A ROBUST CLUSTERING TECHNIQUE OF WSN BASED ON WEIGHTED PARAMETERS

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Abstract

Wireless sensor nodes have deployed with limited energy sources. The lifetime of a node usually depends on its energy source. The main challenging design issue of the wireless sensor network is to prolong the network lifetime and prevent connectivity degradation by developing an energy-efficient routing protocol. Many research works are done to extend the network lifetime, but still, it is a problem because of the impossibility of recharging. In this paper, we present a hierarchical clustering technique for wireless sensor network called Clustering with Residual Energy and Neighbors (CREN). It is based on two basic parameters, e.g., number of neighbors of a node and its residual energy. We use these properties as a weighted factor to elect a node as a cluster head. A well-known method, LEACH had a high performance in energy saving and the quality of services in the wireless sensor network. Like Low-Energy Adaptive Clustering Hierarchy (LEACH), CREN rotates the cluster head among the sensor nodes to balance the energy consumption. The simulation result shows the proposed technique achieves much higher performance and energy efficiency than LEACH.

Keywords: Wireless Sensor Networks, Clustering Algorithm, Cluster Head, Energy-efficiency, Residual Energy, LEACH.
I. Introduction

Wireless communication systems revolution for only human interaction with each other but now a days also machine-to-machine communications also needed in many applications. For monitoring the environment and tracking is one of these applications is using wireless sensor network (WSN). It has a wide application area in infrastructure monitoring and health care system based on the Internet of Things (IoT). WSNs contain several sensor nodes, computing and communication abilities and used as practical tools for gathering data in various situations. Each nodes plying role in simple computations and communicate with nearby other sensors or with the base station. An important feature of a traditional wireless sensor networks can be characterized by severe power, computation, and memory constraints. A wireless sensor network cannot be recharge from environment after deploying. Thus due to limited and non-rechargeable energy characteristics it is very important to prolong the network lifetime.

The basic operation of WSN is the arranging and transmitting of sensed data to a base station (BS) to be process. All of the routing protocols that are proposed for WSNs can be classified into three types they are either data-centric or hierarchical or location-based. The energy and time saving for periodic data hierarchical routing protocols perform better than other solutions. In hierarchical protocols divide the sensor nodes in several clusters. The primary goal of clustering scheme is to partitioning a network into several segments which are generally called by clusters. Each cluster has a special node head (CH) is the leader of each cluster. All sensors in WSNs are organized into the clusters where each sensor has its CH. The main advantage of clustering is to communicate with the nearby nodes over short distance from CH. The main function of the cluster head is to aggregate the data come from the member nodes. This way the overall network traffic can be significantly reduced.

Since within a sensor node, the dominant energy consumer is the radio unit. Thus, energy efficiency will be significantly enhanced. However, the conventional clustering algorithms suffer the problem of uneven energy consumption problem, where the CHs drain energy much faster than the cluster members. Also, a CH lost its power rapidly than other cluster heads if it has more member nodes than others CHs. Many researches indicate the Selection of CHs is a crucial step for the cluster-based algorithm because CH has the great influence to improve the overall performance of network. Under normal circumstances, whether a node can be a CH or not depends not only on its energy but also on other factors such as energy consumption rate, the channel lost and neighbor density, etc..

LEACH protocol used randomizes the rotation of cluster head. In leach each successive operation is called a round. In each round there are two steps, one is set-up and another is cluster head selection. When clusters are formed, the network enters a steady- state stage and starts sensing and data transmission. The CHs are selected without considering the position and current energy level, and this may cause unbalanced energy consumption and shortened network lifetime in the long run. Our main contribution is to proposing an efficient algorithm based on the node parameter
that can able to increase the efficiency of the network and increase the network lifetime. We also show that the packet drop reduced prominently and achieve better performance than LEACH.

The rest of the paper is organized as follows. We review the related works in Section 2. Our proposed clustering technique is described in detail in Section 3. The simulation technique and performance evaluation results are presented in Section 4. Finally, in Section 5, we conclude.

II. Related Work

There have been various researches on clustering scheme to achieve energy-efficiency for wireless sensor networks. The existing clustering algorithms differ on the criteria for the selection of the CHs. The most leading criteria for clustering are the residual energy of nodes. Node position, link quality, quality of service, etc. are considered as well.

