# ENERGY EFFICIENT ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS

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**ABSTRACT**: Efficient energy consumption of limited battery resource nodes plays a crucial role in the design of wireless sensor network to enhance the network lifetime. In this paper, a modified protocol is proposed by incorporating an efficient cluster head replacement and dual amplification power level techniques, based on two existing routing protocols (LEACH and M-GEAR). The simulation study reveals better performance achieved by the proposed protocol in comparison to both LEACH and M-GEAR in terms of improved network lifetime.

**KEYWORDS:** LEACH; MODLEACH; Routing Protocol; M-GEAR; Wireless Sensor Networks.

## INTRODUCTION

Wireless Sensor networks (WSNs) are one of the most interesting areas of research. It is a self-configured network which is used to monitor physical or environmental conditions, which include temperature, sound, vibration, light, pressure and weather monitoring as per requirement. WSN plays a pivotal role in diverse applications ranging from home to industry and from medical arena to military. Most of these applications need some form of self-configuration and automatic functionality. WSN comprises of a sensor field and a sink. A sink node may be fixed or mobile. A sink or base station acts like an interface between users and the network as shown in figure 1.

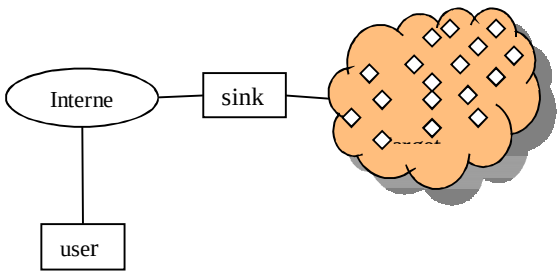


Figure 1: Architecture of WSN

The sensor node consists of four basic components as sensing, processing, communication and power units. The battery life of the sensor nodes is limited, thus necessitating designing algorithms which provide more life-time to sensor nodes, so as to increase the network lifespan.

One of the major issues in WSN is development of efficient routing protocols which are capable of consuming minimum energy. Different protocols have been developed by researchers to meet this goal [1]. LEACH (Low Energy Adaptive Clustering Hierarchy) [2] is one of the popular clustering algorithms used in WSN designed with a goal to increase the network lifetime. The operation of LEACH (as illustrated in figure 2) is divided into two phases.

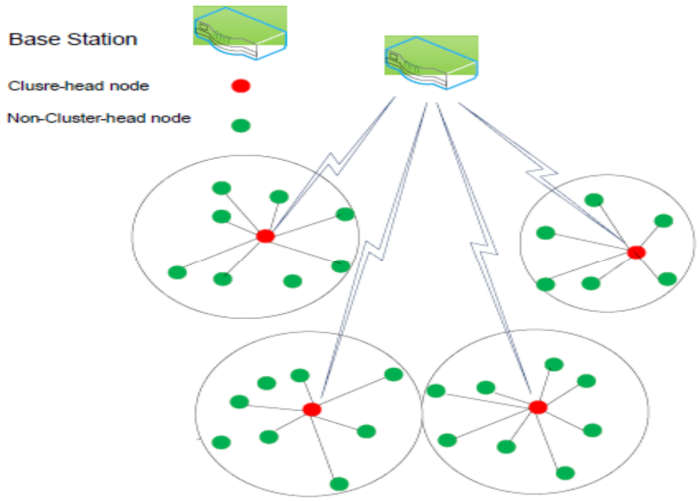


Figure 2: Illustration of LEACH protocol

Each phase begins with a set-up phase when the clusters are organized, followed by a steady-state phase where several frames of data are transferred from the nodes to the cluster-head and onto the base station. Introducing clustering into the network's topology reduces number of transmissions in the network [3]. The steady state phase duration is longer than the set up phase duration. It also provides energy efficiency as cluster heads aggregate the data from its cluster members, thereby reducing duplicity of transmission and enhancing the network lifetime [4].

MGEAR was developed with a goal to design a gateway based energy aware multi-hop routing protocol. Such an approach meets the two requirements. The M-GEAR model is illustrated in figure 3.

Network is divided into four logical regions [15]. Region 1 uses the direct mode of communication to base station. Region 2 comprises of direct communication to the gateway node. The remaining regions 3 and 4 use the cluster hierarchy. Network division into regions and usage of gateway node reduces the average transmission distance. So, it saves network energy and prolong network lifetime. CH selection in each region is independent of other regions, so there is definitely a CH existing in each region. These two protocols are combined with some modifications in this work to achieve better results. The structure of the remaining paper is as follows: The related work is discussed in section 2. The proposed protocol in detail is described in section 3. The network parameters are described in section 4 and simulation results are exhibited in section 5. Finally section 6 gives conclusion.

