Research Paper Engineering

Fuzzy Inference System (FIS) Based Unequal Clustering Algorithm for Large Wireless Sensor Network.

* Savita Mamadapur ** Rajashekar K

* PG Scholar, Dept of Electronics &Communication, GM Institute of Technology Davangere - 577004

** Assistant Professor, Dept of Electronics & Communication, GM Institute of Technology, Davangere - 577004

ABSTRACT

In this paper we present an novel approach of unequal clustering algorithm based on fuzzy inference system (FIS). Firstly, to extend lifetime of wireless sensor networks (WSN), the network region is divided into several virtual blocks (VBs). Secondly, the residual energy of node, proximity to base station (BS) and centrality of the node within VB are used to construct CH selection based on FIS, which can balance network load. Thirdly, in the CHs routing phase, the energy consumption of the whole network is reduced. We compare this algorithm with the low energy adaptive clustering hierarchy (LEACH) algorithm. Simulation results prove FIS based clustering approach performs better than LEACH and significantly prolongs the network lifetime in large area WSN scenarios.

Keywords : Wireless sensor networks, Unequal cluster, Routing Protocol

I. Introduction

A wireless sensor network (WSN) consists of a large number of sensor nodes and a base station (BS). These sensors collect data and send them to the BS via radio transmitter. They have limited power and computational capacity. WSNs can be used in many applications such as military, biomedical, and environmental applications. It is not easy to find the route and reserve it, because the limited amount of energy and sudden change in the position of the nodes creates unpredictable changes [1][2][3]. The energy is the major challenge for designing the routing protocol in WSN. Network lifetime is an important indicator of design in WSN [4, 5]. The routing technology in network layer has an important impact on the performance of WSN. Currently, many routing protocols have been proposed to reduce energy consumption and extend the network lifetime [6]. This paper discusses a novel approach of reducing energy consumption and extends the network lifetime. Following this introduction, we briefly review related works. In section 3, we discuss our proposed methodology for unequal clustering algorithm. Section 4 & 5 is our result and conclusion.

II. Related Work

In this section, we discuss techniques that have been used in unequal clustering algorithm. Currently, many routing protocols have been proposed to reduce energy consumption and extend the network lifetime [6]. LEACH [7] is one of the first cluster-based routing protocols. However,

LEACH only uses random number to select CHs without considering the residual energy and node location information, which cannot guarantee the reasonable distribution of CHs and less energy consumption. DCHS [8] introduces residual energy which is an important parameter in WSN to threshold calculation of CHs. The node with relatively low energy consumption has priority to become CHs. But it still has uneven distribution of CHs _some CHs are too near to each other and some non-cluster-heads are too far from CHs _ leading to unbalanced energy consumption. At the same time, since the way CHs communicate directly with BS leads to the sharp increase in energy consumption, LEACH and DCHS are not suitable for large monitoring area. M-LEACH [9] uses the multi-hop communications from CHs to BS, which has less energy consumption than single-hop algorithm in a large area. However, the CHs nearer to BS forward more data packets leading to more energy consumption and earlier death, which is called “hot spots” problem. In order to solve the “hot spots” problem, EEUC [10] and RBMC [11] adopt unequal clustering strategy to reduce the energy consumption of CHs near to BS and solve the “hot spots” problem. But the parameters of EEUC are mainly chosen from experience and EEUC does not make good use of node location information. In RBMC, the network region is divided into several layers and clusters of unequal size which are built based on optimal number of CHs in different layers. However, the selection of CHs in RBMC still uses a random number without considering node location information, which leads to uneven distribution of CHs. While RBMC doesn’t consider node residual energy, which makes nodes with less energy be CHs and is not conducive to saving the energy of the whole network.

III. Problem Statement

The main objective of the project work is to develop unequal clustering algorithm based on fuzzy inference system (FIS) which balance the network load and significantly extend the network lifetime in large network region.

IV. Proposed Algorithm

In this section, we discuss our proposed algorithm for unequal clusters.

