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EECACL: Energy Efficient Clustering Algorithm using Cross Layer for WSN

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Abstract

Wireless Sensor Network (WSN) consists of micro Sensor Nodes (SNs) with limited energy and processing ability. Sensors are grouped into several clusters to avoid long distance and redundancy in WSN. From the view of energy efficiency, it is important to choose a distinct node as Cluster Head (CH). The CH is selected without considering the distance and residual energy in Low Energy Adaptive Cluster Hierarchical (LEACH) routing protocol. The objective of this paper is to present a new algorithm for reducing the energy consumption in the network. The optimal cluster size, number of CH's along with residual energy, cross-layer information, and distance from SN to the sink node are considered during selection of CH in WSN. An algorithm uses cross layer information for energy efficiency in WSN with a novel clustering scheme called Energy Efficient Clustering Algorithm using Cross Layer for WSN (EECACL). The simulation result of the proposed approach is more efficient in increasing the network lifetime with more number of live nodes, reducing end to end delay, less packet drop with low message cost in a network as compared to the advanced existing protocols.

Keywords: Cluster Head, Cluster scheme, Energy Efficiency, Wireless Sensor Network, LEACH, Threshold, Cross-layer, MAC.

1. INTRODUCTION

WSN is comprised of smaller SNs to observe certain changes in an unattended sensing area. It is comprised of dense autonomous energy constrained SNs, less processing ability and less storage space. The recent development in engineering science led to a significant drive in the sensor network and their applications [1]. The entire network operation of WSN relies on batteries. But continuous recharge or energy supply is difficult in a harsh environment. So, utilizing low battery power is crucial while designing an energy efficient WSN routing protocol in order to increase the lifetime of the network [2].

Dense numbers of SNs are randomly distributed in a harsh environment for sensing the target and consequently for transmitting the data to BS [3]. Distributing CHs evenly over the entire network is the main factor for successful clustering [4]. Closer or far neighbor CHs selection does not prolong the lifetime of the network [5]. The clustering approach is more effective in attaining energy efficiency in WSN.

Clustering gathers a group of SNs in clusters and choosing the CHs for every cluster. Figure 1 shows a basic diagram for data collection using clustering in WSN.

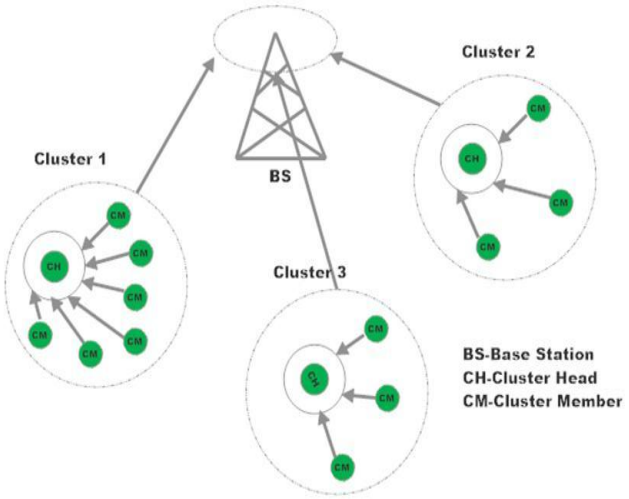


Figure 1 WSN with cluster scheme

A routing requires the cooperation among different layers in the protocol stack for preserving sensor energy and for improving the performance of the application in sensor network. The lifetime of the sensor network is improved by using many existing clustering algorithms. The prime clustering protocol LEACH is developed for reducing the consumption of energy [6]. The routing protocols are responsible for choosing an optimal path from nodes to sink such that the consumption of energy can be minimized in WSN.

In the OSI model, each layer functions independently such as the routing protocol selects the optimal path without concerning physical and MAC layer. In a network, cross-layer information helps to communicate network status among different layers for finding the optimal route and for improving the lifetime.

The cross-layer method allows exchanging information with remaining layers in the network. The protocol stack layers provide information that is used in the proposed routing design for increasing the network performance and reducing the consumption of energy in WSN.

Network layers integrate with MAC and a physical layer to enhance the energy efficiency in WSN.

This paper proposes an optimization of network lifetime and avoids low residual energy node to become CH. EECACL is a new approach, that focuses on the energy efficiency of the network and reduces the energy consumption of node using the deterministic strategy of clustering using the parameter of optimal cluster size, cross-layer information, and optimal count of CHs.

