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Framework for Cross Layer Energy Optimization in Wireless Sensor Networks

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Abstract

Cross-layer routing technique interacts among the various layers of the OSI model and exchanges information among them. It enhances the usage of network resources and achieves significant performance improvements in Quality of Service (QoS) parameters. The Low Energy Adaptive Clustering Hierarchy Protocol (LEACH) routing algorithm consumes higher energy due to communication overhead and thus, a hierarchical model-based routing protocol named Cross-Layer Energy Efficient Scalable-Low Energy Adaptive Clustering Hierarchy Protocol (CLEES-LEACH) is proposed. This increases scalability using the Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) protocol between the intermediary node and cluster head, with the overhead of latency. A Linear Programming model is used, which further makes use of scheduling to overcome latency. Energy efficiency and latency are addressed with the proposed cross-layer routing algorithm CLEES-LEACH. The cross-layer design establishes Physical, Media Access Control (MAC), and Network layer interactions in the proposed algorithm. The present LEACH algorithm also increases the network overhead as there is no mechanism for communication among the network layer and consumes high energy. In the proposed algorithm CLEES-LEACH, latency is reduced to 25% and throughput is maximized to 20% compared to existing Energy-Efficient Distributed Schedule Based protocol (EEDS) and Integer Linear Programming (ILP) protocols. The energy consumption is also reduced to 20 % and the scalability is increased to 10 % compared to the existing LEACH and CL-LEACH protocols. These results are shown by using NS3 simulation.

Keywords: Cross Layer Design, Energy Efficiency, Latency, Quality of Service (QoS), Scalability, Throughput, Wireless Sensor Networks.

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1. Introduction

Wireless sensor network (WSN) has become a more privileged wireless system and various sensor-based applications are carried out by this system. Sensors can be fixed anywhere in the global environment; intended to promote various activities like monitoring of parking lots, the tracking of soil circumstances in the garden and industrial automation. Moreover, dwelling place sensors are used for safety purposes, to regulate lighting, provide ventilation etc. All these are collectively said as a smart home. The WSN consists of a few hundreds to a thousand sensor nodes and a wireless means of communication is made among them [1]. In WSN, data is passed by each sensor node through the network to a prime node often said as a sink node. Here, the data is distributed among themselves i.e. they arrange themselves either in clusters or tree structures. Depending upon the battery power of each sensor node, the consumption of energy varies. Thus, while communicating, the transmission power of each sensor node must be reduced to enhance the communication duration of a node. Furthermore, apart from energy consumption, various other challenges are, throughput, scalability, and routing.

1.1 Motivation of Cross-Layer

Traditional OSI protocol stack avoids exchanging information among non-adjacent layers which affect its usage in WSNs. Thus, the above-mentioned challenges and issues must be addressed; therefore, a unified cross-layer design approach is mandatory which must deviate from the conventional approach. The quality of services (QoS) can be accomplished in WSN by integrating the layers of OSI protocol stack and thus certain improvements in performance like higher network capacity and energy efficiency can be made. Interaction with various layers of the OSI model and thus generating interconnection or linkage enclosed by two or more layers is said as Cross-Layer Design [2].

These relationships among various layers are employed to produce the finest solutions about throughput, latency, and energy conservation.

Data packets can get transmitted from source to sink node through network layer and to handle this, routing mechanism is necessary. The packet is then sent off by the best possible route to its destination — a path that all the other packets in the message, or none of the other packets in the message, will take. Using a clustering mechanism, data can be forwarded to the sink node in a resource conserved manner. Clustering is a process by which a mission can be achieved by grouping sensor nodes [3]. Comparing to non-clustered WSN, cluster-based WSN plays well and thus the routing mechanism is simpler and easier. Networks need to interact with higher layers having less bandwidth or energy to select an energy efficient path. This can be made by using a cross-layer technique.

1.2 Contribution

A hierarchical clustering routing protocol called LEACH, has the feature of organizing themselves and lifetime maximization of the network. The main desire of this protocol is to reduce energy consumption while transmitting data by using clustering and data fusion methods. In a typical LEACH algorithm, data cannot be shared by the individual layer. Also, cluster heads are irregularly spread which may result to indiscriminate cluster formation. And, only single-hop communication is made thereby energy is supposed to be drained quickly [4].

To overcome these issues, the conventional LEACH algorithm is promoted by cross-layer based optimization model. Therefore, a clustering routing algorithm is designed. For transmitting packets, the intake energy of individual nodes is considered, and also the power taken while transmitting can be efficiently regulated according to the proposed routing mechanism. The appropriate energy required for transmission is made by assimilating network, physical and MAC layers. The proposed routing protocol uses the exhausted energy during cluster formation in LEACH. By using this model, a new routing algorithm called CLEES-LEACH is proposed. Moreover, combine scheduling and CLEES routing (CSCR) technique is proposed to solve the delay problem which is generated during transmission. Here, both link scheduling and CLEES routing are done in a single optimization model using a linear program. Therefore, parameters like energy consumption and delay can be reduced and throughput along with scalability can be improved and can produce better results than existing works.

1.3 Organization

The rest of this paper is systematized as follows: Section 2 explains on related works; Section 3 describes the model of the network; Section 4 explains about the framework of the cross-layer optimization model; Section 5 describes an efficient CLEES routing mechanism; Section 6 a mathematical model for optimization is analysed; Section 7 presents the simulation parameters and settings; Section 8 represents implementation and performance analysis of our experiments and Section 9 offers a conclusion.

2. Literature Survey

In wireless sensor networks, nodes are inadequate due to various factors like energy efficiency, lifetime, reliability, latency, throughput, and so on. To make these factors compatible, many cross-layer protocols have been proposed.

To improve the efficient usage of the network [5], cross-layer collaborative communication (CL-CC) is proposed. To conserve the energy of each sensor node, continuous monitoring is done and states such as active and sleep are generated. These states gather data from the MAC layer using the interaction method. Spatial and temporal information is used in sensor nodes. In CL-CC temporal correlation is used to extract data from the MAC layer to achieve various parametric measures like accurate data, latency, and consumed energy. The generated algorithm calculates the next sleep duration and next forwarding time to conserve energy and to enlarge network lifetime.

