A Distributed Clustering Technique for Energy Efficient Wireless Sensor Network

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Abstract - Energy of the sensor nodes is the key resource for designing a Wireless Sensor Network. The network lifetime depends upon the battery present in the sensor nodes. These sensor nodes are irreplaceable once deployed. Therefore, steps to minimize the network energy consumption is required. In this regard, clustering is found to be a beneficiary approach, but static clustering leads to energy scarcity. This paper proposes a distributed clustering approach for balancing the energy consumption among the nodes in the network. The idea is to divide the network into cluster and use residual energy as the periodic cluster head selection parameter. The cluster head will use multi-hop routing for transmitting the aggregated data to the sink. Simulation results shows that more number of nodes are alive for long duration of time and thereby balancing the energy consumption of nodes in the network.

Index Terms: Cluster; Cluster Head, Distributed clustering, Energy-efficient, Network lifetime, Residual Energy, Wireless Sensor Network

1. INTRODUCTION

With the advancement of wireless communication networks deployment of small, low cost sensors for real time applications is increasing radically. Wireless Sensor Network (WSN) consists of a large number of low power sensing devices that are placed at the remote environment in non-uniform manner. These sensing devices measures the occurrence of some events i.e. changes in any physical quantity such as temperature, weight, distance, pressure etc. across the monitoring field [1]. Based on the information pre-stored in its program memory, it captures the data and forwards it to the sink node. The sensed information at the sink node is then used by the end user for further processing.

Once the sensor nodes are positioned in the environment they remain inaccessible to the end users for its entire lifetime. They monitor the physical environment independently and has the potential to compute the data and perform communication. The major constraint of a sensor node is its finite energy resource [1] and it mainly depends upon battery life for energy. Energy depletion of the node is mainly due to sensing of information, computation, evaluation and data forwarding processes [2].

Although the sensor nodes are self-coordinating in nature the maximum amount of energy is consumed in communicating the data from one node to the other or to the destination. The continuous dissipation of energy can lead to the failure of sensor node. Non-functioning of a single node can disrupt the entire network communication, which in turn may degrade the performance of the network [3]. Therefore, development of energy-efficient algorithms to improve the network lifetime is necessary.
In network clustering, the Cluster Head (CH) node consumes maximum energy for data gathering and forwarding process. Assignment of fixed CH for complete network lifespan may result in network failure due to exhaustion of the CH [4]. To overcome this issue, this paper proposes a distributed clustering approach. The main idea is that the node acting as a CH does not remain fixed for entire network lifetime.

For minimizing the energy consumption of each sensor node, we employ a method to rotate the node acting as a CH within discrete time interval. In each cluster, a sensor node that has maximum residual energy is considered to be elected as CH that transmits the aggregated data to the sink. Also, the CH is assumed to be at one hop distance from the member nodes. The CH then uses multi-hop routing for data forwarding to the sink Therefore, this results in balancing the energy levels of all the nodes in the network and thereby allowing maximum number of nodes to be alive for complete lifespan of the network.

Contents of the paper is organized as follows: A brief background of the proposed work is described in Section II. Section III presents the literature of related previous work. Section IV discusses distributed clustering approach for energy enhancement. Section V explains the simulation results and discussions. Section VI concludes the outcome of our work and gives brief idea for future extension of the work.

2. CLUSTERING IN WSN

In WSN, each sensor node transmitting the sensed data directly to the sink node is an energy consuming process. Clustering involves the topological distribution of network into multiple small sub-networks called clusters each having two or more sensor nodes. In each cluster, a node is chosen as prime node called CH and all the remaining nodes are called the member nodes that performs event monitoring. The CH collects the data from all the member nodes and transmits it to the sink [5]. This aggregated data at the sink is used by the end user or is either forwarded to another network. Therefore, Clustering is an energy-efficient approach where each node gets fair chance to transmit the data to the sink [6]. Clustering technique can be basically performed in either of the two forms i.e. centralized or distributed.

2.1 Centralized Clustering

In centralized clustering, all the nodes in the network are controlled by the central Base Station (BS). For each cluster, the BS directly selects the CH and allocates time interval during which the member nodes can transmit the data to the pre-defined CH [7]. This method of clustering leads to overhead at the BS and therefore is applied in application specific WSNs that operates within less coverage area.

