stands for Low Energy Adaptive Clustering Hierarchy and the concept was projected by the Heinzelman *et al.* LEACH is a hierarchical clustering algorithm with two levels of the hierarchical system instead of a conventional wireless sensor network [1, 13-15]. As discussed earlier, in level -1 cluster head collect the information from the associated nodes within the cluster. Whereas in level two the collected data of the cluster head is forwarded to the destination. The major advantage of this system approach is the reduction of energy consumption but introduces eth delay compared to other conventional wireless sensor network topologies such as PEGASIS [23]. The collection of the data by the cluster head is carried out on the principle of the Time Division Multiplexing approach. Afterwards, the data is compressed for removing the redundancy and transmitting this data to the sink node or the base station. On the other hand, the major limitation of this technology is the drainage of cluster head energy at a faster rate compared to the other node of the cluster. To minimize the energy consumption problem of the cluster head, the LEACH protocol provides a provision to change the cluster head on a random basis on the basis of fix number of rounds[16-18]. Therefore, the concern of the researcher has shifted to optimising the cluster network. In this direction, a number of researchers have designed protocols to improve wireless sensor network efficiency[19]. it is also observed that only 5% of the total number of nodes are able to act as a clustering hand and able to work optimally. Moreover, few researchers have also worked in the direction of developing the 3-level hierarchical system to improve the effectiveness of the sensor network in terms of energy efficiency[8]. These approaches have incorporated the heuristic algorithm[21]. The mathematical representation of the energy is expressed in the given relation.

$$T(n) = \begin{cases} \frac{P}{1-P*\left(r \bmod \frac{1}{P}\right)} & \text{If } n \in G \text{ otherwise.....1} \\ 0 \end{cases}$$

This equation represents the threshold energy during each node where P indicates the level of residual energy within the network, and r represents the round of the network. The simulation of the network is carried out until all the associated nodes of the network and the entire network die due to the unavailability of energy. In this direction, a routing algorithm is proposed to minimize the energy consumption of the network to improve the network lifetime of the wireless sensor network. This algorithm will help to optimize the network cluster nodes based on the parameters of the nodes and neighbour nodes during the rounds.

II. METHODOLOGY

The routing approach in wireless sensor networks is different from the other wireless communication networks as well as from the ad-hoc networks. The major concern for developing a routing approach for wireless sensor network is to minimize the energy consumption and use the available energy of sensor nodes in an effective manner [22]. LEACH is one of the most used algorithms in the domain of wireless networks and is used by many researchers to improve network lifetime. The researchers have explored the various direction of the LEACH protocol to enhance the efficiency of the wireless sensor network. The main features covered by the wireless sensor network included random allocation of cluster head and coordinate localization. In this direction few other protocols also emerged such as PEGASIS [23]. PEGASIS stands for Power-Efficient Gathering in Sensor Information System where sensor nodes form a chain for forwarding the information to the other nodes [8]. This approach is a token system-based approach where data is transmitted from the base station. This token is passed to all the nodes to collect the data and forward eth data to the base station. The major limitation of this approach is knowledge of the path that needs to follow to collect the data and transfer it to the base station. Another, routing approach in routing the wireless sensor network is HEED [10]. HEED stands for Hybrid Energy Efficient Distribution where the cluster head node is selected based on the remaining energy of the sensor node through uniform distribution.

Furthermore, a concept of Multi-hop LEACH is also in use. This approach uses a cluster head as a communication station for transmitting the sensor data to the base station. This approach follows the 2-tier to 3-tier method for developing the LEACH architecture with the help of a relay node to control the load and network efficiency[21]. In this case, the relay node transmits all the data to the cluster head and the cluster head further transfers the data to the sink node or base station. The limitation of this work energy consumed by the relay node. This energy consumption is high and needs extra energy to carry out the dedicated task of the relay node. Another improved version of the LEACH protocol is available known as LEACH- DE [22]. This approach employs the differential Evolution of the routing algorithm by dividing the sup phase time into small phase time in the cluster head and formation of the cluster in order to reduce the distance for communication between the node. Centralized LEACH is another improved version of the LEACH protocol which works at the sink node or base station in comparison to distributed approach. In this case, the base station is responsible for the selection of the cluster head. The energy consumption in this method depends upon the distance from the base station.

