Energy Efficient Dynamic Clustering using Mobile Sink in Wireless Sensor Networks

Rashmi G. M[1], Mallanagouda Patil[2], Rajashekhar C. Biradar[3]

[1]*M. Tech Scholar, BNMIT, Bengaluru-70, Karnataka, India*
[2]*Department of CSE, BNMIT, Bengaluru-70, Karnataka, India*
[3]*School of ECE, REVA University, Bengaluru-64, India*

***Abstract*: Wireless Sensor Network (WSN) is a collection of small sensor nodes in a geo-graphically distributed area to keep track of physical or environmental conditions. If each node in the network transmits the sensed data to the Base Station (BS), the energy consumption is very high which directly affects the network lifetime. By using clustering techniques, network lifetime can be prolonged by making Cluster Head (CH) to communicate with BS on behalf of other cluster members. We have proposed a Mobile Sink (MS) scheme where the sink node has more energy and resources compared to other sensor nodes. The sink node moves near the clusters and gathers the sensed data from the CH. Clustering is done and CHs are selected based on the Residual Energy (RE) parameter. Simulation results and analysis show that there is an improvement in throughput, delay, packet delivery ratio with reduction in energy consumption compared to schemes that use static sink or BS, where all the CHs communicate the gathered data from the clusters members to the static sink node. Thus mobile sink scheme increases the network lifetime by reducing energy consumption.**

***Keywords:* Clustering, mobile sink, residual energy, transmission range.**

I. INTRODUCTION

The sensor nodes can sense, transmit, receive, and gather data with the help of wireless communication [1]. The sensor nodes are distributed in a geographic area of interest. WSNs are used in military applications, health care, natural calamity monitoring, wild life tracking, air pollution monitoring, and many other applications. From the environment the data is sensed by the sensor nodes, processed and transmitted to the BS directly or via gateway.

Energy conservation is a critical issue in WSNs as it is impossible to recharge or replace sensor nodes (if the battery is depleted) as sensor nodes are usually deployed in harsh and hostile environment [2]. Energy is consumed in WSN for transmitting and receiving the sensed data. In hierarchical architecture, the nodes in the network are grouped into clusters. In Low Energy Adaptive Clustering Hierarchy (LEACH) clustering algorithm, the nodes are grouped into clusters, where CH is selected randomly with some probability. Within the cluster, all the nodes sense the data and transmit to the CH, and the CH in turn transmits that data to the BS directly or via other CHs. The hierarchical clustering is divided into static and dynamic hierarchical clustering. In static clustering, once the clusters are formed, CHs and cluster members remain intact throughout the lifetime of the WSN. In dynamic clustering the CHs and their members are formed dynamically [3]. The selection of CH is significant as it is directly related to the lifetime of WSN. In literature there are many approaches proposed in this regard. Some of the relevant approaches have been discussed in the next section.

II. RELATED WORKS

A few Clustering techniques and Mobile BS techniques are discussed in this section. The operations in LEACH [4] are divided into set-up phase and steady phase. Formation of clusters and CHs selection is carried out in set-up phase. The energy required to sense the medium can be reduced by using the set of parameters such as message length, node energy, number of requests and message urgency [5]. Sensing and transmission of the sensed data to the BS through CHs is taken up in the steady phase. In LEACH, CHs are selected in rounds based on the network size. In each round, a random number between 0 and 1 is selected by the node to decide whether it becomes a CH or not for the current round. If the number generated by sensor node is less than the threshold value T(n), then that node becomes a CH for the current round. Threshold T(n) is given by the equation 1:

$$T(n) = \begin{cases} \frac{p}{1-p*(r \bmod \frac{1}{p})} & n \in G \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

Where the current round is indicated by r, the set of nodes G that have not become CH in the last 1/p rounds and p=k/n, k is the expected number of CHs in the round and n is the number of nodes in the network. The drawback of LEACH is the CHs selection is randomized, so the CH which is selected in the current round can be the CH for the immediate next round irrespective of the RE. So the nodes may die soon, as they are frequently selected as CH.