2.2 Distributed Clustering

Distributed clustering is dynamic in terms of nodes involved in data transmission. Nodes in a cluster alternately becomes CH based on varying parameters such as distance from the BS, hop count, cluster size, remaining energy etc [8]. This rotation of node forming CH reduces the chance of failure of a single node due to exhaustion of energy, which is the case in centralized clustering [15]. It helps in improving network handling process and is reliable when applied in large network applications.

3. LITERATURE REVIEW

Various clustering algorithms has been proposed for conserving the energy in WSN. Each of these uses varying parameters for electing a CH and each has its own advantages and limitations. Related to our proposed method we present a brief overview of existing works in this section.

EESR algorithm proposed in [9] employs a spanning tree as a multi-hop routing between CH and sink. Each link in the network is assigned a weight parameter. For transmitting a single bit across the routing tree the weight on the link is computed. The maximum weighted link is chosen for data transmission. This repeated computation of weight metric along with the calculation of shortest spanning tree may result in depleting more network energy. Hence is not optimal approach.

Multihop EEBCDA algorithm proposed in [10] involves the division of network into grids. In each grid, a node is selected as a CH. All the member nodes in smaller grid transmits the data to the CH. The CH will transmit the data to the next CH at the grid towards the sink. This form of data communication increases the overhead at the CH. Data is forwarded from one level of CH to the other. This increments the network overhead since CH in any one level may get depleted early due to frequent data transmission process. In addition to this, more amount of energy is required in informing all the member nodes about the position of grid and routing path.

MR-LEACH and MH-LEACH protocols have been compared for multihop routing in [11]. The LEACH-1R protocol is integrated with these two multihop routing protocols. In LEACH-1R, BS groups the network into clusters and selects a CH for each cluster. The CH transmits the gathered data from all nodes to the BS using multi-hop data communication. The CH is selected by the BS and this CH remain fixed for the entire network until it runs out of energy which is not an energy efficient process.

In [12], the clusters are formed as one hop and 2 hop neighbours from the CH. The chain topology is used for data transmission between CH and sink. The data is forwarded from one CH to another in chain. The node which is close to the BS can only perform data transmission to the sink. This may result in the death of the nodes closer to the BS. Hence no nodes will be available at near to the BS for data communication to the sink. It leads to routing overhead at the BS. Also, no clear idea about routing method being used is discussed.

Although various algorithms have been developed for minimizing the energy consumption in WSN they do not necessarily handle the applications with real time traffic, thus efficient techniques are to be resolved.

4. PROPOSED APPROACH

For effective utilization of energy across the overall network we present a distributed clustering algorithm. The main objective is to organize the sensor nodes into clusters such that the energy level of each node in the network at any interval of time remains almost equal. The network lifetime will be increased as the more number of nodes will be alive serving the monitoring purpose for more time duration.

4.1 Cluster Formation

The sensor nodes are mobile across the network area moving with a very low speed. Euclidean distance is used to calculate the distance between two nodes. Clusters of varying size is formed such that each neighbouring node in a cluster is at one hop distance with another node.

4.2 Cluster Head Selection

At discrete time intervals, a node with maximum residual energy than all other nodes in a cluster is selected as CH. All the remaining member nodes at one-hop distance in a cluster send the sensed information to the selected CH and the process continues until the existence of the entire network. The process of change in CH ensures that a node will remain a CH for short time interval and will not get exhausted frequently. No change in the CH takes place if the previously elected CH is found to be having maximum residual energy.

4.3 Data Communication

Within each cluster a node is chosen as a cluster head. The CH will transfer the aggregated data to the sink node using dynamic multi-hop routing. CH will transmit the RREQ message to all its non-cluster neighbour and finds out the next forwarding node with the shortest distance from it towards the destination and maximum residual energy as the next hop selection parameter. This forwarding node in turn computes the next hop and the process continues until the data is transmitted to the sink. Thus, forms the intra-cluster communication.

This energy balancing mechanism among all the nodes in the network guarantees that each node will continue to exist in the network for complete network existence time and thus resulting in improving network function.

