Improving The Energy Efficiency By Mobile Sink Based Data-Gathering For Heterogeneous Wsns

Praveena N G , Aishwarya N , Manju M

Abstract: Wireless sensor networks (WSNs) have been broadly functional in different practical applications that require gathering an enormous amount of heterogeneous sensorial data. However, majority of the data-collecting methods in WSNs cannot remove the hotspot problem in the whole network. This affects the network connectivity and diminishes the network lifetime. Additionally, timely delivery of sensory data is another significant factor in WSNs. In order to address these challenges, an effective Energy Efficiency by Mobile sink Based Data-Gathering for Heterogeneous WSNs (EEMD) algorithm is proposed. In this algorithm, advanced nodes (AN) are introduced which limit the route length of Mobile Sink so the delay time of data delivery to Base Station is greatly reduced. Hence, the Mobile Sink reduces the multipath communication and energy consumption of Cluster Heads. The EEMD approach is experimentally tested with both quantitative and qualitative evaluations to verify its efficacy. The Simulation results shows that EEMD approach is superior to the state-of-the-art methods with reduced delay time and improved network lifetime.

Index Terms: Advanced Node, Connectivity, Heterogeneous WSNs, Mobile Sink, Cluster Head, Transmission Range, Energy Efficiency

1 INTRODUCTION

Heterogeneous WSNs have been widely applied in various applications such as disease analysis, source detection, sea searching, patient monitoring, equipment monitoring, pollution monitoring, tide monitoring, and fault prediction [1]. The Rapid Development of the Wireless communications and low power consumption embedded system gives birth to WSNs. In addition to the characteristics of low-power consumption and low-cost in WSNs, self-organization have also brought a revolution in information perception. WSNs is composed of vast number of tiny sensor nodes deployed in monitoring areas, and forms a multi-hop self-organizing network through wireless communication [2]. Compared with conventional WSNs [3,4] sensor network's computing, energy, and storage ability are limited. Therefore, to extend the network lifetime, the design of routing algorithms and efficient usage of nodal energy is becoming a focus of the WSN research. In WSN routing protocol, clustering is considered as one of the most favorable energy-saving method. Clustering routing algorithm uses nodes within the network to organize the structure of the cluster. The nodes in the cluster are responsible for collecting the data, and the cluster head (CH) helps to forward the final data either through a single hop or multi-hop way to reach the Base Station. But the residual energy (RE) [5] of the CHs are reduced which results in reduced network lifetime. The recent studies [5,6] show that the multi-hop communication between cluster head and aggregation node is more conducive to increase the network lifetime. But, the timely delivery of sensory data is a crucial factor in real time target tracking in battle environments which needs to be addressed.

- *Dr. N.G. Praveena is currently an Associate professor at R.M.K College of Engineering and Technology, Anna University, Chennai, India. E-mail: drpraveenang@gmail.com*
- *Ms. N. Aishwarya, is currently an Assistant Professor at R.M.K College of Engineering and Technology, Anna University, Chennai, India E-mail: aishwarya8914@gmail.com*
- *Ms.M.Manju, is currently an Assistant Professor at R.M.K College of Engineering and Technology, Anna University, Chennai, India E-mail: manjuvit@gmail.com*

Motivated by these concerns, an effective Energy Efficiency by Mobile sink Based Data-Gathering for Heterogeneous WSNs (EEMD) algorithm is proposed in this paper. In this algorithm, advanced nodes (AN) are instigated to limit the route length of the Mobile Sink which reduces the delay time of data delivery to Base Station. Also, the Mobile Sink reduces the hop-count on the routing path and energy utilization that improve the network data delivery in WSNs. The main contributions of this paper are

(i) The sink is mobile which helps to enhance the network lifetime.

(ii) The Advanced Node combined with the Mobile Sink reduces the multipath communication and energy consumption of Cluster Heads.

The remainder of this paper is structured as follows. Section 2 deals with the related research works in various aspects. Section 3 mainly focuses on the proposed algorithm for effective data collection at mobile sinks in WSN environments. Section 4 discusses about the simulation results and analysis. Lastly, Section 5 concludes the paper.

