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Lifetime Enhancement of WSN using Cooperative Game Theory based Routing Protocol

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***Abstract*— Wireless Sensor Network (WSN) plays a major role in collecting physical data from various locations using battery powered sensor nodes and forward it to the sink node. Limited energy resource is the major constraint associated with WSN, since in most cases it may not be possible to change or recharge batteries. For successful communication, the lifetime of sensor nodes or motes play an important role. Hence, designing of energy efficient routing algorithm is one of the key challenges that need to be addressed for extending the life time of the network. In this paper, cooperative game theoretic approach is applied in A Novel Clustering Algorithm for Energy Efficiency (G-ANCAEE) and low energy adaptive clustering hierarchy (G-LEACH). The G-ANCAEE performance enhances the life time of the nodes by minimizing energy consumption during data transmission. The G-ANCAEE involves fixed clusters and randomized weighted algorithm for cluster head (CH) selection which efficiently reduces the energy consumption. Cooperative game theory is used to select healthier cluster-heads having sufficient residual energy with high trust level. Simulation results of the G-ANCAEE shows that the energy expended in the network can be reduced as the number of frames per round is increased compared to G-LEACH protocol.**

Keywords— WSN, energy consumption, cooperative game, G-LEACH, G-ANCAEE

I. Introduction

Wireless Sensor Network (WSN) is a network which consists of a large number of tiny spatially distributed radio-equipped sensors called nodes. The sensor node not only senses but also processes to make it into a meaningful data using its embedded microprocessors and communicates through the receiver. Nodes are used for gathering information needed by smart environments and are particularly useful in unattended situations where terrain, climate and other environmental constraints may hinder in the deployment of wired/conventional networks [1].

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A. *Related Work*

The important aspect of WSN is that nodes are often unattended after deployment and their energy cannot be replenished. Traditional routing protocols used in wired and existing wireless schemes may not be applicable to WSN due to limited energy and bandwidth of wireless links connecting the sensor nodes. The routing protocol must meet the design targets of being power efficient and reliable.

LEACH is the first cluster based routing protocol for WSNs, which uses a stochastic model for CH selection. LEACH has motivated the design of several other protocols which try to optimize energy consumption in different ways, [1-3]. This method helps to minimize the overheads. The operation of LEACH protocol is divided into rounds. Each round consists of set-up phase and steady-state phase. During the set-up phase, sensor nodes are organized into different clusters based on the received signal strength and CHs are selected for each cluster as routers to the base station. The CHs are selected based on an elective percentage of deployed nodes by considering so far how many times an individual node performed the role of CH.

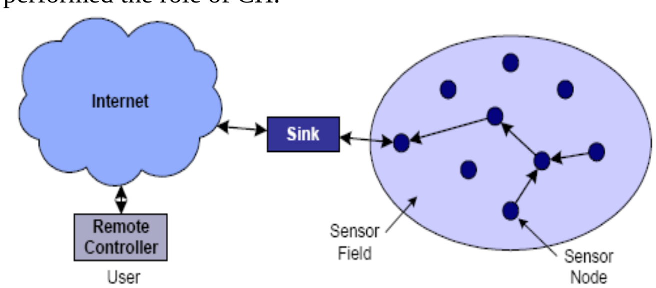

Figure 1 Sensor Network Architecture

When the network diameter is increased beyond certain level, distance between CH and base station (BS) is increased enormously. This scenario is not suitable for LEACH routing protocol in which base station is at single-hop to CH. In this case energy dissipation of CH is not affordable. To address this problem Multi-hop LEACH (M-LEACH) is proposed with the extension of LEACH routing protocol to increase energy efficiency of the wireless sensor network.

This algorithm saves energy, since only CHs are allowed to transmit data to the base station rather than all nodes. It allows CHs to rotate randomly to balance energy consumption of nodes in the networks. Basically, each node elects itself to be a CH in a given round. LEACH achieves reduction in energy consumption seven times compared with direct communication and between 4 to 8 times compared with minimum transmission energy (MTE) routing protocol [5]. Despite these benefits, LEACH suffers several shortcomings. CHs are not uniformly distributed in LEACH, CHs may be chosen from one part of the network. If this occurs, energy dissipation will be more than conventional protocols [6-9].