LEACH Centralized (LEACH-C) [6], also has the steady phase but in set up phase each node sends its location and energy information to the BS. The BS decides the CH according to the average energy. There is overhead and high energy consumption because each time the nodes have to communicate with the BS.

The communication between the CHs and BS can be a direct or multi-hop communication. In direct communication, CH directly transmits data to the BS. Energy consumption is more in case of direct communication. In multi-hop communication, the CH which is located far away from the BS, communicates with the one or more intermediate CHs to transmit the data to the BS. Likewise intra and inter-cluster communication occurs within the network [3]. The multi-hop communication leads to the hot spot problem where the CH located near to the BS dies early when compared to the other CHs. To overcome this, the idea of mobile sink concept is considered.

The improvisation of LEACH can be done by making the BS mobile [7]. Initially the BS is kept far away from the nodes and for each 100 rounds, the BS moves incrementally from its initial position towards the sensor nodes. By making the BS mobile, the communication distance between the clusters and BS is reduced and energy needed to transmit the data to the BS is reduced, which directly increases the lifetime of the network. The network lifetime can be increased to some extent when compared to the basic LEACH protocol. But the drawback is, for every 100 rounds the BS is moved, the some nodes may die until BS is moved to those nodes.

The BS location is determined by the residual energy of the CHs [8]. At the beginning of each round, clusters are formed and CHs are selected. Then all CHs send a status packet across the network in which they propose a maximum distance they can support for data communication to BS. The optimal point for BS's new location is where data communication is efficient for all CHs. The BS makes the final decision after inspecting the energy efficiency of all CHs in the network for data communications and BS moves to the location of that node. As the BS moves to new location every time for collecting data from CH, delay in data transmission happens.

The network lifetime can be increased by Particle Swarm Optimization (PSO) [9]. The BS initially collects all the data regarding the position from the sensor nodes. By using PSO algorithm, the BS gets a set of feasible sites where the BS will start to tour within the network. Using the nearest neighbor algorithm it starts the journey. When a BS moves to a feasible site, the nearby sensor nodes transmit the sensed data in one hop to the BS. After gathering data from sensor nodes around the selected feasible sites, the BS moves to the next selected site in the tour. In this method, delay is more as the BS moves near all the sensor nodes.

In [10], the BS is moved in a circular fashion. Initially the BS is at centre, and then moves circularly in a square sensing field and then returns to its original position in order to recharge the energy in every round. The clustering is based on the LEACH protocol. The drawback of this work is that the delay increases as the BS is moved each time near a cluster to collect the data.

The researchers in [11], proposed an approach where the sink is moved near intermediate node called as Rendezvous Point (RP). RPs are a subset of sensor nodes where the sensor nodes transmit the data to the nearby RPs. The sink node moves near RPs and collects the data. The RPs are used for transmitting data to sink, hence less energy is consumed thus increasing the lifetime of WSN using the RPs. But the drawback is the nodes used as RPs also have limited battery power.

In the work [12], an interruption scheme is proposed where clusters are formed and CHs are selected by considering the residual energy parameter. And then the clusters are merged and re-formed and the CHs are re-selected. The clusters are merged based on following principles: 1) The clusters having equal distances can be merged. 2) Less number of nodes are present in the clusters that are far away from the BS. 3) The clusters having less average residual energy have less number of nodes to balance the load. The interruption scheme performs dominantly in load balance since it can make node with higher residual energy to be the CH for a longer period.

All the approaches discussed above, contribute to high energy consumption, more delay and less throughput, pdf for the WSNs. To overcome these drawbacks, we have proposed "Energy Efficient Dynamic Clustering Mechanism using Mobile Sink (EEDCMS)", where MS is used to move around the network to establish the connection and collect data from CHs. Next section describes our contribution.