To solve the problems, present in the OSI model, the cross-layer approach method can be used as it acts as a good optimization method by interacting with the stack of protocol layers [6]. Self-nominating and flossing are the two protocols that have been taken in this paper. Using these protocols, data is gathered from sensor nodes. Also, to accomplish synchronization and decrease complexity present in the network, the MAC and time synchronization are planned. Here, optimization is done using cluster head and it upholds a list of correlation coefficients for all nodes. A Dynamic-Multi-Attribute Cross-Layer Design, DMA-CLD has been created by including interfaces, abstractions, and interrelationships between each layer and also to maintain an adaptability, optimization agent framework is used.

To maintain energy efficiency in wireless sensor networks, a framework for cross-layer optimization, UCLEAH is designed [7]. The UCLEACH model separates the nodes into three categories such as sensor nodes, cluster heads, and border nodes. Physical, network and data link layers are the three layers used for interaction and thus by using their functionality, the lifetime of wireless sensor networks can be maximized. To use the packet length of the physical layer frame structure, alteration is made in the Centralized network topologies to minimize resource consumption.

Achievement of energy-efficient techniques in large-scale environments is considered as a difficult task. Many research works have been going on to establish an energy efficient routing protocols in wireless sensor networks. LEACH is the original cluster-based routing protocol in wireless sensor networks.

In paper [8], a planned cross-layer clustering approach is used to enhance the traditional LEACH. This method is used to address the issue for large scale networks. Here the traditional LEACH technique is improved by importing dual residual energy and SNR thresholds. Multihop communications have been designed to trace the finest path from the source CH and the destination. Lifetime of the network, low consumption energy and packet delivery rates are improved here.

In paper [9], a clustering algorithm named Dynamic, Distributed, and Randomized (DDR) algorithm is used. It has been shown that cluster-based routing protocols are far better compared to non-cluster-based protocols with respect to energy-efficiency. High importance is provided to the node with higher energy while selecting the cluster head. Here, the cluster head selection algorithm is used to control the inherent randomness by using MAC layer information.

Many clustering protocols are proposed in the past decade to enhance energy efficiency in LEACH. Initially Cluster Head elected from a group of clusters randomly to gather and aggregate data, then transmit the gathered data to base station (BS). The rounds performed in the network for a cluster head has to be chosen based on remaining energy and average distance. However, choosing CH in a random manner results in high quantity of CH's and also nodes with low residual energy might have a chance to become a CH. CH is irregularly spread in the network, thus some clusters are generated with few nodes and some with a large number of nodes, therefore energy consumption increases, and the energy of the nodes become exhausted, which leads to less network lifetime [10].

To minimize the consumption of energy, Cell-LEACH splits the clusters additionally to the reduced size named cell [11]. The reduced size formation of the cluster is done at the setup phase and carried throughout the entire lifetime of the network. Also, the selection of cell and cluster head is done dynamically and updating is done regularly. The members of a cell pass their information to the corresponding cluster heads through their cell heads.

Likewise, a super cluster-head (SCH) concept FLLEACH [12] is generated. Here an intermediate node is chosen as the supercluster head that acts between cluster heads and the base station. An adaptive structure is used by MMR-LEACH, where the vice cluster head is chosen i.e. one node within a cluster [13]. In divergence, a multihop approach is used in Multi-LEACH where the signal to noise ratio for various links are considered and modification is done in the CH's selection process [14].

To enhance the usage of energy efficiently for wireless sensor networks, a Cross-Layer Energy-Efficient Protocol (CLEEP) is proposed in [15]. However, the outcome was not much efficient and there exists a few errors. Thus, by having the idea of CLEEP, an Energy Efficient Cross layer Protocol (EECP) is proposed in [16]. Interrelationship is made between physical layer, MAC layer, and network layer. A neighbour table is created and maintained in EECP and thus, based on the table, the appropriate nodes are evoked to transmit the data. In the MAC layer, a mechanism named wake-up is used to eradicate overhearing. An adaptive threshold routing protocol for WSN with an energy efficient cross-layer technique is proposed in [17].

A Cross-layer Energy Efficiency (CEE) model is presented in paper [18] for Mobile Wireless Sensor Network and this model has various features for efficient usage of energy, maximization of throughput and minimum latency. In [19] proposed a Cross-Layer Optimization in WSN. Here, the Markov model is used to send a beacon. Rayleigh fading channels are used to evaluate the latency in WSNs. A cluster tree topology is constructed and interrelationship is made for the physical, MAC, and network layers.

Cross-layer approaches that use Interaction between MAC and Network are used to jointly build a scheduling and routing mechanism in the WSN. In Paper [20] proposed an integer linear program (ILP) model to provide an increased network lifetime. This model is verified through different numerical examples and these results have been combined with EEDS which is the best method to jointly build routing and schedule for WSN. In paper [21] Latency and Lifetime-Aware Clustering and Routing in Wireless Sensor Networks is proposed. To minimize latency, sensor nodes are partitioned into various layers. A disjoint cluster is made by clustering heuristics which partitions the sensor nodes. A routing tree is constructed using the ILP algorithm for inter-cluster communication and thereby lifetime of wireless sensor networks can be maximized. Any cluster head from the base station's hop distance should not exceed the initially assigned value. By using polynomial-time heuristics and ILP algorithm constraints like energy efficiency can be improved.

A Cross-Layer Scheme for reducing Delay is proposed in paper [22] for Multihop Wireless Networks. In both sensor and mesh networks, latency plays a major constraint. To transmit the data packet without any error, a sufficient condition on a conflict-free transmission is identified. By having this condition as a constraint, a linear programming model for routing information with less interference is generated.

In paper [23], a cross-layer protocol is formulated for obtaining a trade-off between the energy and throughput. To solve routing and bandwidth allocation problems, a parameter called network utility is included in the framework for traffic flow assignment. Routing tree construction is used to maximize the throughput. In Paper

[24], a cross-layer optimization for multi hop wireless networks is proposed to treat multi-hop based flow routing and power allocation at both physical and network layers. From the above analysis, an energy-efficient model along with QoS requirements such as scalability, latency, and throughput must be achieved.