2 RELATED WORKS

This section briefly describes the works done previously in the domain of Wireless sensor networks along with their pros and cons. Wang [7] introduced an unequal clustering routing algorithm which determines node's position and the cluster radius is calculated by considering node's residual energy and distance between node and the base station. The cluster adjacent node is applied to transport data and reduces the energy-loss of cluster heads. This algorithm can effectively reduce the energy-loss of CHs and balance the energy consumption to improve the network lifetime. However, this algorithm does not work for mobile sink and for heterogeneous networks. Cheng High Energy First (HEF) [8] clustering algorithm proved an optimal clustering policy under certain ideal conditions. This algorithm derived bounds of the predictability provide accurate estimations of the system lifetime. HEF algorithm is shown an optimal cluster head selection algorithm that maximizes the network lifetime. Adaptive Decentralized Re-Clustering Protocol (ADRP) [9] by considering the residual energy of each node in the network as well as the average energy of each cluster, the cluster heads and next heads are selected. Longer lifetime and mode data message transmissions are achieved than current important clustering protocol in wireless sensor networks. But it fails to address optimum mode of communication in the network. An Improved Harmony Search Based Energy Efficient Routing Algorithm (IHSBEER) [10] based on Harmony Search algorithm was proposed. This algorithm focuses on improvement of the encoding of harmony memory based on the characteristics of routing in WSNs. In this, the local search strategy is used to enhance the local search ability to improve the convergence speed and the accuracy of routing algorithm. Roughly, deliberately distributed clustering algorithms can cause nodes to become isolated from CHs. Regional energy aware clustering method [11] used to isolate the nodes. In this scheme, the CHs are selected based on weight. This Weight is determined according to the residual energy of each sensor and the regional average energy of all sensors in each cluster. This scheme improves the lifetime and stability of a network. Energy Efficiency and Quality of Data Reconstruction through Data-Coupled Clustering scheme [12] increases the technique of energy efficiency without sacrificing the data quality. Second-Order Data-Coupled Clustering (SODCC) and Compressive-Projections Principal Component Analysis (CPPCA) algorithm achieved a perfect balance between quality of reconstruction, controlled by the compression ratio, and the energy expenditure of the data gathering process. However, this algorithm does not work properly in a dynamic environment. A trade-off factor costing [13] is ignored when compared with the efficiency and network lifetime. Particularly lifetime of the network becomes questionable when the nodes are installed under heterogeneous networks.Fair Efficient Location-based Gossiping algorithm [14] used to address the problems of Gossiping and its extensions. This approach increases the network energy and as a result maximizes the network lifetime also this protocol reduces propagation delay and loss of packets. This algorithm improved network lifetime and sensing coverage. A trust mechanism for efficient CH election is introduced in a WSN utilizing Artificial Bee Colony algorithm. This scheme improves the Quality of Service (QoS) and reduces the energy utilization in the network. Improved Velocity Energy-efficient and Link aware Cluster Tree (IVELCT) scheme [15] that minimizes the energy exploitation and reduces the end-to-end delay in WSNs. Mobile sink is implemented which reduces the energy consumption. Balanced Clustering and Static Multi-mobile base station Trajectory (BC-SMT) model [16] improves the network lifetime by selecting CH and Mobile base station which adopts static trajectory for data collection from the CH which introduces delay in WSNs. Hybrid hierarchical clustering approach (HHCA) [17] considered a hybrid of centralized gridding and distributed clustering. In HHCA, the grid heads are determined in a centralized manner, and then the CHs are determined in a distributed manner. By introducing three-layer hierarchy, the number of nodes that communicate with base station reduced, resulting in energy saving. However, this scheme takes more time to deliver the data to Base Station in WSNs.

3 PROPOSED METHOD

It is a well known fact that the sensors in wireless sensor networks are responsible for sending and receiving the data, data processing and data aggregation. This implies that the energy consumption must be effectively utilized which in turn also increases the network lifetime. To achieve this intent, Mobile Sink Based Data-Gathering Algorithm for Heterogeneous WSNs is proposed in this work. Fig. 1 shows the architecture of proposed EEMD scheme in which the sensor nodes, advance nodes are deployed randomly for monitoring the environment. The sensor nodes operates either in sensing mode for monitoring the environment or in CH mode for gathering , compressing and forwarding the data to the advanced node. To reduce the Mobile path length in WSNs, the concept of Advanced Node is introduced. The Advanced Nodes contain additional resources than any other nodes; thus, it acts as communication points for data transmission. The Advanced Node can help ease sensors that are greatly loaded by high network traffic, as a result extending the network lifetime. Finally, the advanced node transmits the data to the Base station through mobile sink which is located outside of the deployment field. Assume the total number of sensor nodes in the network is N. The fraction of advance nodes are m and normal nodes are (1-m). The energy of the advance nodes is m times more than normal nodes. Let E_{nrm} is the initial energy of normal node, E_{adv} is the initial energy of advance nodes. The total initial energy of the heterogeneous network E_{total} is given by,

$$E_{total} = E_{nrm} + E_{adv} \quad (1)$$

$$E_{total} = N(1-m)E_o + NmE_o(1+a) \quad (2)$$

Let P_{adv} is the probability that advance nodes became a cluster head and P_{nrm} is the probability that normal nodes to become a cluster head.

