Energy Efficient Zone Divided and Energy Balanced Clustering Routing Protocol (EEZECR) in Wireless Sensor Network

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ABSTRACT

Wireless sensor network has proven its significance in almost every field in today's era. Wireless sensor network consists of large number of sensor nodes distributed randomly in some areas. In WSN the main objective has been increasing the network lifetime. There is zone divisional approach which has shown sound improvement in increasing the network lifetime over the Leach and EEUC protocols. The proposed protocol Energy efficient zone divided and energy balanced clustering routing protocol (EEZECR) has not only much higher network lifetime as compare to ZECR and it also has much better load balancing in the network. In the EEZECR the concept of double cluster head in a cluster is introduced which reduces the load on cluster head and very efficiently does the task of load balancing in the network thoroughly which makes this protocol favorite for many real time applications. Simulations are performed in MATLAB.

Keywords

Wireless sensor network (WSN), Cluster head (CH), Assistant Cluster head (ACH)

1. INTRODUCTION

A Wireless sensor networks are acting as a bridge to the physical world. Recent advancement in wireless sensor networks have led to many new protocols specifically designed for sensor networks where energy awareness has been an essential consideration. In wireless sensor network the energy of battery has been the most concerning issue as battery of sensor node is not feasible to replace once deployed. Since transceiver is the biggest consumer of energy in a sensor node, still transmission of data takes much stock of energy as compare to reception. To have efficient transmission of data, routing of data has to be made efficient among the nodes or from nodes to Base station. There are various routing protocols which have been developed to minimize the energy consumption among nodes. In this paper our research is focused to hierarchical routing protocols. In these protocols clustering of nodes is done and cluster head does the task of collection of data from various nodes and then forwarding it to further Base station. This paper is organized as follows: section 2 discuss the application of wireless sensor network. Section 3 presents the architecture of WSN node. In section 4 different deployment phase has been given. Section 5 discuss about clustering. Section 6 discuss about zone divisional network. Section 7 and section 8 gives the simulation results and conclusion respectively followed by reference listing.

2. APPLICATIONS OF WSN

There are various applications of Wireless sensor network. In military areas the sensors are deployed to detect intruders and also monitoring of their activities can be done with the information retrieved from sensors. In environmental applications these sensor network significantly perform the task of forest fire detection, flood detection, earthquake detection, monitoring volcano eruption and many more. In habitat monitoring and Medical applications these sensor network have been in hot spot in their applicability.

3. WIRELESS SENSOR NODE

Wireless sensor node is employed on the basis of its applicability. It consists of ADC which converts the analog signals into digital signals and then they are fed into the processing unit. Processing unit allows the sensor node to collaborate with other nodes for performing the assigned task. A transceiver unit does the task of transmission and reception of data. Power is the most important component of WSN.

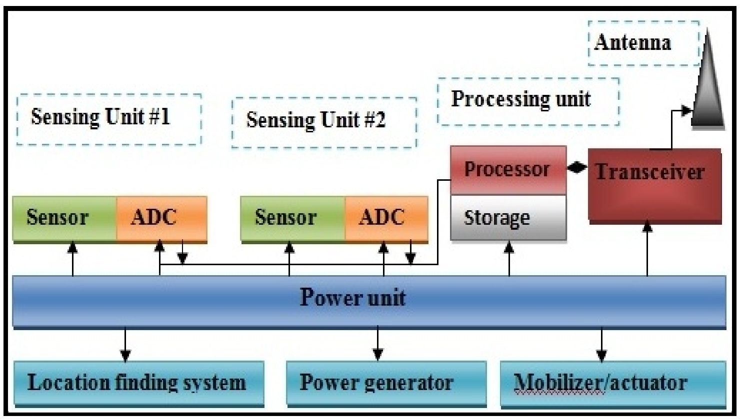

Fig 1 Architecture of Sensor Node[1]

The basic architecture of sensor node has been shown in Fig.1

4. CLUSTER FORMATION

In order to make data aggregation more efficient in a network, nodes are grouped into a number of small groups called clusters. In each cluster one sensor node is selected as cluster head which performs the task of data collection from various nodes and thereby forwarding it further. This clustering scheme increases the life time of network by minimizing unbalancing of energy load throughout the network [7]. The significant advantage of clustering is the scalability that it provides to the network.