Few other versions of routing algorithms are also available such as Hybrid GA-PSO, LEACH-TLCH, and MODLEACH. GA- PSO algorithm depends upon the genetic algorithm which is used to enhance the life span

of the network. LEACH is used to endure the energy for creating a cluster head node whereas LEACH-TLC is the method of creating two cluster heads based on the residual energy and distance of the cluster head. On the other hand, MODLEACH is again a modified version of LEACH which works on the two-threshold energy level to reduce energy consumption and improve the network lifetime. The proposed LEACH protocols in work can be differentiated compared to other leach protocols as:

1. In the proposed algorithm energy is estimated by the cluster contained and improves the life span of the network. On the other hand, the wireless sensor network normally computes the average energy of every alive sensor node.
2. Further the clustering of the proposed approach stabilizes the threshold level based on the distance between the cluster head
3. Instead of using changing the cluster head of the network system in very rounds, the proposed approach transfers the threshold energy of the cluster head. This approach helps to control the packet flow of the sensor node. And reduce the energy utilization within the sensor network.

III. MODELLING AND RESULT ANALYSIS

The network is consisted of an N sensor node by providing a sink node. The sink node has allocated with a unique id which is spread randomly on the allocated area. The sensor node is grouped according to cluster whereas the sink node is placed at an appropriate position is 0.5xXm and 0.5xYm. This sink node is responsible for collecting all the data from the sensor nodes. In this case, each round of the LEACH algorithm allows divided into two categories as illustrated in figure 2.

The set-up phase is responsible for the aggregation of the cluster head which depends on the required percentage of not becoming a cluster head during round p. The node has a higher percentage among the all checked for the threshold limit. If a node fulfils both the requirement then that node is chosen as the cluster head node. Now this selected cluster head node transmits a message for the setup of the network by requesting the other linked sensor to get associated with the cluster head. Meanwhile, the minimum distance between the sensor node and cluster is also considered during the modelling. The second phase is the steady phase where rounds are divided based on the uniform time interval and during each slot, the cluster head will be able to receive the data for the sensor node associated with the cluster head.

The radio transmission model is shown in figure 3. The energy consumed by this module for transmitting the L bits can be estimated.

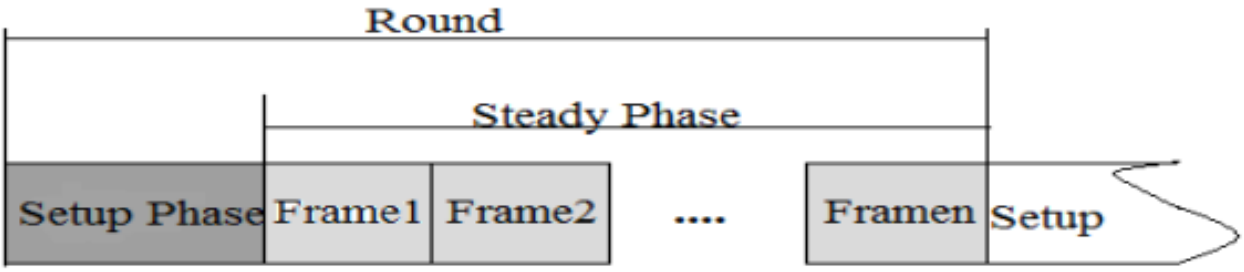

Fig. 2. LEACH step phases.