2.1 Objectives

The main Objectives are
1. Minimize Energy Consumption
2. Minimize Latency
3. Maximize Throughput
4. Maximize Network Lifetime
5. Improve Scalability

3. Methodology

The methodology of this work is as follows:
1. A Cross-layer QoS framework of the wireless sensor network is presented here. In this framework, QoS requirements such as energy, scalability, latency, and throughput are fulfilled by having an interrelationship between network layer, routing layer and MAC layer (link layer).
2. The CLEES-LEACH routing algorithm is proposed, to make the system energy efficient. Residual energy and the average distance of a node are considered and based on these values; cluster head is selected. Choosing nodes with high residual energy as cluster head (CH) will lead to a more alive node in the network, and thus consumption of energy will be low.
3. To make the routing protocol scalable, an intermediate node is chosen by the CH. A channel access mechanism named CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) is used among cluster members and the intermediate node, which would considerably improve the scalability of the network.
4. For the optimization of latency and throughput, a combined scheduling and CLEES routing (CSCR) mechanism is proposed using the linear program. This mechanism provides a solution by generating a path for transmitting data packets. Link data rates and time slot is assigned for transmitting data through every link.

3.1 Network Model

The Network Model focuses on sensor nodes, the formation of clusters and selecting cluster head. A four-sided, square field is established as the network and here the nodes are distributed randomly. Once the sensor node gets positioned, no locomotion is made. Each node grabs data from the field and it transmits the data to the base station. As the sensor nodes are randomly placed, it has to be placed in a normal manner and so, the initialization of the cluster is done. Thus, nodes are grouped based on the distance between them and base station. From each cluster, a head is chosen and the inter-cluster communication activities are managed by a Cluster-Head. Alternatively, cluster members have the role of detecting and accumulating information.

3.2 Assumptions

1.All nodes are randomly distributed in the network.
2.Nodes present in the network are allotted permanently.
3.Each selected Cluster Head must handover the information to the single base station.
4.A node goes to a dead state when depletion of battery energy occurs.
5.The energy utilized by each node is different.

3.3 Energy Model

A CLEES-LEACH strategy is proposed to reduce energy usage and improve the service life of the network. CLEES-LEACH increases the network lifetime by consuming a small percentage of total energy dissipated in the network. Energy required for conveying 'q' bits of the data packet to a node which is position 'd' meters away from the source node can be written in the form,

$$T_E(u,v) = qE_{elec} + q\varepsilon d(u,v)^{\alpha} \quad (1)$$

$$= \begin{cases} qE_{elec} * l + q\varepsilon_{fs} * l * d(u,v)^2 & d(u,v) < d_0 \\ qE_{elec} * l + q\varepsilon_{mp} * l * d(u,v)^4 & d(u,v) \geq d_0 \end{cases} \quad (2)$$

In equation (1), $T_E(u,v)$ denotes the energy required for transmitting q bits of the data packet. u is assumed to be the transmitting node and v the receiving node. The distance between the nodes u and v is denoted as $d(u,v)$. ε is a constant. α is the path loss exponent and when α = 2, distance becomes $d(u,v) < d_0$. Similarly, when α = 4, the relation becomes $d(u,v) \geq d_0$, where d_0 denotes the breakdown point distance. Here, using the following equation d_0 is computed as,

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (3)$$

Where E_{elec} is the energy consumed by a receiver or sender for a single bit. ε_{fs} is a free space model and ε_{mp} denotes the transmission parameter for multi-path fading model .To get the data of packet length s transmitted from a node located at a distance d, consumption of energy R_E can be denoted as,

$$R_E = E_{elec} * s \tag{4}$$

Table 1. List of Notations

Parameters	Description
ε_{fs}	Free Space Model
ε_{mp}	Multi-Path Fading Model
E_{elec}	Energy Consumed by a Receiver or Sender
R_E	Consumption of Energy
D	Distance
$T_E(u,v)$	Energy Required for Transmitting
$d(u,v)$.	Distance Between the Nodes U And V
ε	Constant
α	Path Loss Exponent
d_0	Break down Point Distance.

4. Cross Layer QoS Framework

A cross-layer framework is proposed to conserve energy along with QoS parameters. It assembles the layers keeping in mind the interconnection, synchronization, and flow of data among the layers. Figure 1 shows the cross layer QoS framework. This framework allows those features to happen with the help of a routing mechanism that uses cross-layer interaction to provide a solution, by applying a simple alteration in the protocol stack.

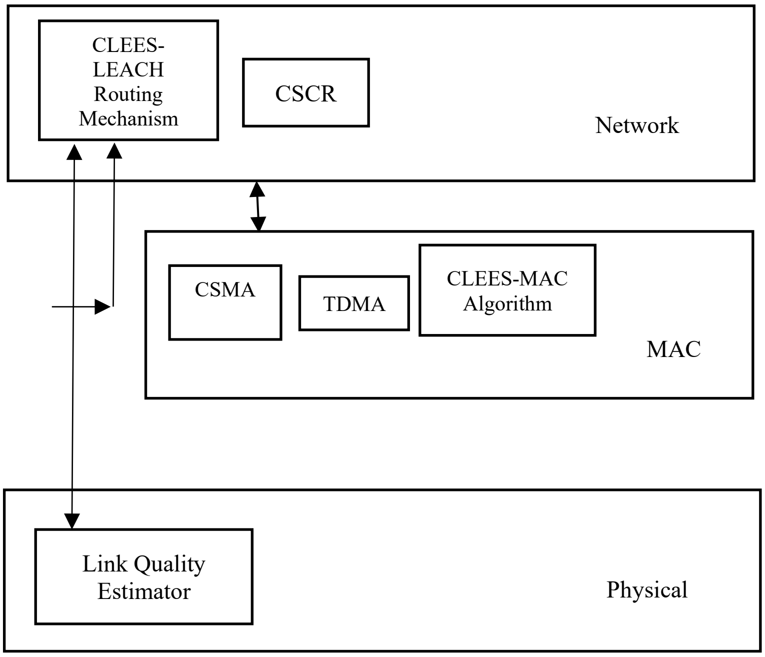

Figure 1. Cross Layer Framework

If a cluster head is selected for a round, an acknowledgement is passed to all the cluster members. According to the strength of the signal, cluster members take the request message and choose whether to join or not. Again, to eradicate collision of data, CH transmits Time Division Multiple Access schedules to all associates of a cluster to convey a packet of information at varying slots.

The same progression takes place for all remaining rounds. To minimize the energy consumption for the whole network, a cross-layer optimization is done for the bottom three layers; routing can be made at network layer through clustering approach; the members of a cluster are assigned with fixed and variable time slots at MAC layer; various modulation schemes could be applied at the physical layer on the cluster members. The bottom three layers of the OSI model is optimized and thus a maximum number of alive nodes can be achieved leading to an increase in wireless network lifetime.