III. OUR CONTRIBUTION

As energy conservation is a critical issue in WSN, we have proposed EEDCMS scheme that includes the MS concept where the sink moves near clusters to collect the sensed data, thus reducing the energy consumption of the sensor nodes. With this scheme, the simulation results have shown that there is an improvement in delay, packet delivery ratio, throughput and reduction in energy consumption.

3.1 Proposed Work: Sensing and communication of data are the possible energy losses that a sensor node can experience in the network. The energy required for communication is much greater than the energy required for sensing the data. The communication cost can be efficiently reduced. The proposed approach aims at reducing the energy required for transmitting and receiving data as much as possible using MS technique thereby increasing the network lifetime. The main steps of the proposed approach include

1. Node Deployment

2. Formation of Clusters
3. RE calculation of each node
4. CH selection based on RE
5. Sensing of MS by the CHs
6. CHs energy conservation

3.2 Node Deployment

Initially the nodes have to be deployed into the network based on the co-ordinate values given as input. Flat Grid model is used to deploy the nodes. The algorithm 1 describes the node deployment procedure.

Algorithm 1: Node Deployment

Input: x and y co-ordinate values of the nodes
Output: Nodes successfully deployed in the network
Step 1: Start
Step 2: i=1: N_{Nodes}
Step 3: compute the distance between the neighboring nodes $((x_2 - x_1)^2 + (y_2 - y_1))^{1/2}$
Step 4: Generate the Node_ID as i
Step 5: Create the Map of (Node_ID, PositionOfNode)
Step 6: i=i+1
Step 7: Stop

The x and y co-ordinates values are given as input to deploy the nodes, then the distance between the neighbor nodes is calculated using Euclidian distance formula. Node_ID will be generated for each node. The table containing Node_ID and Position Of Node is created.

3.3 Formation of Clusters

Once the nodes are deployed in the network, the network gets partitioned. The partitioned groups send the Hello messages within them to know the neighbors. The node that receives the reply messages from other nodes creates the neighbor table which contains the Node_ID of the replied nodes and they form the clusters. The neighbors are those that are located at one-hop distance from each other. The algorithm 2 describes the cluster formation procedure.

Algorithm 2: Cluster Formation

Input: No. of clusters to be formed, End points of clusters and No. of nodes in each cluster
Output: Clusters
Step 1: Start
Step 2: Pick appropriate x and y end point for the cluster.
Step 4: Execute Node Deployment algorithm and place the nodes in the cluster
Step 5: Generate the cluster_ID for the cluster
Step 7: Stop

Once the nodes are deployed in the network, the no. of clusters to be formed, end points of the clusters and no. of nodes in the clusters are given as inputs. Based on the x and y co-ordinate values nodes are deployed into the clusters. For each cluster Cluster_ID is generated.

3. 4 RE Calculation

Once the nodes are deployed in the network, energy is consumed for each and every activity taken up by a node. For example, SleepPower- the power consumption in sleep state, TransitionPower- the power consumption from sleep state to idle state and so on. The algorithm 3 describes the RE calculation procedure.

Algorithm 3: Residual Energy calculation

Input: Nodes with Initial Energy (IE) in Joules
Output: RE of each node
Step 1: Start
Step 2: i=1: N_{Nodes}
Step 3: Compute the energy consumed at each node using the equation $E=E_{tx} + E_{tr}$
Step 4: Calculate the RE using the equation RE= IE-CE
Step 5: Generate the table of Node_ID and RE
Step 6: i=i+1
Step 7: Stop

At the beginning, the nodes will have the IE. After sending the Hello messages, transition time, sleep time consumes energy which is denoted using Consumed Energy (CE). It is calculated using the equation $E=E_{tx}+ E_{tr}$, where E_{tx} is energy consumed for transmitting the data and E_{tr} is the energy consumed for receiving the data. The RE is calculated using the equation RE= IE-CE. Based on RE, the CH is selected.

3.5 CH selection

Once the clusters are formed, the RE of each node in the cluster is calculated and the node having the highest energy is selected as CH. The algorithm 4 describes the CH selection procedure.

