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An Enhanced Routing Mechanism for Energy Reduction in Wireless Sensor Networks

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Abstract

In the recent years, wireless sensor networks (WSNs) are treated as one of the emerging fields in the network communication. In WSNs, routing protocols are considered as the major issue and it is framed as the NP hard problem. Though, many routing mechanism are proposed, still there are some research issues to be addressed. In this paper, we are considering the reduction of consumption as the objective function for the proposed routing protocol. The proposed routing protocol considers the Quality value (Q-Value) of the nodes for packet forwarding. The Q-value is calculated based on the battery life and cost of the node. Based on the Q-value, the cluster head (CH) is selected automatically. The proposed protocol is evaluated based on the objectives such as network lifetime, packet delivery and energy consumption.

Keywords: WSNs, Energy, Learning Approach

1. Introduction

Wireless sensor networks [10] are composed of number of sensor nodes and each sensor node is restricted to some battery power, so the energy is the major concern factor in the WSNs. In the routing protocols, the attention over the packet delivery, bandwidth and reliability is high but those are not concentrating on the energy issue. In the recent trends [3], the researchers are more concentrated on the energy issue when they understand the importance of the energy in the WSNs. The WSNs are composed of small sensor nodes which have minimum battery power and it is almost impossible to recharge those batteries in most of the applications. Therefore, the designing of routing protocols plays major role in saving the energy of the WSNs. The hierarchical routing protocols have the advantage of energy efficiency. The cluster based routing protocols are fit for some applications.

The hierarchical routing protocols [5] are most appropriate for energy saving in WSNs. In these protocols, the network is divided in to multiple clusters and each cluster is organized by the cluster head (CH). The communication between the clusters has been carried by the cluster heads. The cluster heads are act as the bridges between the clusters. The researchers proposed numerous clustering approaches in WSNs. For instance, in some of the protocols [6, 8], the cluster head is selected first and then the cluster head selects the remaining members. The selection of members in the cluster is depending on the distance between the nodes, residual energy and the node distance to the base station. In another protocols, each node is aware of their position to which cluster it belongs to and selects the cluster head to the cluster.

In this paper, the nodes in the cluster are selected first then the nodes in the cluster selects the cluster head. The optimal selection of cluster head improves the network performance by reducing the overhead. The new protocol was developed for reducing the energy consumption by balancing the network overhead and reliability. The fault tolerance approach is incorporated in to the new protocol i.e., the failure path doesn't leads to the loss of data.

2. Proposed algorithm

In the proposed protocol, the clusters in the network are constant and the sizes of the clusters are variable. It is dependent on the distance of the clusters from the base station. If the cluster is nearer to the base station, the size of the cluster is small other it will increase with the distance. The nodes nearer to the base station consumes more energy and it leads to the node failures and the data transmission will be interrupted, so the cluster size is small means it leads to some sort of reduction in energy consumption. Figure 1 shows the representation of clusters in the proposed protocol. The sensor nodes contain the node IDs and each cluster is assigned with cluster ID. If the node wants to communicate with the other cluster, then it uses the cluster ID for intra-cluster domain. The cluster ID is crucial in routing and the CH node selection, figure 1 shows the different sizes of clusters in the WSNs. The one of the important issue in the WSNs is stability of the clusters. In the proposed approach the clusters is fixed and stable. As already described that the network is divided in to different sizes of clusters, sensor nodes need not to identify the CH node. A sensor node sends the information about the cluster ID and the information about the adjacent nodes to the base station. The sensor nodes are not involved in the election of CH node, so the energy consumption of the sensor nodes is reduced. The selection of CH node is based on the current state of the nodes and their neighbours and the distance between them. The Q-leaning approach [6] was utilized by the proposed method for optimal CH node selection. The Q-Learning Method is given below.

$$\text{Q-Value (i)} = X\ (i) * Y\ (i) \tag{1}$$

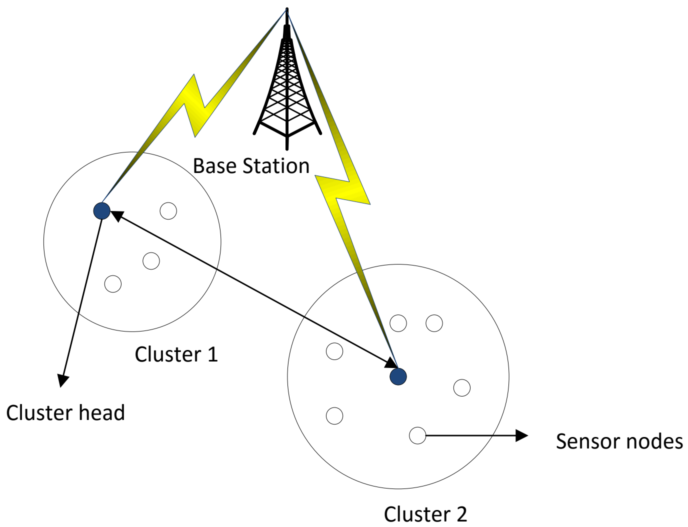

Figure 1: Cluster formation in WSNs

In the equation 1, the X (i) represents the distance between the node and the base station, the Y (i) represents the Q-value of the node action i.e. the battery level of the sensor node. If the battery level is high, the X (i) has the high impact the Q-value otherwise Y (i) has the higher impact in the Q-value.