II. System Model

A Novel Clustering Algorithm for Energy Efficiency in WSN (ANCAEE) has been applied to achieve good performance in terms of minimizing energy consumption during data transmission and uniformly distributed among all nodes. ANCAEE utilizes new method of clusters formation and election of CHs. The algorithm ensures that transmission of data from node to CH is with one hop and from CH to base station with multi hop. It involves grouping of sensor nodes together, so that nodes communicate their sensed data to the CH. CHs collect, aggregate and transmit the aggregated data to the processing centre called base station (BS) for further analysis.

A. *Cluster Heads Selection*

In order for a node to become cluster head the following assumptions were made.

- All nodes should have equal initial energy.
- There are *s* nodes in the sensor field.
- The number of clusters is *k*.

Based on the above assumptions, the average number of sensor nodes in each cluster is *m* which is given in equation

$$m = \frac{s}{k} \quad (1)$$

After *m* rounds, each of the nodes must have been a CH once. each node have unique identifier N_i for all 0,1,2,3,4,…s-1.Variable *i* is used to test whether it is the turn of a node to become a CH. Originally, all nodes are the same, *i.e.* there is no CHs in each cluster, *j* = 0 where *j* is CHs counter.

A node *q* is selected among all nodes and continuously executes the following steps:

- First, *q* increments *i* by 1 and check if *i* is even. If yes that node is selected as the CH for that round and announces its new position to all member nodes in the cluster.
- Else if *i* is odd, it cannot be a CH for that round, it will wait for the next round and be ready to receive advertisement message from the new CH.
- A predetermined value is set (threshold value) for the new CH to transmit for that round.

When the value has reached, *j* will be incremented by 1 and the process of selection of new CH begins. It tests if the following two conditions hold.

- That a sensor node has not become CH for the past *(1/p)* rounds.
- That the residual energy of a node is more than the average energy of all the sensor nodes in the clustering.

Thus, the probability P_i of a node becoming a new CH is

$$P_i = \frac{e_{res}(i) \times k}{e_{avg}(i) \times m} \quad (2)$$

where e_{res} is the remaining energy in node (*i*), e_{avg} is the average energy of all the nodes in a cluster which is given

$$e_{avg} = \frac{\sum_{i=1}^{m} N_i . e_{res}}{m} \quad (3)$$

Where e_{avg}-Average energy in a cluster and $N_i.e_{res}$-Residual energy of node i in a cluster. The procedure continues until *j* = *k*. The algorithm stops when *j* = *k*. The new CHs collect sensed data from member nodes, aggregate them, and transmit the compressed data to the next CH or BS.

B. *Cluster Formation*

The next step in the clustering phase is cluster formation after CHs have been elected. The description of new cluster formation is as follows

Step 1: The new CHs elected above broadcast advertisements (ADV) message to all non-cluster nodes in the network using Carrier Sense Multiple Access (CSMA) MAC Protocol.

Step 2: Each sensor node determines which clusters it will join, by choosing CH that requires minimum communication energy.

Step 3: Each non-cluster node uses CSMA to send message back to the CHs informing them about the cluster it wants to belong.

Step 4: After CHs have received messages from all nodes, Time Division Multiple Access (TDMA) scheduling table will be created and send it to all nodes. This message contains time allocated to each node to transmit to the CH within each cluster.

Step 5: Each sensor node uses TDMA allocated to it to transmit data to the CH with a single- hop transmission and switch off its transceiver whenever the distance between the node and CH is more than one hop to conserve energy.

Step 6: CHs will issue new TDMA slots to all nodes in their clusters when allocated time for *G* has elapsed, for each node to know exact time it will transmit data to avoid data collision during transmission that can increase energy consumption.

Step 7: CH transceiver is always turn-on to receive data from each node in its cluster and prepare them for inter-clusters transmission. Inter-cluster transmission is of two types: single hop and multi-hop. We adopted multi-hop transmission in order to save more energy during inter-cluster transmission.