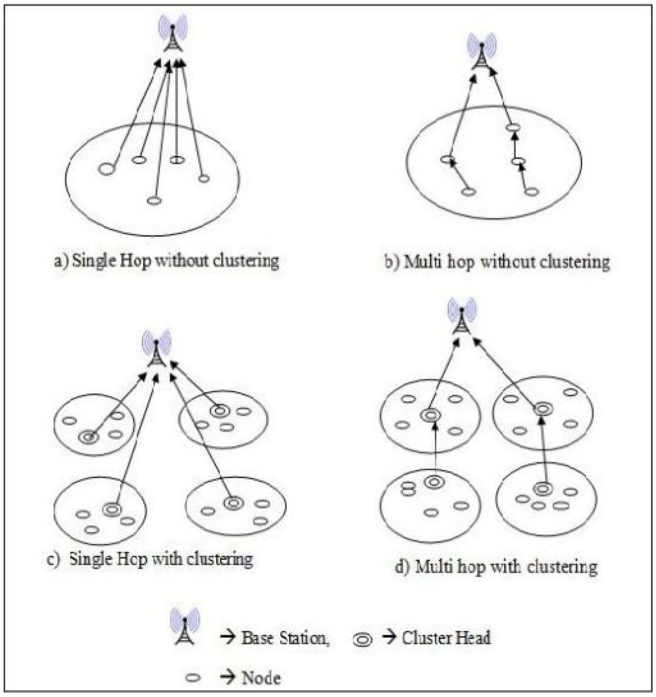

Fig.2. Single-Hop and Multi-Hop Communication [8]

5. ZONE DIVISIONAL NETWORK

In this whole network is divided into different zones [10]. Zone number is assigned according to the distance from the Base station. In every zone there can be any number of clusters depending upon the number of nodes being employed. The size of zone 1, i.e nearer to Base station will be smaller than then the zone 2 and so on. It is done to conserve the energy for data forwarding. The Zone number is allotted by the equation (1).

$$Z(i) = [(di\_bs - di\_min)/r)] + 1 \quad (1)$$

Here Z(i) is the zone number, di_bs is the distance of node from the BS, di_min is the minimum distance of node from BS.

5.1 Network Model

It is assumed that sensor node deployment is randomly uniform in a square area. Assumption is made that all nodes in the network has the following properties:

I. All nodes are considered to be static, which means there is no movement of nodes once they are deployed. The main objective of sensor network is that nodes collect data from the environment periodically and send to the base station.
II. All the nodes are same and have the same initial energy at the beginning.
III. Each node is having the ability to merge the redundant data. All sensor nodes are assumed to have limited batteries and recharging them is really infeasible.
IV. Nodes do not posses any GPS equipment and their relative distances are calculated on the basis of received signal strength.

5.2 Energy Consumption Model

The radio model for receiving and transmitting a *l*-bit message is used. In comparison with communication energy , the energy consumed on computing and storage process is much lower. Energy consumption on communication is considered for simplicity.

$$Etx(l,d) = lEelec + lEefsd^2 \text{ for } d<d_o \quad (5.1)$$
$$Etx(l,d) = lEelec + lEefsd^4 \text{ for } d>d_o \quad (5.2)$$

and to receive this message the radio expends:

$$Erx(l) = lEelec \quad (5.3)$$

To merge the number m such message the energy consumes:

$$Edx(l) = mlEda \quad (5.4)$$

In Equations(5.1) , (5.2) and (5.3) , *Eelec* represents the energy consumption of transmit or receive 1 bit message. In equation (5.4) , *Eda* represents the energy consumption of merge 1 bit message.

Here d_o shows the threshold value, when the distance is less than d_o , the free space channel model is used (d^2 power loss) ; When the distance is more than d_o , the multi-path fading channel model (d^4 power loss) is used.

5.3 EEZECR protocol

The proposed work has been directed to make Zone Divided and Energy Balanced Clustering Routing Protocol (ZECR) more energy efficient by introducing the concept of “Double cluster heads” in a cluster. Zone divisional approach divides the network into different zones according to the distance from Base station. Zone number is computed for each zone according to the distance from Base station.

