Energy Estimated Mobile Sink based Routing Protocol in Wireless Sensor Network

Enamur Rahman Shamsi [1], Ritesh Sadiwala [2],
[1,2]*Department of Electronics & Communication Engineering,*
RKDF University, Bhopal, India

***Abstract*—In this modern world Internet of Things, Wireless sensor network (WSN) is an operational research area and advanced concepts are introduced regularly. Clustering method provides an efficient and effective way to increase the network lifetime of a WSN. The clustering algorithms discussed in literature review basically utilize two techniques, first the selection of a cluster head (CH) with more residual energy and second the rotation of cluster heads (CHs) on the probability basis periodically, for an equal distribution of energy consumption among sensor nodes in each cluster and enhance the lifetime of the WSN. To forward data packets to the base station, cluster heads usually cooperate with other cluster heads, the cluster heads is selected basically on the probability bases and high residual energy node may not be selected as cluster head (CH) and low residual energy node may be selected as cluster head (CH). To address this problem, an EEMSR (Energy Estimated Mobile Sink based Routing) protocol in Wireless Sensor Network is proposed which is based on residual energy level estimation of sensor nodes The simulation results shows considerable improvement of energy efficiency of WSN.**

***Keywords*— WSN, Clustering, CH, Network Lifetime, LEACH, EEMSR**

I. Introduction

WSN comprises hundreds or thousands of distributed sensor nodes and base station (sink) attached with each node through wireless access in real-time environment [1]. The sensor nodes are deployed such a way that it should be able to sense the environmental conditions like temperature, humidity, pressure, motion and other physical properties. The collected information is transfered to the base station (BS) where it is carried out through the Internet and read out by the user. In Wireless Sensor Networks (WSNs), one-time battery power, signal bandwidth, transmission power of antenna and processing capabilities are primary constraints which influence maximum energy dispersion and consumption [2]. So there is a requirement of some techniques or strategies which minimizes energy consumption. Basically, routing protocols of clustering technique are applied for gaining higher energy efficiency and for enhancing network life-time also [3].

WSNs provides many real-time applications such as target tracking, gas pipeline observation, environmental and agriculture monitoring, habitat observation, building monitoring, military monitoring, and so on [4, 5]. Many applications need only the collected information value to be reported at the base station (BS). Today, maximum population of people are living in the urban regions, concept of 'Smart City' becomes essential and deployment of sensor network with Internet of thing (IoT) is required. The Smart city brings up the development and growth of communication technologies (ICT), deployment of Internet of thing (IoT) and provide method to secure communication in the cities [6].

In WSN, energy consumption in environment sensing, data communication and transmission is the main challenging issue because the reason of one-time battery backup, recharge or replacement of battery is not possible once the network is deployed. Different routing protocols are applied to reduce energy consumption in WSN, that results into enhancement of the network lifetime. The hierarchical based routing protocols is well-known for minimizing power consumption. In this network, the whole WSN is grouped into several clusters, where all of these clusters have their sensor node which works as a cluster-head [7].

II. Related Work

Heinzelman *et al.* [8] initiated LEACH (Low Energy Adaptive Clustering Hierarchy) protocol, it is first clustering-based routing protocol which reduces global energy utilization by distributing the load equally to all the nodes at different points in time. LEACH has become a well-known standard model for clustering hierarchy concept based routing protocol. LEACH exceeds static clustering protocols by requiring sensor nodes to work as high-energy cluster-heads (CH) and conforming the corresponding clusters based on the nodes which are selected to be cluster-heads at a given time. LEACH protocol works in two phases, first phase is set-up phase and second phase is steady-state phase. The cluster formation occurs in first phase and data transmission to the base station (BS) occurs in second phase. LEACH protocol is completely distributed, no control information is required from the base station and also knowledge of the global network is not required for node in order to operate LEACH protocol.