C. *Energy Consumption*

Basically, the energy required for transmitting a signal is highly related to the distance. The following equation shows the energy consumed when sending a signal to a distance *d* by an amplifier.

$$\text{Energy Consumption} = \begin{cases} \varepsilon_{fs} * d^2, \text{if} & d \le d_0 \\ \varepsilon_{tr} * d^4, \text{if} & d > d_0 \end{cases} \quad (4)$$

using d_0 as a threshold, if the transmission distance is shorter than d, a free-space propagation model is used to calculate the consumed energy, which is proportional to the square of distance. If transmission distance is longer than calculation and the consumed energy is proportional to the fourth power of distance. In that case, the consumed energy has a great influence on the wireless communication system. In the above equation, ε_{fs} and ε_{tr} are the parameters for the free-space propagation model and two ray ground propagation model. Here, d_0 is defined as $\sqrt{e_{fs}/e_{tr}}$ which is the threshold of transmission distance and its value is about 87.7. The energy for data aggregation at the CH is given as e_{DA}. On implementation with the number of bits transferred the equation (4) becomes to transmit an l-bit message to a distance d_0

$$e_{tx}(l,d) = e_{tx\text{-}elec}(l) + e_{tx\text{-}amp}(l,d)$$

$$= \begin{cases} (l \times e_{elec}) + (l \times \varepsilon_{fs} \times d^2), \text{if} & d \le d_0 \\ (l \times e_{elec}) + (l \times \varepsilon_{tr} \times d^4), \text{if} & d > d_0 \end{cases} \quad (5)$$

and to receive this message, the radio expends the energy

$$e_{rx}(l,d) = e_{rx\text{-}elec}(l) = l * E_{elec} \quad (6)$$

where the electronics energy, e_{elec} depends on factors such as the digital coding, modulation, filtering, and spreading of the signal, where as the amplifier energy, $\varepsilon_{fs} d^2$ or $\varepsilon_{tr} d^4$, depends on the distance to the receiver and the acceptable bit-error rate. With n nodes distributed uniformly and k clusters, there are on an average n/k nodes per cluster (one cluster and $(n/k)-1$ non-cluster head nodes (i.e.) normal nodes). Each CH dissipates energy receiving signals from the nodes, aggregating the signals, and transmitting the aggregate signal to the sink node. Since the sink node is far from the nodes, presumably the energy dissipation follows the multipath model (power loss). Therefore, the energy dissipated in the CH node during a single frame is

$$e_{CH} = l * e_{elec}\left(\frac{n}{k} - 1\right) + l * e_{DA}\left(\frac{n}{k}\right) + l * e_{elec} + l * \varepsilon_{tr} * d^4_{to\,sink} \quad (7)$$

where l is the number of bits in each data message, $d_{to\,sink}$ is the distance from the CH node to the BS, it is assumed that it has perfect data aggregation. Each non-cluster head node only needs to transmit its data to the CH once during a frame. Presumably the distance to the CH is small, so the energy dissipation follows the Friss free-space model (d^2 power loss). Thus, the energy used in each non-cluster head node is calculated

$$e_{non\text{-}CH} = l * e_{elec} + l * \varepsilon_{fs} * d_{toCH} \quad (8)$$

where $d_{to\,CH}$ is the distance from the node to the CH

III. Game Formulation

Game theory (GT) is a mathematical model that describes the phenomenon of conflict and cooperation between intelligent rational decision-makers. In particular, the theory has been proven very useful in the design of wireless sensor networks (WSNs). Furthermore it also helps to predict the possible outcomes of the interactive decision problem. A game is defined by a set of players, a set of actions for each player, and the payoffs for the players. A player chooses an action and the complete plan of action is referred to as the strategy. When the action is chosen deterministically, it is called a pure strategy.

Cooperative games consider the set of joint actions that any group of players can take. On application of the co-operative game theory concept to the existing protocol like LEACH, we obtained a better result; the similar better result is obtained by implementing it in ANCAEE. This would result in further lifetime enhancement. Here a pre-defined threshold value for each node is calculated, which helps in estimating the successful transmission. In addition to the weight calculation, a utility value is also calculated. The calculated value, if greater than the threshold, is titled as a 'successful transmitting node' and given the strategy as one (i.e) a win situation. Else it is given the strategy of zero (i.e) a lose situation. With the strategy as one, the node forwards data else it remains idle and the process looks for another successful transmitting node. With strategy 'one', the utility value is more, showing that it has more chances in becoming CHs in the next rounds .Since it specifically chooses the efficient CH in transmission, the time taken for choosing the CH is reduced and hence the unwanted checking of the ineffective CH is not made, which reduces the overhead.

