Volume: 13 Issue: 05 Pages: 5095-5101(2022) ISSN: 0975-0290

Lifetime Enhancement of Wireless Sensor Networks Using Energy Centric Clustering Algorithm

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ABSTRACT

The major issue in Wireless Sensor Networks (WSN) is energy consumption. Over the past years, various protocols have been proposed to prolong the lifetime and minimize the energy consumption of the sensor node. The main limitations in WSN are limited battery capacity, communication range and storage capacity. A suitable routing protocol is required to improve the network lifetime and minimize energy consumption. In this paper, we propose an Energy Centric Clustering Routing Protocol for WSNs (EC2RP). In EC2RP, node residual energy and distance parameters are considered. Further, the data aggregation rate is proposed which allows the cluster heads (CH) nodes to aggregate the data before it sending to the next CH node or base station node. The simulation results show that EC2RP reduces energy consumption and extends the network lifetime.

Keywords - C**luster Head, Residual Energy, Energy Consumption, Wireless Sensor Networks.**

Date of Submission: Mar 04, 2022 Date of Acceptance: Apr 27, 2022

1. INTRODUCTION

A wireless sensor network (WSNs) is trending and emerging as a booming area in today's world. This led to developing low-cost, low-power consumption and multi characteristic sensor nodes. However, the predominant reality is that often sensor nodes run out of energy due to various factors such as distance between the nodes, link failure and continuous sensing, etc. Energy consumption is the main issue in WSNs and to deal with this issue, many authors have introduced different energy-efficient schemes for extending the lifetime of the network. This is the fact that many routing protocols in WSNs are focused on enhancing energy efficiency.

In Wireless sensor networks (WSNs), a large number of sensor nodes are used to sense the surrounding environment, sensed data will be transmitted to the base station (BS) or end-user for further analysis [1]. These sensor nodes are constraints nodes that differ from other wireless networks [2, 3]. The sensor nodes are energy-constrained in terms of sensing, processing and storage capacity. These sensor nodes are equipped with on board battery and these batteries cannot be recharged or replaced in unmanned areas of applications. Therefore, the major problem in WSNs is energy consumption [4]. To reduce the energy consumption WSNs, numerous routing schemes have been proposed, like cluster-based routing approach, hierarchical routing, flat-based routing approach and location-aware routing, etc. However, the majority of the routing techniques are distributive or self-organized. The cluster-based routing approach is one of the best solutions to make it more energy efficient in WSN. The entire network is further divided into clusters based on the number of sensor nodes are deployed on the network area. In every cluster, one node can be selected as cluster head (CH) and other sensor nodes can be called cluster members (CM). To minimize energy consumption during data transmission, CM nodes send the data packets to their corresponding CH, and further CH nodes can perform long-distance transmission to BS node using direct communication or multi-hop communication [2].

In this paper, an Energy Centric Clustering-based Routing Protocol (EC2RP) for Wireless Sensor Networks is proposed. The EC2RP protocol is based on the improved algorithm of LEACH, the suitable node can be selected as CH node based on the node residual energy and distance. Further to transmission efficiency is improved by introducing the data fusion rate.

The remaining section of the paper is structured as follows. Section 2 described related work, while section 3 discusses LEACH algorithm, section 4 discusses the proposed EC2RP protocol and section 5 discusses the results obtained and followed by the conclusion.

2. Related Work

In WSNs, the prime motive is to reduce the energy consumption and network lifetime of sensor nodes. In a Wireless sensor network, the design and implementation of energy-efficient clustering protocols are demanded, and many problems will arise during runtime scenarios.

In WSN, the network is divided into clusters; every cluster consisted of a group of sensor nodes. The clustering technique can enhance the lifetime of the network and improve overall scalability. In every cluster, the cluster members periodically transmit the data to the respective cluster head nodes, which are responsible for aggregating the data and responsible for sending the data to the sink node or BS node. The CH node consumes high amount of energy than its members because CH performs data aggregation before sending it to the sink node. Therefore to balance the energy consumption between the sensor nodes, the role of CH must be rotated periodically between the nodes in each cluster. Hence, the cluster formation technique, and CH selection are important things in the design of clustering algorithms as discussed in [5].