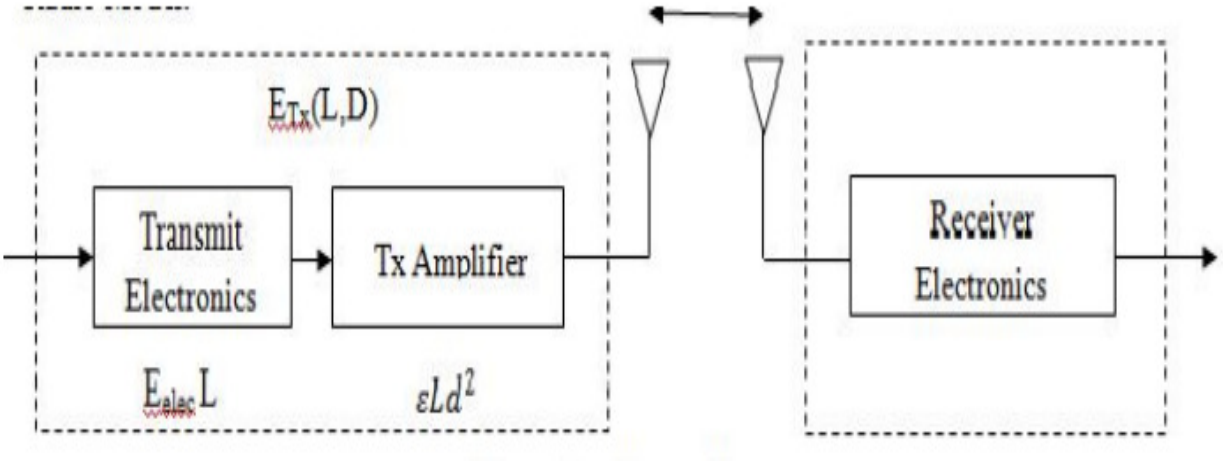

Fig. 3. Transmitting model.

$$E_{CN} = E_{Tx} + E_{CHsel}$$

$$E_{CHsel}(L, d) = (E_{elec}\, L + \varepsilon L d^{n}) + R_{ais} * E_{elec} + P_{s} * E_{elec}$$

$$E_{Tx}(L, d) = E_{elec}\, L + \varepsilon L d^{n} \quad (\text{if } D > d \text{ then } n = 4 \text{ otherwise } n = 2)$$

The total energy consumed by Cluster Head (ECH) is:

$$E_{CH} = E_{CHsel} + E_{CHAD} + E_{CHcom} + E_{CHf}$$

$$E_{CHsel}(d) = E_{elec} + \varepsilon d^{n}$$

$$E_{CHAD} = p * n * E_{elec}$$

$$E_{CHcom}(L, d) = (N_{f} * E_{elec}) + (E_{elec} L + \varepsilon L d_{tosink}^{n}) \ (\text{if } D > d \text{ then } n = 4 \text{ otherwise } n = 2)$$

The cluster head change is based on the difference in the energy at every round. This is more energy-consuming as after the subsequent round therefore there is a need to set a threshold distance between the cluster head. The proposed algorithm divides the whole region of the wireless sensor network into three layers and each layer works on a different protocol. Further, the selection of the protocol is based on fuzzy logic. Fig. 4 shows the cluster pattern where no cluster head is close to N1 and N2. Hence there will be more energy consumption for transmission of the sensed data to the base station. Further, the cluster head node surrounded by the nodes having a higher upper threshold or some of the nodes having a less level than the threshold limit will consume more energy. In the previous approaches in the domain of LEACH protocols, every sensor node is responsible for the transmission and reception of the advertising packet. This advertising packet is also known as a control packet which again contributes to the consumption of energy. However, in the case of the proposed algorithm the sensor node will transmit or receive this control packet whenever the transition in the state occurs, therefore the change in the state occurs during the transition and every control packet is comprised of different information. In layer 1, every senor node works independently from other nodes and works on the token. The token protocol is when every node transmits its data during its turn. To create the difference between the layer a unique id is allocated to the layer. For layer 2, nodes form cluster heads following the TOPSIS approach. The cluster head forwards the data only when collecting the data and filling the entire packet and waiting for the next node to act as a cluster. Fig. 4 shows the LEACH protocol.

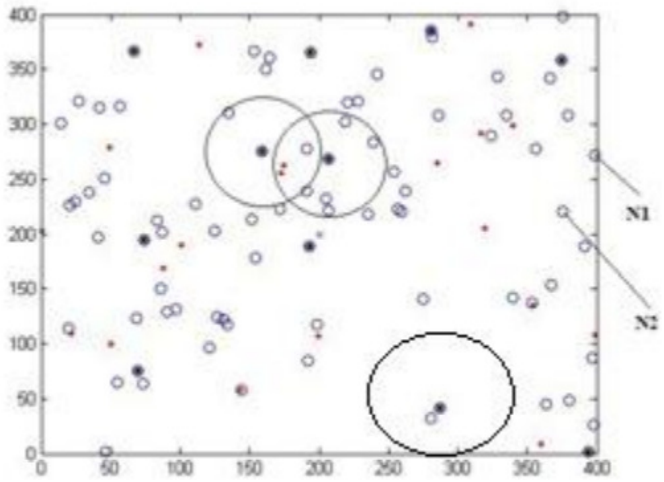

Fig. 4. LEACH protocol.

