Energy Conservative Clustering Protocol for Wireless Sensor Network

Harshita Patidar
Student (M.Tech.)
CSE Department
LNCT Bhopal

Sadhna Mishra
Professor
CSE Department
LNCT Bhopal

Vineet Richhariya
HOD
CSE Department
LNCT Bhopal

ABSTRACT
Wireless Sensor Network (WSN) is the network of tiny sized sensor motes. Due to the limited size, sensor mote is limited in processing, memory and energy. The limitation of energy and memory in sensor mote create challenges for routing in WSN. Cluster based routing protocols in WSNs has recently increase interest for energy efficiency. A leader represents all sensor motes in the cluster called cluster head (CH) and collects sensed data from them. To balance the traffic load and the energy consumption in the network, the CH should be rotated among all motes. In this paper, we proposed energy conservative clustering protocol (ECCP), ECCP elects CH based on motes near to the sink distance and residual energy of the motes. In WSNs energy is mostly consumed for data transmission to sink. In this paper, the optimal sink distance is considered which decrease the length of path to sink. In addition, residual energy is also considered in the CH election in order to increase the network stability and lifetime. Furthermore, the reclustering of cluster head conserves the energy in data transmission to sink. The simulation results show that ECCP conserve more energy in data transmission compared to the well-known exiting clustering algorithms LEACH and TL-LEACH. ECCP also prolong the network stability period and lifetime than LEACH and TL-LEACH protocols.

Keywords
Wireless sensor network, clustering, energy conservation.

1. INTRODUCTION
Wireless sensor network is the network of tiny sensor motes having limited radio range, memory, processing power and most important energy. WSN uses in many applications like target detection, monitoring, tracking etc. But some of the applications are where human cannot survive like disaster, battle field, etc. In this type of the application we need a WSN that is self configurable. But in this type of application battery can't be replicable. There are many protocols for clustering to save energy of WSN, but they are not much energy efficient in inter cluster communication. LEACH is the clustering protocols use a threshold for cluster head selection but does not consider the remaining energy of the sensor motes. Most of the threshold based clustering protocols considered parameters like remaining energy of sensor motes, relative distance from cluster head to base station, number of time a sensor mote already has become cluster head and number of neighbor mote a cluster head has. But the combination of these parameters can be used to conserve energy in clustering and data reporting process.

In this paper we considered two parameters to derive the threshold are remaining energy of sensor motes, relative distance from cluster head to base station. Using this threshold protocol will select cluster heads which is nearer to base station and having more energy to serve the cluster member. We also reduce the inter cluster communication using reclustering process. The reclustering process increases the stability period and network life time of the sensor network.

The rest of the paper is organized as follows. In Section 2, we present related work. In section 3 present the radio energy model. In Section 4, we propose ECCP protocol for energy conservation in WSN. In Section 5, we provide simulation results and performance analysis of ECCP protocol. In Section 6, we conclude this paper.

2. LITERATURE REVIEW
In wireless sensor network energy conservative clustering protocols is a major problem to increase the network lifetime. It is also difficult to create energy efficient clustering protocol due to the completed energy configuration and network operation. There are many communication protocols have been proposed to realize power efficient communication in these networks. LEACH is one of the first hierarchical routing approaches for wireless sensor networks [2]. This protocol selects cluster heads periodically on the basis of threshold and balance energy consumption by rotation role of sensor motes. LEACH performs well, but its performance becomes badly in the heterogeneous network. In PEGASIS, sensor motes will be organized in the network as a chain, only one sensor mote of the chain aggregate all data and send it to the sink [3]. The problem in this protocol is that it based on the requirement of the global knowledge of the network topology. The HEED protocol is another distributed cluster based routing protocol in which the selection of cluster head dependent upon the residual energy of the sensor mote and also selects these cluster heads stochastically [4]. In EECS which chooses the cluster heads with more residual energy through local radio communication [5]. In cluster formation phase, EECS considers the tradeoff of energy expenditure between sensor motes to the cluster heads and the cluster heads to the base station. But, it increases the need of global knowledge about the distance between the cluster heads and the base station. In DEEC the cluster heads are selected on the basis of probabilistic threshold based on the ratio between remaining energy of sensor motes and the average network energy [6].