The remaining part of the paper is organized as follows: Section 2 discusses the related work. Section 3 explains the preliminary and mathematical models. Section 4, describes in detail the proposed model and mechanism steps. The analysis of the result is presented in Section 5. Finally, Section 6 explains conclusion with future enhancement..

2 RELATED WORK

Many clustering protocols are proposed in the past decade to enhance energy efficiency in WSN. In LEACH [7], CHs are randomly selected by SNs for aggregating information and eventually sent to the BS directly. In LEACH, CH is chosen on ignoring the SNs residual energy, optimal clusters count and average distance. Further, the selection of CH is random which leads to rise in the CH's count and also leads to an increase in the chances of low energy node to become a CH. The CHs are unevenly scattered and some clusters formed with few nodes and other clusters with more nodes thus consumption of node energy increases and decreases the network lifetime.

Minimum path loss, the degree of a node and average energy are the weighing factors in a cluster based distributive algorithm for the selection of CH in a network [8]. The algorithm focuses on load balancing with a number of cluster formations to conserve energy in the network but, CH requires more energy for transmitting information directly to BS. This, in turn, results in an early depletion of node energy in the network.

The Cluster-based routing protocol [9] is based on energy-aware routing algorithm, where nodes are distributed randomly in the network. The main objective is to regulate the consumption of nodes energy for extending the lifetime of the network. The above algorithms fail to solve the energy hole problem efficiently, although the role of CH is uniformly shared among the nodes in the WSN. The sum of energy consumed by a receiver and the transmitter power amplifier are taken as major aspects for the diminution of energy.

In WSN's scheme of routing with information of several data together this gains data correlation along with the multi-hop transmission. During a selection of CHs, the residual energy parameter is used in WRECS [10]. Member nodes elect the CHs and these elected CHs won't participate in remaining rounds. However, the consumption of energy for CH does not depend on cluster member. WRECS simulate with the first node death versus time and are incapable to balance the entire network energy consumption.

The preferred CHs are nearest to BS in Energy Efficient Clustering Scheme (EECS) [11]. Although the energy usage of CH's are balanced, the entire network consumption of energy remains unbalanced.

The Sensor Medium Access Control (SMAC) [12] adopts periodic sleep and listen, avoiding overhearing for reducing contention latency in WSN.

All node stores schedule table consisting, information of all its known neighbors. SMAC doesn't suit for the cluster-based network, although it reduces the consumption of energy through periodic sleep schedules. The residual energy of nodes is considered for electing CHs in Hybrid Energy Efficient Distributed (HEED) [13].

The nodes with the least distance to CH are their neighboring nodes. The consumption of energy is minimized however the energy of closer nodes to the sink is depleted in the network. R.Singh and Kumar verma [14] proposed energy efficient cross-layer routing protocol rely on the adaptive threshold function. The CH selection is based on the factor by dividing the entire network nodes average energy by the remaining energy of each node. It is an approach for reducing the consumption of energy but it failed to handle route failure in the WSN.

Y. Sun, et.al [15], optimizes the cluster scheme on considering residual energy, distance, constructing routing tree during data transmission in WSN. However CH selection and minimization of energy consumption remains ineffective in a homogeneous network.

Adv-MMAC [16] is an energy efficient multichannel MAC protocol that works on two phase's namely, data phase and ADV phase, which are concurrently running for communication in WSN. It consists of several states such as network initialization, synchronization among nodes, channel discovery, and contention of the medium. It suffers from sending different types of data and compromises between the requirement of Quality of Service (QoS) and energy efficiency.

Randomness in the election of CH is controlled in LEACH-MAC [17] and stabilizes the selection of CH, maintaining an optimal count CHs in the network. The process of electing CH is continued till the given optimal count along with assuming the placement of CH in the network. However, the distribution of CH's is not even in the WSN. To stabilize the CH's energy over the network, Distributed Unequal Clustering using Fuzzy approach (DUCF) [18] creates clusters with varied size. Each cluster is defined with a predefined count of nodes, whenever CH is elected with the desired number of nodes. Consequently, no more nodes are permitted in the network. Thus, the node has to select far CH otherwise one hop transmits to BS leading to a decrease in the lifetime of the network.

Above all, protocols are less effective in the selection of CH, and they improve the lifetime of the network.

Several existing works emphasize only on the routing layer but the proposed work combines the physical layer, link access in the MAC layer, and routing layer for enhancing the energy in WSN. The EECACL is routing model which minimizes the consumption of energy and maintains an optimal count of active nodes with less message transmission cost in the network.