In the case of layer 3, communication between the cluster head to layer takes place. This layer is responsible for the transmission of the data from cluster to layer 2 based on the fixed number of rounds. This helps to save the energy in layer 3 as layer 3 is at more distance from the sink node. This helps to reduce energy consumption and improve the network lifetime. Moreover, the SoS message in layer 1 can be sent directly without the delay. And layer3 will send this message directly to the base station during an

emergency situation. The algorithm and its various steps are explained as follows:

Initialization: In this phase, the node is randomly deployed in the specified area and the base station is placed at the centre of the network. All the information is saved as the matrix of a specified number of rows and columns.

Fitness calculations: The next step is to calculate the fitness value. This parameter is useful for the normalization and criteria decision algorithm TOPSIS.

Decision phase: During this step, every node-set its protocol based on the fuzzy system and the fitness value and the entire network is divided into the 3 layers based on the node's decision.

Transmission and compression Phase: This phase is responsible for the transmission and compression of the data which take place at different layers on the basis of public key distribution. The packets are divided into categories such as normal packets and SoS packets. The decision of transmission of the packet is based on the type of packet as SoS has assigned higher priority compared to the normal packet. Further, the wireless sensor network creates a backbone for the transmission of the data on the basis of the rank of the sensor node. Afterwards, every node updates the fitness value by detecting the variation in the parameters in the initial phase of the network.

The proposed algorithm follows the distributive method. In this approach, every node decides the protocol on the basis of distance from the sink node and other associated alive nodes with the help of fuzzy logic. As earlier discussed, the proposed approach is set for three phases where phase 1 decides the set of protocols and this phase is executed for a fixed number of rounds. Phase 2, the decided protocol checks the possibility of transmission of the data to the cluster head and phase 3 is responsible for the transmission of the data.

$$S(i).fvalue = (N + (D_{\max} - S(i).d + S(i).P)^{\wedge(S(i).E - E_{avg})}$$ Where:

S(i).fvalue : face value of node

N: Number of Alive nodes in neighbor/number of alive nodes

DMAX: Maximum distance between base stations to node

S(i).d: Distance between node and base station

S(i).P: number of rounds that node become non cluster head

S(i).E : remaining energy of node.

Eavg : average energy of neighbor nodes

The comparison of the average energy is presented in figure 5. The average energy represents the remaining energy within the network at a time. Figure 5 shows that the proposed method is better than the previous LEACH protocol. This is due to the optimized allocation of the cluster head. It is observed in the case of conventional LEACH that the energy decline rapidly from 100 to round 500 due round due unstable position of the cluster head. On the other hand, the proposed algorithm shows an improvement in energy.

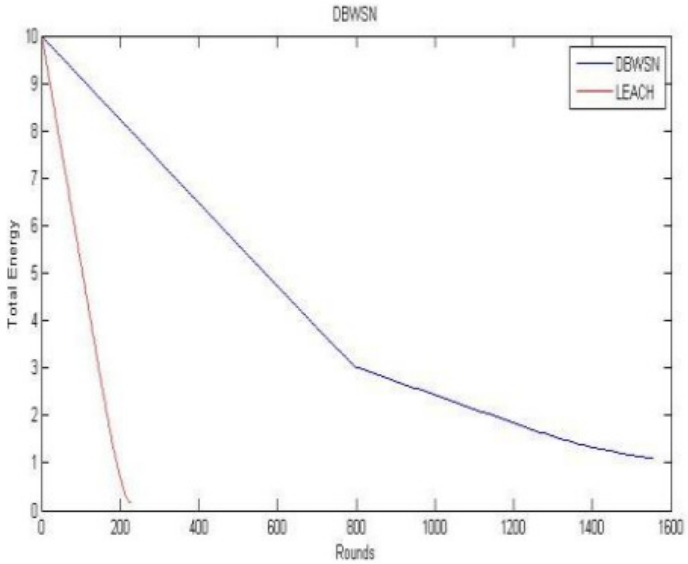

Fig. 5. Total energy comparison.