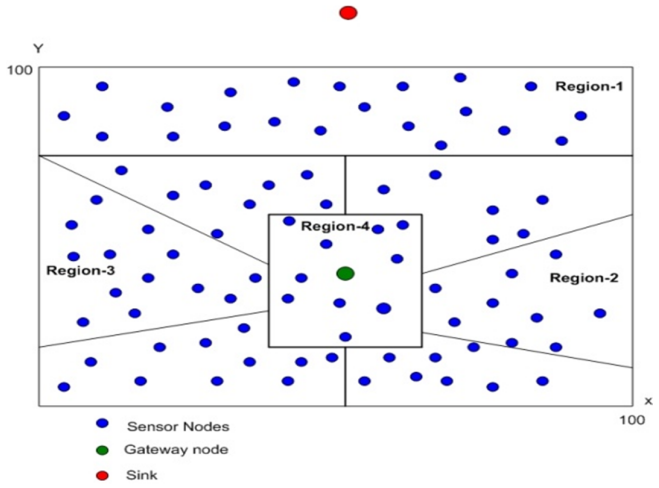


Figure 3: M-GEAR Model

**RELATED WORK**

CHB Wendi Rabiner Heinzelman *et al.* proposed LEACH [2], a clustering based routing algorithm for WSNs and subsequently many modifications are available in literature proposed by various researchers from time to time [6]. M Tong *et al.* introduced LEACH-B [7] (Balanced) in which an enhanced version of LEACH was proposed by finding the number of optimal Cluster Heads (CHs). X H Wu *et al.* introduced LEACH-C [8], during the CH selection stage round; the Base Station (BS) knows the location of nodes. Accordingly, the BS selects the most suitable nodes to be CHs and divides the rest of the nodes between CHs to form the clusters. D Zhu *et al.* proposed LEACH-P [9] (Performance) protocol which considered the probability selection of EAMR (Energy Aware Multipath Routing) into LEACH algorithm and made a better choice of selecting CHs and optimizing the chance of cluster rebuilding. A Sepasi *et al.* [10] introduced EEPSC (Energy- Efficient Protocol with Static Clustering), a hierarchical static clustering based protocol that partitions the network into static clusters once during the network action, it also eliminates the overhead of dynamic clustering and also engages high power sensor nodes for power consuming tasks. Chengfa Li *et al.* [11] introduced EEUC (Energy-Efficient Unequal Clustering), a clustering algorithm that partitions the nodes into clusters of unequal size, and the clusters closer to the base station have smaller sizes than those which are farther away from the base station. This provides a way to solve the hot spots problem. D S Kim *et al.* [12] proposed LEACH M (Mobile) with a mobility factor. It used the same threshold formula of the original algorithm to calculate the threshold, but took into consideration the mobility of nodes during data transfer phase, which LEACH does not. G S Kumar *et al.* [13] presented LEACH-ME as an enhanced version of LEACH-M. It was proposed to enhance the baseline algorithm by selecting the less mobile nodes relative to its neighbors to be the CHs. A Al-Zou'bi. *et al.* [14] introduced the Vice-LEACH protocol, which consumed lesser energy than LEACH, thereby enhancing network lifetime. Q Nadeem *et al.* [15] presented Gateway based energy-efficient routing protocol (M-GEAR) for WSNs. The performance comparison of LEACH with MGEAR showed that latter is better in terms of energy consumption and network lifetime. D Mahmood *et al.* [16] proposed modified

LEACH (MODLEACH) by introducing efficient cluster head replacement scheme and dual transmitting power levels.

As collected, LEACH protocol is well studied in literature and many improvements have been done by researchers in it. The proposed work is based on exploiting the good features of LEACH and M-GEAR protocol.

## PROPOSED PROTOCOL

In this work, to reduce the energy consumption, the process of cluster head election is improved by introducing efficient cluster head replacement scheme and the amplification energy levels are varied at inter, intra and CH to BS communication. Performance of the proposed protocol is well analyzed in terms of energy consumption, throughput and network lifetime.