The authors in [6] and [7] developed Low Energy Adoptive Clustering Hierarchy (LEACH). The cluster heads were spread over and designated in a distributive pattern based on its predetermined probabilistic approach in a random manner. By using this scheme the clustering will be in an adoptive manner which thus improves the energy efficiency. Despite this, we encountered the depletion of energy levels due to the random selection of the cluster heads. From this work, it is clear that to enhance the energy efficiency it was suggested to use the sensor nodes with lower remnant energy and can be chosen as cluster heads.

The research work proposed in [8] is based on Hybrid Energy-Efficient Distributed (HEED) which focuses on communication cost and residual energy. In this work, the WSNs were deployed in a heterogeneous manner with various multiple levels of power in its sensor nodes. From this study, it was clear that the cluster heads were chosen based on an iterative process by considering residual energy in each of its sensor nodes along with its proximity to nearby sensor nodes. Despite this, it was clear that the overhead in communication due to the neighboring cluster head along with its regular communication has increased in extra cost for communication. The research work carried out in [9] proposed a dynamic scheme for clustering in heterogeneous networks. The CH was chosen based on its residual energy such that it adaptively ensured efficient clustering. In this work, the authors have not evaluated the extra cost of communication so there were challenges in the estimation of average energy in the network. In [10], the authors discussed efficient CH selection protocol for adjusting the cluster size and rotating CH locations for load balancing in all the nodes. This protocol was mainly designed for the modification of LEACH protocol and the node becomes a CH based on node residual energy. In [11], the authors proposed cluster head selection technique based on the decision tree (DT) algorithm. To enhance the lifetime of WSN, the authors used distance, node remaining energy, and signal to noise ratio (SNR) parameters to select the CH node. In [12], the authors proposed energy adaptive clustering protocol. Here they claimed that the optimization of the LEACHs random selection algorithm ensures balancing energy depletion over the whole network thus enhancing the lifetime. In [13], the authors proposed an efficient CH selective algorithm, which was an extension of LEACH. The authors considered the remnant energy for every node and the averaging the residual energy for all neighbor nodes to overcome the uneven distribution of energy in the LEACH protocol. This approach made the nodes to be dependent on each other.

In [14], the authors developed an algorithm based on LEACH protocol to enhance the lifetime of sensor nodes and minimize the energy consumption using the K-means algorithm.

Authors [15] proposed a cluster-based routing algorithm to minimize to improve the energy efficiency and further organize the nodes using the clustering method. Based on the dynamic selection of node energy it improves the network lifetime. In [16], authors considered node remaining energy and distance as parameters to select the suitable cluster heads for enhancing the lifetime. In [17], an energy-efficient routing protocol for WSNs is proposed. In this paper, CH selection is based on node residual energy, distance, Signal to Noise Ratio (SNR). Further node responsiveness factor was used for strengthening the cluster.

In [18], the authors proposed a cross-layer model-based routing protocol for WSNs. In this paper network congestion, link quality estimation and service differentiation parameters are used to minimize the energy consumption and improve the network lifetime. In [19], the authors proposed Energy-Aware Routing Protocol for Cooperative WSNs (EARPC). In this protocol, the CH selection is based on node residual energy levels and current energy consumption for all nodes. Further, the nodes having the lowest energy levels are less likely to be CH nodes.

In [20], the authors proposed K-medoids algorithm to select the random clusters which aim to reduce the energy consumption of a sensor node and extend the lifetime of the sensor node.

In [21], improvement of LEACH algorithm for WSNs algorithm was proposed. It uses static clustering to minimize overhead, and further, the network divides into various regions. In this approach, multi-hop routing was introduced to forward the data to the sink or base station to reduce energy consumption. In [22], authors proposed least cost optimization algorithm based on the LEACH protocol. The new cluster technique was used to create the uniform clustering and further data fusion rate proposed to minimize the energy consumption during the data transmission. In [23], authors demonstrated advantages and limitations of various renowned LEACH protocol in the industry usage.

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3. LEACH ROUTING ALGORITHM

LEACH stands for Low Energy Adaptive Clustering Hierarchy and it is a round-based protocol. In each round, one node will become a cluster head. This protocol is mainly designed to reduce energy consumption and extend the network lifetime. The LEACH algorithm divides the entire network into clusters. A group of sensor nodes forms a cluster and in every cluster, there will be a superior node called a cluster head (CH) node. The remaining sensor nodes act as cluster member (CM) nodes. In every cluster, the CM nodes are aware of their CH node. The CM nodes sense the surrounding environment, and sensed data will be further forwarded to the respective CH node. The CH node gathers the sensed data from all the CM nodes and further performs the aggregation to filter the redundant data. Once the data aggregation is over, forward it to the base station or sink node. LEACH is a round-based protocol, and the role of the cluster head is rotation-based. In each cluster, every node will get a chance to become CH node to avoid too much burden on a single node. To achieve energy efficiency, clusters are formed in a shorter. While forming the cluster, a random number from 0 to 1 is assigned during the cluster formation phase and this random number is generated by the control node. If the node has the highest threshold value, that node can be elected as CH node. The threshold value $\tau(n)$ can be calculated as follows.