DEEC does not require any global knowledge of energy at every election round. It can also well perform in multilevel heterogeneous sensor networks. In EECRP the Base Station selects the Cluster Heads for sensing field [7]. The cluster head selection procedure is carried out in two stages. In the first stage, all the sensor mote become candidate nodes for becoming CH are listed, based on the parameters like relative distance of the candidate node from the Base Station, remaining energy level, probable number of neighboring sensor motes the candidate node can have, and the number of times the candidate node has already become the Cluster Head. But EECRP protocol is centralized, which consume lot of energy in communication between sensor motes and base station for parameter collection. In three layered LEACH, cluster-heads elected at first phase [11]. Cluster heads does not communicate directly with base station. Authors reselect another N'* p (N' stands for the number of the level l cluster-heads and N'=N*p, while p is the percentage of level 2 cluster-heads) motes as the cluster heads to send data to the base station. Information from other cluster heads will be fused in these N'*p motes and then be transmitted to the base station. When the level1 cluster-heads selection finished, level 2 cluster-heads which communicate with base station will be selected among these level l cluster-heads based on the left power of them. The TL-LEACH is not suitable for densely deployed sensor network. We need a distributed approach to consider parameter as many as possible.

3. RADIO ENERGY MODEL

According to the radio energy dissipation model, in order to achieve an acceptable Signal-to-Noise Ratio (SNR) in transmitting an l -bit message over a distance d, the energy expended by the radio is given by:

$$E_{TX}(l,d) = \begin{cases} lE_{elec} + l\,\epsilon_{fs} d^2, d > d_0 \\ lE_{elec} + l\,\epsilon_{mp} d^4, d > d_0 \end{cases} \quad (1)$$

Where

E_{elec} *is the energy dissipated per bit to run the transmitter or the receiver circuit*

ϵ_{fs} *and* ϵ_{mp} *depend on the transmitter amplifier model*

d is the distance between the sender and the receiver

By equating the two expressions at $d = d_0$, we have

$$d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}.$$

To receive an l -bit message the radio expends

$$E_{RX} = l * E_{elec}$$

4. PROPOSED APPPORACH

In this section, we present ECCP protocol for wireless sensor networks. The following assumptions with respect to the ECCP protocol are made.

- Sensor motes and base station are static.
- The base station not limits to energy.
- Sensor motes do not aware about their geographic location.
- Sensor motes know the relative position of the base station in the field.
- The sensor motes are randomly distributed over sensing field.
- The Sensor motes are densely deployed in the sensing field. This dense deployment of sensor network achieving Quality of Service.
- Sensor motes are homogenous in their architectures.
- Sensor motes are able to measure the current energy level.

4.1 The ECCP protocol

In the ECCP clustering process accomplish in 2 phases, it requires $2 * T_{max}$ (T_{max} is the time require for clustering).In first phase cluster head is selected on the basis of probabilistic threshold (based on residual energy and distance to base station). At the end of first phase all the cluster heads are selected and formation of cluster is accomplished. In second phase reclustering process starts where all the selected cluster heads reselect the new leaders on the basis of threshold used for cluster head selection with different probability. After the completion of second phase leaders receive aggregated data from nearest cluster heads and again aggregate this data then send it to the base station as shown in figure 1. This prolongs the time interval before the first mote die. It is very crucial for many applications where reliability about feedback needed.

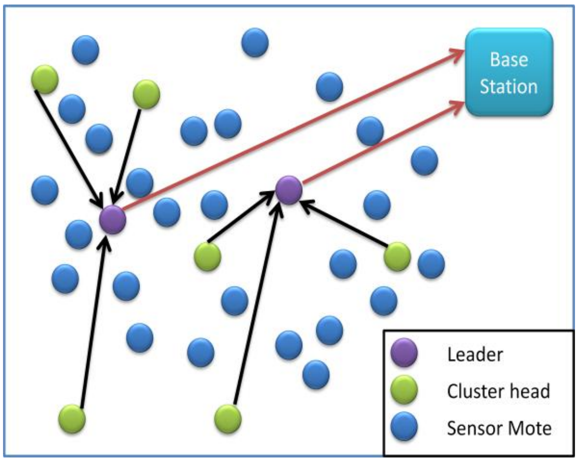


Fig 1: The ECCP protocol

4.1.1 Phase –I

The first phase includes cluster head selection and cluster formation process. In the cluster head selection process each sensor mote chooses a random number between 0 and 1 separately. If this number is lower than the calculated threshold T (i) for mote i, then the sensor mote i become a cluster head.