This paper focuses on energy efficient cross-layer cluster model for optimizing energy in WSN using residual energy, distance, and cluster size with MAC layer information in the network.

3. PRELIMINARIES

This section describes the network models and provides necessary notations and definitions of the algorithm.

3.1 Network Model

The following are the assumptions:

- Every node is arbitrarily distributed in the network.
- The nodes are fixed and homogenous.
- All nodes are configured with equal energy levels.
- There is a single BS
- All the CHs transmit data to the BS.
- One Sink node for receiving data from all CHs
- Node dies on the exhaust of battery energy.
- MAC layer is present in each node.
- Consumption of energy varies among all nodes.

3.2 Radio Energy Dissipation Model

The radio model for analyzing the energy consumption in the WSN is depicted in the Figure 2.

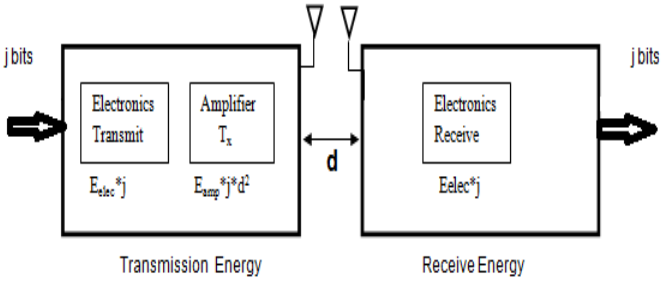


Figure 2. Radio Transmitter and Receiver energy consumption model

Transmitting message bits [11] for the given distance 'd' the required energy is as shown in equation 1.

$$E_{TX}(l,d) = \begin{cases} E_{elec} * l + \epsilon_{fs} * l * d^2, for\ d < d_0 \\ E_{elec} * l + \epsilon_{fs} * l * d^4, for\ d \geq d_0 \end{cases} \quad (1)$$

Where d_0 is computed using the following equation

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (2)$$

The energy consumption for receiving l bit

$$E_{Rx} = E_{elec} * l \quad (3)$$

4. PROPOSED MODEL

This paper prolongs the lifetime of the network using the information obtained by rest of the network layers. It selects CH using remaining energy, distance, optimal cluster size, and cluster headcount.

The entire process of proposed model steps is as follows:

Step 1: Initially discover the neighbors on broadcasting the energy and ID among sensors and compute the average distance in the network.

Step 2: Detect positions of all nodes.

Step 3: Compute a distance from sink node and calculate the residual energy, retrieving information from the cross-layer approach.

Step 4: BS sends the start packet to every node in the network for the initialization of the cluster. Nodes join their CH based energy loss for the packet to be sent within the cluster.

Step 5: Information on residual energy with node identity collected through all CH's. BS compares the initial energy of node with Total energy and distance to BS, if the result is lesser then that node is selected as CH.

Step 6: Based on the cross-layer information the residual energy retrieved and compared with threshold value which is greater than the multi-hop relay node is chosen and data is transmitted through the selected path.

4.1 Cluster Initialization

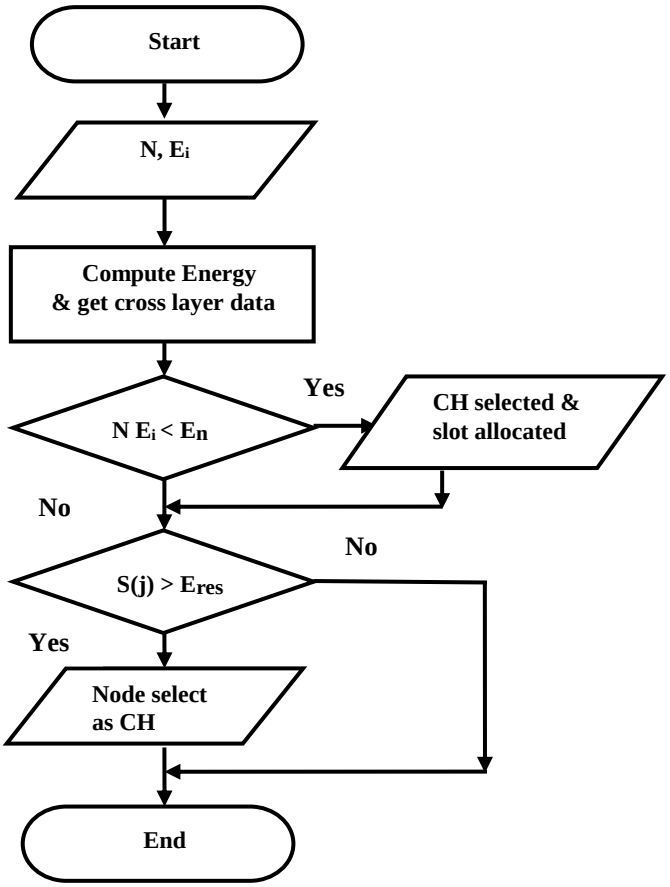
Initially, BS sent an initial message to every nodes for retrieving its node ID with distance, and the routing table is maintained in WSN. After the construction of routing table by each node the EECAL initiates the selection of CH in a distributed manner.