$$\tau(n) = \begin{cases} \dfrac{P}{1 - P * \left(r \, mod \left(\frac{1}{P}\right)\right)}, & if\ n \in G \\ 0, & otherwise \end{cases} \quad (1)$$

In the above equation, p is the proportion accounted for CH nodes in the network and r indicates the total number of rounds; $r \, mod \left(\frac{1}{p}\right)$ refers the total nodes chosen as cluster head (CH) in a round-robin. G indicates nodes that are not chosen as CH nodes after the ending of 1/P in the cluster. The clustering consists of two phases, the establishment phase and the stabilization phase. In every cluster, the CH broadcasts its schedule to cluster members. Upon receiving the schedule message from its respective CH, the CM nodes check the signal strength of the message and decide which cluster they are belonging and forward its cluster request message to CH. Once the CH node collects request messages from CM nodes, the CH creates a routing table and further it assigns a TDMA schedule for all cluster member nodes. The CH node gathers the information according to the TDMA schedule from its CM nodes and also performs the data aggregation. The aggregated data further will be forwarded to the base station. The selection process is the same to select the CH for every round [24, 25]. The LEACH protocol is illustrated in algorithm 1 as follows.

Algorithm 1 LEACH algorithm

```
i←random (0, 1)
 if τ(n) > i then
BCH = Broadcast CHM ( )
Cluster members = wait (BCH)
 RM = Request Message ( )
Cluster Heads = receive (RM)
TS = Broadcast TS ( )
 while (Time ⩽ TS) do
Cluster Heads = receive (Data)
End while
else Bi = Broadcast CHM( )
Cluster Heads = wait(BCH)
Nodes = get (TS)
Cluster Heads = receive (Data)
SFD = Send Fusion Data ()
BS = receive (SFD)
```

Where Broadcast CHM () indicates cluster head broadcast message, Broadcast TS () refers TDMA slots and send Fusion Data () is information about the fusion data.

4. EC2RP ALGORITHM

In the proposed EC2RP algorithm, the round-robin concept is used to select the CH node. In the EC2RP protocol, the new formula is used to select the CH node and also avoid the random selection process for CH selection. Here the data fusion rate is used to minimize the energy loss in CH data acquiring and a combination of the free-space model and the multi-path fading model. In EC2RP, initially, the sensor network region gets separated from high and low-energy nodes. With the consideration of node remaining energy and distance as parameters, the new formula is derived to select the CH which is further used to divide the network region into clusters. The CH node will wait for CM nodes to complete the data communication, and further CH node is used the data fusion formula to perform the data fusion. During the data transfer phase, the free-space and multi-path fading models are used to estimate the distance between the nodes which can minimize the energy consumption for proper selection of sensor nodes. The proposed EC2RP protocol is illustrated in algorithm 2.

Algorithm 2 The improved algorithm

```
i←random ()
if i > Nodes High Energy Number then
HEN = High Energy Nodes ( )
else LEN = Low Energy Nodes ()
WR = weighted RER()
DP = distance SP()
HT = transform (HEN)
LT = transform (LEN)
if (HT & LT < τ(n)) then
BCH = Broadcast CHM()
Nodes = receive (BCH)
else ordinary Nodes = wait(BCH)
```

