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Energy Efficient Clustering scheme to Maximize Network Lifetime (EECMNL)

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ABSTRACT: *In recent years of wireless communication, wireless sensor network (WSN) is a most interested field of research due to some powerful applications but at the same time pose formidable challenges, such as the fact that energy is a scarce and usually non-renewable resource. To minimize energy usage we propose an Energy Efficient Clustering scheme to Maximize Network Lifetime (EECMNL) which is basically a modification of existing routing scheme Low Energy Adaptive Clustering Hierarchy (LEACH).Similar to LEACH the clusters is formed. In LEACH only residual energy of a node is concerned to choose a node as Cluster Heads (CH) while in our work Cluster Heads (CH) is selected based on two parameters location and residual energy of the nodes. To start with, Base Station (BS) randomly chooses a fixed no of nodes each to act as Responsible Cluster Head (RCH) for an individual cluster, the RCH computes the central location of the cluster with the help of mathematical relationship established in the form of Lemma to be mentioned later. RCH selects a node which is closest to the centre of the cluster as well as having minimum threshold energy to act as CH.*

Keywords: *Cluster Heads (CH), Energy-Efficiency, LEACH, Responsible Cluster Head (RCH), Wireless Sensor Network (WSN);*

I. INTRODUCTION

In recent years of wireless communication, wireless sensor network (WSN) is a most interested field of research due to some powerful applications. WSN is consisting of a large number of small sensing self-powered nodes which gather information or detect special events and communicate in a wireless fashion, with the end goal of handling their processed data to a base station. Sensing, processing and communication are three key elements whose combination in one tiny device gives rise to a vast number of applications. Sensor networks provide endless opportunities, but at the same time pose formidable challenges, such as the fact that energy is a scarce and usually non-renewable resource.

Many works are so far reported towards energy-saving. One of the ways is employment of clustering. Clustering is defined [5] as the grouping of similar objects or the process of finding a natural association among some specific objects or data. It is used in WSN to transmit processed data to base station minimizing the number of nodes that take part in long distance communication leading to lowering of total energy consumption of the system.

The works related to energy saving approaches exploiting cluster-based data gathering in WSNs are summarized as follows.

W.R. Heinzelman et.al proposed LEACH, a distributed cluster formation algorithm [5]. LEACH is the first clustering algorithm which employs single-hop communication. It has two phases such as set-up phase and steady-state phase. It dynamically selects cluster heads targeting to distribute energy load among the sensor nodes evenly so that energy consumption of the WSN is reduced. However, the scheme does not give any guarantee about the placement of cluster head nodes resulting sometimes poor clustering set-up. To overcome this problem the authors propose another scheme [6] that employs centralized cluster formation LEACH_C instead of distributed one. Major drawback of this scheme is that each node has to send their current location and energy level to the base station/ sink node. During cluster head selection both LEACH & LEACH_C [5][6] assume uniform energy consumption for cluster heads.

To overcome the said problems O. Younis and S. Fahmy have proposed HEED, a distributed clustering scheme [9]. It gives guarantee of good cluster head distribution. The time complexity of cluster head selection is O(1). However, cluster head selection is performed based on two parameters such as residual energy and a node proximity to its neighbors. When LEACH [5][6] applies single-hop communication HEED adopts multi-hop communication to reduce energy consumption further.

M. Ye et. al have proposed EECS [10], a LEACH-like cluster formation scheme. When in LEACH cluster heads are selected randomly, EECS selects cluster head in such a manner that always there is a high-probability node to be selected as cluster head resulting load distribution among the nodes evenly.

Further step towards developing energy-efficient routing protocols gave shape to an approach in which static clustering formed the base.

A.S. Zahmati et.al proposed EEPSC [11], a clustering scheme which eliminates the overhead of dynamic clustering by utilizing the temporary-cluster-heads to distribute the energy-load among high power sensor nodes; EEPSC outperforms LEACH in terms of network lifetime.

In EEPSC, after the formation of distance based clusters, cluster head selection is performed on the basis of residual energy of individual nodes.