Assistant cluster head (ACH) is introduced in each cluster which has residual energy less than energy of Main Cluster head (MCH). ACH will collect the data from all the nodes in the cluster and after removing redundant data it will forward to MCH. Then that cluster head forwards that data to Main Cluster head of adjacent cluster which is nearer to Base station. This will make the multi-hop transmission more energy efficient in inter-cluster communication.

The load on Main Cluster Head (MCH) of each cluster will be reduced by assigning the task of data aggregation to Assistant Cluster Head (ACH), so that redundant data is removed by ACH and efficient data is transmitted to MCH and thereafter inter cluster communication routes the data to Base Station.

The proposed algorithm includes following steps:

5.3.1 Initialization of parameters.
5.3.2 Deployment of sensor node

5.3.3 Zone Divison

5.3.4 Computation of size of cluster radius

5.3.1 Initialization of Parameters

There are some experimental parameters are shown in table 5.3

Table 5.3 Experimental Parameters [22]

Parameter	Value
Network coverage	(0,0)~(100,100)m
BS location	(50,150)m
Node Number	100
Initial energy	[0.3,0.5]J
Eelec	50nJ/bit
Efs	10pJ/bit/m^2
Emp	0.0013pJ/bit/m^4
d_0	87m
Eda	5nJ/bit/signal
Data packet size	4000bits

This table gives the values of different parameters like Network Coverage, BS location, Node number, Initial energy of nodes before deploying, Eelec which represents the energy consumption of transmit or receive 1 bit message. Eda which represents the energy consumption of merging 1 bit message. d_o is the threshold value of the distance required to determine whether its free space channel model or it is multi path fading channel model.

5.3.2 Deployment of sensor nodes

The deployment of sensor node is done randomly throughout the network by maintaining uniform density and location of sensor node is also defined randomly. The number of sensor nodes to be deployed is 100 and they are being deployed in (100 X 100) m area.

5.3.3 Zone division

In this zone divisional approach network is divided into different zones according to the distance and selection of cluster head in each zone is done independently. After the deployment of nodes, Base station (BS) broadcast the zone divided message (Zone_Msg) in the whole area, including the zone radius r in the message.

Nodes calculate their distance to the BS (di_bs) based on the received signal strength. The zone number is distributed by the equation given below

$$Z(i) = [(di\_bs - di\_min)/r)] + 1 \qquad (5.5)$$

So the minimum Zone number is 1 and if a zone is farther from BS, it will have a larger zone number. Every node can get its zone number by the equation. As all nodes are static, so zone division is done once after the nodes are deployed. Energy consumption in this phase can be ignored as compare to energy in the long time.

5.3.3 Computation of size of cluster radius

After the network area is divided into zones, the next phase is to compute the cluster radius of each zone by using the equation

$$Ri = \left(1 - c \times \frac{Zmax - Z(i)}{Zmax}\right) \times Rmax \qquad (5.6)$$

Here Zmax denotes the maximum zone number in the area and Z(i) denotes the zone number of node i. In the equation *Rmax* is the maximum competition cluster radius, c is constant coefficient between 0 and 1. The optimum value of c is given as 0.4. In the equation *Rmax* is optimum cluster radius calculated by the equation

$$Rmax = Ropt = 2 \times \sqrt[4]{\frac{(2\pi \square A \square Eda)}{27NEfs}} \qquad (5.7)$$

In this protocol, the cluster radius in the same zone is same which reduces the complexity of the algorithm.

5.3.5 Cluster set up phase

Once all the nodes get their zone number and cluster radius, the cluster set-up phase begins.There are following steps which comes under the cluster set up phase.

5.3.5.1 Structure of Node Message:

Each node maintains a neighbor node table Table_Node and broadcast their own information Node_MSG in the range of cluster radius. The structure of Node_Msg is as Table 5.3.5:

Table 5.3.5 Structure of Node_Msg

ID	Energy	Zone
1	0.37J	1
2	0.46J	1
3	0.32J	2
4	0.42J	2
5	0.48J	3

Where ID is unique identifier of node in the network, Energy is the residual energy of node and Zone is the zone number of node. Each node only receives message that comes from the same zone, ignores the others and updating of table is done accordingly.