Proposed Algorithm:

1: Create a wireless sensor network scenario.
2: Configure Energy Model for each node.
3: **Initialize:**
4: Number of nodes - *N*
5: Initial Energy of each node - *IE*
6: Coordinates of a sensor node - (*X,Y)*
7: Node Range - *R*
8: Distance between two nodes - *Dij*
9: Energy at time t - *E(t)*
10: Current Energy - *CE*
11: Residual Energy - *RE*
12: Neighbour Node - *n*
13: Initially, all nodes move randomly with the speed (s) of 10m/s.
14: **Random Waypoint Mobility:**
15: **for** i=*1 to N* **do**
16: X = *rand() * X*
17: Y = *rand() * Y*
18: *Dist(X,Y)*
19: **end for**

20: **Cluster Formation:**
21: Calculating Euclidean distance between two nodes:
22: **for** i = *1 to N* **do**
23: **for** j = *1 to N* **do**
24: Dij = $\sqrt{(xj - xi)2 + (yj - yi)2}$
25: **end for**
26: **end for**
27: One-hop Neighbour Calculation:
28: Set *R = 250*
29: **if** *D <= 250 & i! = j* ***then***
30: Set *m = j*; where m is neighbour node.
31: *c = c + 1*
32: count c
33: **end if**
34: Number of neighbours of a node is c.

35: **Cluster Head Selection:**
36: At discrete time interval E(t), the residual energy of each node is computed.
37: IE = *100J*
38: **for** i = *1 to N* **do**
39: *REi = IEi -CEi*
40: *IEi = REi*
41: **end for**
42: The node with the maximum residual energy is selected as CH.
43: **for** i = *1 to N* **do**
44: **for** j = *1 to N* **do**
45: **if** *RE(i) > RE(j)* **then**
46: *Max = RE(i)*
47: **else**
48: *Max = RE(j)*
49: **end if**
50: **end for**
51: **end for**
52: The sensor node in a cluster will send the data to the CH.
53: The CH will transfer the aggregated data to the BS through multihop communication.
54: End

55: **Data Transmission:**
56: Node sends the RREQ message to its neighbours:
57: **for** i = *1 to n* **do**
58: **for** j = *1 to n* **do**
59: Compute *Dij(n)*
60: **if** *Di;j(ni) < Di;j(nj)* **then**
61*: s = ni*; where s is shortest path next hop
62: **else**
63: *s = nj*
64: **end if**
65: *k = k + 1*
66: *count k*
67: **end for**
68: **end for**

69: Number of next hop from source *i* destination *j* is *k*.

5. RESULTS AND DISCUSSIONS

For analysing network performance, we assess the simulation results of the proposed algorithm. Simulation of proposed method is done in NS2 network simulator. We consider mobile nodes and a static sink node. The initial energy of each node is fixed.

The Random Waypoint Mobility Model [13] is used for mobile nodes. In this model, the nodes move randomly at a point in the simulation area with the pause time of 10m=s. The speed with which the node moves is slow so as to minimize the frequent change in clusters. The following simulation parameters are used:

Parameters	Values
Total number of nodes	50
Area (Network size)	800x400
Initial energy of node	100J
Simulation Time	30s
Mobility Model	Random Waypoint

Table 1 Simulation Parameters

Initially, at time 2s, node 24, 44 and 15 are selected as CH randomly. Since all the nodes has equal energy levels at initial stage, this random CH selection is fair. All other member nodes of the cluster send the data packets to these CHs.

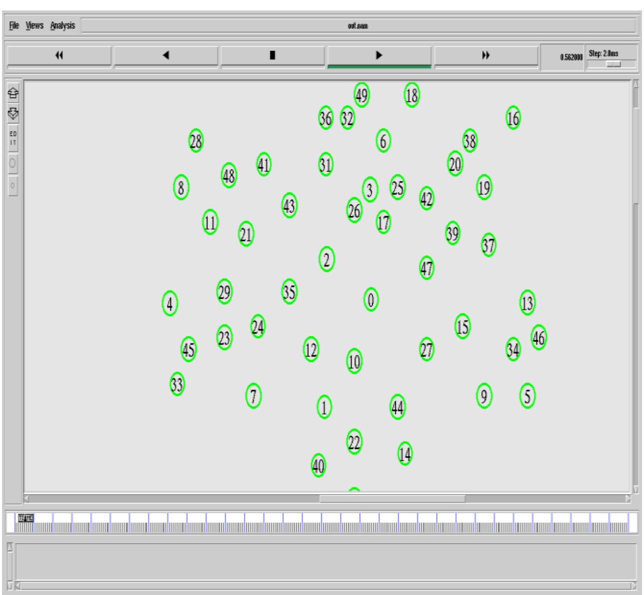

Figure 1 Deployment of WSN Scenario.