To be more specific, node with the maximum residual energy is selected as cluster-head for the current round whereas node with the least amount of residual energy is selected as temporary-cluster-head for the next round. Then the data transfer among the nodes and base station takes place. Though EEPSC [11] outperforms LEACH [5], often election of nodes located nearer to the boundary as cluster-heads may increase the communication overhead for the nodes lying on the other side of boundary which may result in the quick drain of battery mounted on the nodes. With this background we proposed the scheme where node is more centrally placed having minimum threshold energy considered as a CH so that energy-consumption due to intra-cluster communication is minimized thereby increases network lifetime.

The rest of the paper is organized as follows. Section II describes the proposed scheme along with the corresponding algorithm. Performance-evaluation and simulation results are presented in section III. The entire work is concluded in section IV.

II. PROPOSED SCHEME

2.1 Problem Formulation

This section contains the proposed scheme, Energy Efficient Clustering scheme to Maximize Network Lifetime (EECMNL)) followed by the algorithm of the proposed scheme. The present scheme is a modification of an existing scheme, Low Energy Adaptive Clustering Hierarchy (LEACH). Here we propose a modification on LEACH by choosing a node as cluster-head based not only on residual energy of the node but also on the relative location of the node within a cluster. The target is to select a node is more centrally placed within the cluster having minimum threshold energy as cluster-head. The desired goal is prolonging network lifetime.

2.1.1 Network model

We consider a WSN with the following properties [5]- [6], [9]-[11].

- All sensor nodes are immobile and homogeneous with a limited stored energy.
- The nodes are equipped with power control capabilities to vary their transmitted power.
- Network adopts the continuous data flow model and not the event-driven model.
- Base station is fixed and not located among the sensor nodes.
- None of the nodes knows its location in the network.

2.2 Protocol architecture

Like LEACH [5], EECMNL is also a self organizing algorithm having benefits of both static & clustering schemes. The whole network operation is consisted of several rounds where each round divided into two phases- setup phase, data transfer phase.

2.2.1 Set-up phase

To start with i.e. before any round starts fixed number (k) of Responsible Cluster Heads (RCHs) are selected randomly. However, next time onwards whenever clusters will be formed, k number of nodes will be chosen as RCHs for k number of clusters. These RCHs are selected according to their residual energies. If residual energy of a node is greater than or equal to a threshold value (T), the node is selected as one of the k number of RCHs. The threshold T is considered as the minimum energy required transmitting a fixed number of data from a maximum-distant node to the base station/sink. Once the RCHs are selected these RCHs broadcast a short range advertisement message (ADV).this message contain the node's ID and a header that distinguishes this message is an announcement message. Each non RCH node determines its cluster based on received signal strength of advertisement message. Every node in turn sends their acknowledgement message to their respective RCHs. Once the clusters are being formed the RCH computes the central location of each cluster using Lemma given later. Then RCH selects a node as a Cluster Head (CH) which closet to the centre of the cluster as well as having minimum threshold energy.

The CH node sets up a TDMA schedule and transmits this schedule to the member nodes of each cluster. After the TDMA schedule is known by all member nodes in the cluster the set up phase is complete.

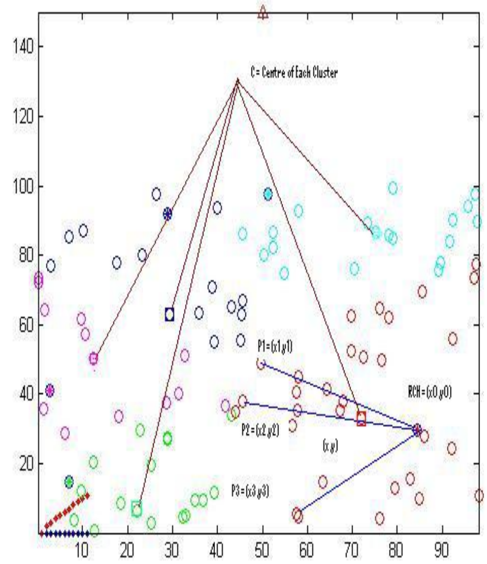

Figure1 Clusters and Cluster heads, RCH of different clusters

2.2.2 Data transfer phase

Once the clusters are formed and their respective Cluster Head (CH) is selected data transfer starts. The CH of each cluster takes the responsibility of aggregating and forwarding the data sensed by the member nodes of the respective cluster to the base station. When the residual energy of CH becomes below threshold it goes to sleep mode and the round is completed.CH of current round selects a node nearest to it as a RCH for next round and the process goes on.

