

Cluster based Optimal Energy Efficient Routing Protocol for Wireless Sensor Networks

S. Gopinath¹; K.B. Gurumoorthy²; S. Lakshmi Narayanan³; M. Kasiselvanathan⁴; Pragadeswaran⁵

¹Associate Professor, Karpagam Institute of Technology, India.

²Assistant Professor, Sri Ramakrishna Engineering College, India.

²gurumoorthy.kb@srec.ac.in

³Assistant Professor, Sri Ramakrishna Engineering College, India.

³lakshminarayanan.s@srec.ac.in

⁴Assistant Professor, Sri Ramakrishna Engineering College, India.

⁴kasiselvanathan@gmail.com

⁵Assistant Professor, Karpagam Institute of Technology, India.

Abstract

Balancing the energy consumption and location accuracy is one of the critical tasks in WSN. Energy consumption of sensor nodes is measured in terms of route discovery, packet forwarding and data transmission. In this research work, it is proposed that scheduling based Optimal Energy Clustering Scheme (SOECS) to attain the maximum location accuracy and energy efficiency during route maintenance. It contains three major modules. In first module, the node deployment is done using Gaussian distribution function to route the packets effectively. In second module, Cluster heads are chosen and energy is estimated for optimal cluster heads. In third module, TDMA scheduling algorithm is introduced to improve the energy efficiency using stable routes and scheduling table. The work is evaluated using network simulation tool. The proposed scheme produces high performance than existing schemes.

Key-words: Gaussian Random Distribution Function, Node Deployment, Energy Efficiency, Network Lifetime, Location Accuracy and TDMA Scheduling.

1. Introduction

In past few decades, WSN became most popular networks and the growth of WSN rises rapidly. The wider detection range and flexibility was provided effectively due to radio waves and sensor nodes. The changes in the real time environment are monitored by the sensor nodes. The data

gathering is done by sensor nodes and reported to master node. Energy efficiency [2] is the major issue in WSN and the consumption of energy can be measured based on various applications.

In this research work, optimal cluster heads [7] are chosen based on remaining energy, distance to sink node and node capacity to increase the network lifetime. In previous work, it is concluded that balancing energy consumption and location accuracy is the biggest task in the sensor network.

2. Previous Work

Lingfeng Shao et.al [1] proposed the distributed optimization issue for the energy of wireless sensor network. The nodes or the players completed the iterative solution to increase the energy utilization rate. Meanwhile the energy of WSN was improved with the new revenue model. Individual constraints were converted into players to provide better energy efficiency.

Shafiabadi et.al [3] developed an self-organized map based energy efficient model to improve the network lifetime. It was based on two criterias i.e. energy level and spatial coordinates. Due to that, the longevity and coverage were improved.

Ahmad Sheleba and Shayesteh Tabatabaei [4] developed the energy efficient clustering protocol based on decision making algorithm to increase the energy level of sensor nodes in the cluster. The maximum number of high energy nodes was used to choose the cluster head and self-mapping was used to attract low and high energy nodes. The intermediate nodes were not required to create clusters based on energy value, intermediate nodes, node density and distance to destination node.

Zhu et.al [5] presented a joint utility optimization technique for maintaining power control, routing and scheduling in an efficient way. It was done with the deployment of Lyapunov optimization technique and perturbation technique. The trade-off between network utility and backlog was maintained with dynamic systems. The energy was not only exchanged but also harvested between nodes. The network stability was maintained based on Lyapunov drift where queue size is low. The explicit estimation of energy was determined based on queue backlog bounds in multi-hop sensor networks.

Warriera and Kumar [6] explored energy efficient model for sensor networks. The design of the protocols aimed to meet the requirements of scalability issues. Scalability was provided using hierarchical architecture to improve the network lifetime. The energy consumption of sensor nodes was maintained in multi-hop communication within a cluster region to achieve data aggregation. The

number of transmitted messages was reduced to destination node. The cluster properties such as cluster size, number of cluster size and cluster communication inside and outside the zone. The chosen CH can be adopted as stationery or dynamic based on coverage area.