4.2 Cluster Head selection

Initial energy of these nodes with the location is updated for all its neighboring nodes in WSN. The initial energy of each node is compared with the total energy and distance for selecting temporary CH. The residual energy of the remaining nodes is compared with temporary CH for selecting final CH. Consequently, a suitable slot is allocated for transmitting data to the BS. Thus high residual energy node is selected as CH, avoiding low residual energy node in the network.

The notations used in the flowcharts are: N reference to Number of nodes, E_i reference to initial energy, BS_d reference to Base Station distance, E_{res} reference to Residual energy, S(j) reference to slot of the node, N_E reference to Node energy, Ni's reference to Neighbor list.

The process of selecting cluster initialization and cluster head selection is shown in flowchart 1.



Flowchart 1 The cluster Head selection process

4.3 EECACL Model

The location of the node and its neighbor nodes distance are computed. If the node is present in the neighbor list then the node residual energy is compared with a threshold value for choosing the relay node. All Source nodes find their relay node within its transmission signal comparing energy with threshold value before relaying data to BS with the minimum path in the network.

Residual energy is calculated as follows:

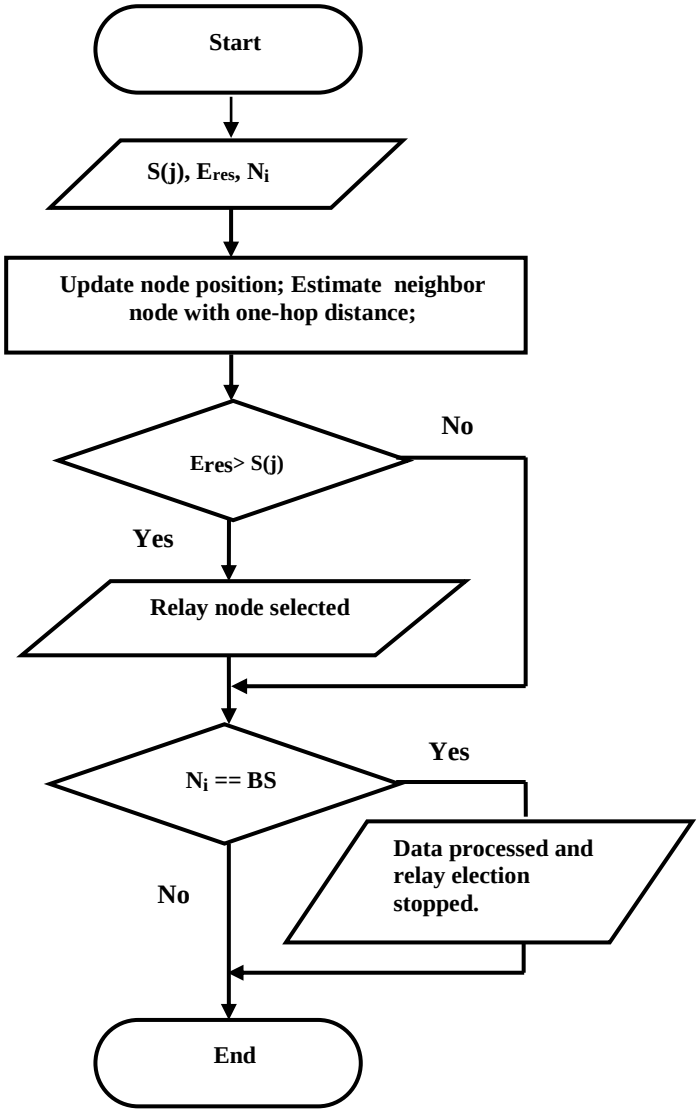
$$E_{res} = E_i - C_e(t) \quad (4)$$

Where E_{res} is Residual energy, E_i is initial energy and C_e is consumed energy.