Nabi *et al.* [9] presented two improvements in LEACH protocol, firstly, the selection of cluster head bu calculating the residual energy of the sensor node and distance between sensor node and sink (base station), the random number is adjusted generated by the sensor node. The random number generated by the nodes whose residual energy is high and the distance from sink (base station) is less, have higher probability to become cluster head. Secondly, they proposed the optimal number of cluster heads, that can ensure the load balancing of the sensor network by adjusting the quantity of cluster heads in the optimum range. Their proposed work presents the improved algorithm which effectively reduces the energy consumption and enhances the network lifetime of sensor nodes.

Nayak *et al.* [10] proposed MERA–A (multi-clustered energy efficient routing algorithm) in WSN. In this network model, nodes participate in different activities such as multiple nested clustering, chaining by searching the nearest neighbor, cluster chain leader selection from each cluster and transmitting combined data into the neighbor and ultimately to the base station (sink). The battery utilization also decreases significantly due to very less distance communication among neighbors, for which the presence of active nodes in the area hold for a larger time. The primary aim of this model is fulfilled by scattering the load equally among all nodes through multiple nested clustering.

Pambhar *et al.* [11] proposed a innovative cluster-head selection conceptual model in Energy–LEACH (E–LEACH) routing protocol which is based on most popular LEACH protocol which can improve the energy efficiency and distribute load uniformly which is not balance in LEACH protocol. This task will be considered for how to implement the proposed algorithm for cluster-head selection process in Energy–LEACH protocol. Figure 1 presents working process of E–LEACH protocol.

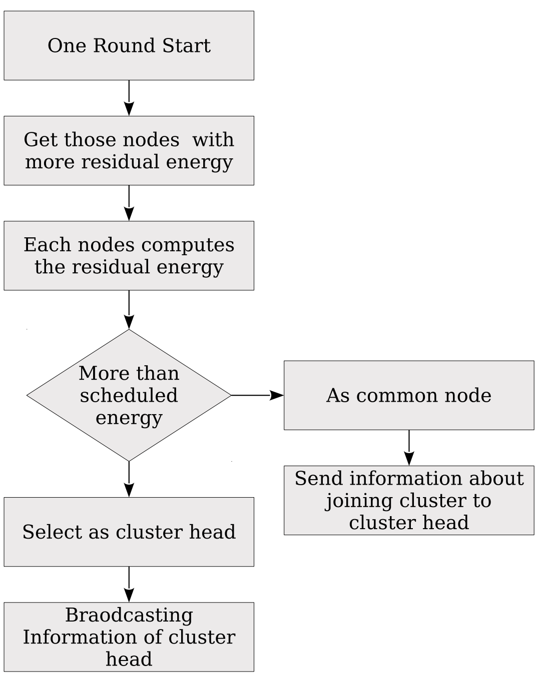

Fig. 1. E-LEACH Protocol

Energy consumption for routing and sensing has been a critical issue in WSN, and it has been becoming one of major challenging task due to limited battery power of sensor node. As a solution of limited energy problem, Aghera *et al.* [12] proposed MMR–LEACH protocol which uses multi-tier concept by selection two cluster-heads. The whole sensor network is grouped into many layers of clusters in multi-tier concept. Another sensor node is selected for the data transmission as Vice Cluster Head (VCH) rather than Main Cluster Head (MCH). MCH is responsible for data collection, aggregation and transmission from sensor nodes to base station and selection of VCH is based on node residual energy. VCH works as an inter-mediator between lower layer main cluster head and base station for the data transmission purpose. MMR–LEACH protocol presents higher lifetime of sensor network as compared to traditional routing protocols.

Basumatary *et al.* [13] proposed a multi-clustered energy-efficient routing algorithm (MERAM–C). The network lifetime of the WSN using MERAM–C is longer than the lifetime of the WSN using the standard WSN LEACH protocol. MERAM–C protocol presents mobility of base station with mobile sink node moving in clockwise direction. It was also observed that the mobility of sink node not only decreases the load on the cluster head but also enhances the network lifetime. Further improvement can be done on the mobility pattern of the sink node considering larger network area for wireless sensor networks.