4.1 Energy Efficiency

The foremost challenge in WSNs is to extend network lifetime. As sensor nodes are obsessed with inadequate battery, depletion of energy occurs during computation and packet transmission. Therefore, to solve this; an energy efficient method must be implemented within each and every layer of the network. WSN comprises of sensor nodes, the number of which is denoted by N, and a base station.

Energy consumption will grow higher when the nodes are located at a higher distance. Here, clustering approach is used and so sensor nodes in the network are formed into smaller groups called clusters. Again, a head is selected from the group of nodes. To have a considerably efficient transmission with minimum energy loss, cluster-head is selected initially among the members present in a cluster.

4.2 Cluster Head Selection

In this model, the Cluster Head is chosen based on both the residual energy and average distance. For this process, the comparison must be made between energy and distance. Each node's initial energy is related to the node's total energy, and then the distance between individual cluster members and the base station is calculated. Using these constraints, the cluster head is chosen very carefully. A major challenge in WSNs is to select appropriate cluster heads.

The cluster head selection process is done by considering the node's initial energy which is taken as input. Location is updated for every node and they are organized with the help of updated information. At the initial stage, the distance for the current node and base station is computed and if the outcome is such that the particular node's distance, X_D is lower than BS_D, then the specific node is chosen as head for the cluster temporarily. Again, it compares the node's initial energy with the total energy. If the node's initial energy E_I is lesser than E_N, then the selected Cluster head is provided with the appropriate slot. Thus, a node with high residual energy is chosen as the cluster head, evading nodes low residual energy in the network.

If a cluster head is selected for a round, an acknowledgment is passed to all other cluster members. According to the strength of the signal, cluster members take the request message and choose whether to join or not. And once again, the CH transmits Time Division Multiple Access schedules to all associates of the cluster. The same progression takes place for all remaining rounds.

Algorithm 1: Cluster Head Selection

Input: Node *N (1), E_1*
N (1), Node1
E_1, Initial energy of Node 1
Output: *Cluster Head (CH)*
Begin:
1. Update Each node information like location, id and neighbour node;
2.Arrange node based on location;
3.Compute each node says (x1) distance with next node (x2);
 If *(XD <BSD)*perform comparisons with energy
 Compare initial energy with total energy of each node;
 If *E1<E2*select as a temporary CH;
4.Check *RES_E* of temporary CH to threshold value *T(M);*
 Check *(RES_E<T(M))*
 Choose this node as a cluster Head;
5.Cluster Head send acknowledgment to all the cluster member;
 Based on signal strength member join to a cluster time slot is provided;
6.If all conditions are not satisfied then goes step 2;

End

4.3 Routing Mechanism

Routing forms the main part, during which the data packet gets transmitted to the base station. A large quantity of energy is absorbed while sending and receiving a data packet. As a result, there arises a necessity for generating an effective routing protocol. The routing protocol must be able to preserve the energy of a node while transmitting data. Thus, the proposed CLEES-LEACH algorithm monitors each node and its distance as soon as locomotion is made by a node during transmission. If a cluster member continually travels away from one node to another against the path, then generating a route is not conceivable. Therefore, to sustain the route, the neighbour node recognizes its movement, and consequently the route will be discovered to reach the sink.

4.4 Route Discovery

The path must be discovered from the source node to reach the destination. When a node desires to transmit a data packet, at first no route is sustained. Based on the routing mechanism described above, the path is revealed and routing will be done. If any failure occurs during path establishment, then it gets terminated and the best path can be elected again from the start.

4.5 Distance Calculation

In WSN, the sensor nodes are arranged randomly and thus while creating clusters, it must possess both members and a head for a cluster. The nodes connect with the head by means of the smallest distance and deliver a message to the adjacent cluster head. After selecting the cluster head, distance amongst every member and head of the cluster is measured. Between the base station and a node, direct communication is done only during the time the node's cluster head is located at a higher range to the base station. For other circumstances, member nodes are connected with their cluster compatible with the shortest distance. The distance matrix for sensor nodes $DM(p*q)$ can be expressed as

$$DM(p*q)=\begin{bmatrix} d_{Ch1,y_1} d_{Ch1,y_2} \ldots\ldots\ldots d_{Ch1,y_q} \\ d_{Ch2,y_1} d_{Ch2,y_2} \ldots\ldots\ldots d_{Ch2,y_q}. \\ \vdots \\ \vdots \\ d_{Chp,y_1} d_{Chp,y_2} \ldots\ldots\ldots d_{Chp,y_q} \end{bmatrix} \quad (5)$$

In Equation. (5) d_{ch} indicates the distance between the head of a cluster (ch) and a sensor node relative to its location. Here, $y_1, y_2, y_3, \ldots.. y_n$ are the nodes present in the network. For instance; two nodes, a and b are taken and their positions are denoted by (a_m, a_n) and (b_m, b_n) respectively. The distance between these nodes can be calculated as

$$d_{a,b}=\sqrt{(a_m-b_m)^2+(a_n-b_n)^2} \quad (6)$$

As stated above in the distance matrix, in Equation. (6) a denotes cluster head and b represents the sensor node. Thus, the distance between the member node and cluster head can be evaluated using the above formula. Once the least distance to the base station is found, the remaining energy for each node is evaluated.

To calculate the node's residual energy, RES_E during time interval t, the difference between the initial energy value E_I and the consumed energy is computed as shown in the following equation

$$RES_E = E_I - Cos_E \quad (7)$$

Where, Cos_E represent the consumed energy of a node. A node consumes energy during packet transmission and receipt, and a significant loss of energy occurs in the idle state of a node. Moreover, while a node is at the sleeping stage too, little consumption is seen. Thus, consumption of energy Cos_E can be calculated as,

$$Cos_E = T_E + R_E + I_E + S_E \quad (8)$$

From the above equation, the term T_E represents the energy taken during transmission, R_E is the response energy, I_E is the indolent energy, and S_E is the scalable energy.

5. CLEES Routing Mechanism

Figure 2 shows the block diagram of CLEES-LEACH. In the CLESS-LEACH model, the source node id and position are taken into account. The combined design of scheduling and CLEES Routing (CSCR) mechanism is proposed, and the routing mechanism is handled by taking the residual energy, cluster member, and node as the input. A table is maintained for each node in the network, which contains information about its position and neighbour(s).