Pseudo code

```
Assign old=present energy value of CH1.
Select the nearby clusterhead
CH2<-nearby clusterhead
  if(the selected CH2 has more energy comparatively)
    Calculate the energy consumed by CH1 for hopping to CH2.
    Calculate the energy consumed by CH2 for reception of that
     data.
      if(the CH2 has still more energy to forward the data to sink
         node)
         CH2 is elected for hopping purpose.
      else
         CH1 finds other CH2 or straightly forward the data to sink
         node.
      end
  end
```

IV. Results and Discussion

MATLAB 10.0 is used to validate the proposed game. The parameters considered for simulation is summarised in Table 1. The performance of proposed game based routing protocol was evaluated in terms of alive nodes and residual energy in the network.

PARAMETERS	VALUES
Number of sensors nodes deployed	100
Network size	$(100x100)m^2$
Initial Energy	0.5J
Energy for Transmitting the data (e_{tx})	50nJ/bit
Energy for Receiving the data (e_{rx})	50nJ/bit
Sink Position	(50,150)
Free space propagation model (ε_{fs})	$10pJ/bit/m^2$
Two ray ground propagation model (ε_{tr})	0.0013pJ/bit/m4
Energy for Data Aggregation e_{da}	5nJ/bit/signal
Control packet length	200 bits
Packet length	6400 bits

The nodes are deployed in the network area of 100 × 100 which is divided into sectors. The nodes deployed in each sector to form a cluster. These clusters remain constant throughout the network lifetime. The node which has the maximum weight is chosen as the CH for a round. The CH changes in each round based on the calculated weight

A. *Analysis of Alive Nodes among Protocols*

. Fig. 2 shows the comparison of the alive nodes of LEACH and ANCAEE protocols. Lifetime is defined as the total period for the network to be alive to perform successful transmission. LEACH which is the basic protocol has its total death of nodes around 800-1000 rounds and ANCAEE which has energy efficient CH election has a little longer period for its total node death and it is around 1050-1300 rounds. Based on these criteria, there is distributed energy utilization in ANCAEE.

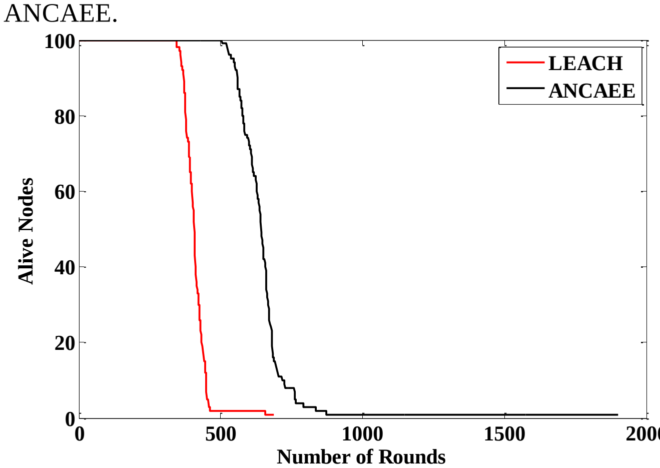

Figure 2 Alive nodes Vs number of rounds

B. *Analysis of Residual Energy among Protocols*

The residual energy analysis of LEACH and ANCAEE is shown in Figure 3. Residual energy is the left over energy in a node after its successful transmission and reception. The average residual energy for the network is 0.5. The residual energy is 37.8% more in ANCAEE compared with LEACH when the analysis at the round 300. This is even distribution of energy in the network.

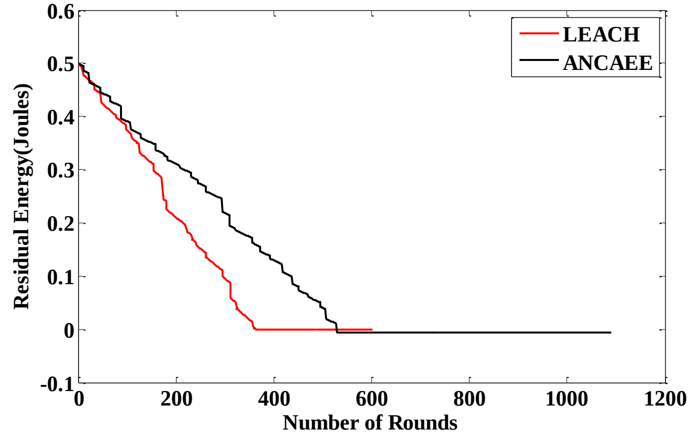

Figure 3 Average Residual Energy Vs number of rounds

C. *Analysis of Alive nodes among protocols with Cooperative Game*

The comparison of the protocols LEACH and ANCAEE along with its cooperative game is shown in Fig 4. Cooperative game is a paradigm which is used to elect healthier CHs having sufficient residual energy and high trust level during the selection of CH and transmission. Cooperative game refers to the concept that each node is known of the other node's energy before its transmission. It is seen that on application of cooperative game theory to each protocol there is 20% - 40% increment in lifetime (number of rounds). Hence, G-ANCAEE is an efficient protocol which has 65% - 70% lifetime increment when compared to the basic LEACH protocol.

