Energy Efficient Cluster based Reactive Algorithm in Wireless Sensor Networks

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Abstract

Objectives: To eliminate hot spot problem and achieve uniform load distribution among many cluster heads (CHs), we propose a cluster based reactive (CBR) algorithm with threshold based data transmission. **Methods/Statistical Analysis**: This study achieves innovation through the incorporation to two phases namely cluster head selection using the vote-based measure as well as transmission power of sensor nodes and reactive data transmission. In reactive data transmission, the sensor node sends data only while the sensed value exceeds the threshold value. **Findings:** A series of experiments are carried out to validate the goodness of the CBR algorithm in terms of energy utilization and network lifetime. From the experimental results, it is absolute that network lifetime of the proposed method is increased by 55.72% and the energy consumption is reduced to 50% when compared to LEACH. **Application/Improvements:** The proposed method can be implemented in real time WSN.

Keywords: Clustering, Network Lifetime, Reactive Protocol, WSN

1. Introduction

A Wireless Sensor Network (WSN) includes a group of little sized, low energy sensor nodes with the ability to detect and transmit the physical phenomenon to base station (BS)¹. It finds useful in various areas like border surveillance, power plants, industries, environmental monitoring, industrial automation and so on². In contrast to conventional wired systems, the deployment cost of WSN is very low. Further, the WSN has the capability for adapting with the varying environmental conditions³. The sensing field can be the physical environment, buildings otherwise an information technology structure. The sensor node includes four main components namely sensor module, processor module, power supply and communication module. The sensor module converts the sensed data to electrical form where each node forwards the sensed data to BS through intermediate sensor nodes.

As sensor nodes operate only on the inbuilt battery power, it might be employed in hazardous or difficult environments; it is very hard or not possible for recharging or replacing the power supply⁴. So, clustering and routing protocols are needed to enhance the lifetime of WSN. The lifetime of WSN may be able to be described as Half Node Die (HND), First Node Dies (FND), Last Node Dies (LND), and so on. But, the proper explanation of network lifetime is mainly depending upon the application description. For instance, FND can be represented as lifetime for some of the critical applications like healthcare monitoring, where the depletion of the energy of a sensor node may leads to serious effects. In the other way, the depletion of energy of the sensor nodes that reside in the non-critical application, the lifetime is defined as a particular number of nodes remain alive⁵. In WSNs, routing is a difficult task since it is connected to different features of WSN which makes it different from conventional communication networks, For example, ad hoc networks. Firstly, it is not probable to use a global addressing method while deploying nodes. Next, contrastingly to conventional communication models, every WSN application needs the course of sensed information out off many nodes to a specific BS.

Thirdly, many nodes may acquire identical data in the nearby region which leads to high data redundancy. These redundant data have to be used through the routing protocol to effectively utilize the bandwidth as well as energy efficiency. Then, the sensor nodes are mainly controlled on transmission power, battery and bandwidth. So, there is a node to use better routing to enhance the available energy utilization.

Several studies proved that the energy utilization is mainly minimized by the use of clustering mechanisms. So, different energy efficient clustering algorithms have been presented^{6.7}. Clustering techniques groups the nearby nodes into clusters based on some criteria and leader known as cluster head (CH) would be selected in a cluster. The CH is solely responsible for the particular cluster and the remaining nodes will be termed as cluster members. Though several measures in the literature involved the energy consumption criteria, the major drawback lies in the fact of high data redundancy along with the problem of hot spot issue. Hot spot issue refers the faster energy depletion of CHs located closer to the BS compared to other CHs. To resolve this problem, unequal clustering schemes were introduced, which constructs small clusters near to BS and large clusters far from BS. The overall unequal clustering model is depicted in Figure 1.



Figure 1. Structural design of unequal clustering in WSN.

To overcome the above mentioned problems, this paper presents a cluster based reactive (CBR) algorithm using unequal clustering mechanism and threshold based data transmission. This paper incorporates two main phases: (i) Unequal clustering using vote based measure as well as transmission power of sensor nodes and (ii) Reactive data transmission. In reactive data transmission, the sensor node sends data only when the sensed value exceeds the threshold value. This reactive manner eliminates the data redundancy as well as the amount of data transmission. The simulations were performed to highlight the advantages of the CBR algorithm to enhance the network lifetime with reduced energy consumption as shown in Table 1.