The mechanism is as follows:

Step 1: First, to ensure the presence of nodes in the cluster network, a table is maintained for all nodes about each of its identification, location, and neighbour. The Initial transmission range is set with multi-hop distance. Their presence is confirmed using the table.

Step 2: If the presence of a node is true, the intermediary node I_N is selected by fulfilling certain conditions. The first one is, the residual energy of the Intermediary node must be greater than threshold energy. Secondly, the source of the link's node-Intermediary node and Intermediary node-Cluster head must possess higher SNR value comparing to the threshold value ρth. The selected intermediary nodes have the role to gather and accumulate the data from cluster members.

Step 3: By the usage of the MAC protocol, the selected I_N handover the gathered information to the head node. The nodes will be in energetic form only when they receive the gathered data, else being in a sleep state.

Step 4: If the packet received by the node is the destination, then the intermediary node gets stopped and the algorithm will terminate. A successful acknowledgment is a return to the source node by the sink node, when the packet is received successfully.

Algorithm 2: CLEES Routing Algorithm

Input: Res_E, M_C, N_X

Res_E,- Node Residual Energy,
M_C-cluster Member
N_X -Neighbourhood List

Output: $\boldsymbol{I_N}$Selection
$\boldsymbol{I_N}$- *Intermediary Node*

Begin

1. For every CH, position about their members must be updated i.e. M_C position;
If $(\boldsymbol{N_i} \in \boldsymbol{N_X})$, $\boldsymbol{N_X}$present in the neighbour list goes to step 2;
else go to step 1;

2. To select intermediary node $\boldsymbol{I_N}$, certain conditions must be satisfied;
If $(Res_E\ (Mc\ ) > Th_E\ )$, compare Threshold energy to $Res_E\ or\ M_C$
If the conditions must be satisfied goes to step 3;
else go to step 1;

3. SNR values are calculated for the$N - I_N$and $I_N - CH$ links
If$(\rho N1_N > \rho th\ \&\&\rho\rho_N CH > \rho th)$
Compare Threshold value to SNR values of $N - I_N$and $I_N - CH$links
node which satisfy the condition of both step 2 and 3 is selected as
Intermediary node $(\boldsymbol{I_N}\ )$

4. The Intermediary node $(\boldsymbol{I_N})$ gather and passes sensed data from M_c *to N;*
Then $(N_I =\ dstnt)$,
$data\ will\ be\ transmitted\ to\ sink\ node;$
The Intermediary node action gets stopped;

End

Where, $E_{I_N P}$ is the energy drawn to broadcast an $\mathrm{I_N}$ advertisement

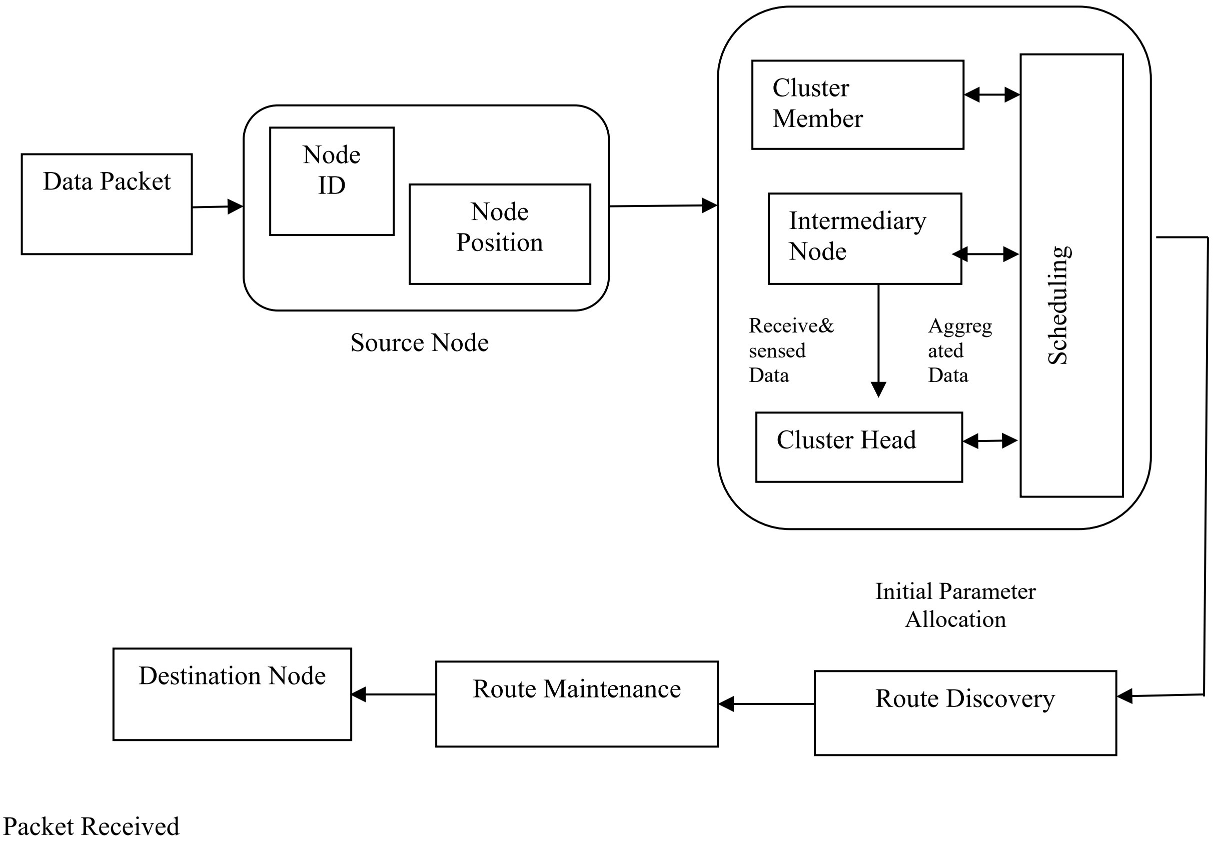

Figure 2. Block Diagram for CLEES-LEACH

5.1. Scalability

The $\mathrm{I_N}$ gathers, accumulates and conveys the data to the destination. Intra-cluster communication is made here with multi-hop distance. If the data is transmitted to the correct destination, then the intermediary node gets stopped and goes to sleep state. The CSMA/CA-based channel access mechanism is done by the member node of the cluster to transfer the data to the intermediary node. The received data by $\mathrm{I_N}$ is forwarded to their respective cluster head in its allotted TDMA slot. Figure 3 shows the TDMA frame structure. The TDMA scheduling is done first and then CSMA/CA access mechanism is made. The usage of this channel access mechanism among members of the cluster and intermediary node increases the scalability of the network i.e. packet delivery rate will be high.