III. Proposed Approach

In this paper, EEMSR (Energy Estimated Mobile Sink based Routing) protocol is proposed for WSN by grouping the sensor nodes into many clusters through the application of clustering protocol. In EEMSR, the ratio of current residual energy to initial energy is calculated for cluster head selection, so the probability to become cluster head of high residual energy will be higher as compared to low residual energy node. Each cluster in the network has its own local sink or base stations (cluster heads) where they send their local sensed data. The sink node at base station having high power source which travels around the whole sensor network area in both clockwise and counter-clockwise direction with respect to a fixed trajectory, and it accumulate the data collection from al cluster head nodes. Essentially the node deployment and clustering steps are followed to save battery power in the sensor node.

A. Sensor Node Deployment

In the proposed EEMSR (Energy Estimated Mobile Sink based Routing) protocol multi-clustered concept is applied to achieve energy efficient data transmission, random node deployment at fixed positions within network. It is assumed that each deployed sensor have similar properties with limited and equal quantity of battery power homogeneity. In each round, there is continuous information flow to the mobile sink node which moves continuously at different locations around the whole WSN area.

B. Network Clustering

In this model, whole network is divided into multiple groups called cluster and, each node decides to become either a cluster head or to remain as the normal node for each round. To become a cluster head, a number whose value lies between 0 and 1 is selected at random by each sensor node.

Then, threshold value $T(n)$ is calculated using the suggested probability of becoming cluster head, P, the current round r and the ratio of current residual energy E_{residual} to initial energy E_{initial} of the sensor node. The threshold $T(n)$ calculation is given in Equation 1 and it is improvement over the LEACH protocol:

$$T(n) = \begin{cases} \frac{P}{1 - P \cdot \left(\mod (r, \frac{1}{p}) \right)} \times \frac{E_{\text{residual}}}{E_{\text{initial}}} & \text{if } n \in G \\ 0, & \text{else} \end{cases} \tag{1}$$

G shows the list of nodes which were not cluster heads in the previous $\frac{1}{P}$ rounds. Each sensor node uses same amount of energy to become a cluster head. E_{residual} represents residual energy of sensor node whereas E_{initial} represents initial energy.

C. Energy Model

The energy models of EEMSR uses similar model of LEACH protocol. These energy models are represented by Equation 2–6. Around 50 nJ/bit (E_{elec}) energy is exhausted to execute the trans-receiver process and 100 pJ/bit/m^2 (ϵ_{amp}) energy to execute transmitter amplification power. Figure 2 represents the energy model.

$$E_{\text{TRS}}(k,d) = E_{\text{TRS\_elect}}(k) + \epsilon_{\text{amp}}(k,d) \tag{2}$$

$$E_{\text{TRS}}(k,d) = E_{\text{elect}} * k + \epsilon_{\text{amp}} * k * d^2 \tag{3}$$

$$E_{\text{RCV}}(k) = E_{\text{RCV\_elec}}(k) \tag{4}$$

$$E_{\text{RCV}}(k) = E_{\text{elec}} * k \tag{5}$$

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \tag{6}$$

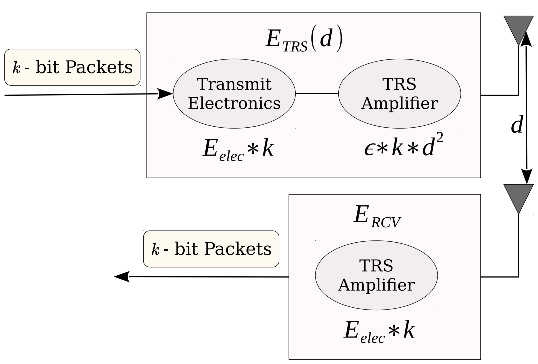

Fig. 2. Energy Utilization Process on Transceiver at d Distance

D. Sink Mobility

EEMSR protocol uses the concept of mobility of base station or sink node having power source to move around the sensor network. The performance of sensor network is determined by round parameter. The base station collects the sensed data from cluster head of each cluster, then it finish one round of the network. The base station moves continuously, in a clockwise or counter-clockwise direction with a path of pre-defined route. The base station moves into north, east, south and west directions (clockwise) or opposite counter-clockwise, to complete its data collection from the cluster head from each cluster. This rotation movement of the base station keep going till the simulation accomplishes to its final round.