The clustering scheme proposed in uses probability to select CHs. It works similar to LEACH, i.e. the operation is divided into rounds, and each round consists of set-up phase and steady-state phase. The difference is in the CH selection process which selects the cluster-heads not randomly but considering the relative position and residual energy of nodes in the network and portion of cluster-heads among the nodes at the beginning. Simulation identifies that this approach extends the lifetime of the sensor network for about 50% compared to LEACH scheme. Recently, unequal clustering algorithms have focused on the hot spots problem which is an energy imbalance among the CHs. A useful cost function is used to select CHs which considers residual energy and node load. It does not need any global knowledge of energy and field location of sensor nodes. Improved Three-Layer Clustering Hierarchy selects the lower level head by using dispersed hierarchical approach. The entire workflow executes in three stages, firstly sensed information is transmitted through sensor nodes to the CH. Secondly, and grid head (GH) receives the data and gathers and finally data to be compressed and aggregated data to be sent to BS for more processing. The features of the immune system are immunological learning, memory and recognition methods. It uses dynamic balance function with a grid control system. It firstly selects some initial cluster head node as an ordinary node concerning probability then it applies k-means and distance factor for finding the initial antibody group. It considers the affinity function of distance factor and node energy to calculate the affinity of antibodies and antigens. The termination condition is used to select some excellent antibody solution.

The clustering based routing algorithm is proposed a system, where CH selection will be in a hierarchical way. CH's are selected by some probabilistic parameters or randomly and considering specific parameters like CH current iteration number, time gap or sensor node ID. In DCHSM, CH's are select in two phases after dividing the total monitoring area using the Voronoi diagram. In the first phase, CH is selected using the perceived probability concept, and in the second phase, CH is selects based on survival time estimation. If the first class selected, CH nodes are dead then elect
second class of CH nodes from the remaining nodes. Recently Huamei proposed energy-efficient weighted clustering algorithm (RE²WCA) clustering algorithm takes the residual energy and group mobility into consideration by restricting minimum iteration times. They proposed a distributed fault detection algorithm and cluster head backup mechanism to achieve the periodic and real-time topology maintenance to enhance the robustness of the network.

Figure 2. A clustering wireless sensor network model.

According to this perspective, we propose a clustering algorithm for hierarchical sensor network called Clustering with Residual Energy and Neighbors (CREN) based on residual energy and number of neighbors of a node. The key idea of our proposed algorithm is that a node that has adequate power and associated with a large number of neighbors should have priority to select as CH for collecting data from the neighbors. The CHs selection uses a probability scheme. Each node generated a random number and determines whether it can be the CH only if the random number less than a threshold value based on a set of neighbor nodes, residual energy of that node and number of clusters in the network. The CHs are selected locally, and after a certain time interval, all clusters reconstruct to distribute the energy load among the sensor nodes evenly in the entire network.

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Figure 1. Nodes displacement schematic and associated parameters [7].

III. System Model

Before presenting the proposed technique, we assume the following network model. We consider a wireless sensor network similar to the network model used in [IV], [VI], [VII], [VIII], with the following properties:

- There is only one Base Station (BS) existing in the sensor network. The BS does not have energy constraint. For example, it may have AC power source.
- BS is fixed and not located between sensor nodes.
- All the sensor nodes are uniformly distributed in a field, and they are stationary.
- Sensor nodes are homogeneous with the same capabilities. Each node is assigned a unique identity (ID).
- All the nodes have the same energy. Each node has several transmission power levels and power control capability to vary their transmission power.
- The nodes can measure the signal strength of any received signal.
• Sensors are capable of operating in an active mode or a low-power sleeping mode.
• None of the nodes know their location in the network.
• Each node senses the environment at a fixed rate and always has data to send to the BS.
• The communication model within a cluster is single hop but the CH to BS is multihop depends on distance.

Fig.3 Radio energy dissipation model

Here, we assume a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver consumes energy to run the radio electronics, as shown in Fig.1. The wireless channel model is composed of the free space model and the multipath fading model based on the distance between the transmitter and receiver. If the distance is less than a threshold ($d_{crossover}$), the free space ($f_s$) model is used; otherwise, the multipath ($mp$) model is used.