5.3.5.2 Main Cluster head selection

In the proposed routing protocol, main cluster head selection is done on the basis of residual energy of each node in the cluster. The average energy of all the nodes in a cluster is calculated and that value is used as threshold. If a node has energy greater than threshold only that node is eligible to participate in main cluster head election competition. The energy of node is computed with the equation given below

$$T = {Eoi}\Big/{\left(\sum_{j=1}^{n-1} Eoj\right)}\Big/{n-1} \qquad (5.8)$$

Among the equation, Eoi indicates the initial energy, n indicates the number of nodes within the scope of adjacent nodes, ∑Eoj indicates the sum of other nodes' energy.

If T>1, node i is eligible to participate in the election of main cluster head. So node with the highest residual energy is declared as main cluster head.

5.3.5.3. Assistant cluster head selection

After selection of Cluster head, the selection of Assistant cluster head (ACH) is done similarly on the basis of residual energy, node with the minimum difference in the residual energy with the cluster head is selected as ACH.

Equation to be followed for selection of ACH is given by

$$Qi = \frac{q1 \times Ec(i) \times (Eo(i) - Ec(i))}{\sum_{j=1}^{n} \frac{Ec(i)}{n}} + q2 \times T(i) + q3 \times dist \qquad \text{........(5.9)}$$

Here q1, q2 and q3 are non negative weight value factors, Ec(i) is the current energy, Eo(i) is the initial energy, T(i) is the times of being cluster head and dist as the distance from the base station, Q(i) is used for obtaining the likelihood of node to be cluster head.

5.3.5.4 Data Transmission Stage

The task of data transmission is done in the intra cluster and inter-cluster communication.

i. **Intra cluster communication:** In this stage, data is transmitted from sensor nodes to Base station via ACH and MCH, through single hop if the cluster is nearest to Base station, multi-hop if there is another cluster nearer to base station. TDMA scheduling is used for transmission of data from each node (other than MCH) to ACH. Data is transmitted from nodes to ACH then to MCH in a cluster of a zone then to next zone and finally data reaches to the Base station from various zones.

ii **Inter-cluster multi-hop routing phase:** This protocol adapts to multi-hop strategy in inter clustering routing phase. In this the cluster head of sufficient energy is selected for multi-hop transmission, for this overall energy of cluster is considered so that there might not be the chance of selecting the cluster head of low energy cluster region.

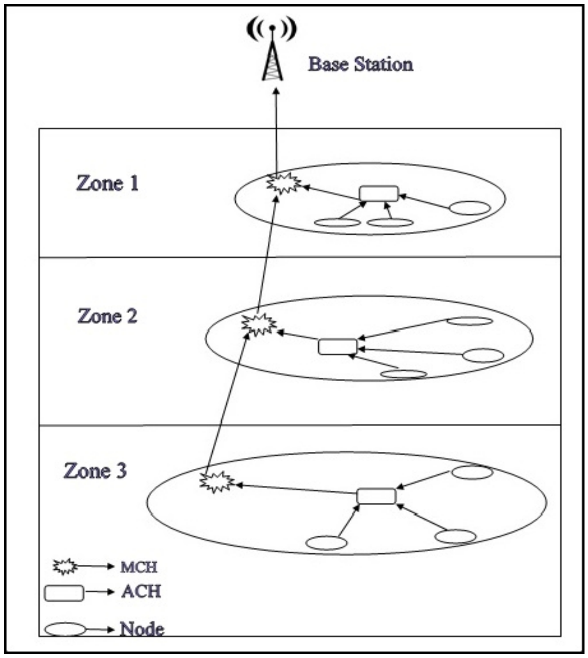

Fig. 3 Intercluster and Intracluster communication in Zone divisional Network

6. SIMULATION

The simulation is performed in Matlab 2011a. Here in Fig. 4 the simulation has been shown in which Data transmission occurs in different zones in multi-hop communication between clusters. Here “Red” lines show the direct transmission to Base station from cluster head. “Blue” lines show the transmission from one cluster head to another cluster head.