E. Algorithm

The pseudo-code of the proposed multi-clustered energy level based efficient routing (EEMSR) algorithm with mobile sink node moving in a either clockwise or counter-clockwise direction is given below:

Pseudo-Code of EEMSR

Deploy the sensor nodes randomly across the network area.
for all sensor nodes ***do*** $i = 1$ to n, $S(i) = (X_i, Y_i)$
    Randomly establish the sensor nodes.
end for
    Calculate E_{residual} and E_{initial} along with P and r.
    Elect the cluster heads (CHs) based on $T(n)$.
    Form the clusters, using elected CH.
for every cluster
    Transmit the sensed data to the CH.
    CH forwards it to the sink node.
end for
    Move the sink node to its next location.

IV. Result Analysis

The proposed protocol (EEMSR) is simulated through Scilab, and its simulation results are compared with the MERAM-C protocol by taking only 100 rounds of simulation. The initial parameters presented in section IV are taken for the simulation. The initial energy of each sensor nodes is equal amount of energy ($E_0 = 0.5\ J$), the simulation is started and the number of rounds in MERAM-C protocol and EEMSR is determined when 20%, 50% and 100% of sensor nodes die. The all sensor node as well as the entire network is considered dead once all node reaches its residual energy level 0 or battery of the node discharged completely. In proposed protocol (EEMSR), the base station moves around the network area in a clockwise or counter-clockwise direction with a fixed trajectory continuously. The total number of alive nodes are taken into count in each round up to 100 rounds where initially, 100 alive sensor nodes were considered.

TABLE I
Network Parameters

S.No.	Network Parameter	Value
1.	Network Size	$100 \times 100\ m^2$
2.	Total No. of Nodes	$n = 100$
3.	Initial energy of sensor nodes	$E_0 = 0.5\ J$
4.	Packet Size	$k = 4000$ bits
5.	Data Aggregation Energy Consumption	EDA=5 nJ/bit
6.	Amplification Energy ($d > d_0$)	$E_{mp} = 10\ pJ/\text{bit}/m^2$
7.	Amplification Energy ($d \leq d_0$)	$E_{fs} = 0.0013\ pJ/\text{bit}/m^2$
8.	Transmitter Electronics ($E_{\text{TRS\_elec}}$)	$E_{\text{elec}} = 50\ nJ/\text{bit}$

During the simulation for a $100 \times 100\ m^2$ network area, the number of rounds that was reached when 20%, 50% and 100%nodes die is noted down. Figure 3 represents the comparison plot for dead nodes versus number of rounds in MERAM-C and EEMSR. In proposed protocol (EEMSR), the first node died at 25^{th} round, but in MERAM-C, the first node died at 15^{th} round. The last node died at 100^{th} round in MERAM–C, and in proposed protocol (EEMSR), the last node may get died at beyond 200^{th} round. Figure 4 represents the comparison plot for alive nodes versus number of rounds that each node completes before reaching to energy level zero. The lifetime of the network reached at 100^{th} rounds in MERAM-C, whereas in proposed protocol (EEMSR) the network lifetime reached at beyond 200^{th} rounds. From these figures, it is present that the network lifetime of WSNs using the proposed protocol (EEMSR) is longer than using MERAM-C protocol.