### Deployment

- A rechargeable gateway node is deployed at the centre of the network
- The deployment of BS is done far away from the sensing field
- Sensor nodes, gateway node and BS are stationary after deployment
- The homogeneous sensor nodes with same computational and sensing capabilities are used
- Each sensor node is assigned with a distinctive identifier (ID)

### Energy Model

For wireless communication system of this proposed protocol, the radio model has been used as in [4] (figure 4). If communication distance is less than distance $d_0$ free space channel model is used otherwise multipath model is used [17]. So the transmission energy of transmitting a *k*-bit message over a distance *d* using this radio model is defined in equation 1:

$$E_{TX}(k,d) = k * E_{elec} + k * E_{amp} * d^n \quad (1)$$

Where path loss component 'n' (=2 or 4) and amplification factor $E_{amp}$ both ($E_{fs}$ or$E_{mp}$) are defined in equation (2) and (3) for free and multipath environment respectively.

$$E_{TX}(k,d) = k * E_{elec} + k * E_{fs} * d^2 , d < d_0 \quad (2)$$

$$E_{TX}(k,d) = k * E_{elec} + k * E_{mp} * d^4 , d \leq d_0 \quad (3)$$

$E_{elec}$ is the transmitter circuitry dissipation per bit. The receiving cost is calculated as in equation (4).

$$E_{RX} = E_{elec} * k \quad (4)$$

The operation of the proposed protocol is described in the following phases described below.

### Setup Phase

After receiving all information of nodes, sink divides the nodes into four logical regions as shown in figure 3. Nodes near to the sink and gateway node use the direct communication, while clustering technique alike LEACH is used in other two regions.

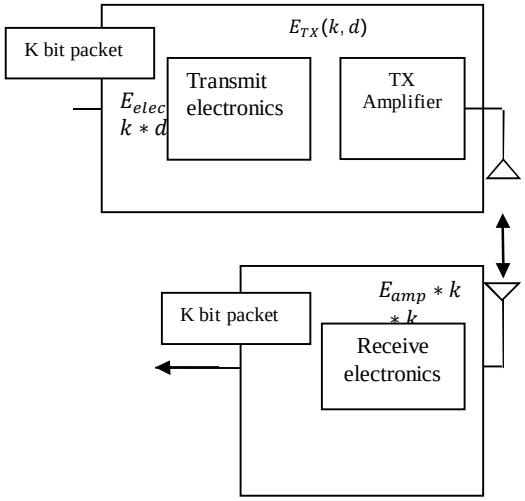


Figure 4: Radio Model

**Cluster Head Selection**

According to LEACH each node elects itself as a CH once every 1/p rounds [4]. A node generates a random number between [0-1]. If the generated random number is less than a predefined threshold T (n) value, then the node becomes CH for that round [18].

$$T(n) = \frac{p}{1 - p\left(r \bmod \left|\frac{1}{p}\right|\right)} \qquad if \quad n \in C$$

Where,

p = Desired percentage of CHs
r = Current round
C = Set of nodes not elected as CH in current round.

However, in every round, the proposed protocol will check if the energy of a cluster head is more than the pre-defined threshold value, only then it will undertake CH and cluster formation process; else same CH will continue its operations as in the LEACH algorithm. This is how, energy wasted in routing packets for new cluster head selection and cluster formation can be saved. Further, in the cluster hierarchy, two levels of power are used to amplify signals depending upon the nature of inter cluster, intra cluster or CH to BS transmission. A low power level is used for intra cluster communication thus conserving the energy.

**Steady state phase**

After the formation of clusters all the associated nodes transmit their sensed data to CH in its own scheduled time slot. Then CH aggregates data, forwards to Gateway node. Gateway node aggregates data and forwards to sink.

## NETWORK PARAMETERS

The proposed strategy is analyzed through simulations. The parameters used are described in table 1. The location of gateway is at (50, 50) and the base station is kept at (50,120) in our experiments.

Table 1: Simulation parameters

| | |
|---|---|
| Network Size | 100*100m sq |
| Number of nodes | 100 |
| Packet Size | 4000 bits |
| Initial energy $E_0$ | 0.5 J |
| Data aggregation energy Eda | 5nJ/bit/report |
| Transceiver idle state energy | 50 nJ/bit |
| Amplification Energy Efs | 10pJ/bit/m¹ |
| Amplification Energy Eamp | 0.0013pJ/bit/m¹ |
| Amplification Energy Efs1 (intra cluster) | Efs/10 = Efs1 |
| Amplification Energy Eamp1 (intra cluster) | Emp/10 = Emp1 |

## SIMULATION RESULTS

The simulations were carried out using above parameters and the comparison of LEACH, M-GEAR with the proposed protocol has been taken up and presented below.