Further, figure 6 shows the comparison of residual energy and a significant improvement in the proposed approach is observed. This is further observed that the node with zero energy is unable to communicate or transfer the data to the cluster head due to no residual energy. The values are also presented in table 1.

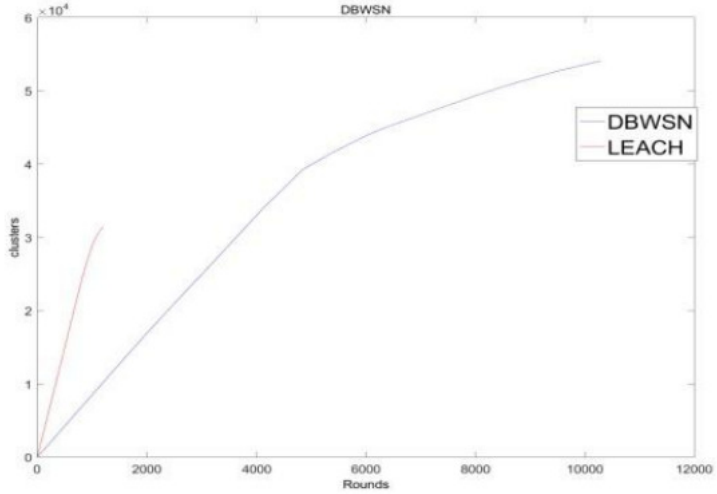

Fig. 6. Comparison of residual energy.

Table 1: Residue energy.

No of Rounds	10	50	75	100
Proposed Algorithm	137	630	852	1078
LEACH	634	4239	6720	9073

Another, the important parameter is PDR, *i.e.* packet delivery ratio. This PDR is used to estimate the efficiency of the network. In this regard, a comparison of the PDR is presented for conventional LEACH and the proposed approach. The PAD is again improved in the proposed approach and in between the range of 4 and 5. There is less drop in the packet delivery ratio hence it improves the efficiency of the network.

Table 2: Comparison of PDR.

No of Rounds	100	500	1500
Proposed Algorithm	5.3	4.8	4
LEACH	10.3	9.6	8.9

Further, the data packet ratio also gives information about the flow of data packets that are redundant. Data packets carry the sensed information and control and status of the packets about the transmission of the data. The control information does not carry any data and this information is known as redundant information. The aim of this work is to reduce energy consumption and also control the pack flow. In the initial stage at every round, the cluster heads forward the control message to all the nodes and the sensor node sends the information which again spends energy in the conventional LEACH. In the proposed scheme the algorithm omits the control packets and saves energy. The observation of the data packet is shown in figure 7.

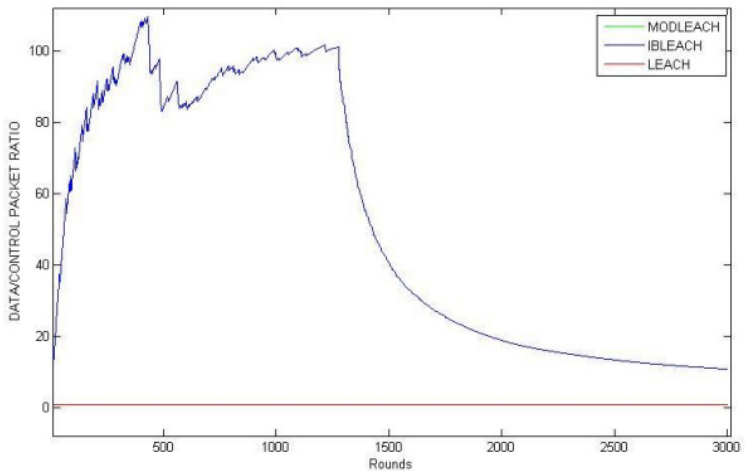

Fig. 7. Comparison of data packet.

IV. CONCLUSION

In this paper, an efficient algorithm is proposed for improving the efficiency of the wireless sensor network in terms of energy and network lifetime. The performance of the proposed algorithm is compared with the conventional LEACH. Further, a discussion on PEGASIS and MODLEACH is also presented. During the investigation, it is observed that the proposed system has the ability to improve the efficiency of the wireless network. The comparison of PDR and data packet ratio is also presented.

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