The consumed energy is calculated using formula

$$C_e(t) = E_{TX}(l, d) + E_{RX} + E_i \quad (5)$$

Selection of relay node is initiated after the finalization of CH on considering residual energy, threshold value with node identity as shown in flowchart 2.



Flowchart 2 Relay node selection process

Where $E_{TX}(l, d)$ and E_{RX} transmitting and receiving the energy of radio model. E_i is idle energy.

5. RESULTS

This section shows the simulation result of the proposed EECACL routing model. The result is analyzed with the identified number of active nodes for a subsequent number of rounds and alive nodes energy in the network. Find the energy efficiency of the entire network on tracking the number of active nodes with the capacity of sending a total number of the data packet. The proposed model is examined and evaluated with results of the earlier scheme using simulator NS2.34.

Table 1 shows the simulation parameter used for analysis of results.

Simulation parameters	Values
Number of nodes	100
NS version	NS-2.34
Simulation area	1000*1000 m2
Simulation duration	100 ms
Transmitting energy	0.1 J
Receiving energy	0.1 J
Interface queue	Drop tail
Data packet s	500 bytes
Packet header	25 bytes
Initial energy joules	100J
e_{fs}	10 pJ/bit/m2
e_{mp}	0.0013 J/bit/m4
Eelec	50 nJ/bit

Table 1 Simulation parameters

5.1 Rounds versus Number of active nodes

In Figure 3, networks of 100 nodes at 50 rounds are considered for analyzing the lifetime of the proposed routing model. The result shows that the number of active nodes is improved by 15%, 19% as compared to LEACH and CL-LEACH.

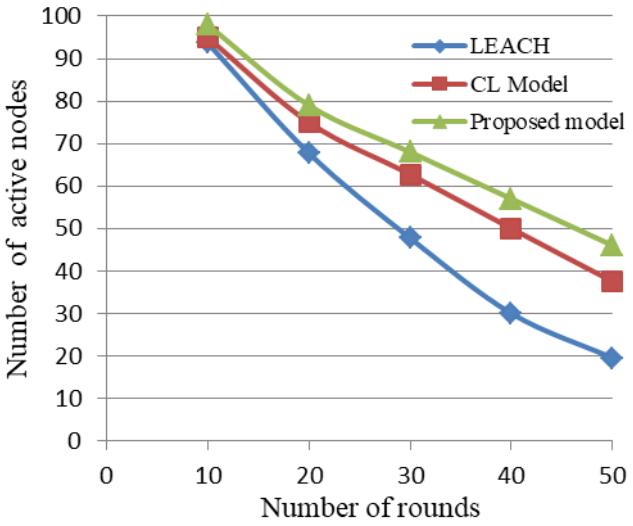


Figure 3 Number of round vs. Number of Active nodes

5.2 Number of alive nodes versus Total data packet sent

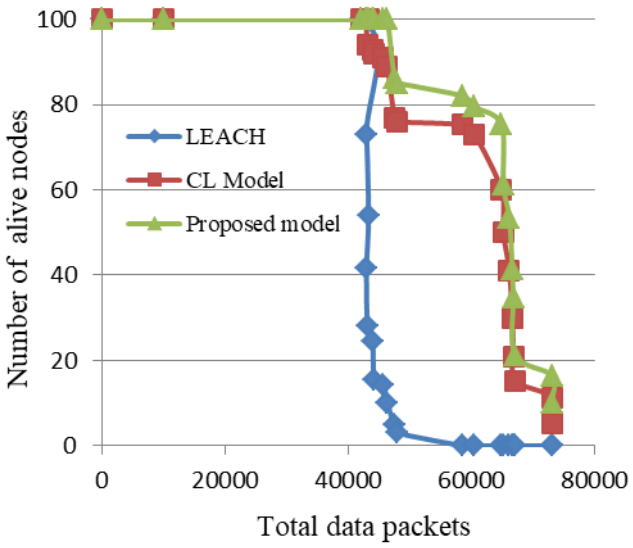


Figure 4 Total data packet send vs. Number of nodes alive.

The average throughput in sending data across network is increased as compared to earlier benchmark model LEACH and advanced existing model CL-Model.

5.3 Error rate with the cost of message

Figure 5 shows the result comparison between LEACH, CL MODEL, and proposed a method with an increasing error rate. The message cost decreased to 1470 as the error rate is 0.8 which is less message communication cost as comparison to LEACH, CL-LEACH.