Algorithm 4: CH selection

Input: Clusters
Output: Node with highest RE is selected as CH
Step1: Start
Step 2: i=1: $N_{cluster}$
Step 3: Compute the i^{th} node energy
Step 4: i=i+1
Step 5: After computation of RE of the nodes in a cluster, compare the RE of the nodes
Step 6: node with highest RE is selected as CH
Step 7: Stop

Once the energy of each node is calculated in a cluster, the node with highest energy is selected as CH. In case if the CH fails to transmit the data, the node with second highest RE is selected to carry out transmission.

3.6 Sensing of MS by the CHs

Once the CH is selected, the sink gets the information about who have become the CHs for the current round. The sink has the ability to move throughout the network. It has more resources and energy compared to the other nodes in the network. Once the sink gets notification from the BS, it starts moving towards the clusters. While moving from its initial position, it keeps sending the Hello messages and moves with a constant speed. When the CH receives the packet, first it checks whether the sink is within its range (range of CH < range of mobile sink). If it gets reply from the CHs, its stops at that position which is known as Polling Point (PP) and the CHs transmits the data to sink and in turn the sink transmits that data to the BS. Likewise the BS moves throughout the network and collects data from all CHs. The Multiple Inputs and Multiple Outputs (MIMO) concept is used where the sink is incorporated with the dual antennas, so that it can receive data from one or more CHs at a time and it can also transmits that data to the BS.

3.7 Nodes energy conservation

By using the MS technique, the sensor nodes energy can be conserved. Once the CHs collect the data from their cluster members, the sink moves near the clusters to collect that data thus saving the energy of the CHs that was required by CHs to transmit the data to the sink. Likewise the energy consumption of the nodes in the network reduces thus increasing the network lifetime.

3.8 Simulation parameters

The parameters chosen for implementation are shown below:

1. Total number of static sensor nodes = 48
2. Total number of mobile sink=1
3. Initial energy of the sensor nodes= 100J
4. Range of sensor nodes= 550m
5. Range of the Mobile Sink = 716m
6. Speed of the Mobile Sink= 950m/sec
7. Mobility model= Constant speed mobility
8. Area of the network= 1300m x 1000m
9. Simulation Tool = NS2

IV. RESULT ANALYSIS

The graph of EEDCMS Vs EEDC for average energy, throughput, delay, overhead and packet delivery ratio have been showed below.

Average Energy

The Average Energy is the total energy consumed by the nodes in the network. The average energy is given by the equation 2:

$$\text{Average Energy} = \frac{\text{Total Energy}}{\text{Number of Nodes}} \qquad (2)$$

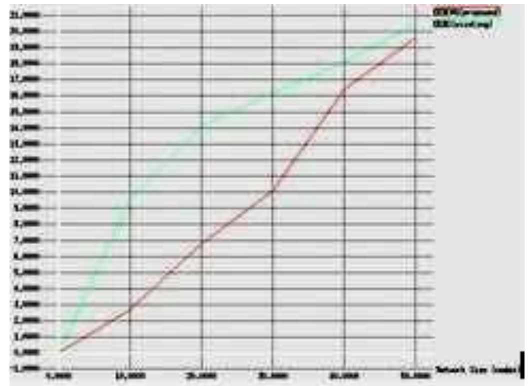

Figure 1: Graph of Average energy consumed Vs Network size

The figure 1 shows a graph of Average energy consumed Vs Network size. The proposed approach EEDCMS consumes less energy when compared to the EEDC scheme. The reason for decrease in energy consumption in EEDCMS is that as the MS moves throughout the network to collect the data from CHs, the energy of the CHs required to transmit the data to the BS, is saved thus increasing the lifetime of the network.