Ramluckun and Bassoo [8] introduced an energy efficient chain cluster based intelligent routing algorithm to extend the network lifetime. The load distribution was enhanced with routing algorithm to improve network performance and energy efficiency. The Power Energy Gathering in Sensor Information Systems protocol and Ant Colony Optimization were integrated together to find the optimal chain in order to reduce the data redundancy, distance between intermediate nodes and delay of data transmission through longer length links. The overall chain length and transmission distance were reduced to achieve load balancing and to find the least hop optmail chain using the routing method.

Elshrkawey et. al [9] developed an enhancement approach to minimize the consumption of energy by the nodes using the concept of energy balancing. The cluster head selection method was adopted to reduce the energy wastage on packet transmission during data communication. The time division multiple access schedule was adopted to optimize the energy consumption. The progression of cluster head movement, energy conservation and packets transmission to the base station were monitored with LEACH protocol. In initial phase of the algorithm, stable cluster head was chosen to route the packets effectively.

Nigam and Dabas [10] introduced the concept of enhanced set of optimization rule with LEACH routing protocol to improve energy efficiency. The concept of Particle Swarm Optimization algorithm was adopted to provide optimized clusters. The major inputs were the fitness functions, set of rules and residual energy estimation. The special CH was chosen based on average cluster energy, replacement of CH with least value of fitness function and hub density distribution.

Mahakud et.al [11] introduced the concept of power efficient gathering in sensing information systems to extend the network lifetime. The optimal chain based protocol was implemented to improve the network lifetime. Nearest intermediate node was communicated with each node to select a head based on data collection from the intermediate nodes and selection report was sent to base station. The bandwidth requirement and energy consumption was reduced and to strengthen the network lifetime.

Kakhandki et. al [12] developed the method of selective hop communication to extend the node lifetime. The cooperative based communication was attained based on energy efficiency. The hop devices were chosen for co-operative transmission. Cooperative transmission was adopted to

extend node lifetime based on energy efficiency. The distributed medium access control was presented with optimization technique to choose hop device to reduce energy per bit transmission.

The proposed SOECS is organized into five sections. Section 1 deals with overview of WSN and need for energy efficiency. Section 2 surveys the various methods and protocols relevant to proposed approach. Section 3 discusses the proposed approach that contains node deployment, optimal energy estimation of cluster head and routing methods. Section 4 deals with simulation results and last section concludes the proposed work.

3. Optimal Energy Clustering Scheme

In this section, nodes are deployed according to Gaussian distribution and the energy consumption for transmission of packets and clusters. The selection of Cluster Head (CH) is based on residual energy, distance to destination node and node capacity. Scheduling algorithm is adopted to save the energy during packet transmission.

Deployment of Sensor Nodes

The location and position of sensor nodes may influence the data authentication and security of the network. Location of nodes which is located near to the sink node, is used to monitor the packet deliverability and identify the energy consumption rate. The parameters are updated to source node or CH and stored in routing table.

Maximum energy consumption may influence the network performance. Location of sensor node is needed to be update periodically to the cluster head. The concept of triangular and Gaussian method is used to locate the CH, cluster members and cluster anchor member. By considering the standard deviation of network lifetime of nodes, the triangular and Gaussian method [13] is able to balance the location accuracy and energy consumption of nodes. All cluster members are located near to centroid and its geographical position is identified by cluster zone ID. In such case, CH is able to track the sensing zone to locate the cluster members. CH announces the packets to all cluster members that contains energy management of node. It will ensure that all nodes must keep minimum energy level to transmit or receive the packets. If any route is failure or broken, the node will take time to consume energy for retransmission of packets. By locating nodes near to centroid, packet loss and energy consumption can be reduced dramatically.

Cluster Energy Estimation Method

In this method, the following steps are used to estimate the cluster energy after the selection of CH. From the voting system, the cluster members can elect CH based on proposed metrics i.e. remaining energy, capacity, stability of node and average hop count metric. These parameters will be announced to all cluster members. Once the initial route maintenance is over, parameters will be estimated. The radius of neighbor cluster member is given as,

$$R_{neighbor} = \sqrt{\frac{M^2}{\pi * H_k}}$$

Where M is an number of cluster members present in the network and H is the centroid radius. From that, radius of neighbor node is measured. In this phase, optimal sequence number is generated by all cluster members. The sequence number will be compared with trust threshold value which is generated by CH. CH announces that cluster members are allowed to participate in its zone.