A. Network Model

As is shown in Fig. 1, this paper assumes that N sensor nodes are immobile after being distributed uniformly in the equal interval concentric circles region. The maximum radius of the region is R [12]. The number of layers is L and the interval of the layers is δ. So the radius R=L*δ. BS is fixed and its energy is not limited. It is located in the center of the circles region.

In this paper, it is assumed that each sensor node has the

following properties:

1) Sensor nodes are isomorphic with the same initial energy, computation, data fusion and communication capabilities. All the nodes are location aware and can communicate directly with BS.
2) All the nodes have power control capabilities to save energy.
3) Each sensor node has a unique identification (ID) _a layer serial number a serial number of VB and is able to calculate its current residual energy.

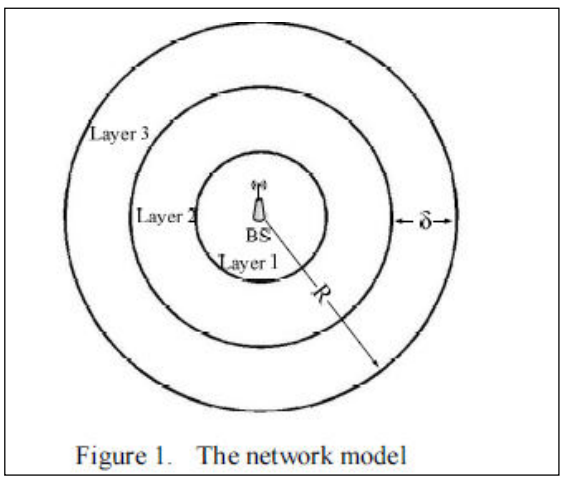


Figure 1. The network model

The energy dissipation of data fusion is:

EDA (l) = lEda …….. (1)

Where Eda is the unit energy consumption for fusing one bit. DA is the fusion coefficient.

The average energy consumption of each node per round in

$$E_{consum}(k) = \frac{N_k(E_{elec} + E_{DA}) + \sum_{i=k+1}^{n} m_i(2E_{elec} + E_{fs}E[d^2_{chk,k-1}]) + m_k E_{fs} E[d^2_{chk,k-1}]}{N_k}$$

……(2)

Above equation is the estimate of the energy consumption of each node per round in kth layer.

=B. The Proposed Algorithm

FIS based unequal clustering algorithm is a multi-hop clustering routing algorithm which can obtain more uniform distribution of CHs, can balance the energy consumption and extend lifetime effectively. This algorithm contains 3 main components: VB construction, CHs election, and CHs routing.

a) VB Construction

In VB construction phase the entire network region is divided into several virtual blocks (VB). Each VB is again divided into big virtual block (BVB) and small virtual block (SVB). The number of BVB in each layer is same to the optimal number of CHs in each layer.

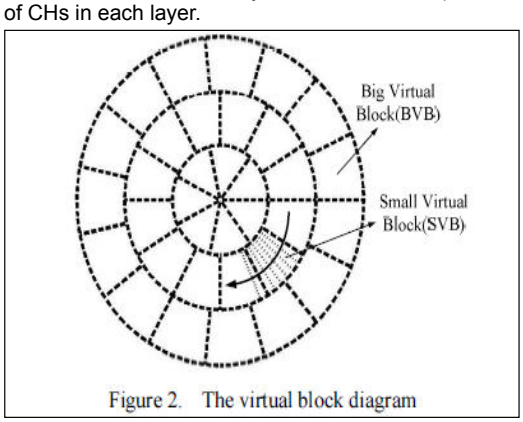


Figure 2. The virtual block diagram

b) CHs Election

Using FIS the CH election is done. The residual energy of the node, proximity to BS, centrality of the node is used for the selection of the cluster head (CH)[13]. Initially the energy of the node is 0.1J. Here comparison is made among different sets of sensor nodes to select a set with maximum qualification as final CHs in the current round. The centrality parameter is measured by total distances from cluster members to the cluster heads. Proximity to BS parameter is also measured by total distance from cluster heads to the BS. In addition, the BS is capable of measuring the distances among all CHs. In this algorithm these three parameters are considered as the inputs to the fuzzy system and sensors' qualification parameter for becoming a CH are considered as the output. We used Mamdani method for fuzzy inference technique. The maximum range of membership functions are determined by maximum values of input parameters. These values can be

$$Max\ centrality = (n-1)\sqrt{x_m^2 + y_m^2} \quad \text{…… (3)}$$

$$Max\ proximity\ to\ BS = (0.05 \times n)\sqrt{x_{BS}^2 + y_{BS}^2} \quad \text{….(4)}$$