Algorithm 1: Calculating computing cost of each node (Q-value of node)

i is the number of nodes
C is the cost of each node
$D_{k,l}$ is the distance between node k and node l

1. C(BS) represents the cost of Base Station which is equal to i
2. for each node in the range of base station the cost is calculated as

$$C_i = C(BS) \times (1 - (1/(n-1))) + 1/D_{BS,i} \tag{2}$$

Base station (BS) sends the value of C_i to node i

3. The neighbours of node i receive the C_i value and calculate the new C to the each neighbouring node by using step 4.
4. $C_i = C_k \times (1 - (1/(n-1))) + 1/D_{k,i}$
5. Repeat step 3 until all the nodes receives the C value.

Algorithm 1 calculates the cost of nodes in the WSNs through the eq. 2 and 3. Initially the cost of the base station is identified. The cost of the base station is equal to the number of active nodes within the range of the base station. For each ode in the base station calculates the cost and distribute the cost value to the neighbouring nodes. The cost between the selected node and neighbouring node is calculated by using the eq. 3. And finally continue this process until all the nodes receives their cost value.

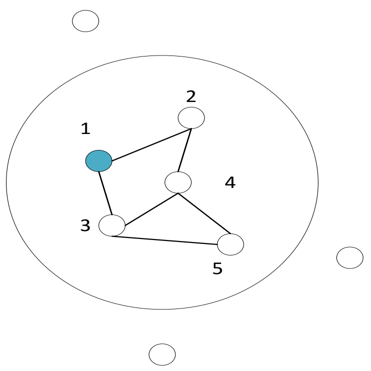

Figure 2a: Connected nodes with in the cluster

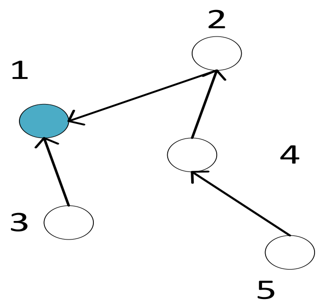

Figure 2b: Connected nodes with in the cluster after running the proposed algorithm

In the figure 2, the nodes in the cluster send the packet to the neighbouring node which having the highest Q-value. The Q value is calculated by the algorithm 1 and comparison made with the neighbouring nodes by using the algorithm 2. The cost and remaining battery of each node is listed in the table 1. This algorithm selects the cluster head based on the learning approach and finds the optimal path. In all the time, the cluster doesn't have one single CH node. But it has multiple CH nodes and the algorithm operates well in reducing the learning time.

Table 1: The cost and battery consumption of the nodes after applying the proposed algorithm

Node	Battery	Cost	Distance
1	70	64.3	1
2	65	65.7	1
3	85	66.3	2
4	54	56.3	3
5	71	49.8	4

The Q-value of the node is calculated by using the algorithm 2. The Q-value is a combination of cost and battery life. If the node having the battery power less than 50 %, then two by third of the battery power and one by third of the cost is consider for the Q-value calculation. Otherwise, one by third of the battery power and two by third of the cost is used.

Algorithm 2: Calculating battery level of node (Q-value of node action)

Begin

i is the number of nodes in the network

Z is the number of neighbouring nodes to the node i

Y(i) is the battery level of node i

A(i) is the Q-value of node action

C_i is the cost of node i

If (Y(i) ≤ 50 %)

$$A(i) = 2/3 \times Y(i) + 1/3 \times C_i \tag{4}$$

Else

$$A(i) = 1/3 \times Y(i) + 2/3 \times C_i \tag{5}$$

end

3. Simulation Environment

The simulation environment for the proposed protocol is developed by using the NS2 [2]. The performance of the proposed protocol is compared with the three existing protocols called as LEACH [9], EEUC [4] and FAF-EBRP [7]. For conducting the simulation, the packet size is taken as 250 bytes; area size is considered as 1000 m*1000 m and energy consumption of the node is taken given as 40 nJ/bit.