From the computation of neighbor node radius, the threshold value of sequence number is generated with respect to time period and it is determined as,

$$T(n)_m = \begin{cases} T(n) \times \frac{d_{toACM}}{d_{toCh}} & \text{if } n \in V \\ 0 & \text{elsewhere} \end{cases}$$

Where n is the number of cluster members and V is maximum cluster members allowed. The sequence number is the maximum optimal point which is used to locate the sensor node in the cluster zone. The energy consumption metric is determined based on least hop count.

$$E_m = \frac{N_m}{H_m}, 0 \leq m \leq M$$

From the single frame transmission, the energy is computed as follows

$$E_{CHTOCM} = nE_N n_m / H_m + nE_{ank} n_M / M_M + n\epsilon_m D_{toCH}^4$$

Where

E_n is the energy spent on signal spreading, packet loss and modulation.

E_{ank} is the energy computed during data transmission.

d_{toCH} is the distance estimated between cluster member and cluster head. The energy calculated for packet transmission to CH is determined as,

$$E_{CH} = nE_n + m\epsilon_k d_{toCH}^2$$

The distance between non cluster head or cluster members is given as

$$d_{toCH}^2 = \frac{M_m^2}{2\pi H_m}$$

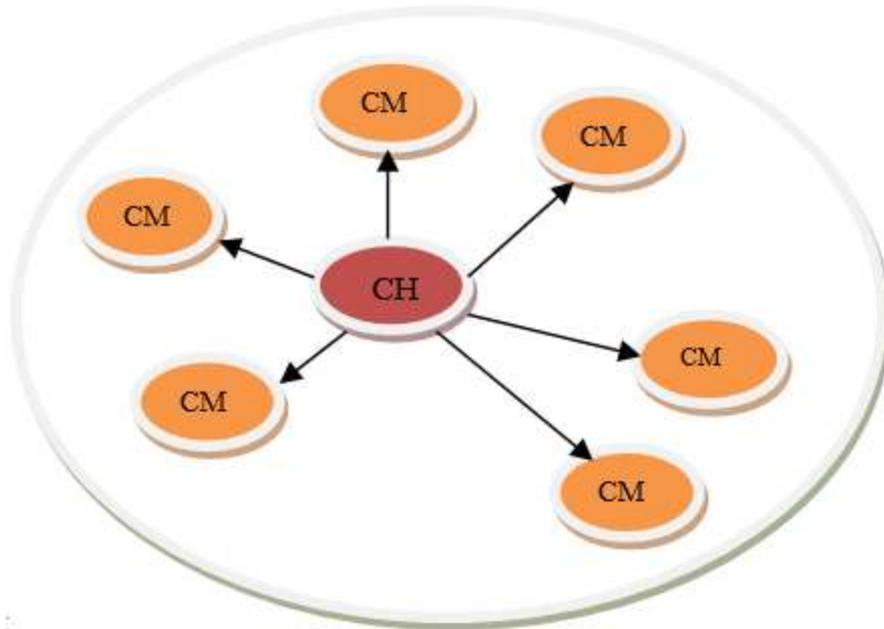
The whole energy is computed from both cluster head and non cluster head as

$$E_t = E_{CH} + E_m N_m / H_m$$

The optimal energy computation is done for cluster head based on modulation and energy value. The Stable and optimized CHs are used to reduce the energy spent by all cluster members by announcing energy limit threshold message to all. This message will be forwarded to all nodes to keep their energy minimum level for transmission. The aggregated data is sent to CH in the predefined time slots only. If time period is expired, nodes are not allowed to update the collected data to CH. Sometimes the energy unbalancing may be observed due to failure in the node sensing. The concept of Time Division Duplex (TDD) is enhanced to route packets with least energy consumption. Each node contains expiry time and packets are forwarded before its expiry. The distance between CH and cluster member is reduced to enhance the network lifetime and chance to become CH based on parameter updation.

The cluster head selection is shown in Figure 1.