Throughput

The Throughput is the total amount of data received in a particular amount of time and it is given by the equation 3:

$$\text{Throughput}= \frac{\text{Recieved Size}}{\text{Transmission Time}} \qquad (3)$$

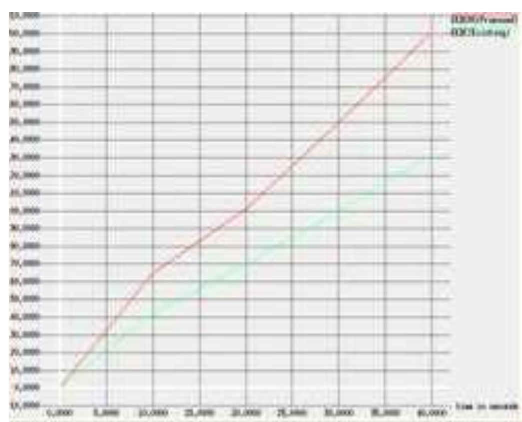

Figure 2: Graph of Throughput Vs Transmission Time

The figure 2 shows the graph of Throughput Vs Transmission time, where the throughput of the EEDCMS approach is more compared to the EEDC scheme. The reason for the increased throughput is as the sink is incorporated with the dual antennas, multiple inputs and multiple outputs are possible by the sink which increases the throughput.

Delay

The Delay is that how long it can for a data to send from source to destination and it is given by the equation 4:

$$\text{Delay} = \text{End Time} - \text{Start Time} \quad (4)$$

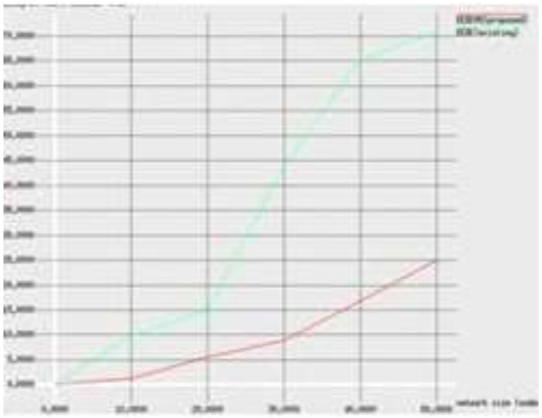

Figure 3: Graph of Delay Vs Network size

The figure 3 shows the graph of Delay Vs Network size. The delay of the proposed EEDCMS approach is less compared to the EEDC scheme as the mobile sink moves near the clusters and collects data thus reducing the transmission time for sending and receiving the data.

Overhead

The Overhead in the network occurs due to sending of beacon or control messages required for co-ordination among the sensor nodes to form the clusters and the sink also sends the messages in order to sense the CHs and it is given by the equation 5:

$$\text{Overhead} = \frac{\text{Number of Control (Hello) Packets}}{\text{Total Number of Data Packets}} \quad (5)$$

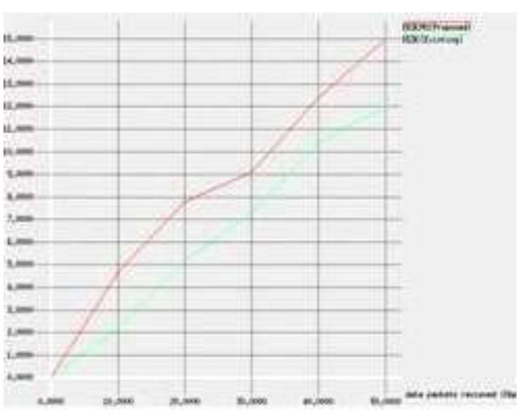

Figure 4: Graph of Overhead Vs Data Packets Received

The figure 4 shows the graph of Overhead Vs Data packets received. In the proposed EEDCMS approach the Hello messages are sent by the sink to know the CHs that are within their transmission range. Hence the overhead is more compared to the EEDC scheme where there is no need for the beacon messages.