Moreover, the total intake of energy by Intermediary node E_{I_N} for every round can credibly be computed as,

$$E_{I_N} = E_{I_N P} + E_{cgr} + E_{dap} + E_{GS} \qquad (9)$$

E_{cgr} is the energy intake to get sensed data from $\mathrm{I_N}$. E_{dap} is the energy drawn by information aggregation process.

$$E_{I_N P}(s) = N_{gm} * S_c * E_{elec} \qquad (10)$$

Where, N_{gm} are the nodes present in each group. S_c is the size of the control packet. E_{ele} is the energy consumed by a receiver or sender for a bit.

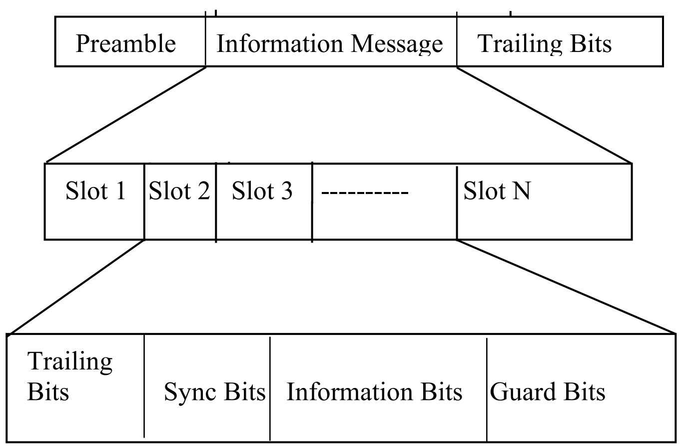

Figure 3. Structure of TDMA Frame

$$E_{cgr} = k * \left(N_{I_N} * s_d * E_{elec}\right) \quad (11)$$

Where, k is the number of data frames per round. S_d is the size of the data packet. N_{I_N} is the no. of intermediary nodes.

$$E_{dap} = m_{cor} * \left(s_d * E_{DA}\right) \quad (12)$$

Where, m_{cor} is the no. of the correlated data frame.

$$E_{GS}(s,d) = k * s_d \left(E_{elec} + \varepsilon fsd^2\right) \quad (13)$$

Where, εf is the free space factor and $E_{GS}(s,d)$ is the energy consumed while transmitting a packet between source s and destination d .

5.2 Route Maintenance

Once the path is discovered, routing is done based on the algorithm chosen. While routing, there is a high probability of occurrence of a rupture in any of the links. If a rupture occurs, the source node can find the existence of a route, or its absence, and use a different path to transmit data to the destination, in case of the latter.

5.3 Combined Design of Scheduling and CLEES Routing (CSCR) Mechanism

Combine Design of Scheduling and CLEES routing (CSCR) mechanism is employed to attenuate delay and maximize throughput. An 0-1 integer variable is assigned as Z_{xy} for every node in the network $n_i \in N_n$. If a node is recognized as the source node while generating the trees $n_i \in N_n^{t}$ the value becomes, $Z_{xy} = 1$. A positive real variable for each $n_i \in N_n$ are assumed as p_{ij} which signifies the actual data rate of n_i such that $p_{ij} = 0$ if n_i is not contained within generated routing tree. If so value of Z_{xy} changes to zero. To include edge in the generating tree an assumption of another 0-1 integer variable is assumed as e_{ij} for each edge $\left(n_i, n_j\right) \in E$. If there presents an edge in the tree, the value of the integer variable e_{ij} becomes 1. Besides, another positive integer variable f_{ij} is assumed for each edge $\left(n_i, n_j\right) \in E^{t}$ which represents the volume of data diffused from node n_i to node sink node n_j .

For transmission of data rates on each link, a time slot assignment must be done. $p_{ij,g}$ is an 0-1 positive real integer variable where (i, j) denote the link which is used to pass data from flow g. An assumption of decision variable $st_{ij,t} = 1$ denotes the direct link (i, j) use the particular slot t. For link L, if i and j are endpoints then slot can be defined as $st_{L,t} = sl_{ij,t} + sl_{ji,t}$. Here $sl_{L,t}$ is a 0-1 variable, as both links (i, j) and (j, i) couldn't access the slot t. To find an undirected link, the variable L is used. Based on the assumption of variable and the linkage between nodes the height of the TDMA frame can be made.

Let us consider the data g transmit through an intermediary node I_n from one of cluster members. Intermediary node I_n get data packet through inward link (m, I_n) and pass the data to outward link (I_n,n). Therefore, the latency generated at intermediary node I_n can be stated as $D_{g,mI_n,I_n n,q}$ where q represents the qth packet.

When a data packet is transmitted by the intermediary node there cause a delay based on data replication before forwarding to the destination. While forwarding information among the network, there occurs loss of energy and thereby using the above proposed routing mechanism conservation of energy is done. Furthermore, there may cause a higher delay and lower throughput. Furthermore, there may cause a higher delay and lower throughput. To overcome these limitations, combined delay and CLEESLEACH routing (CSCR) is formulated.

Table 2. lists the notations which will be used in this paper .

Table 2. List of Notations

Notation	Description
Z_{xy}	Integer Variable
f_{ij}	Positive integer variable
$p_{ij,g}$; P_f	Positive real integer variable
e_{ij}	Edge between two nodes i and j
I_n	Intermediary Node

st	Time Slot
L	Link
L'	Other links that are conflicting with L
g	Data flow
q	Data packet
Y_{ij}	Integer Variable
β_x	Assigned threshold value

6. Mathematical Model

The optimization problem for minimizing the delay and maximizing throughput is discussed here.