The threshold T (i) is given by

$$T(i) = \left(\frac{p_1}{(1 - p_1 \times \mathrm{mod}(r, \mathrm{round}(1/p_1)))}\right) \times \frac{er}{e_{max}} \times \frac{dist_{max}}{d}$$

Where

p_1 is the optimal probability for intial cluster head

r is the current round

er is the remaning energy of sensor mote

e_{max} is the maximum or initial energy of sensor motes

$dist_{max}$ is the maximum distance of sensing field

d is the distance between sensor mote and base station

In the cluster formation process each cluster heads broadcast a join message within the sensing field. On reception of join message each non cluster head sensor mote decide to join the cluster head, if it received the join messages more than one then sensor mote join nearest cluster head. After a constant time interval cluster head received join request messages from non cluster head sensor motes. It creates a TDMA schedule for data transmission within the cluster and sends to its cluster members.

4.1.2 Phase –II

The second phase includes reclustering process and data aggregation process. In the reclustering process leaders are selected on the basis of threshold and random number. The threshold $T(l)$ for leaders shown below:

$$T(l) = \left(\frac{p_2}{(1 - p_2 \times \mathrm{mod}(r, \mathrm{round}(1/p_2)))}\right) \times \frac{er}{e_{max}} \times \frac{dist_{max}}{d}$$

Where
p_2 *is the optimal probability for leaders*

After the leaders selection recluster the cluster head under the newly elected leaders. Each leader broadcast the join leader message within the sensing field. Cluster head join the nearest leader by sending confirm message. After a constant time each leader create a TDMA schedule for cluster head and send to its respective members cluster head. Each cluster head send aggregated data at the time slot allocated to it.

In the data aggregation phase each non cluster head sensor motes send sense data to its respective cluster head in the allocated time slot. The cluster head aggregates data received by its cluster members and send it to the respective leaders in the allocated time slot. The leaders receive data from its member cluster heads and aggregated it then send this data to the base station. The clustering process shown below:

Algorithm: Clustering Algorithm

Notation:

$T(i)$ *Threshold for cluster head selection*

$T(l)$ *Threshold for leader selection*

1. *Received initialization information from base station*
2. *Each sensor mote genrate the random number*
3. *Calculate the threshold* $T(i)$*and compare to random number*
4. *if random number* $<$ *threshold* $(T(i))$
5. *sensor mote become cluster head and*
   Send Cluster Head join message
6. *again generate random number and*
   calculate threshold $T(l)$
7. *if random number* $<$ *threshold* $(T(l))$
8. *cluster head become leader*
9. *Send leader join message*
10. *Wait for Join request messages*
11. *Send TDMA schedule to member cluster heads*
12. *Receive and transmit aggregated data to base station*
13. *else*
14. *remains cluster head and create TDMA schedule*
    for cluster members
15. *Wait for leaders join message and send TDMA schedule to cluster members*
16. *Send join request to nearest leader*
17. *Wait for TDMA schedule of leader*
18. *Receive and transmit aggregated data to leader*
19. *end*
20. *else*
21. *Sensor mote become non cluster head and*
    Wait for Cluster Head join message
22. *Send join request to nearest cluster head*
23. *Wait for TDMA schedule of cluster head*
24. *Sense and transmit data to cluster head*
25. *end*

5. SIMULATION RESULT

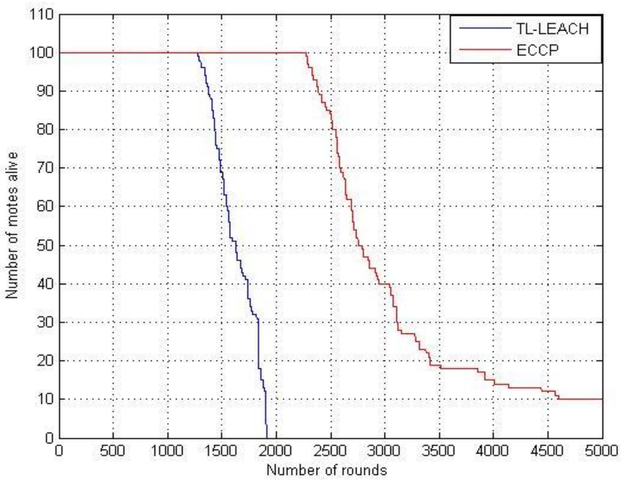
We simulate a clustered wireless sensor network in a field with $100x100\ m^2$ dimension. The total number of sensors mote n=100. The sensor motes are randomly distributed over the sensing field. This mean that vertical coordinate of each sensor motes are randomly selected between 0 and maximum value of dimension. The base station is outside the sensing field. The initial energy of a sensor mote is set to 0.5J. The radio characteristic uses in our simulation are summarized in table 1 show in below.