Figure 1- Optimal Cluster Head Election



Before route transmission process, the cluster head will be nominated to enhance the energy level and network lifetime.

Scheduling Algorithm

The energy gap between the cluster members is reduced by adopting the scheduling algorithm. Each cluster member sends its sensed data to CH within its allocated slot time during steady state condition. Here it is divided into frames, CH receives the data from all cluster members in each round. The energy level of cluster member and CH decides the network lifetime. The round trip time of steady state condition is same in the energy consumption period. The scheduling algorithm is illustrated below.

Step 1: Based on number of requests, the sensor nodes are allocated to Cluster heads.

Step 2: CH broadcasts message to all nodes which are attached to remaining cluster heads and obtain the capacity of cluster.

Step 3: The cluster capacity determines the TDMA schedule to route the packets effectively.

Step 4: Data is transmitted by all nodes to CH according to TDMA schedule. Small clusters go to sleep mode after sending all information to CH.

Algorithm 1: SOECS

1. Start
 2. Group the nodes
 3. Create cluster group
 4. If residual energy of sensor node is high
 5. {
 6. Choose it as CH
 7. else
 8. Retransmission begins
 9. }
 10. Adopt TDMA schedule
 11. Increased Residual energy and network lifetime
- End

The algorithm 1 shows algorithm of SOECS. At the end, the network lifetime is improved without degrading the performance of network.

SOECS Packet Format

Figure 2- Proposed Frame Format

CH id	TTL	Residual energy	TDMA	FCS
2	1	2	2	4

Figure 2 illustrates the frame format of SOECS. In this packet format, CH id occupies 2 bytes and time to live decides the lifetime of sensor nodes that occupies 1 byte. The residual energy of node is occupied in the fourth field. TDMA initiates the scheduling that occupies 2 bytes and last field is Frame check Sequence for error correction.

4. Simulation Setup

The proposed method is evaluated using the open source simulator NS 2. 34. This tool is used for getting traces and showing the graphs effectively. The following metrics are used to analyse the performance of the proposed scheme.

Network lifetime: It is the energy spent by cluster head and cluster members.

Packet arrival rate: It is the number of packets arrived at the sink node with respect to time period.

Computation Overhead: It means the excessive control packets in the particular route.

Energy consumption rate: It means the rate to determine the energy consumed by cluster members.

Packet delay: It is the delay where node consumes time period for packet forwarding.

Table 1- Simulator Settings for SOECS

Sensor nodes	100
Coverage area	1000 x 1000 sq.m
Simulation time	100 msecs
Node mobility model	Random Way Point
Traffic	Possion
MAC	IEEE 802.15.4
Packet rate	5 pkts/sec

The performance of SOECS is evaluated with ESO-LEACH [9] and PEGASIS [9].

Figure 3- Energy Consumption Rate Vs No. of Packets

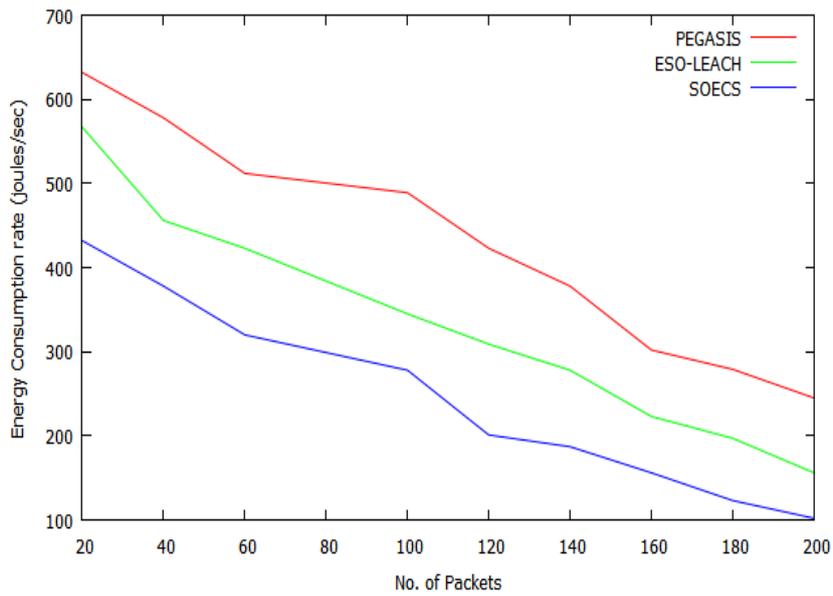


Figure 3 shows the energy consumption rate while varying the number of packets from 20 to 200. The proposed scheme achieves less energy consumption than existing schemes due to the energy estimation of cluster head and non-cluster head.