 Table 1.
 Network lifetime

Parameter	LEACH	CBR algorithm
First Node Die	812	1334
Tenth Node Die	901	1477
Last Node Die	1421	3054

2. Literature Survey

LEACH, being a popular and foremost clustering algorithm, is widely used in periodical gathering of data applications in WSNs. The nodes selection itself as CH by means of little possibility. This selection of possibility to become of CH depends on the consideration which every sensor nodes initiates with similar quantity of energy; in addition to that every node will send data in its time frame. When the nodes with variant quantity of energy, the node need high energy needs to become CH than nodes with low energy, to verify which all the nodes depletes its energy at the similar instance.

In HEED⁸, every sensor node has the possibility to become CH depend on the residual energy. The sensor which has not been under any CHs with twice fold possibility to become CH. The sensor selects the node as CH with typical lowest reach-ability power (AMRP) while it is inside the cluster radius of many CHs. In similar way as LEACH, every sensor node would communicate to its respective CH and the CHs transmit the aggregated data to BS through multihop communication.

In² presented a general weight-based clustering technique which integrates every sensor in the midst of some weights. In WCA, the weight is computed using some local information about the sensors like transmission power, degree of the node, mobility as well as level of battery of sensor node. The CHs are chosen from the nodes with less weight compared to their nearby nodes. This algorithm employs single hop communication in which every node straightly transmit the data to the CH. In UCS¹⁰, the foremost unequal clustering strategy is presented for uniform load distribution among the CHs. The BS is placed at the middle of the target region and it gathers data from WSN. The location of CHs are fixed earlier, with all CHs are sorted in the form of concentric circles in the region of the BS. Each cluster is comprised of nodes in the Voronoi area approximately the CH. The sensed value of each and every sensor in the clusters is gathered on the CH that does aggregation of data and broadcast the data towards the BS. In EEUC11, an energy efficient Unequal-Clustering protocol for periodic applications of data gathering. Through the use of unequal clustering along with multihop communication, the nodes are properly organized to clusters. EEUC be a competitive

algorithm, wherever CHs be chosen by partly opposition and the intermediate node with high remaining energy to forward the data. WCA algorithm employs voting scheme to elect CH in UCRA. In¹² the cluster setup phase, the nodes exchanges information to compute vote and it select the node with maximum vote will be considered as CH. The CH broadcasts the control messages to intimate remaining nodes. The CHs broadcasts the manages messages to notify additional nodes. The left nodes select the most excellent CH to connect based on the fitness. This process undergoes iterations till every node goes under a CH.

3. Proposed Algorithm

The overall structure of unequal clustering routing is demonstrated in Figure 2 that the unequal size circles denote the unequal size clusters and the technique of multi-hop forwarding is demonstrated through traffic between CH. The parameters are given in Figure 2. The maximum competition radius is denoted through Rmax that is predefined, d0denote the every sensor node radiation radius, dmin and dmax demonstrate the minimum and maximum distance among the sink and sensor nodes.



Figure 2. Cluster construction by CBR algorithm.

Partitioning of nodes into clusters is known as clustering. Every cluster comprises of CH and few normal nodes as its members. A novel voting based unequal clustering scheme for WSN is proposed. During the CH competition, the CH is elected mainly depends on every node weight. Here, the CH is chosen depends on the node's weight. The CHs nearer to BS supports small cluster size because of high energy utilization. Consequently, more clusters will be produced at the location nearer to BS. In other way, it can be represented as; the decrease in distance to BS enhances the cluster counts as well as reduces the size of the cluster. Let R_{max} is the high competition radius, which is fixed. A R_i of node viserves as a function of its towards the sink distance:

$$R_{i} = \left(1 - c \times \frac{d_{max} - d(v_{i}, BS)}{d_{max} - d_{max}}\right) R_{max}$$
(1)

where, $d(v_i, BS)$ indicates the distance among vi and BS, c is a constant coefficient lies in the range of 0 to 1. The competition radius ranges between from $(1-c)R_{max}$ to R_{max} using Equation (2).