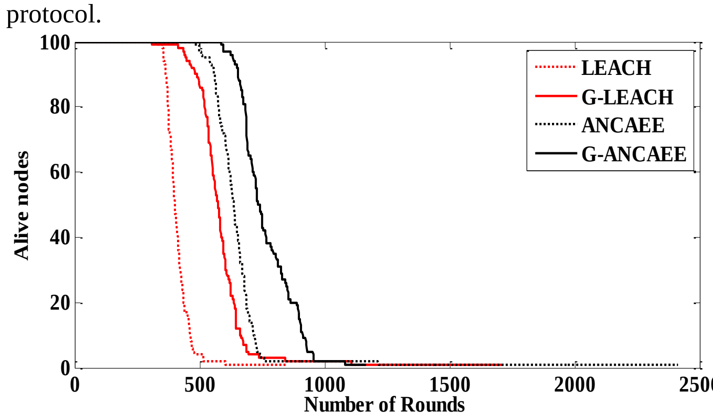

Figure 4 Alive nodes Vs Lifetime (in rounds)

D. *Analysis of Residual energy among Protocols with Cooperative Game*

Fig. 5 shows the residual energy analysis of LEACH and ANCAEE with its cooperative game. The cooperative game based protocols (G-LEACH and G-ANCAEE) show better results than its origin protocols. It can be seen that the G-LEACH has 15% - 20% more residual energy than LEACH at 500 rounds. On comparison with ANCAEE and G-ANCAEE, it has 20%-30% more residual energy. Hence G-ANCAEE is more efficient in energy utilization compared to other protocols.

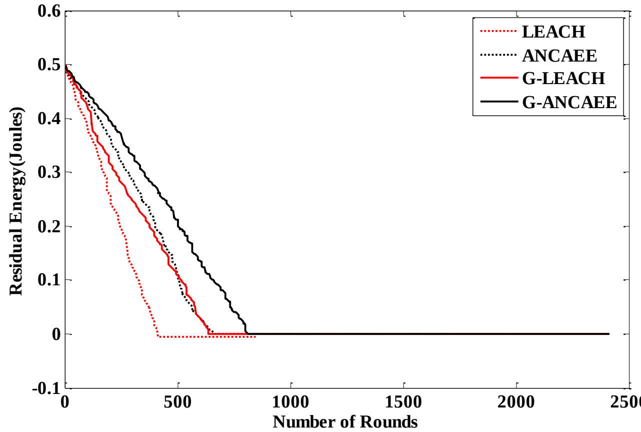

Figure 5 Average residual energy Vs number of rounds

E. *Comparison of the Protocols in terms of Node Deaths*

Fig. 6 gives a clear note on the death of 10% of the nodes and 90% of nodes in all protocols. There is a gradual death of the nodes in ANCAEE and G-ANCAEE. It is seen that there is sudden death of nodes for LEACH, ANCAEE and its derivatives where the CH election is random irrespective of its residual energy. Hence G-ANCAEE's efficiency is more comparatively.

