Performance Analysis of Distributed Routing Protocol of Heterogeneous Wireless Sensor Networks

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Abstract

Wireless communication technologies continue to undergo rapid advancement. In recent years, there has been a steep growth in research in the area of wireless sensor networks (WSNs). Sensor nodes are small devices with sensing, computing and wireless communication capabilities. Such devices form a WSNs which can be used for many applications like gathering of environmental data and even monitoring enemy activity on a battlefield. In order to achieve this efficient routing protocols must be used. Such routing protocols are of prime research interest. There exist many different approaches most of which are studied through simulation only. At the same time real hardware platforms for this research become widely available and affordable. In this paper we will investigate the performance of distributed heterogeneous WSNs protocol: DDEEC, EDEEC and EDDEEC. I have analysed these protocol in terms of lifetime of the network and data transferred through each and every nodes of the network. The performance of these routing protocols is then measured and compared through simulation environment deployment of the WSNs.

Keywords: *Cluster Head, DDEEC, EDDEEC, EDEEC, Sensor node, WSNs.*

1. Background

Wireless sensor networks are formed by small sensor nodes communicating over wireless links without using a fixed network infrastructure. Sensor nodes have a limited transmission range, and their processing and storage capabilities as well as their energy resources are also limited. Routing protocol for wireless sensor networks have to insure reliable multi-hop communication under these conditions.

Routing in wireless sensor networks differs from conventional routing in fixed networks in various ways: there is no infrastructure, wireless links are unreliable, sensor nodes may fail, and routing protocols have to meet strict energy saving requirements. Many routing algorithms were developed for wireless networks in general. Routing algorithms that perform end-to-end message delivery with host-based addressing can be classified as topology- based, if the destination is given by an ID, or as position-based, if the destination is a geographic location. The latter are also called geographic routing algorithms. Both topology-based and geographic routing algorithms are address-centric, and besides these types the data-centric routing paradigm has become popular in the area of sensor networks. Data-centric routing is based on queries that are issued by the sink to request data. These request are not addressed to specific sensor nodes. Instead, the sensor nodes that can deliver the requested data will answers the query [1].

Routing protocols for WSNs can be classified according to networks structure and operation of protocols. Which are further classified into Negotiation based, location based, multipath based and flat-based, hierarchical-based and adaptive, depending upon the network structure or operation of protocols [2]. In flat-based routing [3], [4], all sensor nodes are assigned equal role. In hierarchical-based routing sensor nodes play different roles and some certain sensor nodes, called cluster head, are given more responsibility [5]. In adaptive routing certain system parameter are controlled in order to adapt the current networks conditions and available energy levels [6]. Furthermore these protocols can be classified as shown in Fig 1.

2. Brief Description of Heterogeneous Routing Protocols

The sensor nodes are constrained to limited resources itself, so the main target is to design an effective and energy aware protocol in order to enhance the network lifetime for specific application environment. Since sensor nodes are not given a unified ID to identify and

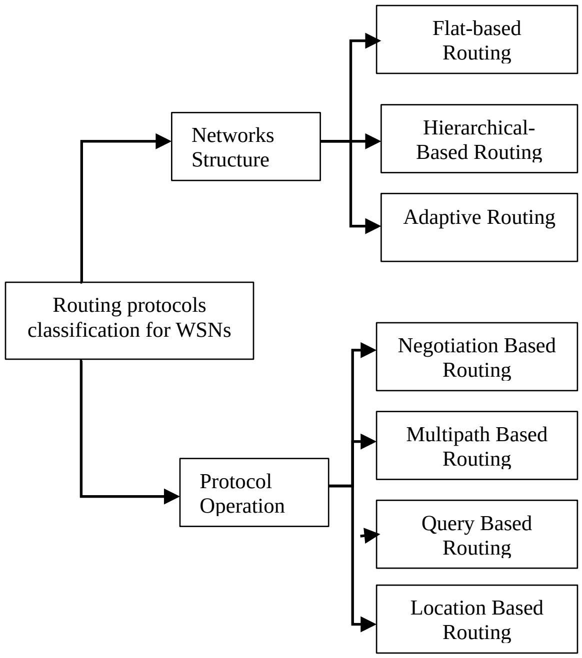

Fig. 1 Classifications of Routing Protocols.

much redundant data collected at destination nodes. So energy efficiency, scalability, latency, fault-tolerance, accuracy and QOS are some aspects which must be kept in mind while designing the routing protocols in wireless sensor networks [7].