In the cluster construction phase, the sensor undergoes election process using vote method. The topology, remaining energy and transmission energy are three factors in the selection of CHs. The topology, transmission and remaining energy are used to elect CHs. The sensors contend with every other while in the clustering stage. When a node contains many neighbors, every neighboring node gets a lesser vote as there exist more candidate nodes for this node. Every neighbor provides few votes towards a sensor node and sensor with huge neighbor's counts has the tendency to get more number of votes. So, for a sensor v_i , the vote it cast over other sensor v_i is:

$$\nu\left(\nu_{i},\nu_{j}\right) = \begin{cases} \frac{e_{j}}{\sum_{d_{ik}e_{k}}}d_{ij} \leq R_{i} \\ 0 \qquad \qquad d_{ij} > R_{i} \end{cases}$$
(2)

where, from sensor v_i to sensor v_k , dik refers the distance and e_j refers the remaining energy level of sensor v_j . The vote total of sensor vi is the total of votes from the entire voters,

$$vote(v_i) = \sum_{d_{ij} \le R_i} v(v_j, v_i)$$
(3)

An advertisement Ai for every node v_i ,

$$A_{i} = \frac{vote(v_{i})}{\sum_{k=1}^{n} \frac{(d_{ij})^{2}}{n}}$$
(4)

where, distance among vi and any of its nth neighbors is referred as d_{ik} . When node comprises none of the neighbors, then the broadcast value will be 1. A node which receives an advertisement node from other node knows the position of the neighbor. The node with higher advertisement will be chosen as CH. To determine the announcement rate, the sensor node is required to identify the neighboring distance and residual energy. It is required to broadcast the node id, position and remaining energy of the nearby nodes. Hence, each node becomes aware of its nearby nodes and the respective distances. On the reception of messages, every sensor node updates and broadcasts the advertisement to all neighboring nodes. The energy utilization of CH is based on the node degree. For proper energy distribution, many sensor nodes should accommodate under a high energy CH. The fitness function indicates the features of a CH. The sensor v_i fitness is represented as:

$$fitness_i = \alpha \frac{e_i}{degree_i} + (1 - \alpha) \frac{d_0}{10d_{ii}}$$
(5)

where, distance among cluster head i and node j is d_{ij} , $degree_i$ is number of neighboring nodes. When a sensor lies in the competition radius of many CHs, it selects the CH with maximum fitness value. When the amount of residual energy is found to be identical, then the CH with high node degree has lower fitness than those with few neighbors.

The majority of the reactive protocols broadcast information occasionally in a periodical way. It enhances the count of data transmission as well as the sensed information would be extremely connected. To enhance threshold, energy efficiency depends on data transmission is projected. This approach allows the CH transmits the attributes to its members and the thresholds are listed below:

Hard Threshold (HT): For the sensed attribute, it is a threshold assessment. It is the complete attribute rate away from that, the node sensing this assessment should control over their transmitter as well as study to the cluster head.

Soft Threshold (ST): It is a little modification in sensed attribute rate that trigger the node to knob over its transmitter and broadcast. The nodes sense the setting constantly. The nodes would subsequently broadcast data within the present period of cluster, alone while *together* the subsequent circumstances are true:

- When comparing with the hard threshold, the present rate of the sensed attribute is higher.
- The present rate of the attribute that is sensed varies out off *SV* through a sum equivalent to or superior when compared to the soft threshold. A data can be transmitted at any time, *SV* is locate equivalent to the in progress sensed attribute rate.

As a result, the hard threshold minimizes transmissions counts through enabling the nodes to broadcast alone while the sensed value in the region of significance. The soft threshold additionally minimizes count of broadcasts through the elimination of data transmissions that may contain or else occurred while here is small otherwise no modifications in the sensed attribute on one occasion the rigid threshold.

4. Simulation Results and Discussion

The projected CBR algorithm is implemented in MATLAB R2014a. A WSN of 200 nodes undergo random deployment in the area of 500x500m². For energy consumption analysis, the first order radio model is employed. The cluster construction of the projected CBR method is illustrated in Figure 3. For validation, the proposed method is validated by comparing its results with the LEACH protocol. The obtained outcomes of the projected CBR algorithm in terms of number of clusters are shown in Figure 4.



Figure 3. Unequal cluster construction.



Figure 4. No. of cluster formed.



Figure 5. Number of alive sensor nodes.