Figure 4- Computation Overhead Vs No. of Links

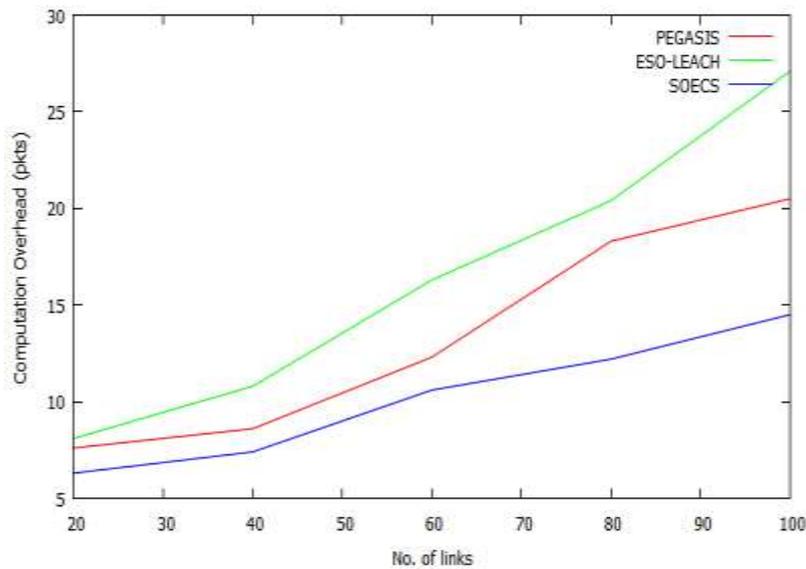


Figure 4 shows the illustration of computation overhead while varying number of links from 20 to 100. From the results, it is seen that SOECS achieves less overhead than ESO-LEACH and PEGASIS.

Figure 5- Packet Arrival Rate Vs No. of Nodes

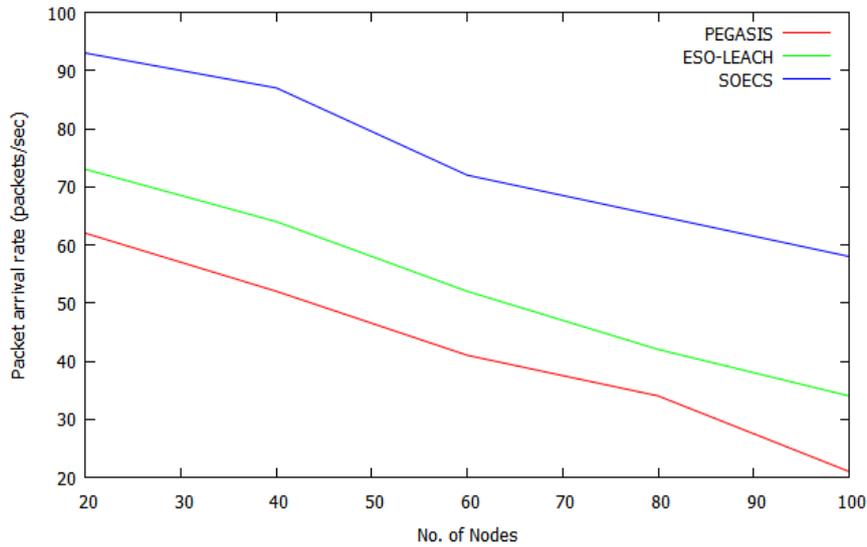


Figure 5 illustrates the performance of SOECS in terms of packet arrival rate. The number of nodes is varied as 10, 20... 100. Due to the deployment of TDMA schedule, packet arrival rate of SOECS is higher than existing schemes.