$$P_{nrm} = \frac{P_{opt}}{1+am} \quad (3)$$

$$P_{adv} = \frac{P_{opt}}{1+am} * (1+a) \quad (4)$$

In Equation (4) and Equation (5), P_{opt} is the optimal probability that a node to be cluster head. For a node to become a cluster head, the optimal probability is divided on the basis of its residual energy. Once the sensor nodes and advance nodes are computed the CHs are chosen based on their residual energy and an estimate of how many of its neighbouring CHs. The CH election is given in (5).

$$P_{CH} = NC \times \frac{RE}{IE} \quad (5)$$

where

NC→ Node Connectivity RE→Energy missing in nodes following certain rounds IE→ Initial Energy.

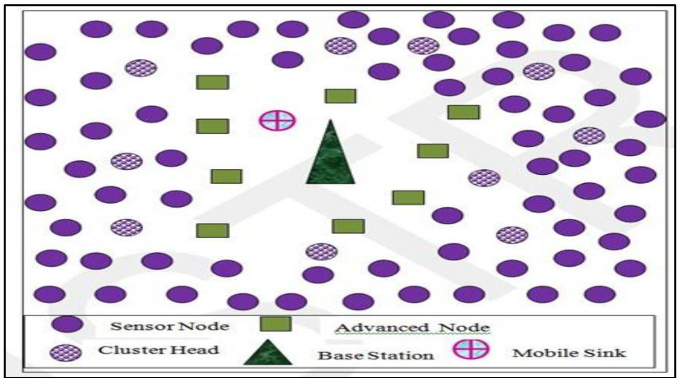

Fig. 1 *Architecture of EEMD Scheme*

Algorithm 1: Node initialization and cluster head formation

// Number of clusters - ‘C_i’
for (i=1; i<=n; i++)
{
//Max number of nodes in each cluster - 'C_{ij} '
for (j=1; j<=m; j++)
nodeID=C_{ij};
}
// Residual energy of node N_{ij} is E_{rij} and exchange it for every round
for (r=1; r<=N_m; r++)
{Exchange E_{rij} value with neighbour nodes};
// Mode change
if(E_{rij}>E_{min})
for (x=1; x<=N_m; x++)
{calculate T(n) value};
else
{send_silent_message&& Switch_to_sleep_state};

Initially, the network can be split-up into number of clusters Ci, where i varies from 1 to n using sensors transmission range (TR). The cluster member Cij, $j \in i$ joins the cluster Ci temporarily, based on Node Connectivity. For every cluster, cluster head CHi is chosen based on the Residual Energy. The detailed steps are explained below. Let us assume E_{min} be the minimum energy required for the node C_{ij} to act as CH_i. For every round r, the energy E_{rij} is calculated for each C_{ij}, $j \in i$ and compared with E_{min}. If max(E_{rij} >> E_{min} , node C_{ij} will act as CH_i else the next node with highest E_{rij} will act as a CH_i. The nodes with lower energy will send silent message to CH_i and enter in to sleep state state. The process of Node initialization and cluster formation is described in algorithm 1.Once the CH_i election process is completed, it broadcast the advertisement message denoted by {CH_{id}, CH_{loc} ,CH_{TR}} to C_{ij}. The sensor nodes receive the message and recalculates the node connectivity to find its cluster C_i. Finally, the sensor nodes C_{ij} join the cluster C_i by sending the join message {S_{id}, S_{loc} ,S_{TR}} to the cluster head CH_i. Now, the CH_i transmits the cluster member data to the Advanced Node A_{ij}. The energy of node C_{ij} is computed and compared with the threshold value Th_{adv}. If it is above the Th_{adv}, the node C_{ij} is selected as the Advanced Node A_{ij}. The selection threshold of the Advanced Node A_{ij} is given below.

$$Th_{adv} = \frac{P_{adv}}{1 - P_{CH}\,[r \bmod (1/P_{CH})]} \tag{6}$$

where

P_{adv} → Percentage of selected advanced node

P_{CH} → Percentage of selected CH

r → Current Round

Finally, the Mobile Sink (MS) visits each Advanced Node A_{ij} collects the sense data from CH_i and transmits the data to the Base Station. Thus, it reduces the inter cluster operation as a result reduce the energy consumption of the nodes in the network. Fig. 2 indicates the flowchart of EEMD scheme.