2.1 Developed Distributed Energy-Efficient Clustering (DDEEC)

DDEEC [8], [9] uses the initial and residual energy level of the nodes to estimation the average energy in the network and cluster Head (CH) selection algorithm. Each node needs to know the global knowledge of the networks as in energy efficient clustering techniques LEACH and DEEC. Difference between DDEEC and DEEC is centred in expression that defines probability for normal and advanced nodes to be a CH. We find that nodes with more residual energy at round r are more probable to become CH, so, in this way nodes having higher energy values or advanced nodes will become CH more often as compared to the nodes with lower energy or normal nodes. A point comes in a network where advanced nodes having same residual energy like normal nodes. Although, after this point DEEC continues to punish the advanced nodes so this is not optimal way for energy distribution because by doing so, advanced nodes are continuously a CH and they die more quickly than normal nodes. To avoid this unbalanced case, DDEEC defines the probability to become CH which is defined in Eq. (1) to save advanced nodes from being punished over and again.

$$p_i = \begin{cases} \frac{p_{opt}E_i(r)}{(1+am)\bar{E}(r)} & for\ Nml\ nodes, E_i(r) > Th_{REV} \\ \frac{(1+a)p_{opt}E_i(r)}{(1+am)\bar{E}(r)} & for\ Adv\ nodes,\ E_i(r) > Th_{REV} \\ c\frac{(1+a)p_{opt}E_i(r)}{(1+am)\bar{E}(r)} & for\ Adv\ nodes,\ E_i(r) \le Th_{REV} \end{cases} \quad (1)$$

DEEC introduces threshold residual energy given by Th_{REV}=bEo.

Where $b = (1 + \frac{AE_{disNN}}{E_{disNN} - E_{disAN}})$

Brahim Elbhiri, [8] had try to find the nearest value of b equal to b = 0.7.

2.2 Enhanced Distributed Energy Efficient Clustering (EDEEC)

Enhanced Distributed Energy Efficient Clustering (EDEEC) [10] method is used for heterogeneous WSNs. It is three level heterogeneous WSNs. It uses same scheme for cluster head choice base on initial, remaining energy of the nodes, radio dissipation and average energy of the network as in DEEC. At beginning of the round, each node makes a decision whether to become a cluster head or not for current round base on threshold. Heterogeneous wireless sensor network have more than two types of nodes so in EDEEC three level heterogeneity are used which contain normal, advance and super nodes and uses different probability of three types of nodes. The probabilities of normal, advanced and super nodes are given as:

$$p_i = \begin{cases} \frac{p_{opt}E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & if\ S_i\ is\ the\ normal\ node \\ \frac{p_{opt}(1+a)E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & if\ S_i\ is\ the\ advance\ node \\ \frac{p_{opt}(1+b)E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & if\ S_i\ is\ the\ super\ node \end{cases} \quad (2)$$

Threshold for cluster head selection is calculated for normal, advanced, super nodes by putting above values in Eq. (2). Threshold for CH selection for all three types of node is as follows as:

$$T(S_i) = \begin{cases} \frac{p_i}{1-p_i(r\,mod\frac{1}{p_i})} & if\ S_i \in G' \\ \frac{p_i}{1-p_i(r\,mod\frac{1}{p_i})} & if\ S_i \in G'' \\ \frac{p_i}{1-p_i(r\,mod\frac{1}{p_i})} & if\ S_i \in G''' \\ 0 & otherwise \end{cases} \quad (3)$$

where G' is the set of normal nodes that have not become cluster heads within the last 1/pi rounds of the epoch where Si is normal node, G'' is the set of advanced nodes that have not become cluster heads within the last 1/pi rounds of the epoch where Si is advanced node, G''' is the set of super nodes that have not become cluster heads within the last 1/pi rounds of the epoch where Si is super node.