Figure 5 demonstrates the alive nodes counts for various rounds. It is absolute from the Figure 5 that the alive nodes counts are at maximum for CBR technique when comparing with the LEACH. The CH is selected through LEACH randomly and it does not involve any parameter to node for selecting the CH. The projected reactive and voting data transmission technique results in efficient CH selection and when compared to the actual period, the node works for long. This tends to enhanced alive sensor node counts within the network. When comparing with LEACH, the CBR algorithm energy utilization is low.

Figure 6 demonstrates the projected technique energy utilization with LEACH. When compared to the LEACH values, the projected method consumes low rate. This shows that using fuzzy logic in dynamic CH selection gives superior outcomes when comparing with LEACH. It is absolute from the network lifetime that had enhanced as 55.72%, and energy utilization is minimized by half when comparing with LEACH.



Figure 6. Energy consumption of sensor nodes.

5. Conclusion

This study presents a CBR algorithm using unequal clustering mechanism and threshold based data transmission. This study incorporates two main phases: (i) Unequal clustering using vote based measure as well as transmission power of sensor nodes and (ii) Reactive data transmission. This reactive manner eliminates the data redundancy as well as the amount of data transmission. The simulations were performed to highlight the advantages of the CBR algorithm to enhance the network lifetime with reduced energy consumption. For examining the energy utilization, the first order radio model is employed that network lifetime of the proposed method is increased by 55.72% and the energy consumption is reduced to 50% when compared to LEACH.

6. References

- Yick J, Mukherjee B, Ghosal D. Wireless sensor network survey. Computer Networks. 2008; 52:2292-330. https:// doi.org/10.1016/j.comnet.2008.04.002.
- Sohrabi K, Gao J, Ailawadhi V, Pottie GJ. Protocols for self organization of a wireless sensor network. IEEE Personal Communications. 2000; 7:16-27. https://doi. org/10.1109/98.878532.
- Chong CY, Kumar SP. Sensor networks: evolution, opportunities, and challenges. Proceedings of IEEE. 2003; p. 1247-56. https://doi.org/10.1109/JPROC.2003.814918.
- Akyildiz IF, Su W, Sankarasubramaniam Y, Cayirci E. Wireless sensor networks: a survey. Computer Networks. 2002; 38(4):393-422. https://doi.org/10.1016/S1389-1286(01)00302-4.
- Shokouhifar M, Jalali A. A new evolutionary based application specific routing protocol for clustered wireless sensor networks. AEU-International Journal of Electronics and Communications. 2015; 69(1):432-41. https://doi. org/10.1016/j.aeue.2014.10.023.
- Kumar V, Jain S, Tiwari S. Energy efficient clustering algorithms in wireless sensor networks: A survey. International Journal of Computer Science Issues. 2011; 8(5, 5-2):259-68.
- Kalantari S, Amiribesheli M, Daliri ZS, Shamshirband S, Ng LS. Routing in wireless sensor network based on soft computing technique. Scientific Research and Essays. 2011; 6(21):4432-41. https://doi.org/10.5897/SRE10.306.
- Younis O, Fahmy S. HEED: A Hybrid, Energy-Efficient Distributed Clustering Approach for Ad Hoc Sensor Networks. IEEE Transaction on Mobile Computing. 2004; 3(4):366-79. https://doi.org/10.1109/TMC.2004.41.
- Chatterjee M, Das S, Turgut D. WCA: A Weighted Clustering Algorithm for Mobile Ad hoc Networks. Journal of Cluster Computing, Special issue on Mobile Ad hoc Networking. 2002; 5:193-204.

- Soro S, Heinzelman WB. Prolonging the lifetime of wireless sensor networks via unequal clustering. Proceedings - 19th IEEE International Parallel and Distributed Processing Symposium, IPDPS 2005. Institute of Electrical and Electronics Engineers, New York City. 2005.
- 11. Cheng-Fa Li, Gui-Hai Chen, Mao Ye and Jie Wu. An Uneven Cluster Based Routing Protocol for Wireless Sensor Networks. Chinese Journal of Computer. 2007; 30(1):27-36.
- Zhang R, Ju L, Jia Z, Li X. Energy Efficient Routing Algorithm for WSNs via Unequal Clustering. Proceedings of the 14th IEEE International Conference on High Performance Computing and Communications, HPCC-2012 - 9th IEEE International Conference on Embedded Software and Systems, ICESS. 2012; p. 1226-31. https://doi. org/10.1109/HPCC.2012.180.