6.1 Delay

The optimization problem can be expressed as follows, Minimizing the delay is in equation (14),

$$\sum_{g}\sum_{I_n}\sum_{i=1} D_{g,I_n,i} \tag{14}$$

The delay modelling can be performed as,

$$sl_{L,t} + sl_{L',t} \le 1, \quad \forall(L, L') \in E', \forall t \tag{15}$$

$$sl_{L,t} = sl_{ij,t} + sl_{ji,t}, \quad \forall L(i,j), \forall t \tag{16}$$

$$sl_{ij,t} = \sum_{g}\sum_{q=1}^{P_{ij,g}} sl_{ij,g,t,q}, \quad \forall L(i,j), \forall t \tag{17}$$

In equation (15), (16), (17), the direct link (i, j) uses the particular slot t is the sum of data flow g with data packet q ranges from 1 to positive integer variable.

$$\sum_{t=1}^{S} sl_{ij,g,t,q} = Y_{ij,g}, \quad \forall Link(i,j), \forall g, \forall q \in \{1,.....P_f\} \tag{18}$$

Consider, in equation (18), an input flow going through an end-to-end path consisting of f virtual servers, 1... In parallel, P_f. For a P_f virtual server, if the number of its input links I j, is greater than 1, there may be other input flows I j Si, j= 2... P_f, which are coded in the following flow 1 Si, according to a network protocol.

$$D_{g,mI_n,I_nn,q} = max\{ D^{\iota}_{g,mI_n,I_nn,q} + (Y_{mI_n,g} + Y_{I_nn,g} - 2)N_o, 0\},$$
$$\forall g, \forall I_n \neq Source(g) \ or \ destn(g),$$
$$\forall m,n \in N_{I_n}, \forall q \in \{1, \ldots.. P_f\} \tag{19}$$

In equation (19), N_o is considered as the largest positive integer. While transmitting the flow of data g, if there exists no routing path on either of the link mI_n or $I_n n$, then by the side any one of $Y_{mI_n,g}$ and $Y_{I_n n,g}$ becomes value zero, therefore the term $Y_{mI_n,g} + Y_{I_n n,g} - 2$ will result in a value less than zero or negative, which implies that the first term $D^{\iota}_{g,mI_n,I_n n,q} + (Y_{mI_n,g} + Y_{I_n n,g} - 2)N_o$ will surely become negative. Subsequently, $D_{g,mI_n,I_n n,q}$ will be set to zero.

6.2 Throughput

Throughput is the quantity of data transported to the sink within the allocated time. As the delay present among the source and destination node is limited by time slot allocation, throughput can be minimized. But many goals need to be achieved in the network, and so there is an increase in the length of a TDMA frame. Thus, a high delay will be generated, which leads to no improvement in throughput. A TDMA frame with a small frame length must be constructed to optimize throughput. An integer decision variable Z_{xy} which has been mentioned earlier in TDMA slot allocation is considered. Here the frame length is chosen as a decision variable and so a threshold value is chosen. Based on this value alone, the number of slots can be allocated during transmission.

This model is established using the SNR (Signal to Noise Ratio) links provided in the routing algorithm. Links are established between the source to the intermediary node and intermediary node to sink for data transmission. To resolve this, the resembling factor is defined.

The resembling factor r is formally defined as follows:

$$r = \left\{ (Z^r_{lx}, Y^r_{ly}) \middle| l \in E, \ x = 1,.........X, y = 1,........Y, \right. \tag{20}$$
$$\left. SNR_l \ge \beta_x, \sum_{x=1}^{X} Z_{lx} \le 1, \sum_{y=1}^{Y} Y_{ly} \le 1 \right\}$$

Where Z^r_{lx} and Y^r_{ly} are the parameters denoting whether the link l is listed in r at x data rate, with the y level of power. β_x is the assigned threshold value.

Equation (20) indicates the number of slots γ_r, an integer decision variable. The resembling factor r is scheduled here. The variable Z_{xy} represents the target t_x for n number of sensors S_n where $n \neq 0$ at traffic T. Furthermore, another integer variable κ_l is used to represent the data packets send through the link l

throughout the entire TDMA frame of length (h). $t(l)$ And $R(l)$ represent the sender and receiver of a link l. σ is considered as a constant and $\Re$ represents the assigned positive variable. The throughput maximization can be solved by the following model:

$$\sum_{S_n \in S} Z_{xy} = q \qquad t_x \in T \tag{21}$$

$$\sum_{\substack{l\in E \\ R(l)=S_n}} \kappa_l + \sum_{t_x \in T} Z_{xy} = \sum_{\substack{l\in E \\ t(l)=S_n}} \kappa_l \qquad S_n \in S \tag{22}$$

$$\sum_{\substack{l\in E \\ R(l)=S_0}} \kappa_l = hq \tag{23}$$

$$\sum_{r\in\Re}\sum_{x=1}^{X} \Theta_x D_s Z_{lx}^{r} \gamma_r - \kappa_l \sigma \ge 0 \qquad l \in E \tag{24}$$

$$\gamma_r \ge 0 \; and \; i, \qquad r \in \Re \tag{25}$$

$$\kappa_l \ge 0 \quad and \; i, \qquad l \in E \tag{26}$$

$$Z_{xy} \in \{0,1\}, \qquad S_n \in S, t_x \in T \tag{27}$$

By having Constraint (21) it is confirmed that the target is enclosed by q sensors. Constraint (22) indicates the data flow preservation rule, the quantity of traffic that arrives at a node is the traffic transmitted by various other nodes and traffic created by target t_x.

It is identical to the traffic released by the node. Constraint (23) gives an assurance that the data packets are collected and received by the destination. Constraint (24) represents the channel capacity, which is the time for which the link l is contained within the scheduled matching represents $\gamma_r > 0$.

Thus, a minimum frame length is constructed and also the generation of traffic is minimized. Constraint (25), (26), (27) are conditions for throughput. Thus, the data packet can reach the destination without delay and the goal of transmitting maximum number of packets can be attained. As a result, maximum throughput is achieved.

7. Simulation Parameters and Settings:

In this part, evaluation is done for the proposed algorithms CLEES-LEACH and the CSCR model about their performance. Comparison is done with existing protocols LEACH and EEDS.

To make this happen, various metrics were considered such as number of alive nodes, number of rounds, delivered packets, average residual energy, throughput, network density, and delay. The CLEES-LEACH and Combine design of scheduling and CLEES routing models have been implemented using NS3 with a python simulator.

The simulation parameters used to examine the exhibition of the previously mentioned algorithms are recorded in Table 3.