4 EXPERIMENTS

To validate the efficacy of the proposed scheme, 100 nodes are randomly deployed in a 500×500m^2 region and the supporting parameters are listed in Table 1.

The simulation is performed in Network Simulator-2 to evaluate the performance of proposed and existing scheme. The following assumptions made in the work are

1. All sensor nodes and base station are stationary.
2. The network is considered heterogeneous and all the sensor nodes will have different initial energy.

4.1 Objective Evaluation Indices

The potency of the EEMD method is statistically assessed by four quality metrics which includes Packet Delivery Rate, Packet Loss Rate, Average Delay, Residual energy [16].

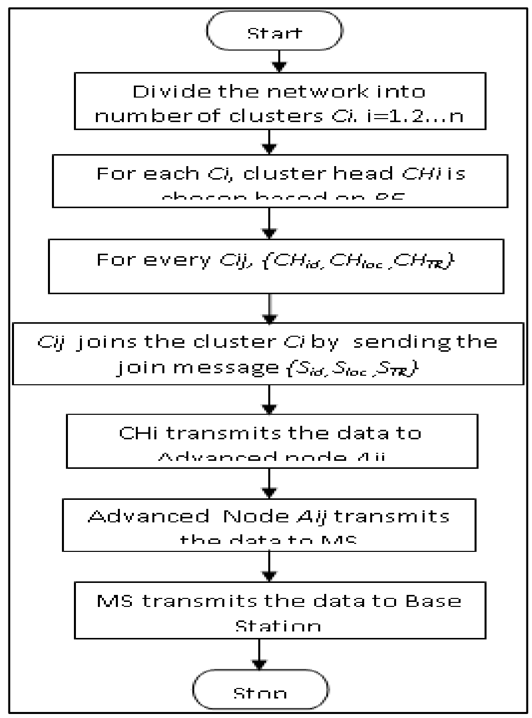

Fig. 2 *Flowchart of EEMD Scheme*

4.1.1 Packet Delivery Rate

Packet Delivery Rate (PDR) is the ratio of packets successfully received by the Base Station to the total number of packets sent by the sender node.

$$PDR = \frac{\sum_{0}^{n} Packets\ Received}{Time} \tag{7}$$

where n defines the number of nodes.

4.1.2 Packet Loss Rate

The rate of packet drops comparing to the total number of packets sent is defined as the Packet Loss Rate (PLR). The equation for deriving Packet Loss Rate is given in (8)

$$PLR = \frac{Pkts\ Dropped\ in\ total}{Pkts\ sent\ in\ total} \tag{8}$$

Parameter	*Value*
Number of nodes	*100*
Network Grid	*500×500m2*
Channel BW	*1 Mbps*
Size of data packet	*1 kB*
Initial energy (Normal Nodes -77)	*1J*
Initial energy (Advanced Nodes -23)	*5J*
Processing Delay	*50µs*
εfs	*10pJ/bit/m2*
εmp	*0.0013pJ/bit/m4*
Eelect	*50nJ/bit*
EDA	*5nJ/bit/signal*
Routing Protocol	*EEMD and HHCA*
Transmission Range	*250*

***Table 1**: Simulation parameters of EEMD Scheme*

4.1.3 Average Delay
The Average delay can be referred as average time taken by the data to travel from the sender node to the Base Station in the network. The delay can be estimated using (9).

$$Average\ Delay = \frac{Pkts\ Rcvd\ Time - Pkt\ sent\ Time}{Total\ Time} \quad (9)$$

4.1.4 Residual Energy
The residual energy is defined as the remaining energy present in the nodes once the process is done. This remaining energy indicates the remaining operational time for the nodes.

$$Residual\ Energy = \frac{Remaining\ energy\ for\ each\ node}{Number\ of\ Rounds} \quad (10)$$

4.2 Simulation Analysis
In order to analyze the performance of the EEMD method, the data delivery rate, data loss rate, delay rate and residual energy of the state-of-the-art HHCA method is compared and the results are shown in Fig. 3 - Fig. 6. As we can see from Fig. 3, the packets delivered in the EEMD scheme is comparatively high than the HHCA method. Since the Mobile Sink is responsible for collecting data, there is considerable increase in the delivery of data packets in the communication network. Fig. 4 shows the packets lost in the EEMD scheme and HHCA method. Mobile Sink collects the data by reaching the CH; therefore there is very minimal chance for the loss of packets in the network, hence the packets loss in the EEMD scheme is drastically reduced when compared to the HHCA.