The following equations present the calculation of transmission and receiving energy consumption for an $l$-bit packet over distance $d$.

$$E_{Tx} = lE_{elect} + l\varepsilon_{amp}d^2 \quad \text{for} \quad 0 \leq d < d_{crossover}$$  \hspace{1cm} (1)

$$E_{Rx} = lE_{elect} + l\varepsilon_{mp}d^4 \quad \text{for} \quad d \geq d_{crossover}$$  \hspace{1cm} (2)

where $\varepsilon_{amp}$ is the energy consumed by amplifier for short and long distance respectively.

The critical distance $d_{crossover}$ is defined as
The energy expended in receiving an $l$-bit message is given by

$$E_{Rx} = lE_{elect}$$

(4)

IV. Proposed Clustering Technique

In this section we present the proposed scheme for the selection of cluster heads in the hierarchical sensor network.

Motivation

In designing the routing protocol for WSN, the main objective is to prolong the network lifetime. To achieve the goal, the energy consumption of the nodes needs to be well balanced. In cluster based routing protocol, the CH collect sensed data and send data to BS. Therefore CH spends much more energy than other nodes. To balance the uneven energy consumption of CH, the role of CH head shift to another sensor node periodically [IV]. The selection of the next CH considers one or more parameters such as node residual energy, communication cost, QoS, location, or randomly. Generally, clustering protocols first consider residual energy of a node. Thus the selection of CH is a crucial task.

In our sense, the number of neighbors of a node is a crucial parameter for CH selection. We consider that when a node associated with a large number of neighbors, it should have priority to select as CH for collecting data from the neighbors. This reason minimizes the complexity of CH selection procedure. This ensures that this node can collect sensed data from their neighbors within a short period. The condition is that it should have energy more than a threshold value. Proposed clustering technique named Clustering with Residual Energy and Neighbors (CREN) is motivated by LEACH [IV]. Therefore, it is necessary to collect information about the neighborhood nodes. As LEACH, CREN is broken up into rounds. These involve CHs selection, cluster formation and transmission of data to the BS.

Cluster Heads Selection

When nodes are deployed in the sensor field, all nodes send HELLO message to find their neighbors. All nodes create a neighbor database before starting the CH selection procedure. Each node first needs to decide whether it will be a cluster head for the current round.

The choice is made based on the threshold, which is calculated using the two factors - residual energy and no. of neighbors. If a randomly generated number is smaller than $T$, the node elects itself as a CH. The threshold is given by:

$$T(n) = \begin{cases} (P \times S(i) \times N) + (E_{th} \times S(i) \times E) \times (P \times \text{mod}(r, 10)) & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

(1)

where $P$= desired percentage of CH nodes in sensor field
Each elected CH node broadcasts an advertisement message to the rest of the nodes. For this “cluster-head-advertisement” phase, the CHs use CSMA MAC protocol. Similarly, others elected CHs to transmit their advertisement using the same transmit energy. The non-cluster-head nodes must keep their receivers ON during this cluster-setup phase to hear the announcements of all the CHs. After the advertisement phase, each node selects its leader based on the Received Signal Strength (RSS) of the advertisement. Usually, nodes choose the strongest signal that has received from a CH. If there are same values then randomly one is chosen. Basically, a node checks with its non-CH neighbors to find out their minimal cost for reaching a CH. The process continues until nodes settle on the most energy efficient intra-cluster topology. After electing the CH, the CH collects data message from its neighbor, aggregate them and sends to the BS. After specified time interval we call this as cluster time \((T_c)\), BS sends messages to all CHs to break the cluster. New cluster builds up again. To solve the scalability problem, we assume after a finite cluster time \((T_c)\) all nodes recheck their neighbors. If new nodes are added to the network, BS initiates neighbor finding procedure.