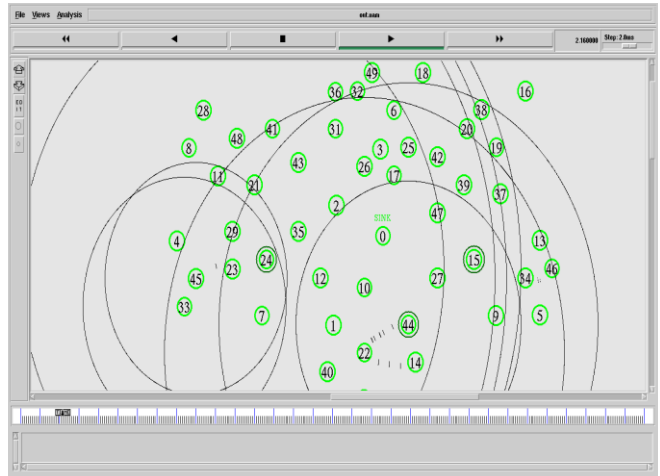

Figure 2. CH Selection

The newly elected CHs advertises its CH id to all other nodes in a cluster that are at one hop distance. Receiving this message, the nodes are informed about the new CH. Then all these member nodes will send the data packets to the CH. The CH in turn transmits the collected data to the sink node using multiple hops as shown in Fig. 3.

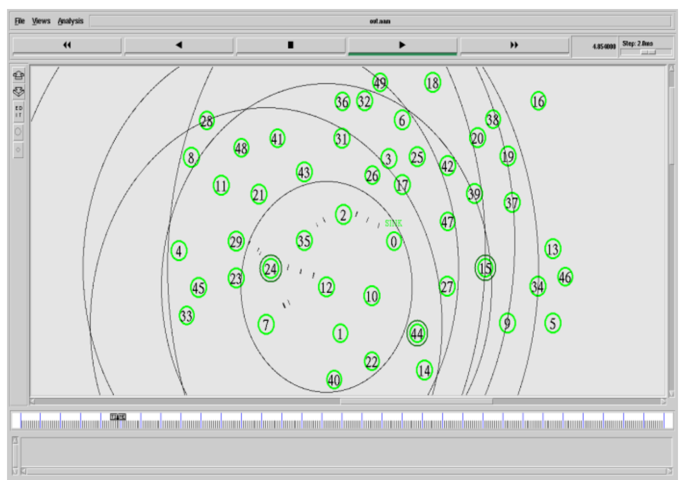

Figure 3. Multi-hop Data Transmission from CH to sink

From Fig. 3. It can be observed that the CH node transmits the data to the sink using multi-hop data forwarding mechanism based on shortest neighbour distance and maximum residual energy of the node as the next hop selection parameter.

The member nodes of the cluster that are involved in frequent sending of data packets experiences energy depletion at a higher rate. Thus, at discrete time interval the node acting as a CH in each cluster gets changed. The node that has maximum residual energy becomes CH. The member nodes now send the data to the newly elected CH. This can be observed from Fig. 4.

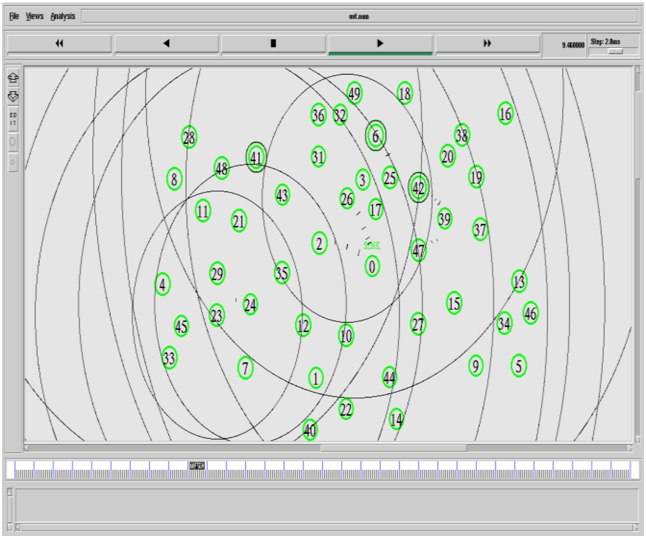

Figure 4. Change in the CH

At the end of simulation, the energy levels of all the nodes gets reduced due to communication in clustered manner but then also no node in the network has been dead due to energy exhaustion. Change in CHs results in allowing all the node to be alive for complete network lifetime. This can be seen in Fig. 5.