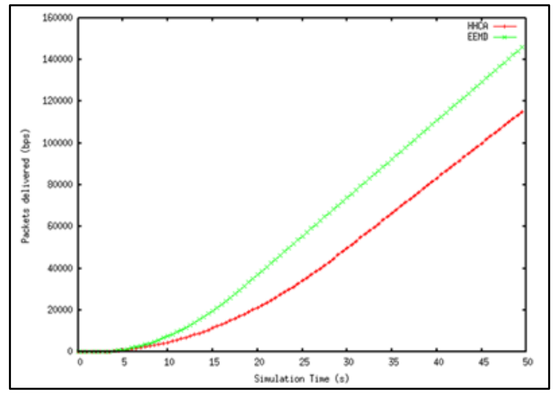

***Fig. 3** Packet Delivery Rate*

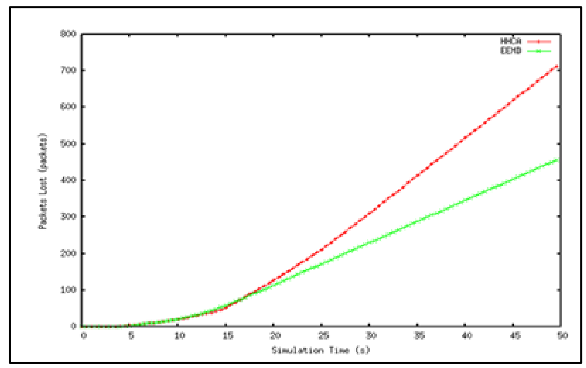

***Fig. 4** Packet Loss Rate*

The average delay and residual energy for EEMD and HHCA method are compared and shown in Fig. 5 and Fig. 6. It is quite obvious from Fig. 5 that the EEMD scheme takes lesser transmission time when compared to the state-of-the-art HHCA method. Since the energy efficiency is improved, the cluster head is capable to send the data to the mobile sink in time. Also, the possibility of dying out of cluster head is much avoided in the network. From Fig. 6, due to the deployment of Advanced Node and Mobile Sink, it is evident that the remaining energy of the nodes in the EEMD scheme is considerably higher than the HHCA method. Hence, the energy efficiency of the network is greatly improved by the proposed EEMD method.

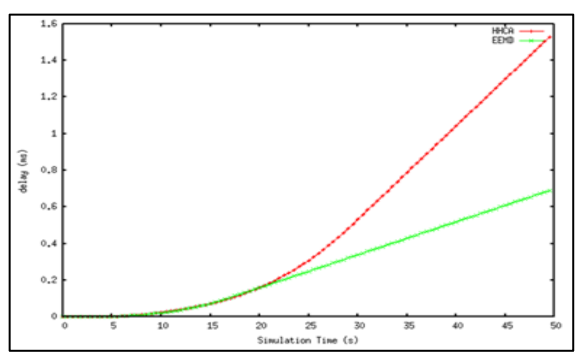

***Fig. 5** Average Delay*

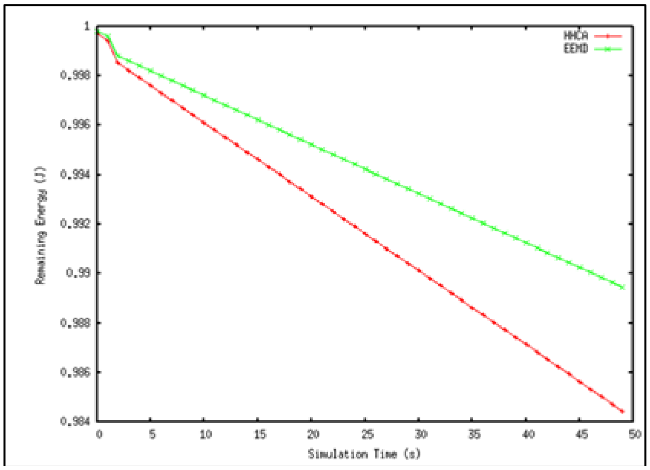

Fig. 6 *Residual Energy*

5. CONCLUSION

Wireless sensor networks (WSNs) has been playing a vital role in various practical applications over the past decades. To enhance network lifetime and to ensure the timely delivery of sensory data EEMD scheme is proposed in this paper. In this scheme, the Cluster Head is elected based on the residual Energy and Connectivity of nodes. In addition, the Mobile Sink is introduced which reduces the multipath communication and energy consumption of Cluster Heads. Also, the deployment of Advanced Nodes reduces the route length of Mobile Sink. The simulation results demonstrate that the proposed scheme EEMD has better performance compared to all quality of service parameters in the WSNs. The future enhancement of the proposed work can be done for the mobile nodes instead of static nodes.

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