In the simulation environment, the distances between the nodes are kept constant and the cluster we are considering three clusters with in the network. In figure 4, it is shown that the proposed protocol had a better network lifetime when compared to the LEACH, EEUC and FAF-EBRP. The proposed protocol had the advantage of selecting the CH Node within the cluster and provides the direct communication between CH to the base station. This will reduce the number of hopes and increase the lifetime of the nodes with in the network.

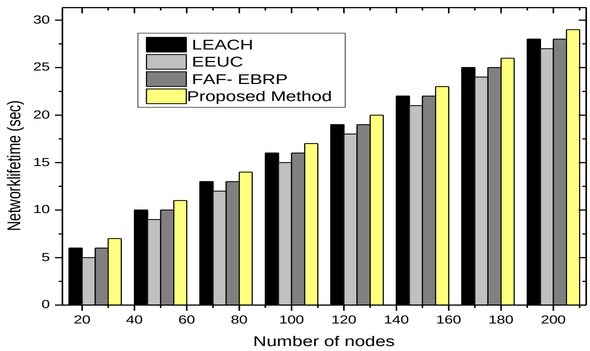

Figure 4: comparison of network lifetime in proposed protocol with LEACH, EEUC and FAF-EBRP

In figure 5, the packet delivery ratio of the proposed protocol is compared with the LEACH, EEUC and FAF-EBRP. It is observed that, the performance of the proposed protocol is slightly high when compared to FAF-EBRP. The FAF-EBRP had similar properties to the proposed algorithm. The packet delivery is dependent on the number of intermediate nodes participated in the network. If the nodes with in the communication are high then the packet delivery ratio will be reduced. In the proposed protocol, the intermediate nodes are selected based on the Q-value of the nodes. So, the efficient nodes are selected for packet forwarding. So, the packet dropping is very less in proposed protocol.

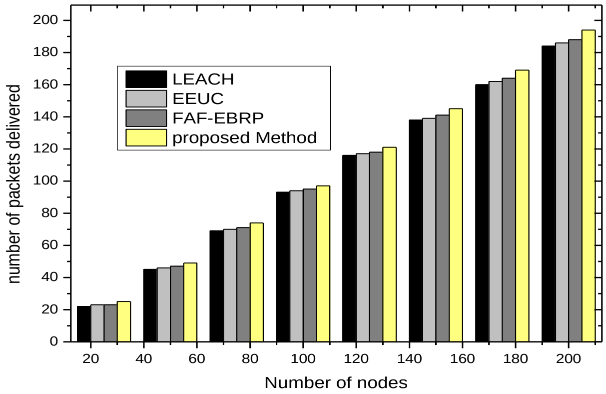

Figure 5: Estimation of packet delivery in proposed protocol with LEACH, EEUC and FAF-EBRP

Figure 6 describes about the energy consumption of the proposed protocol, LEACH, EEUC and FAF-EBRP. The energy consumption of the nodes mainly depends on the utilization of the sensor nodes. The sensor nodes are constructed on the battery power, the less battery nodes are prone to disconnections and leads to the packet loss. In the proposed protocol, the battery power of each node is calculated and forwards this information to all the nodes. Therefore, the sensor node chooses the neighbouring node based on the battery lifetime and cost of the node. This will ultimately reduce the energy consumption of the network by avoiding unwanted intermediate nodes. Figure 6 shows the energy consumption of the proposed algorithm is less when compared to the existing algorithms.

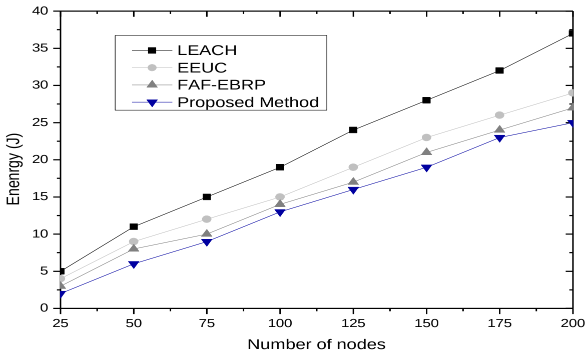

Figure 6: Comparison of Energy Consumption in proposed protocol with LEACH, EEUC and FAF-EBRP

4. Conclusion

Different routing algorithms are studied so far for reducing the energy consumption in the WSNs. But, there is no efficient routing mechanism was proposed for preserving energy in the WSNs. In this paper, we made an attempt to reduce the energy by considering the battery life of the sensor nodes with in the nodes. The efficient cluster head is selected based on the cost function of the nodes. The CH is responsible for transmitting and receiving the packets between the cluster nodes and base station. The Q-value is calculated for each node for identifying the efficient nodes and CH nodes for packet forwarding. The simulation of the proposed protocol is carried by using the well-known simulator called as NS-2. The experimental evaluation shows that the proposed routing protocol outperforms the other existing protocols in different segments.

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