2.3 Algorithm (EECMNL)

```
Begin
    /*Set-up phase*/
    /* Round start */
For round←1 to r_max    /* r_max-> Maximum no. of rounds*/
 For i← 1 to n
E_consume=0                          /* E_consume->Energy consumed by a node */
     /* checking for dead nodes     */
 if( E_resi<0)                      /* E_resi-> Residual energy of a node */
              dead=dead+1;     /* dead-> Number of dead nodes*/
 end if
 /* Cluster head selection*/
if(   E_resi>=T)
      RCH-> the node act as Responsible cluster head
end if
end for
        /* cluster formation*/
 for all node n except RCH
 Calculate min_dis             /*     min_dis->minimum distance of a node to RCH    */
 Include nodes into the cluster with min_dis.
 end for

     /* CH selection*/
For i← 1 to k
For alive_node ←1 to m_i /* m_i members nodes of cluster_i */
```

18. *Find central positioned node*
19. *If E_resi>T_{energy}*
20. *Select Cluster Heads(CHs)*
21. *end for*
22. *end for*

*/*End of set-up phase*/*

/ Data transfer phase Begins*/*

23. *For i← 1 to k*
24. *For alive_node ←1 to m_i*
25. *Send data to CH_i /*data transfers by alive_node*/*
26. *End for*
27. *Send aggregated data to the BS /*data transmission by CH_i */*
28. *End for*
29. *End for /*end of round*/*
30. *END /*end of algorithm*/*

III. PERFORMANCE EVALUATION

3.1 *Qualitative analysis*

To find out the central position of each cluster we follow a Lemma.

Lemma

If a node within a cluster knows the distances of the computation of central location distances of rest of the nodes of the cluster, the location of centre of the cluster is to be known.

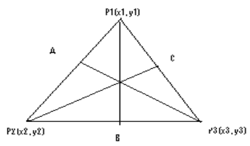

Figure 2

Proof

First we assume that the cluster is a specific geometrical figure. Let the position of centre is(x,y)and distance from RCH is $d_1$and assume the co ordinate of the fixed node is RCH P1 (x1, y1).

Let P2, P3, and P4 ….Pn are the different nodes belongs in same cluster with RCH. Now take any of two nodes which are most distant node from P1. Suppose the distance between RCH and P2& P3 is d_2 and d_3 respectively.

Now using the properties of triangle properties

We can get the middle pt of P1P3 is C=[((x1+x2)/2),((y1+y2)/2)]and P2P3 is B= [((x2+x3)/2), ((y2+y3)/2)].

The equation of straight line through B perpendicular to P2 P3 is

$$:y - \frac{y2+y3}{2} = \frac{-x3-x2}{y3-y2}\left(x - \frac{x2+x3}{2}\right) \qquad (1)$$

The equation of straight line through C perpendicular to P1 P3 is

$$:y - \frac{y1+y3}{2} = \frac{-x3-x1}{y3-y1}\left(x - \frac{x1+x3}{2}\right) \qquad (2)$$

Therefore the point of intersection of equation (1) &(2) is the centre of the circle(x,y) which passes through the point (x1,y1), (x2,y2) and (x3,y3).

3.2 Quantitative analysis

The EECMNL uses the first order radio model values for energy consumption as in [5,6]. Energy consumed by a node for different tasks are as follows.

For transmitting *l*-bit message at a distance d,

$$E_{Tx}(l,d) = E_{Tx-\text{elec}}(l) + E_{Tx-amp}(l,d) = \begin{cases} lE_{\text{elec}} + l\epsilon_{\text{fs}}d^2, & d < d_o \\ lE_{\text{elec}} + l\epsilon_{\text{mp}}d^4, & d \geq d_o. \end{cases}$$

For receiving *l*-bit message

$$E_{Rx}(l) = E_{Rx-\text{elec}}(l) = lE_{\text{elec}}.$$

Where d is the distance between a member node and its cluster heads or between cluster head and Base Station (BS), d_o is the threshold distance; $E_{elec}$is the electronics energy consumption. $_{fs,mp}$ are amplifier energy consumption by a node when d<d_o (member node)and d>=d_o (cluster head node)respectively. Threshold distance d_o is computed by the formula

$$d_o = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$$

In addition to transmission and reception of data, data aggregation performed at CHs needs a significant amount of energy (E_{DA}).