Packet Delivery Ratio

The Packet delivery ratio is the ratio of the number of received packets by the number of sent packets and it is given by the equation 6:

$$\text{Packet Delivery Ratio} = \frac{\text{Number of Recived Packets}}{\text{Number of Sent Packets}} \quad (6)$$

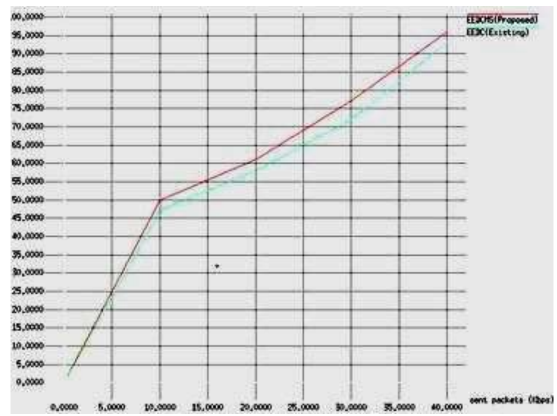

Figure 5: Graph of packet delivery ratio Vs Number of Sent packets

The figure 5 shows the graph of Packet delivery ratio Vs Number of sent packets. The proposed EEDCMS approach increases the Packet delivery ratio compared to the EEDC scheme as the sink moves near the CHs to collect the data, the communication distance decreases and the data can be easily collected by sink.

V. CONCLUSION

The network lifetime can be increased by reducing the average energy consumed by the sensor nodes, for this Energy efficient clustering algorithm with MS is proposed. The CHs are selected based on RE parameter and the sink is moved throughout the network to collect the data from CHs. The energy required by the nodes to transmit the data to the MS is reduced compared to the energy required by the nodes to transmit the data to the static sink. Performance analysis shows that there is an improvement in the delay, throughput, and packet delivery ratio.

REFERENCES

[1]. J.Yick, B. Mukherjee, D. Ghosal, "Wireless sensor network survey in Computer Networks", 2292–2330, 2008.

[2]. M. Patil, R. C. Biradar, "A survey on routing protocols in wireless sensor networks", IEEE, 86-91, Singapore, 2012.

[3]. K. Akkaya, M. Younis, "A survey on routing protocols for wireless sensor networks, in Ad Hoc Networks", 3 325–349, 2005.

[4]. W. R. Heinzelman, A. Chandrakasan, and Hari Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks", Proceedings of IEEE, HICSS, 2000.

[5]. M. Patil, R. C. Biradar, "Media Access Control in Wireless Sensor Networks using Priority Index", Indonesian Journal of Electrical Engineering and Computer Science, Vol. 5, No. 2, 416-426, 2017.

[6]. Mortaza F. K. Abad and Mohammad A. J. Jamali, "Modified LEACH Algorithm for Wireless Sensor Network", IJCSI International Journal of Computer Science, Issues, Vol. 8, Issue 5, No 1, 2012.

[7]. Gunjan Jain, S.R Biradar, "Enhanced Approach of Making Mobile Base Station in LEACH", International Journal of Advanced Research in Computer Engineering & Technology Volume 1, Issue 10, 2012.

[8]. M. H. Khodashahi, F. Tashtarian, M. H. Y. Moghaddam, M. T. Honary, "Optimal Location for Mobile Sink in Wireless Sensor Networks", 2010.

[9]. V. Devaswaran, "Energy Efficient Protocol in Wireless Sensor Networks using Mobile Base Station", IEEE 2nd International Symposium on Telecommunication Technologies (ISTT), Malaysia, 24-26 Nov 2014.

[10]. N. A. A. Latiff, N. M. A. Latiff, R. B. Ahmad, "Prolonging Lifetime of Wireless Sensor Networks with Mobile Base Station using Particle Swarm Optimization", 2011.

[11]. R. J. Rani, C.Tharanidharan, "A Movement of Mobile Sink In Wireless Sensor Networks to Conserve Energy", International Journal of Innovative Research in Science Engineering and Technology, Volume 4, Special Issue 2, 2015.

[12]. X. Qin, Xiong Wang, Feng Ouyangy, T. Wang, X. Gan, X. Tian," A Dynamic Unequal Energy Efficient Clustering in Wireless Sensor Network", National Mobile Communication Research Laboratory, Southeast University, China, 2016.