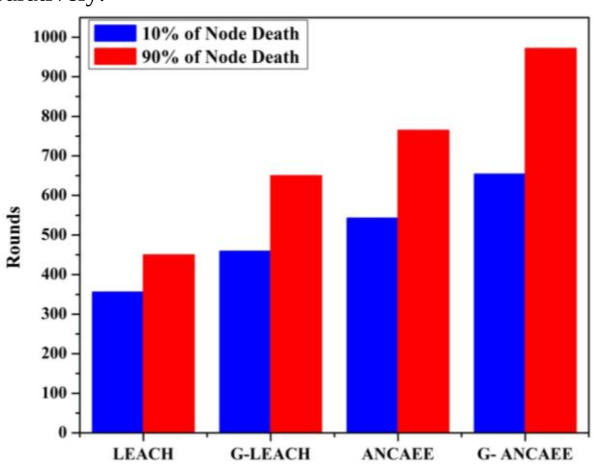

Figure 6 Percentile of Node death

V. CONCLUSION

In this paper, a new objective for maximizing the network lifetime using G-ANCAEE algorithm is discussed. This algorithm partitions the network area into different clusters and elects a node as the CH for each cluster. Each node within the cluster sends its data to the CH with single hop transmission and CHs receives, aggregates the data and transmits it to the base station via multi-hop transmission. Here the clusters are fixed; hence the energy required for forming clusters in each round is negligible. The approach searches for the best CH, based on its weight allocation formulated with energy and distance. Further improved results were obtained when co-operative game theory on energy calculation for successful transmission was implemented on this protocol. Simulation results show that 20-40 % increase in the lifetime of the network on par with protocols like LEACH, ANCAEE.

References

[1]. L. Akyildiz, W. Su, Y.Sankarsubramanian and E.Cayirci, " A survey on sensor networks", IEEE communication Magazine, 40, (8), pp 102-114, 2002

[2]. W. R. Heinzelman, A. 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]. V. Loscri, G. Morabito and S. Marano, "A Two-Level Hierarchy for Low-Energy Adaptive Clustering Hierarchy," *IEEE Vehicular Technology Conference*, Vol. 3, No. 2, 2005, pp. 1809-1813.

[4]. W. B. Heinzelman, A. P. Chandrakasan and H. Balak- rishnan, "An application-Specific Protocol Architecture for Wireless Microsensor Networks," *IEEE Transactions on Wireless Communications*, Vol. 1, No. 4, 2002, pp. 660-670.

[5]. K. Akkaya and M. Younis, "A Survey on Routing Protocols for Wireless Sensor Networks," *Ad Hoc Networks*, Vol. 3, No. 3, 2005, pp. 325-349.

[6]. M. Ahmad, M. Habib, M. Z. Shah, F. Ullah and S. Hussain, "Energy Aware Uniform Cluster-Head Distribution Technique for Hierarchal Wireless Sensor Networks," *International Journal of Computer Science and Network Security*, Vol. 10, No. 10, 2010, pp. 97-103.

[7]. B. Nath and D. Niculescu, "Routing on a curve", ACM SIGCOMM Computer Communication Review, vol. 33, no.1, Jan. 2003, pp. 155-160.

[8]. G. Xing, C. Lu, R. Pless, and Q. Huang, "On greedy geographic routing algorithms in sensing-covered networks", Proceedings ACM MobiHoc'04, Tokyo, Japan, May 2004, pp. 31-42.

[9]. M. Zorzi and R. R. Rao, "Geographic random forwarding (GeRaF) for ad hoc and sensor networks: Mutlihop performance", IEEE Transactions on mobile Computing, vol. 2, no. 4, Oct.-Dec. 2003, pp. 337-348.

[10]. V. Rodoplu and T. H. Meng, "Minimum energy mobile wireless networks", IEEE Journal on Selected Areas in Communications, vol. 17, no. 8, Aug. 1999, pp. 1333-1344.

[11]. L. Li and J. Y. Halpern, "Minimum-energy mobile wireless networks revisited", Proceedings IEEE ICC'01, Helsinki, Finland, June 2001, pp. 278-283.

[12]. Nazia Majadi, "U-LEACH: A Routing Protocol for Prolonging Lifetime of Wireless Sensor Networks", International Journal for Research and Application, Vol. 2, Issue4, July-August 2012, pp.1649-1652

[13]. Mortaza Fahimi Khaton Abad and Mohammad Ali Jabraeil Jamali, " Modify LEACH Algorithm for Wireless Sensor Network", International Journal of Computer Science Issues, Vol. 8, Issue 5, No 1, September 2011

[14]. Taekwook Kang, Jangkyu Yun, Hoseung Lee, Icksoo Lee, HyunsooK kkim, Byunghwa Lee, Byeongjik Lee, Kijun Han, "Clustering Method for Energy Efficient Routing in Wireless Sensor Networks", Proceedings of the 6th WSEAS Int. Conf. on Electronics, Hardware, Wireless and Optical Communications, Corfu Island, Greece, February 16-19, 2007

[15]. Noritaka Shigei, Hiromi Miya jima, ishita, Michiharu Maeda, "Centralized and Distributed Clustering Methods for Energy Efficient Wireless Sensor Networks", Proceedings of the International MultiConference of Engineers and Computer Scientists 2009 Vol I, IMECS 2009, March 18 - 20, 2009, Hong Kong