Table 1: Simulation Parameters

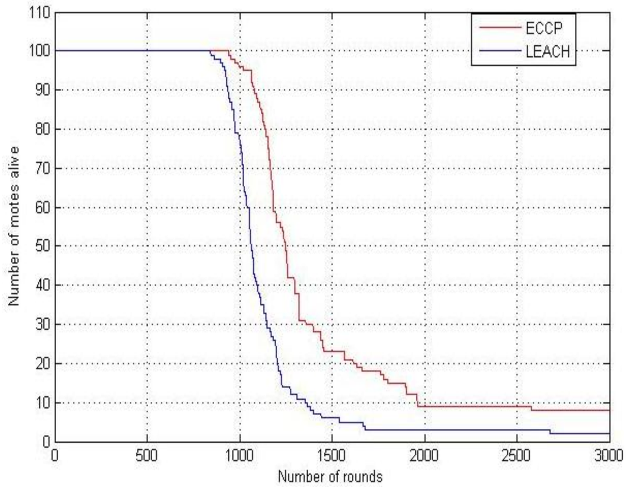
Parameter	Value
Network size	$(50x50\ m^2)$
Number of sensor mote (n)	100
Base station position	$(25\ m, 100\ m)$
Initial energy	$0.5J$
p_1	0.05
p_2	0.2
Transmitter/Receiver electronics E_{elec}	50 nj/bit
Data aggregation (E_{DA})	$5\ nj/bit/report$
Reference distance (d_0)	$87\ m$
Transmit amplifier ϵ_{fs}	$10\ pJ/bit/m2$
Transmit amplifier ϵ_{mp}	$0.0013\ pJ/bit/m4$
Message size (l)	$2000\ bits$
Time for clustering (T_{max})	$500\ ms$

5.1 Stability period and Network lifetime

The stability period and network lifetime are used as key indicators to evaluate performance of the proposed protocol. The stability period shows that the time interval from the start of the operation to the first mote dies. Stability period of the ECCP protocol is about the 2300 rounds as shown in figure 2. The network lifetime is the time interval from the start of operation to the last mote dies. Network lifetime of ECCP protocols is greater than 5000 rounds as shown in figure 2. The data transmissions from sensor motes were simulated until all the sensor motes died.



(a)



(b)

Fig 2: The performance of ECCP in term of stability period and network lifetime

Figure 2 (a) shows the comparative results of TL LEACH and ECCP for network stability period and lifespan [11]. The stable region of ECCP is about 2300 rounds which is larger than TL LEACH stable region (1380 rounds). The network lifetime also increased from about 1900 rounds to more than 5000 rounds. Figure 2 (b) shows the comparative results of LEACH and ECCP protocol for network stability period and lifespan [2]. The ECCP and LEACH protocol are simulated in $100x100\ m^2$ sensing area where 100 senor motes are spreads and base station positioned at $100\ m, 100\ m$. The packet length is 4000 bytes for this simulation. The stable region of ECCP is about 943 rounds which is larger than LEACH stable region (834 rounds). The network lifespan of ECCP is also larger than the LEACH protocol. The observation has been made that the ECCP protocol is best in the second level clustering protocols because it has higher stability period as well as higher network lifetime. The number of packets from non cluster head mote to cluster head motes in ECCP are shown in figure 3.

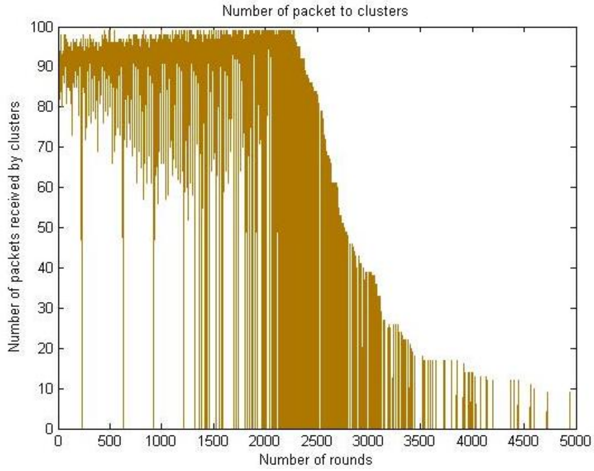


Fig 3: The number of packet received by clusters per round in ECCP

5.2 Packet transmission from cluster head to base station

After the cluster selection, each cluster head transmit aggregated data to base station. Here the analysis is made on cluster formation and packet transmission. The figure 4 shows that the number of clusters formed in a round up to 50 clusters, but figure 5 shows that the number of packet transmitted to base station is lower than the clusters formed in field.