2.3 Enhanced Developed Distributed Energy Efficient Clustering (EDDEEC)

EDDEEC [11] method is used for heterogeneous WSNs. It is three level heterogeneous WSNs. It uses same scheme for CH choice based on initial, remaining energy level of the nodes, radio dissipation and average energy of network as in DEEC. At beginning of the round, each node makes a decision whether to become a CH or not for current round based on Threshold. Heterogeneous wireless sensor network have more than two types of nodes so in EDDEEC three level heterogeneity are used which contain normal, advance and super nodes and uses same probabilities of three types of nodes as described in EDEEC. In EDEEC after some rounds, some super and advance nodes have same remaining energy level as normal nodes due to continually CH selection. Therefore it continues to penalize advance and super sensor nodes for CH choice. Same issue with DEEC, it also continues to penalize just advance nodes and DDEEC is limited only for two-level heterogeneous networks. To eliminate this unbalanced problem in three-level heterogeneous WSNs EDDEEC changes in function which illustrated in EDEEC for calculating probabilities of normal, advance and super nodes. These modifications are based on absolute remaining energy level $T_{absolute}$ that is the value in which advance and super sensor nodes have similar energy level as in case of normal nodes. Using $T_{absolute}$ all kinds of nodes has identical probability for CH selection.

$$p_i = \begin{cases} \frac{p_{opt}E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & for\ N_{ml}\ nodes, if\ E_i(r) > T_{absolute} \\ \frac{p_{opt}(1+a)E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & for\ Ad_v\ nodes, if\ E_i(r) > T_{absolute} \\ \frac{p_{opt}(1+b)E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & for\ S_{up}\ nodes, if\ E_i(r) > T_{absolute} \\ c\frac{p_{opt}(1+b)E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & for\ N_{ml}, Ad_v, S_{up}\ nodes, if\ E_i(r) \le T_{absolute} \end{cases} \quad (4)$$

The value of absolute residual energy level, $T_{absolute}$, is written as: $T_{absolute} = zEo$

Where, z (0, 1). If z = 0 then we have traditional EDEEC. In reality, advanced and super nodes may have not been a CH in rounds r, it is also probable that some of them become CH and same is the case with the normal nodes. So, exact value of z is not sure. However, through numerous of simulations using random topologies, we try to estimate the closest value of z by varying it for best result based on first dead node in the network and find best result for z = 0.7.

Therefore $T_{absolute} = 0.7 * Eo$

3. Network Simulation Model

We have used same simulation environment for all the clustering protocols (DDEEC, EDEEC, and EDDEEC). The implementation in MATLAB environment are as follows.

3.1 Deployment of Nodes

100 nodes were randomly deployed in 100 x 100 m^2 area. Here we have used three types of nodes having different energy level. They are deployed over the network as shown in Fig: 2.There are three types of nodes deployed in network which are normal nodes, advance nodes and super nodes. They are shown in different colors and shapes. The difference between these three types of nodes is their initial energy level. We have assumed that the base station is placed in the center of networks denoted by ‘x’.

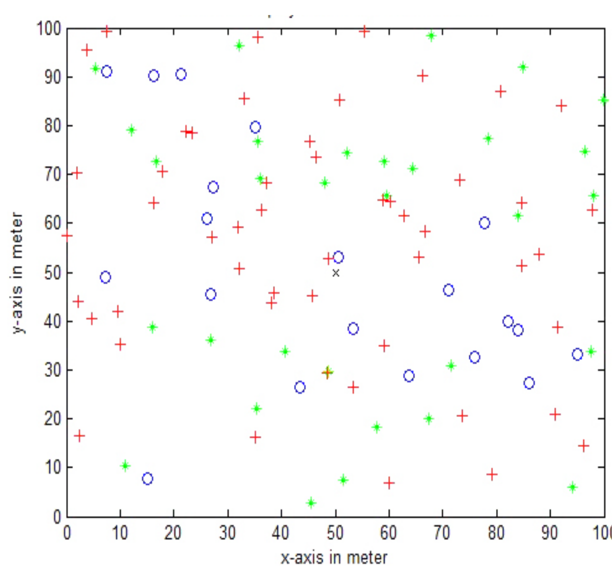

Fig: 2. Random Deployment of Nodes for Heterogeneous protocols

3.2 Energy distribution

In heterogeneous WSNs all the sensor nodes are divided in three types. These are normal nodes, advance nodes and super nodes. These nodes have different energy level but the same sensing radius and communication radius are deployed in heterogeneous network as shown in Figure. They are shown in different colours and shapes. The difference between these three types of nodes in their energy level as represented as follows.

Representation:

Super Nodes	= ‘O’
Advance Nodes	= ‘*’
Normal Nodes	= ‘+’
Base station	= ‘x’

3.3 Simulation Parameter

In this section, we presented the experimental setup which has been used in this research analysis to compute better lifetime, stability, balance energy consumption and maximum data transmission technique for WSN.