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```
RMI = receive MI ()
Cluster = To Join(RMI)
Ri = Request Message( )
Cluster Heads = receive (Ri)
TS = Broadcast TS ()
Nodes = receive (TS)
Cluster Heads = receive (Data)
MS = Message DFR()
Cluster Heads = receive (MS)
SFD = send Fusion Data ()
BS = receive (SFD)
```

Where weighted RER () refers to the weight of energy radio, distance SP () is distance weight scale parameters, receive MI () is the information intensity, To Join () is joining message cluster heads, and Message DFR () indicates data fusion rate.

4.1 Introduction of data fusion rate

Data fusion plays a key role in wireless sensor networks. The main reason why data fusion is important is, it judges the ability of the node in terms of node computing and reduces the data transmission to minimize the energy consumption in the networks [26]. In [27], the authors introduced the data fusion; the weighted formula is used to derive the data fusion information. In [28], the authors introduced a data growth factor, which aims to reduce the delay in WSN when the fusion rate is fixed. In WSN, the information may be lost due to the environment, the distance between the nodes and node energy are factors. In [29], the authors assumed a data fusion rate of 100%, but it is not possible to achieve in a real-time network scenario due to various network changes. So in [30], the authors introduced an energy-saving strategy for WSN based on the data fusion rate which aims to reduce the energy losses in the network. In EC2RP, the new formula is derived in equation 2.

$$\delta_{ij} = \frac{\mu_j}{\sum_{j \in N_i} \mu_j} \tag{2}$$

$$\mu_j = \frac{b_j}{b_1 + b_2 + \cdots + b_n} \tag{3}$$

Where μ_j represents the degree of trust in which other sensor nodes trust the information measured by the jth sensor node, N_i refers to the total number of nodes that are adjacent to the ith node. According to equations (2) and (3):

$$\sum_{j \in N_i} \mu_j = \frac{\sum_{j \in N_i} b_j}{b_1 + b_2 + \cdots + b_n} \tag{4}$$

By combining equations (3) and (4), the data fusion rate is expressed as,

$$\delta_{ij} = \frac{b_j}{\sum_{j \in N_i} b_j} \tag{5}$$

In the above equation b_j represents the weights of all sensor nodes that belong to N_i. Hence the transmitted data fusion rate can be calculated based on the formula.

4.2 Cluster-heads establishment stage

The sensor node energy levels are more when the node consumes less amount of energy, which indicates the probability of CH becoming well. The sensor nodes get divided into ordinary nodes and advanced nodes [31]. Equation (6), β refers to the energy levels being higher than the ordinary node. Where m refers the percentile of advanced sensor nodes, p_{norm} refers the probability of a common node to become cluster head and p_{adva} refers the probability of an advanced node to become cluster head.

$$p_{norm} = \frac{p}{1+\beta * m} \tag{6}$$

$$p_{adva} = \frac{p*(1+\beta)}{1+\beta * m} \tag{7}$$

By considering the parameters such as nodes energy and distance, the new formula is expressed as in equation (8). The purposed formula is to reduce the energy consumption at CH level due to too much burden on a single node and also these equations are used to distribute the sensor nodes in the region. The following $\tau(n)$ formula is expressed as:
For ordinary nodes:

$$\tau(n) = \begin{cases} \dfrac{p_{anorm} * \left(u\left(\frac{E_{resi}}{E_{ini}}\right) + v\left(\frac{d_{present}}{d_{max}}\right)\right)}{1 - P_{norm} * \left(r \bmod \left(\frac{1}{P_{norm}}\right)\right)}, & n \in G \\ 0, & otherwise \end{cases} \tag{8}$$

For advanced nodes:

$$\tau(n) = \begin{cases} \dfrac{p_{aadva} * \left(u\left(\frac{E_{resi}}{E_{ini}}\right) + v\left(\frac{d_{present}}{d_{max}}\right)\right)}{1 - P_{adva} * \left(r \bmod \left(\frac{1}{P_{adva}}\right)\right)}, & n \in G \\ 0, & otherwise \end{cases} \tag{9}$$