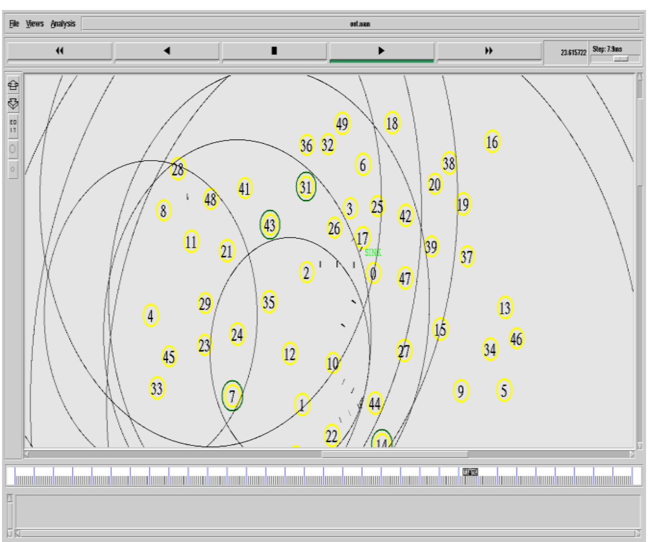

Figure 5. Nodes with minimum residual energy at simulation end

The energy levels of all the nodes in the network is plotted in the graph shown in Fig. 6. We observed that the remaining energy of each node in the network is very near to the energy left in another nodes as a result all the nodes has same amount of energy and thus all the nodes are active up to simulation end time.

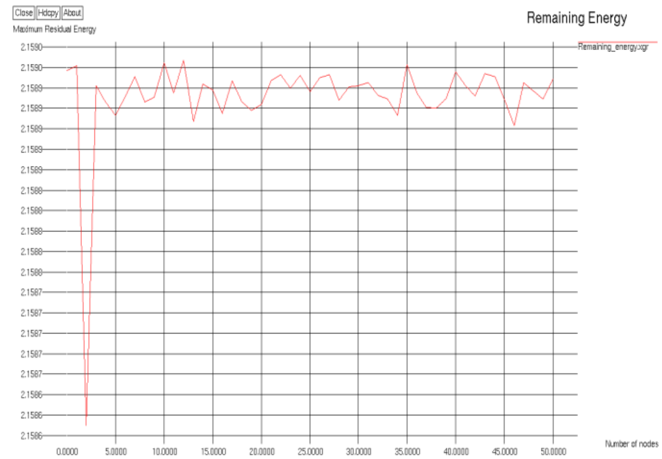

Figure 6. Number of nodes vs residual energy

Throughput is calculated as number of packets received per unit time. From Fig. 7, we found that the throughput curve shows no throughput degradation on data aggregation and transmission processes. The system throughput gets degraded only at point when there is a change in the CH since the member nodes has no cluster representative during CH selection process.

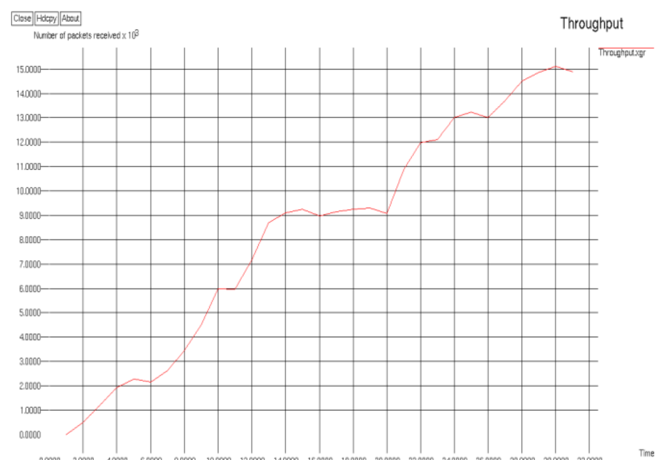

Figure 7. Throughput of the network

6. CONCLUSION

In this research work we implement distributed clustering of homogeneous sensor nodes. Single hop communication of nodes with the CH and multi-hop communication of CH with the BS is taken into consideration. It can be stated that, though the energy of CH nodes gets dissipated more than the other nodes but the process of allowing each node a fair chance to become a CH minimizes the chance of completely losing a node in the network. In contrast to the different approaches taken previously the proposed algorithm ensures optimizing the energy of the system by guaranteeing that no nodes in the network will be failed due to complete depletion of energy. Thus, the amount of energy consumption in the network gets minimized.