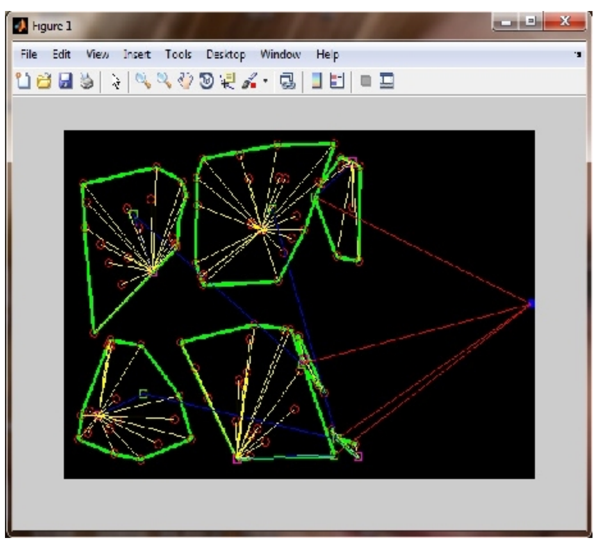

Fig. 4 Simulation of EEZECR in Matlab

7. RESULTS

After running the simulation in MATLAB, the proposed (EEZECR) protocol 1st dead time, 20% dead time, 50 % dead time, 70% dead time, 90% dead time and 100% dead time is found to be increased by 71.4%, 52.5%, 36%, 29.1% , 10.6% and 2.3% respectively, which are improved effectively as compare to ZECR protocol. The overall network life time is highly improved in terms of existence of alive nodes for more number of rounds as shown in the Fig. 5

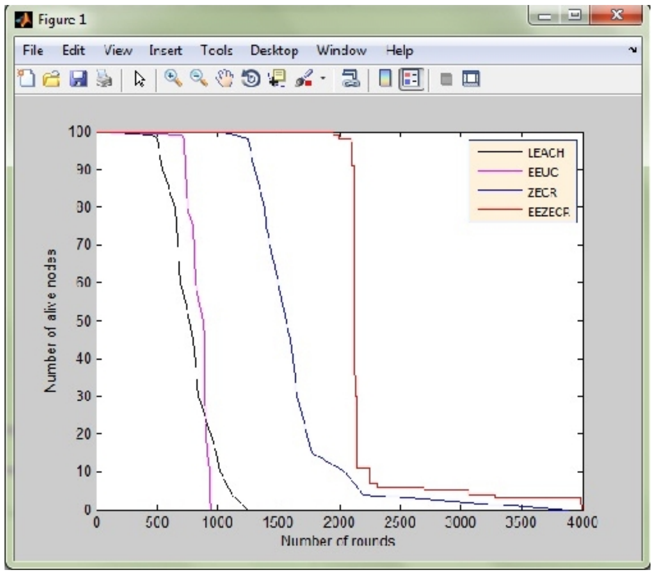

Fig. 5 Comparison of network lifetime of Protocols

Fig.7 shows that the EEZECR has greater network lifetime in terms of increased number of rounds as compare to all other algorithms.

Table: 7 Comparison of EEZECR and ZECR

Time/Protocol	**ZECR**	**EEZECR**	**Improved Rate**
The 1st dead time	1138	1951	**71.4%**
20% dead time	1390	2121	**52.5%**
50% dead time	1564	2128	**36%**
70% dead time	1658	2141	**29.1%**
90% dead time	2038	2256	**10.6%**
100% dead time	3897	3990	**2.3%**

7.1 Aggregated results for overall improvement

The comparison table 8 shows the overall comparison between LEACH, EEUC, ZECR and EEZECR protocols in number of rounds.

Table:8 Overall comparison between protocols

Time/ Protocol	**LEACH**	**EEUC**	**ZECR**	**EEZECR**
1st dead time	463	708	1138	**1951**
20% dead time	647	751	1390	**2121**
50% dead time	766	880	1564	**2128**
70% dead time	841	893	1658	**2141**
90% dead time	1016	936	2038	**2256**
100% dead time	1245	947	3897	**3990**

7.2 Comparison of Load Balancing

As shown in the Fig. 6 there is ideal graph for any protocol to be load balanced for assumed 2000 rounds. As it can be seen load balancing is highly improved in EEZECR as compare to ZECR.