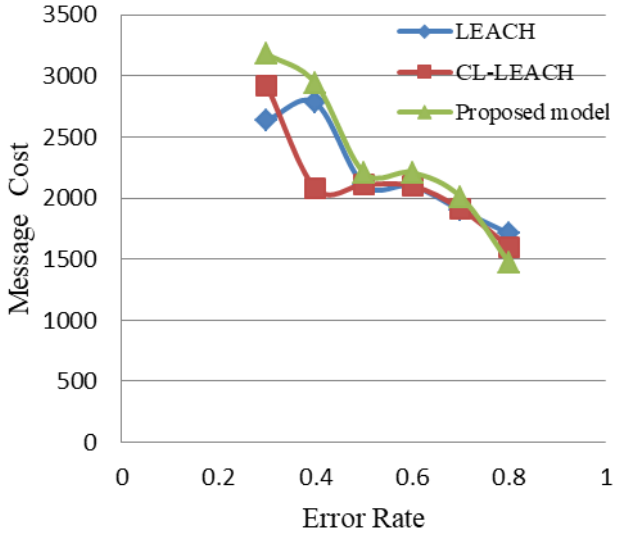


Figure 5 Error Rate vs. Message Cost

5.4 Time and Count of triggered CH processing

Figure 6 shows the activation of CHs selection with respect to time(s). The cluster scheme in the proposed method demonstrates the minimization of CH processing overhead as compared to LEACH and CL-LEACH.

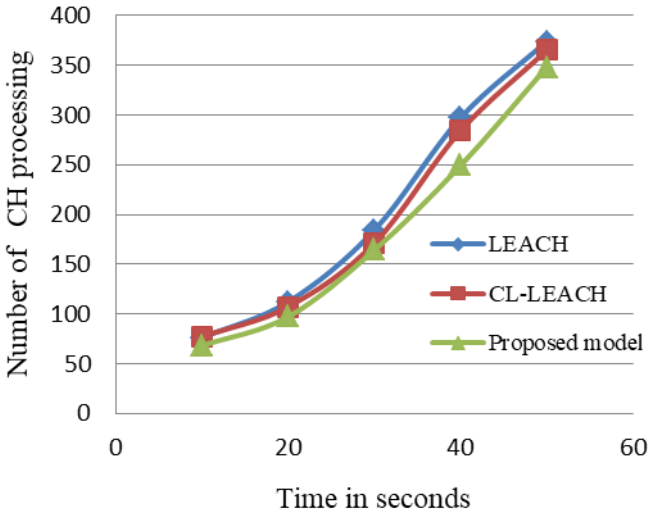


Figure 6 Time vs. Number of Triggered CH processing

5.5 Time and Residual energy

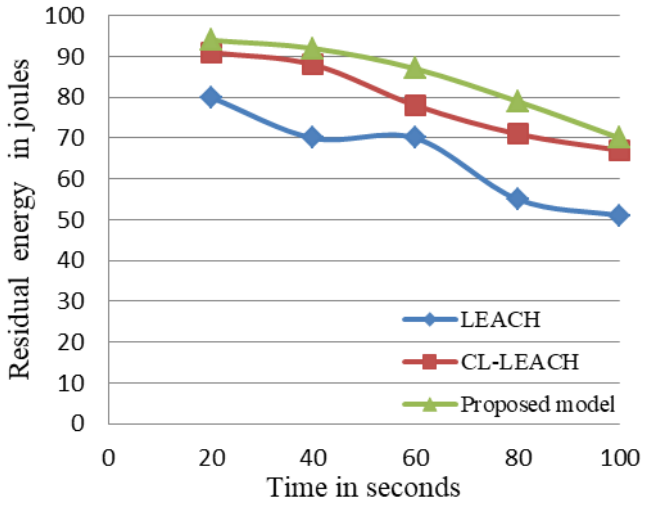


Figure 7 Time vs. Residual energy

Figure 7 shows the comparison of the proposed approach with LEACH and CL –LEACH.

6. CONCLUSION

In this paper, Energy Efficient Clustering Algorithm using Cross-Layer (EECACL) is proposed which reduces energy dissipation and prolongs the lifetime of the network. It considers the average energy, distance, location, cross-layer information, cluster size with CHs count during the selection of CH in the WSN. EECACL balances energy among SNs through a novel strategy of CH selection in WSN with a new framework and optimal probability. EECACL minimizes the energy loss and balances the SNs count in WSN. The simulation results show an enhanced lifetime as compared to advanced existing methods on consideration of residual energy and a total number of alive nodes.

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