3.2.1 Simulation environment

To evaluate the performance of EECMNL, MATLAB 7 is used as a simulation tool. We consider that the sensor nodes are deployed randomly across a plain area. Each node is equipped with equal amount of energy at the beginning of the simulation. Further, we assume that WSN is working in continuous data flow application domain. TABLE1 represents various parameters and their values used in simulation.

Table1 used parameters and their values in simulation

Parameter	Parameter's Value
Network Area	100m x 100m
Base Station's Position	(50m, 175m)
Initial Energy for nodes	2 Joule
Number of deployed nodes	100
Size of data message	4000 bits
E_{DA}	5nJ
E_{elec}	50nJ
ϵ_{fs}	10pJ/bit/m^2
ϵ_{mp}	0.0013pj/bit/m^4

3.2.2 Simulation metric

The Performance of the scheme is evaluated considering network life time as a parameter which is defined as the time until the last node dies in the network []. Network Life time is measured using another way.

- Energy consumption-Total energy consumption of the network is less implies the network life time is longer.
- Numbers of nodes alive –More numbers of nodes alive implies network lifetime lasts longer.

3.2.3Results & discussion

A set of experiments is conducted to compare the performance of present scheme (EECMNL) with LEACH [5].

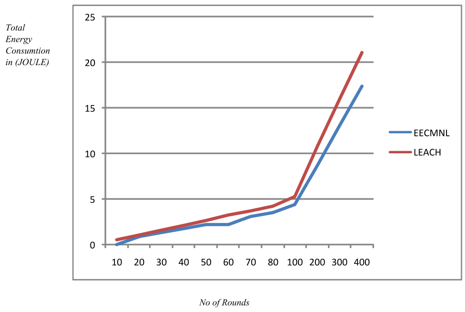

Figure 3 Total energy consumption in EECMNL is less than that in LEACH

In one set of experiment average energy consumption by the system is measured varying number of rounds for both the schemes. The result is plotted in Figure 3, which shows that average energy consumption of EECMNL is lower than LEACH after every number of rounds thereby increasing network lifetime.

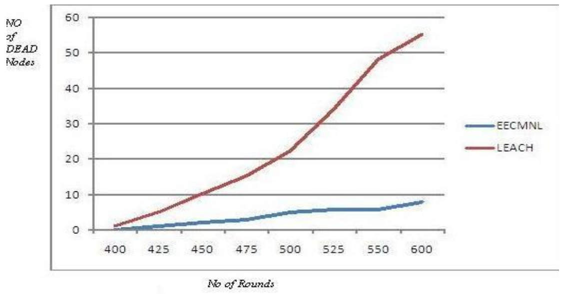

Figure4 Dead nodes comparison between EECMNL and LEACH

Finally an experiment is conducted to observe the rate at which number of dead nodes increases with number of rounds. We simulate both EECMNL and LEACH up to 600 rounds. The result (Figure 4) shows sharp rise of number of dead nodes with rounds in LEACH compared to EECMNL. For example, we observe at the end of last round, when there are 55 dead nodes in LEACH, there is only 8 dead nodes in EECMNL.
Summarily, the results of all set of experiments show, whatever be the measuring parameters that influence network lifetime, our scheme gives significantly better result than LEACH.

IV. CONCLUSION & FUTURE WORK

In this paper an energy efficient routing scheme EECMNL for WSN is proposed. The EECMNL is a modified scheme of an existing routing scheme LEACH. Objective of this scheme is minimizing energy consumption as if the network life time is more, Similar to LEACH the clusters are formed in dynamic fashion. But the Cluster Head (CHs) are selected based on their residual energy as well as more centrally placed in the corresponding cluster to reduce intra cluster energy consumption and prolonging the network lifetime.

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