Figure 6- Packet Delay Vs Simulation Time

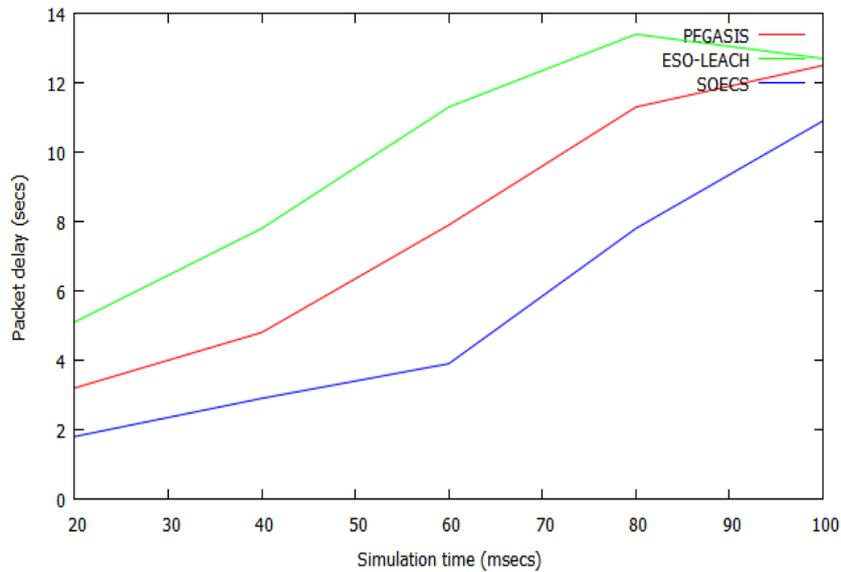
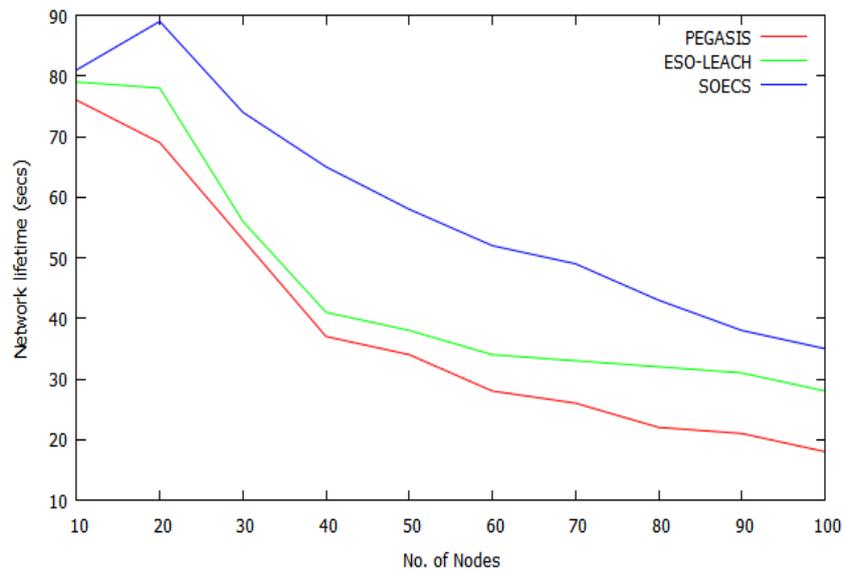


Figure 6 illustrates the performance of packet delay for proposed and existing schemes. Delay of SOECS is low due to the implementation of TDMA Schedule and cluster head election phase.

Figure 7 illustrates the network lifetime comparison. The SOECS achieves more network lifetime than existing schemes due to the adaptation of node deployment.

Figure 7- Network Lifetime Vs No. of Nodes



5. Conclusion

Location accuracy and energy efficiency are the important criteria in WSN. In this research, scheduling based optimal energy clustering scheme is proposed to balance the localization issue and energy efficiency. During node deployment phase, the location of nodes is identified by the cluster heads where the Gaussian distribution is used for performance analysis. The energy estimation of optimal cluster head is done with the help of link efficiency and channel capacity. From the results, SOECS produces better performance in terms of packet delay, packet arrival rate, network lifetime, energy consumption rate and Computation overhead.

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