**Algorithm**

1. Set Initial Energy \(E_i\), Energy Threshold, \(E_{th}\) and Percentage of CH \(P\) in each node.
2. Deploy nodes over the sensor field.
3. After deployment, each node broadcast HELLO message to its neighbor and count all neighbors hello signal within its radio range.
4. Create a node neighbor database with proper ID.
5. Each node generate a random number \(rand\) and calculate the cluster threshold \(T(n) = (P \times S(i).N) + (E_{th} \times S(i).E) \times \{P \times \text{mod}(r, 10)\}\)
6. if\((rand\leq T(n))\) then
   i) Select this node as CH
   ii) CH broadcast its leader property.
   iii) Normal nodes choose its CH according to the Radio range and RSS value.
   iv) The non-cluster node selects its CH and sends its ID to the selected CH.
   v) All the member nodes send their data it’s associated CH after when need.
   end if
7. After cluster Time duration \((T_c)\) CH selection process starts again.

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In our proposed system, we have two types of sensor nodes- CH and general sensor node. CH's energy level is higher than the general nature of sensor nodes. We take two thresholds values for CH and other sensor nodes. The threshold value of CH's must be higher than the threshold value of different sensor nodes. When one node energy level goes to less than its threshold value, then we mark that node is a dead node and terminates transmission from it. When a CH's energy level is going to less than its threshold value than that CH losing the term as CH, it becomes a general type node, and our system elects the second choice node as CH that our algorithm provides. Because CH’s losing energy very quickly more than other nodes, our dynamic CH changing technique works nicely to stable and balancing the nodes energy. After a specified time duration, our system checks nodes energy level regularly.

V. Simulation & Result

In this research work, we use MATLAB for physical node description, interactive environment for algorithm development, data visualization, data analysis, and numeric computation. To measure the performance of our proposed technique we compare our clustering technique with LEACH. For simulation, we consider the parameters of MICA2 node. Other parameters are taken from. They are listed in table-1.

| TABLE I |
| --- |
| **SIMULATION PARAMETERS** |
| Sensor Deployment Area | 100m ×100m |
| Number of Nodes | 100 |
| Data Message Size | 500 bytes |
| Packet Header | 25 bytes |
| Initial Energy | 0.5 J |
| Electrical Energy, $E_{\text{elec}}$ | 50 nJ/bit/m$^2$ |
| Energy Consumed amplifier, $E_{\text{amp}}$ | 0.0013 pJ/bit/m$^4$ |
| Transmission Power, $(P_t)$ | -5 dBm |
| RSSI Threshold | -98 dBm |
| BS Location | (120, 50) m |
| Transmitter/Receiver Antenna Height | 0.082 m |
| Percentage of CH | 5%, 7%, 12% |
| Packet Transfer Rate | 1 packet/2 sec |
| Simulation Time | 2000 Seconds |

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Fig. 4 Network Life vs Number of Alive nodes for different percentage of CH

Fig. 4 illustrates the network lifetime in data collection rounds plotted against the number of active nodes for different percentage of CHs. As shown in Fig. 4 our proposed algorithm enhances the network lifetime significantly. It is found that network lifetime increases when there is more percentage of CH in the sensor network.

Fig. 5 Network lifetime vs Residual Energy for different percentage of CH

Fig. 5 presents the average residual energy of the sensor network with time. From the figure, we observe that as time increases proposed model consumes less energy than the LEACH. The proposed technique preserves a significant amount of energy when no. of CH increases in the sensor network.

Fig. 6: Number of Alive Nodes Vs Packets Sends to the BS for 5% of CH

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Fig. 6 compares no. of packets sent to the base station when there are 5% of nodes are CH. It is observed that the proposed technique CREN can collect more information than LEACH. It can receive 14% more packets than LEACH when simulation times are equal.

From figure 2, 3 and 4 it is observed that the proposed clustering technique CREN has better performance than LEACH in terms of alive nodes and residual energy and data packets. In all cases, CREN shows better performance when there are more cluster heads in the network.

VI. Conclusion

In this work, we propose a new energy saving clustering technique CREN, which selects a cluster head in a sensor network using residual energy and no. of neighbors and percentage. In this technique, those nodes have a high probability of electing as a cluster head if they have high residual energy and large no. of neighbors. In the result it is shown that the proposed technique CREN achieves much higher performance than the standard routing protocol LEACH as compared for the network lifetime and power consumption. Our clustering technique shows better performance than LEACH when no. of cluster heads in the network increases. The limitation of this clustering technique is that we used static homogenous sensor nodes that are not always suitable for many application of sensor network. In future work, the proposed model may investigate for heterogeneous sensor nodes and mobile sensor nodes.

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