Table 1: Various parameter for simulation work

Parameter	Value
Area (x, y)	(100, 100) m
Base station (x, y)	(50, 50) m
Number of nodes	100
Probability	0.1
Initial Energy	0.1J
Transmitter Energy	50nJ/bit
Receiver Energy	50 nJ/bit
Free Space Energy (amplifier)	10 nJ/bit/m^2
Multipath Energy (amplifier)	
a (Energy factor between	0.0013 pJ/bit/m^4
normal nodes and super	3
nodes)	
b (Energy factor between	
normal nodes and advance	2
nodes)	
Number of rounds	
Message Size	10000
M (fraction of advance nodes)	4000 bits
X (fraction of Super nodes)	0.3
	0.3

Table: 1 contains the various variable and constant required to simulate various result. These parameter are standard values used as the benchmark for WSNs.

3.4 Assumptions and Properties of the Network

In the WSN model described in previous section some assumption have to make for the sensor nodes as well as for the network. Hence the assumption and properties of the network and sensor nodes are:

1. Sensor nodes are uniformly randomly deployed in the network.
2. Sensor nodes position are either fixed or micro mobile in the network.
3. There is one base station which is located at the centre of the sensing field that is ’50 x 50’ m.
4. Nodes always have the data to send to the base station.
5. Nodes are location-unaware, i.e. not equipped with GPS-capable antenna.
6. All nodes have similar capabilities in terms of processing and communication and equal signification. This motivates the need for extending the lifetime of every sensor.
7. Each sensor nodes send 4000 bit of data during transmission.
8. Sensor nodes have heterogeneity in terms of energy i.e., different energy levels. All nodes have different initial energy; some nodes are equipped with more energy than the normal nodes.
9. For each sensor nodes, ignore energy loss due to signal collision and interference between signals of different nodes that are due to dynamic random channel conditions.
10. We consider a network containing 20 normal nodes having Eo energy, 32 advanced nodes having 2 times greater energy as compared to normal nodes and 48 nodes containing 3 times greater energy as compared to normal nodes.

4. Performance Criteria

Performance parameters used for evaluation of clustering protocols for heterogeneous WSNs are lifetime of heterogeneous WSNs, number of nodes alive during rounds and data packets sent to BS.

Lifetime is a parameter which shows that node of each type has not yet consumed all of its energy. Number of nodes alive is a parameter that describes number of alive nodes during each round. Data packets sent to the BS is the measure that how many packets are received by BS for each round. These parameters depict stability period, instability period, energy consumption, data sent to the BS, and data received by BS and lifetime of WSNs. Stability period is period from start of network until the death of first node whereas, instability period is period from the death of first node until last one.

5. Result and Analysis

In this section, the existing heterogeneous clustering protocol (DDEEC, EDEEC and EDDEEC) are analyzed in simulation Environment using parameters like lifetime of the network, stability, data packet received by sink node. We have compared the results in different trails to find them more stable and maximum life time of the network.

5.1 Stability Period or Life Time

Stability period of First Node Death is the time interval from the start of the network until death of the first. In this way we measure the round number in which of the first node death of the network. Simulation result shows that the time period of the first node die is better in the EDDEEC protocol compared to DDEEC and EDEEC protocol. Fig: 3. shows that the round of the first node dies are increased and also the total life time of the network. Because of changing the energy level of WSNs and the nodes have to consume large energy to transmit data to base station through cluster head in DDEEC and EDEEC but in EDDEEC node we minimizes the energy consume by transmitting data to its neighbors cluster head or node. To check the stability of the networks, we did 10 simulation trails to check the stability of the network.