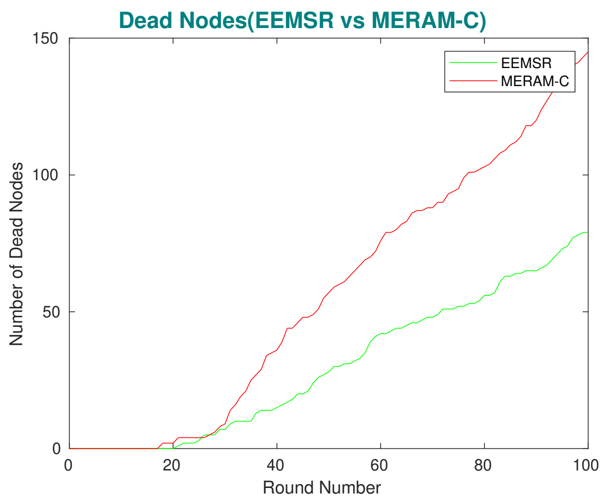

Fig. 3. Dead Nodes during Rounds (EEMSR *vs* MERAM-C)

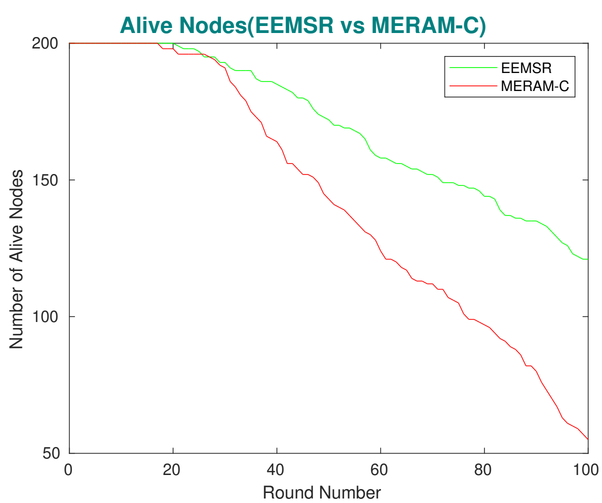

Fig. 4. Alive Nodes during Rounds (EEMSR *vs* MERAM-C)

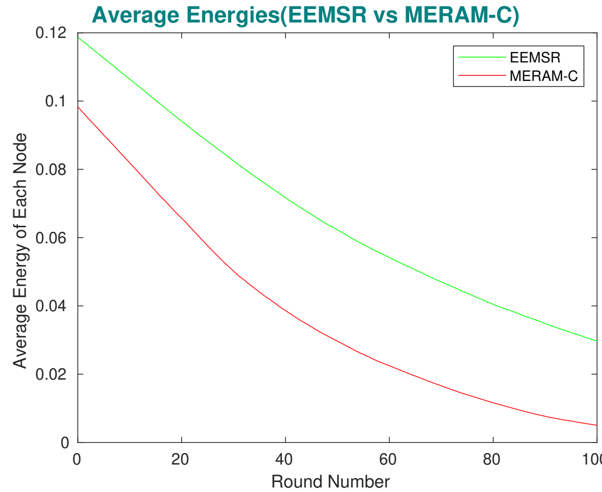

Fig. 5. Average Energy (EEMSR *vs* MERAM-C)

Figure 5 represents the comparison plot for average energy per node in the MERAM–C and proposed protocols (EEMSR). The average energy plot represents that the results of proposed protocol (EEMSR) are better than the MERAM-C protocol.

V. Conclusion and Future Work

In this paper, a Energy Estimated Mobile Sink based Routing (EEMSR) protocol for WSN was proposed. EEMSR uses the ration of residual energy to initial energy for cluster head selection, so high energy node can be selected as cluster head. It presents that the lifetime of the WSN as well as average energy using the proposed protocol is longer than MERAM–C protocol. The concept of mobile base station not only minimizes the work load of cluster head but also enhances the network lifetime. In future, some nature inspired optimization algorithms can be applied to further improve the cluster head selection method.

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