### Network Lifetime

It is the time interval from the start of the network operation till the last node die. It describes the lifespan of network. The *simulation* results in figure 5 shows that proposed protocol has the longer lifetime than M-GEAR and LEACH protocol.

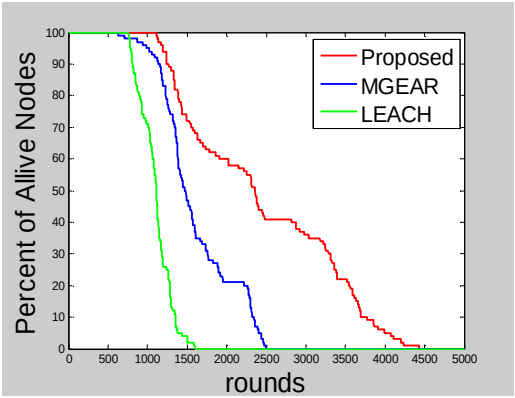


Figure 5: Performance using network lifetime

### Residual Energy

The residual battery energy of network is considered in order to analyze the energy consumption of nodes in each round. Residual energy ensures graceful degradation of network life.

The average residual energy of the network is 50 joule as it is assumed that every node has 0.5 joule of initial energy. Our proposed protocol yields minimum energy consumption than LEACH and M-GEAR as shown in figure 6. Dual amplification power levels are used; thus using low energy level for intra cluster transmissions with respect to cluster head to BS transmission leads in saving much amount of energy.

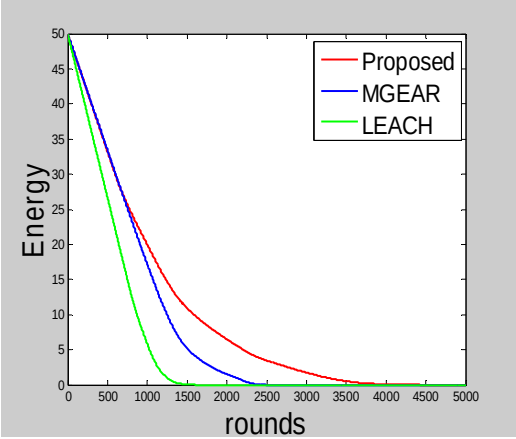


Figure 6: Performance using remaining energy

**Throughput**

To evaluate the performance in terms of throughput, the numbers of packets received by BS are compared with the number of packets sent by the nodes in each round. Our proposed protocol gives better throughput due to increased network life time. Figure 7 illustrates the analysis of throughput comparison with LEACH and M-GEAR.

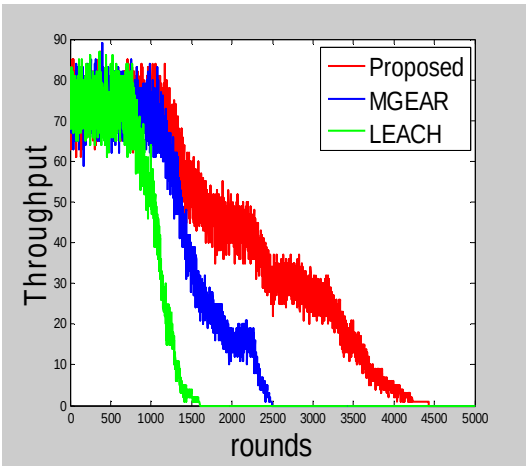


Figure7: Performance using throughput

**Cluster head formation and scope**

All the techniques basically used same algorithm, hence no major difference is there in cluster head formation process; however, our proposed protocol differs in a sense that initially its number of cluster heads remain stable and then cluster head formation behavior goes similar to that of LEACH. The no. of cluster heads may vary in simulations as there is random selection process used but there is increase in stability period in the network than LEACH and M-GEAR. At the end of 5000 rounds these figures are presented in Table 2.

Table 2: Comparison of no. of cluster heads

| LEACH | MGEAR | PROPOSED |
|---|---|---|
| 39 | 30 | 28 |

## C**ONCLUSION**

An improved model of M-GEAR protocol with a goal to improve the network lifetime and utilization of remaining energy of Cluster Heads is presented exploiting the features of MODLEACH in it. The reason behind the increase in parameters discussed above are efficient cluster head replacement technique and dual amplification power levels for intra cluster, inter cluster and CH to BS transmission. The comparison of the three protocols is done and presented in terms of network lifetime, remaining energy and throughput.

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