REFERENCES

[1]. Heinzelman, Wendi Rabiner, Anantha Chandrakasan, and Hari Balakrishnan "Energy-efficient communication protocol for wireless microsensor networks." In System sciences, Proceedings of the 33rd annual Hawaii international conference on. IEEE, 2000.
[2]. Pantazis, Nikolaos A., Stefanos A. Nikolidakis, and Dimitrios D. Vergados. "Energy-efficient routing protocols in wireless sensor networks: A survey." IEEE Communications surveys & tutorials, 2013, 551-591.
[3]. 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), International Conference on. IEEE, 2012.
[4]. Kaur, Manpreet, Abhilasha Jain, and Ashok Kumar Goel." Energy efficient two level distributed clustering scheme to prolong stability period of wireless sensor network." Advances in Computing, Communications and Informatics (ICACCI, International Conference on. IEEE, 2014.
[5]. Sharma, Versha, and Davinder S. Saini." Performance Investigation of Advanced Multi-Hop and Single-Hop Energy Efficient LEACH Protocol with Heterogeneous Nodes in Wireless Sensor Networks." Advances in Computing and Communication Engineering (ICACCE), Second International Conference on. IEEE, 2015.
[6]. Anastasi, Giuseppe, et al." Energy conservation in wireless sensor networks: A survey." Ad hoc networks, 2009, 537-568.
[7]. Mishra, Pooja, and Sanjiv Sharma." A Comparative Study of Existing Cluster-Based Routing Protocols in Wireless Sensor Networks." International Journal of Future Generation Communication and Networking, 2016, 43-52.
[8]. Gupta, Vrinda, and Rajoo Pandey." An Improved Energy Aware Distributed Clustering Protocol for Wireless Sensor Networks." International Journal of Computer Network & Information Security, 2016.
[9]. Hussain, Sajid, and Obidul Islam." An energy efficient spanning tree based multi-hop routing in wireless sensor networks." Wireless Communications and Networking Conference, WCNC IEEE, 2007.
[10]. Pant, Manoj, Biswanath Dey, and Sukumar Nandi."A multihop routing protocol for wireless sensor network based on grid clustering." Applications and Innovations in Mobile Computing (AIMoC), 2015.
[11]. Omari, Mohammed, and Warda Hadj Fateh." Enhancing multihop routing protocols in wireless sensor networks using LEACH-1R." Web Applications and Networking (WSWAN), 2nd World Symposium on. IEEE, 2015.
[12]. Karthikeyan, A., V. Jagadeep, and A. Rakesh." Energy efficient multihop selection with PEGASIS routing protocol for wireless sensor networks." Computational Intelligence and Computing Research (ICCIC),. IEEE, 2014.
[13]. Dong, Qian, and Waltenegus Dargie." A survey on mobility and mobility-aware MAC protocols in wireless sensor networks." IEEE Communications Surveys and Tutorials, 2013, 88-100.
[14]. Swati Dewangan, S. D. Mishra" A survey on Energy Optimization in WSN using Distributed Clustering Approach", International Journal of Innovative Research in Engineering and Computer Science (IJECS) ISSN: 2320-9801, IJIRCCE, Volume 4 Issue 11, 2016, pp. 19020-19023.
[15]. Singh, Shio Kumar, M. P. Singh, and D. K. Singh." Energy-efficient homogeneous clustering algorithm for wireless sensor network." International Journal of Wireless & Mobile Networks (IJWMN), vol.4 Issue 3, 2010, 49-61.
[16]. Shaji, Mariam, and S. Ajith." Distributed energy efficient heterogeneous clustering in wireless sensor network." Advances in Computing and Communications (ICACC), Fifth International Conference on. IEEE, 2015.