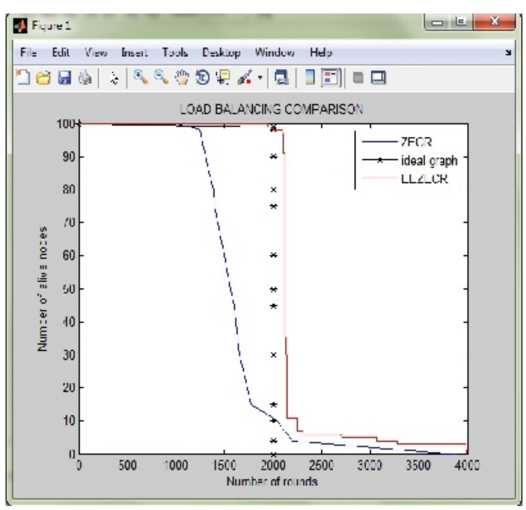

Fig 6 Load Balancing comparison

It has been done by using efficient way of selecting the cluster head on the basis of residual energy and also average energy of the cluster is considered to forward the data so as to transmit it to BS. In Fig the EEZECR is very close to ideal graph as compare to the ZECR. The declination curve in the graph of ZECR shows unbalancing of the load in the network. The more steeper the graph is, the more is the load balancing of the network. So this protocol (EEZECR) not only reduce energy consumption in the network but also improve load balancing in the network which makes it favorite for many applications.

8. CONCLUSION AND FUTURE SCOPE

In the proposed work, dividing the network into different zones has simplified the network topology. It has considered unequal clustering method to solve the Hot spot problem. Results show that energy efficiency has highly improved and lifetime of network is also increased to more number of rounds. There has been tremendous improvement over LEACH protocol in terms of network lifetime. The load balancing is effectively achieved with proposed EEZECR. So more number of nodes will be available for same number of rounds, which thereby increases the lifetime of network. So it can be concluded on the basis of results that the introducing the double cluster head approach in zone divisional network enhances the energy efficiency of the network and it also increases network life time with much more load balancing throughout in the network. Future work will be focused on optimization of routing among nodes.

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REFERENCES

[1] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, .A Survey on Sensor Network., IEEE Communication Magazine 40, 8, pp. 102-114, August 2004.

[2] D. Estrin, R. Govindan, J. Heidemann, S. Kumar, 'Next century challenges: scalable coordination in sensor networks, ACM MobiCom', Washingtion, USA, pp. 263–270, 1999.

[3] P. Bonnet, J. Gehrke, P. Seshadri, Querying the physical world, IEEE Personal Communications,pp.10–15.

[4] http://www.alertsystems.org.

[5] Pradnya Gajbhiye, Anjali Mahajan , "A Survey of Architecture and Node deployment in Wireless Sensor Network" First International Conference on Applications of Digital Information and Web Technologies, ICADIWT 2008. **Page(s):** 426 – 430,4-6 Aug. 2008

[6] Pruet Boonma, Paskon Champrasert, Junichi Suzuk "BiSNET: A Biologically-Inspired Architecture for Wireless Sensor Networks", IEEE 2006.

[7] Rudranath Mitra and Diya Nandy, "A Survey on clustering techniques for wireless sensor network" nternational Journal of Research in Computer Science, Vol.2 Issue 4, pp 51-57, 2012.

[8] Fuad Bajaber and Irfan Awan,"Adaptive decentralized re-clustering protocol for wireless sensor network" Journal of Computer and System Sciences, pp: 282–292, 2011.

[9] J.Yang and D. Zhang, "An Energy Efficient-Balancing Unequal Clustering Protocol for Wireless Sensor Network" Information Technology Journal, Vol.8 Issure 1,pp 57-63, 2009.

[10] S. Taruna, Jain Kusum Lata, Purohit G.N, "Zone Based Routing Protocol for Homogeneous Wireless Sensor Network", International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC) Vol.2, No.3,pp.99-111,September 2011.