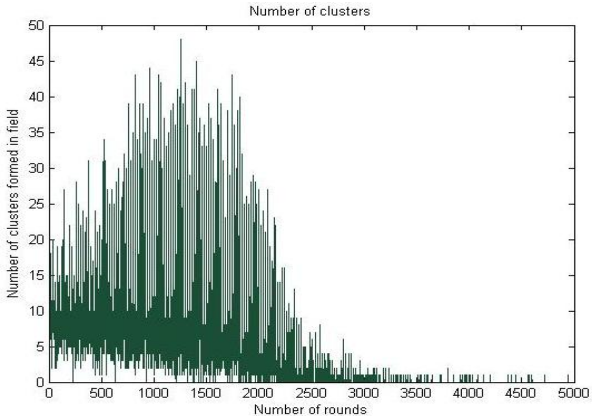


Fig 4: The number of cluster formed per round in ECCP

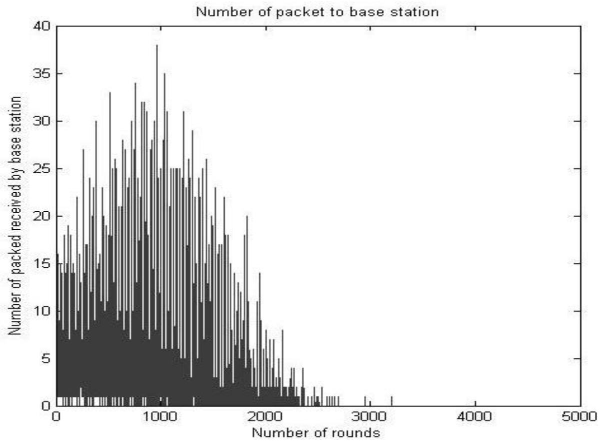


Fig 5: The number of packet received by base station per round in ECCP

6. CONCLUSION

In this paper a new clustering protocol ECCP has been proposed to conserve the energy in clustering process. A new threshold has been formulated for cluster head selection which is based on the remaining energy of the sensor mote and the distance to base station. A reclustering approach also has been proposed to decrease the energy consumption in data reporting to the base station. Simulation results show that ECCP protocol has longer stability period and network lifetime than LEACH and TL-LEACH.

7. REFERENCES

[1] I. F. Akyildiz, W. Su, Y.Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey", Computer Networks, vol. 38, no. 4, pp. 393–422, March 2002.

[2] W. R. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," IEEE Transactions on Wireless Communications, vol. 1, no. 4, pp. 660–670, October 2002.

[3] Lindsey, Stephanie, and Cauligi S. Raghavendra. "PEGASIS: Power-efficient gathering in sensor information systems." Aerospace conference proceedings, 2002. IEEE. Vol. 3. IEEE, 2002.

[4] O. Younis and S. Fahmy, "HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks," IEEE Trans. on Mobile Computing, vol. 3, no. 4, 2004, pp. 366–379.

[5] Ye, Mao, Chengfa Li, Guihai Chen, and Jie Wu. "EECS: an energy efficient clustering scheme in wireless sensor networks." In Performance, Computing, and Communications Conference, 2005. IPCCC 2005. 24th IEEE International, pp. 535-540. IEEE, 2005.

[6] Qing, Li, Qingxin Zhu, and Mingwen Wang. "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks." Computer communications 29.12 (2006): 2230-2237.

[7] Barfunga, Sonam Palden, Prativa Rai, and Hiren Kumar Deva Sarma. "Energy efficient cluster based routing protocol for Wireless Sensor Networks." Computer and Communication Engineering (ICCCE), 2012 International Conference on. IEEE, 2012.

[8] J.N. Al-Karaki and A.E. Kamal, "Routing techniques in wireless sensor networks: a survey," IEEE Wireless Communications, vol. 11, no. 6, pp. 6–28, Dec 2004.

[9] S. M. Guru, M. Steinbrecher, S. Halgamuge, and R. Kruse, "Multiple Cluster Merging and Multihop Transmission", LNCS 4459: AGPC, Springer, pp. 89-99, 2007.

[10] M. Kochhal, L. Schwiebert, and S. Gupta, "Self-organizing of wireless sensor networks," in Handbook on Theoretical and Algorithmic Aspects of Sensor, Ad Hoc Wireless, and Peer-to- Peer Networks, J. Wu, Ed. Auerbach Publications, pp. 369–392, 2006.

[11] Zhixiang, Deng, and Qi Bensheng. "Three-layered routing protocol for WSN based on LEACH algorithm." in IET Conference on Wireless, Mobile and Sensor Networks 2007 (CCWMSN07), January 2007 p. 72 – 75.