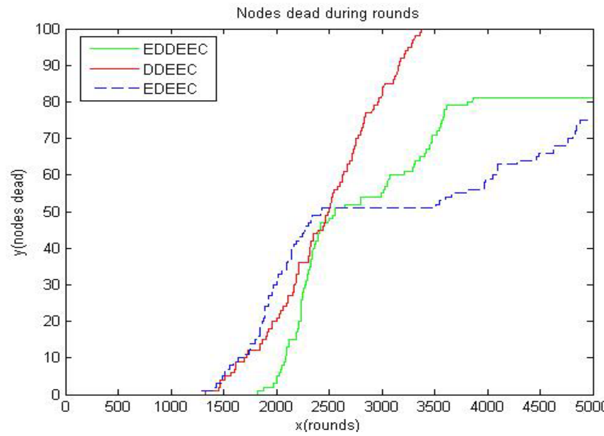

Fig: 3. Life Time of the Node

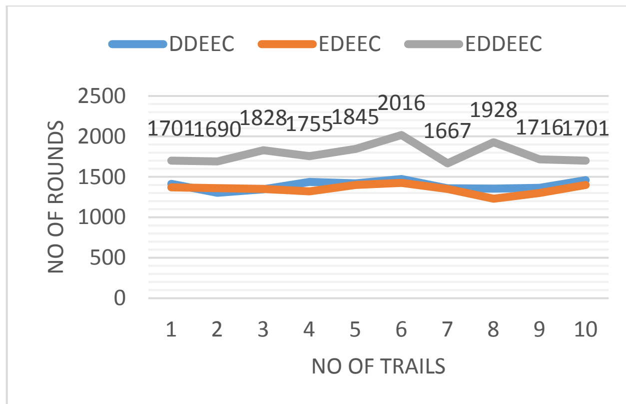

Fig: 4. First Node Death

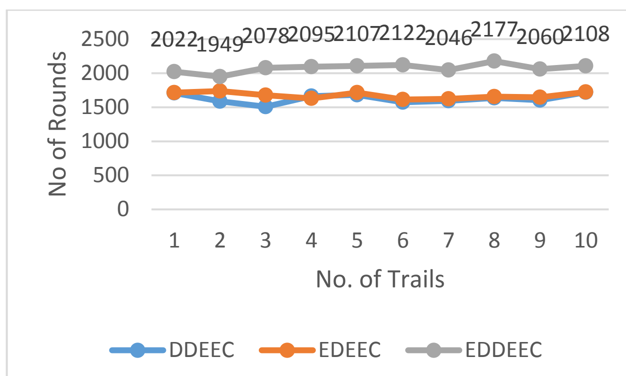

Fig: 5. Tenth Node Death

5.2 Energy Consumption

Each and every node transmit the data to cluster head and cluster head transmit the data to sink node, they consume energy to transmit the data. From simulation result we find that the consumption rate of energy in EDDEEC protocol is better or slower than that of DDEEC and EDEEC protocol. So we observed that EDDEEC protocol is more stable than that other two distributed protocols because of less cluster formation and intra cluster transmission in EDDEEC protocol. We observe from the Fig: 6. that the performance of the EDDEEC protocol is better than the EDEEC and DDEEC protocol. From Fig. 3, We observed that in EDDEEC protocol that the first nodes dies after the 1928 rounds which is far greater than the DDEEC and EDEEC which is 1322 and 1230 rounds respectively. From Fig. 5, we also found that the loss of nodes energy decrease in EDDEEC protocol with the slower rate than that of DDEEC and EDEEC protocols.