In equations (8) and (9), $P_{anorm} = a*P_{norm}$ is the weight of P_{norm}, $P_{aadva} = a*P_{adva}$ represents the weight of P_{adva}, 'a' refers the weightage parameter, whose values changes depending on the network size between 0 and 1, E_{resi}, E_{ini}, d_{presnt}, and d_{max}, respectively, represent the nodes residual energy, initial energy and minimum and the maximum distance of a node from sink node. Where u and v refers the proportional coefficients, whose range is $0 < u < 1$, $0 < v < 1$, and $u + v = 1$.

5. SIMULATION RESULTS

In this paper, MATLAB software is used to perform the simulation. The proposed EC2RP protocol compared with the existing protocol namely, SEC [32] by considering the network lifespan, node residual energy. The parameters used for the simulation for the proposed protocol are shown in table 1. In a 100 x 100 m^2 sensing area, 100 nodes are installed.

TABLE 1 Simulation Parameters

Parameters	Value
Sensing area	100 x 100m^2
Sensor nodes count	100
Network energy (E_0)	50 joule
Packet length (L)	2000 bits
Energy amplification factor (E_{amp})	100/pj/bit/m^2
Energy data aggregation (E_{DA})	20nj/bit
Radio Electronics circuit energy (E_{elec})	50nj/bit

5.1 Comparison of simulation results

Using the MATLAB simulation software, the node remaining energy, nodes survival rate are used to assess the performance of the proposed EC2RP with SEP protocol.

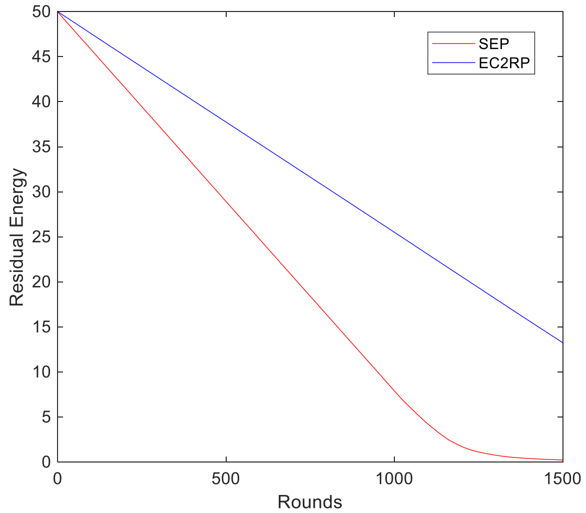

Figure 1 Average Residual Energy

Figure 1 and 2 indicates the simulation results of SEP and EC2RP protocol.

It is observed from the simulation results that the node distribution in the proposed EC2RP algorithm is more uniform than the existing SEP algorithm. The proposed algorithm adopts the new cluster method with the consideration of distance and the node residual energy which aims to reduce the energy consumption between the nodes is uniform.

Figure 1 shows the simulation results of the residual energy of the EC2RP and SEP algorithm. The greater the node remaining energy, the better energy consumption, and the node remaining energy decreases when the number of rounds increases. Compare to SEP, the proposed EC2RP algorithm residual energy is higher than the SEP algorithm.

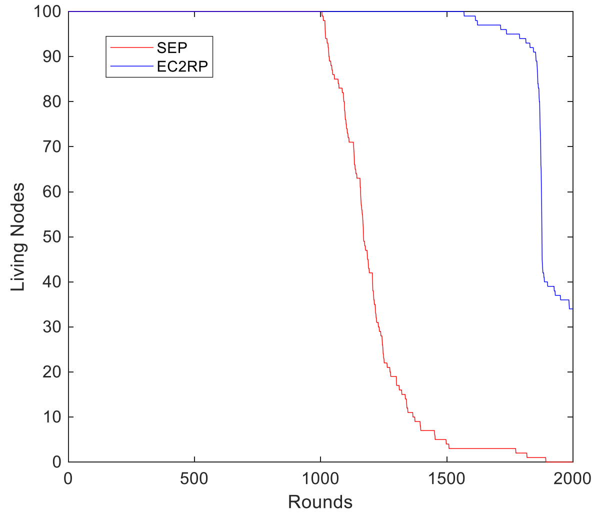

Figure 2 Number of Alive Nodes

Figure 2 shows the node's lifetime of the EC2RP and SEP algorithm. The simulation graph depicts that the proposed EC2RP node survival rate is higher than the SEP algorithm. The total number of rounds are used for the simulation is 2000. From figure 2, it can be seen that the differences start after 1000 rounds, when the number of rounds is increasing, the node's survival rate of the SEP algorithm is decreasing over the EC2RP algorithm. When it reaches nearer the 1800 round, all the nodes of SEP protocol are dead but in the case of EC2RP around 40 nodes are survived. Hence, the EC2RP algorithm gives more effective than the SEP algorithm in terms of energy efficiency.

6. CONCLUSION

The proposed EC2RP protocol aims to reduce energy consumption and enhance the network lifetime. In this paper, node distance and energy parameters are considered for the selection of cluster head nodes. The existing CH selection formula does not suit the selection of CH which further leads to energy consumption and it is not effective for uniform clustering. The proposed EC2RP algorithm considers weighted energy and distance are parameters that can save the nodes having less energy level and further the data fusion rate is introduced to improve the data transmission efficiency. Finally, the simulation results indicate that the EC2RP algorithm reduces the energy consumption and increases the node survival rate over SEP algorithm.

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