Where n is the number of sensors, (xm,ym) is size of network and (xBS,yBS) is the position of BS.

c) CHs Routing

In cluster head (CH) routing phase, all the CHs consider BS as a CH and know the distance between BS and them. BS's layer serial number is 1. CH in Layer 1 directly communicates with BS. Algorithm adopts VB reconstruction strategy which rotates VBs to change the relative position of nodes in VBs in order to achieve load balance.

V. Simulation Results

In this section, we evaluate the performance of our proposed algorithm in MATLAB. The initial energy of the sensors is 0.1J. Simulation was performed for 1400 rounds. We use a simplified model proposed in [7] for the radio hardware energy dissipation. We compare our proposed algorithm to LEACH [8] Lifetime and Network's residual energy.

A. Network's lifetime

Although various definitions has been proposed in the literature, in this paper lifetime is considered as the time when the first node dies. Figure 3 shows the number of alive nodes with respect to the operation of the network in 1400 rounds for different scenarios. The proposed algorithm prolongs the network lifetime effectively compared with LEACH algorithm. When DA=0.5, HNA of FIS based unequal clustering algorithm increases by about 376.1% compared with LEACH algorithm.

B. Residual energy of network

Residual energy of network in each round can be a good metric to measure the energy efficiency of the algorithms. The less steep the figure is the more clearness of balance energy utilization and fairer distribution of energy on the nodes would be. Figure 4 shows the comparison of energy consumption rate of the two algorithms. In the proposed algorithm the residual energy of network is much more than others.

Figure 3: The total energy consumption on different time when DA=0.5

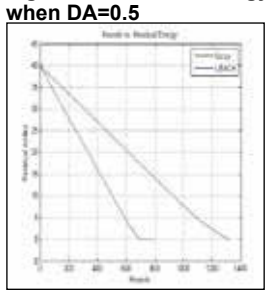
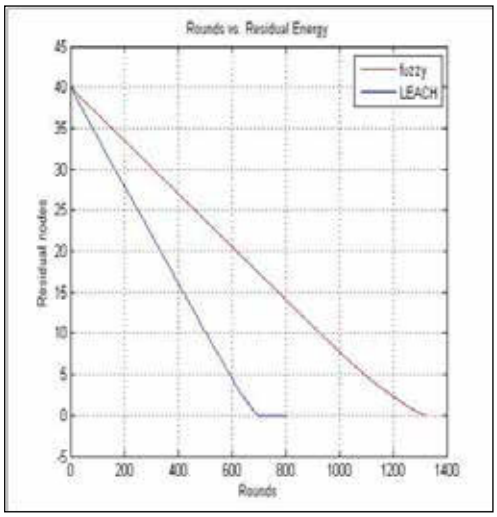


Figure 4: The average energy per round at different instants of time



VI. Conclusion

An unequal clustering algorithm based on fuzzy inference system has been proposed in this paper after doing research on various routing algorithms. The network region is divided into several VBs to form unequal clusters at the beginning of each round, thus “hot spots” problem in multi-hop routing algorithm is overcome and the energy consumption of network is balanced.

In CHs election phase, the residual energy of node, the proximity to BS and the centrality of the node in VB are used to select appropriate CHs. In cluster routing phase, BS is considered as a CH. Each CH finds the nearest CH with smaller serial number of layer as its parent node. And then a routing tree is built from outer layer to inner layer. The proposed algorithm was compared with similar approach LEACH [8] in network lifetime and residual energy of the node. The simulation results show that the improved algorithm can better balance the network load and significantly extend the network lifetime in large network.

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