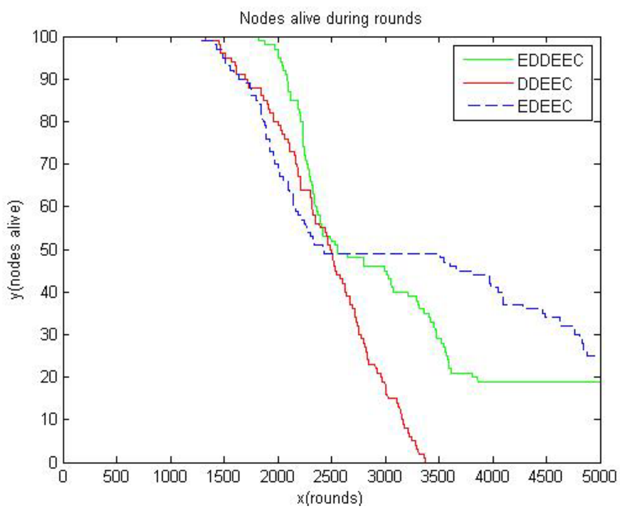

Figure: 6. Total Energy consumption for data transmission

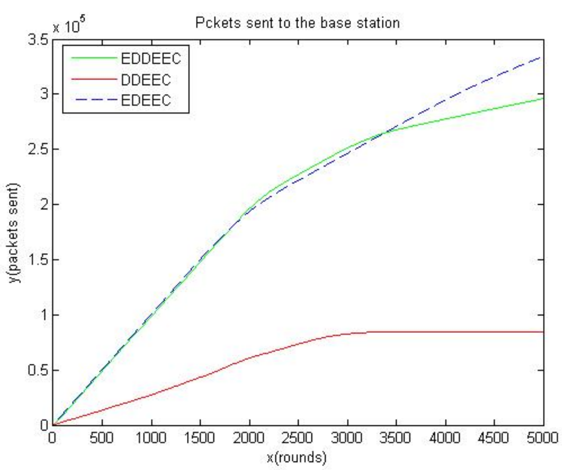

Figure: 7 Transmission of data packets to sink node

5.3 Data Packet

In Fig. 7, the reason why the packets sent to sink are increasing is that the increasing number of sensing nodes creates more sensing data, and, at the same time, they elect more CHs to transmit these data packets to sink. We can also observe from Fig. 6 that EDEEC transmit maximum number of data as compared to other routing protocol DDEEC and EDDEEC. Which indicates that EDEEC has better network monitoring quality than the DDEEC and EDDEEC protocols.

6 Conclusion and future directions

We have examined DDEEC, EDEEC and EDDEEC for heterogeneous WSNs containing different level of Heterogeneity. Simulations proves that DEEC and EDEEC perform well in the networks containing high energy difference between normal, advance and super nodes. EDEEC transmit more data to sink node compared to DDEEC and EDDEEC protocols. We observed that EDDEEC perform well in all scenarios. EDDEEC perform best performance in term of stability period and life time of the network. Our further work will mainly focus on how to further balance the energy consumption of every node by using the unequal clusters and increase the life time of networks. Furthermore, the energy whole problem is to be relieved in the network.

REFERENCES

[1] Ivan Stojmenovic and Stephan Olariu, Data-centric protocol for wireless sensor network, in handbook of sensor network, Chapter 13, pages 417-456, Wiley 2009

[2] Sudip Mishra, Isaac Woungang, Subhas Chandra Mishra, Guide to Wireless sensor networks, in book of Wireless sensor Networks, Chapter 2, pages 27-45, Spinger International Edition 2012.

[3] ChalermekIntanagonwiwat, Ramesh Govindan, Deborah Estrin, John Heidemann and Fabio Silva, "Directed Diffusion for Wireless Sensor Networking", IEEE/ACM Transactions on networking (TON), vol. 11, pp. 2-16, February 2003.

[4] Kaushik Ghosh, Partha Pratim Bhattacharya and P.K.Das, Effect of Multipath Fading and PropogationEnvironment on the Performances of a Fermat Point Based Energy Efficient Geocast Routing Protocol", International Journal of Wireless & mobile Networks, Vol. 4, No. 1, Feb 2012

[5] Ankita joshi and Lakshmi Priya.m, "A survey of Hierarchical Routing Protocols in Wireless Sensor Network", MES Journal of technology and Management, pp.67-71

[6] Joanna Kulik, HariBalakrishnan and W. R. Heinzelman, (1999) "Adaptive protocols for Information Dissemination in Wireless sensor networks", proceeding on 5th annual ACM/IEEE International conference on mobile Computing and networking, pp. 174-185.

[7] Ruqiang Yan(Senior Member IEEE), Hanghang Sun and Yuning, “Energy-Aware Sensor Node Design With Its Application in Wireless Sensor Networks” proceeding IEEE transactions on Instrumentation and Measurement, Vol. 62, No. 5, pp. 1183-1191, 5 May 2013.

[8] L. Qing, Q.Zhu, M. Wang, “Design of a distributed energy efficient clustering algorithm for heterogeneous wireless sensor network”, ELSEVIER, Computer Communications 29, pp. 2230-2237, year 2006.

[9] Elbhiri, B. , Saadane, R. , El Fkihi, S. , Aboutajdine, D. “Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks”, in: 5th International Symposium on I/V Communications and Mobile Network (ISVC), 2010.

[10] Parul saini, Ajay kumar sharma, “E-DEEC Enhanced Distributed Energy Efficient Clustering Scheme for Heterogeneous WSN”, in 1st international conference on papallel, Distributed and Grid Computing (PDGC year 2010).

[11] N. Javaid, T. N. Qureshi, A. H. Khan, A. Iqbal, E. Akhtar, M. Ishfaq, Enhanced Developed Distributed Energy-Efficient Clustering for Heterogeneous Wireless Sensor Networks, Internationa; Workshop on Body Area Sensor Networks (BASNet-2013), Elsevier Procedia computer Science 19 pages 914-919, year 2013.