Table 3. Simulation Parameters

Number of Nodes	100
NS Version	ns-allinone-3.27
Simulation Area	100m X 100m
Packet Size (Bytes)	512
Duration Period of Simulation(msec)	10
Rate of Data (bps)	128
Node's Initial Energy(J)	2
Transmitting Energy(J)	2.31
Receiving Energy(J)	2.28

Initially, cluster is formed by a group of sensor nodes. For each round, a head is selected depending on the distance, energy remaining among the member and head. A node transmits to the sink the packet through the intermediary node. The intermediary node is elected based on both residual energy threshold and SNR value threshold. Figure 4 represents the broadcasting of the packet from the source node to the cluster head through the intermediary node; again, the cluster head passes the data to the destination node.

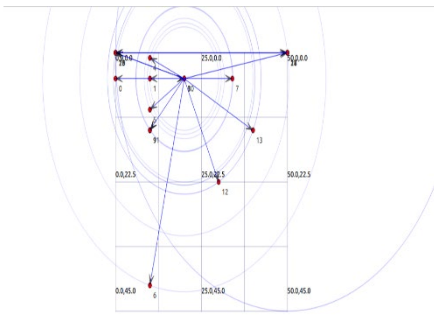

Figure 4. Data Packet Transmission in NS3 Setup

7.1 Performance Measures

The following are the main metrics used to evaluate the performance of the proposed protocol

1. ***Network Life Time:*** The number of Alive Nodes per round is considered as a measurement for network lifetime. Alive nodes represent the number of nodes that have not exhausted all of their energy.

2. ***Throughput:*** Throughput measures the total data rate sent over the wireless network, including the data rate sent from Cluster Heads to the sink node and the data rate sent from the nodes to their Cluster Heads.

Network Throughput is the ratio of the number of packets received by the sink to the number of packets sent from the source in a given unit of time.

3. *Scalability:* Even though the number of nodes is keep on increasing, the performance of the network should not degrade.

To evaluate the most effective one for the scalability, the efficiency of different routing protocols is evaluated.

4. *Energy Consumption*: Energy consumption is the sum of the energy used for transmitting, receiving and processing by all the nodes in the network.

Assuming that each transmission consumes an energy unit, the total energy consumption is equal to the total number of packets sent through the network.

5. *Packet Delay:* The time required by a packet to reach from source to destination is called packet delay. It is calculated by dividing the distance from source to destination by the speed of light.

***6. Latency*:** The average latency of the message is the average time between the start of propagation of data and its arrival at the intended recipient.

8. Implementation and Performance Analysis

In this work, performance is analysed by using the following characteristics: total alive nodes present, average remaining energy, packets delivered and network density. These characteristics of the proposed method are related to other existing works such as LEACH and EEDS.

8.1 Number of Alive nodes

To evaluate the efficient usage of energy, the number of alive nodes present in each round must be estimated. Figure 5 represents that the round increases from 0 to 100. The number of alive nodes must be calculated for each round to find the efficient usage of energy in the networks. In the proposed work, when the number of rounds is 20 the alive nodes present is 80 and for the round 80 alive nodes increase to 92, and finally when the 100th round goes on the alive nodes present gradually increases to 93.

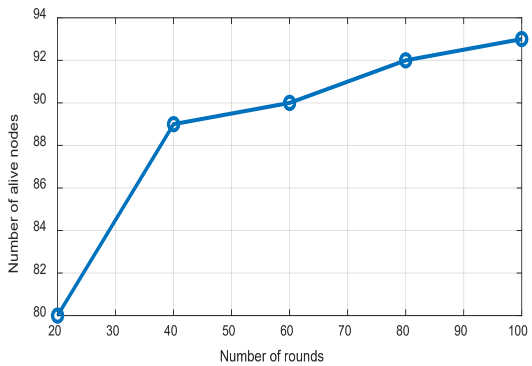

Figure 5. No. of Alive Nodes present in the network for proposed Protocol

The total alive nodes present in the network for both proposed and existing are provided in the table below.

Table 4. Comparison of Alive Nodes Present for Various Rounds

Number of Rounds	LEACH	CLEES-LEACH
20	80	84
40	89	92
60	90	94
80	92	95
100	93	98

Figure 6 represents that the round increases from 0 to 100. The number of alive nodes present gradually increases as the number of rounds increases.

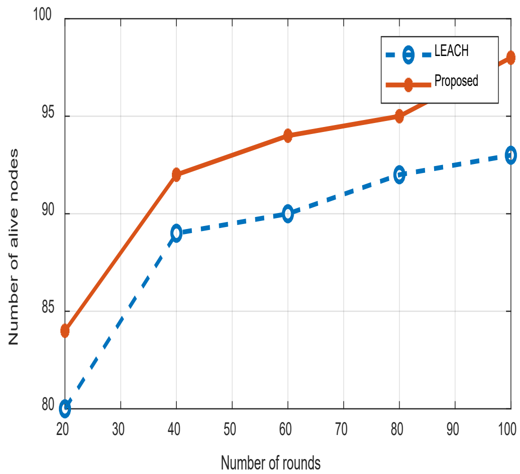

Figure 6. Comparison of Number of Rounds Vs Alive Nodes

8.2 Average Residual Energy

For every node, initial energy is calculated and if the value is more than zero then it is considered as an alive node. According to the cluster head selection algorithm, the cluster head is selected for each round. Association of the nodes will be done with the nearest CH by using cross layer optimization. By using this remaining energy, all nodes are evaluated. In Figure 7, the number of rounds increases from 20 to 100. The residual energy of a cluster during round 20 is 15. There occurs a fall in value at round 40 and again at round 100 tremendous increase of energy to 16.5. Based on this it is assumed that alive nodes present will be higher than dead nodes.

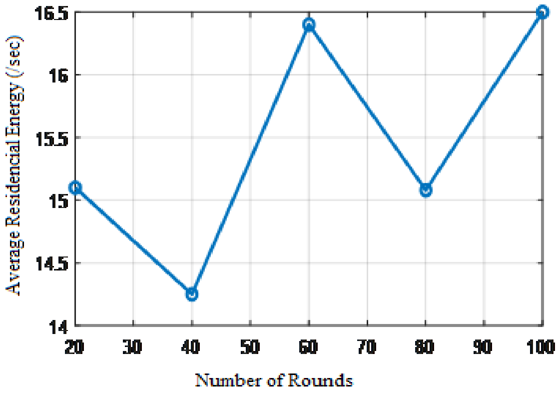

Figure 7. Number of Rounds Vs Average Residual Energy for the proposed protocol

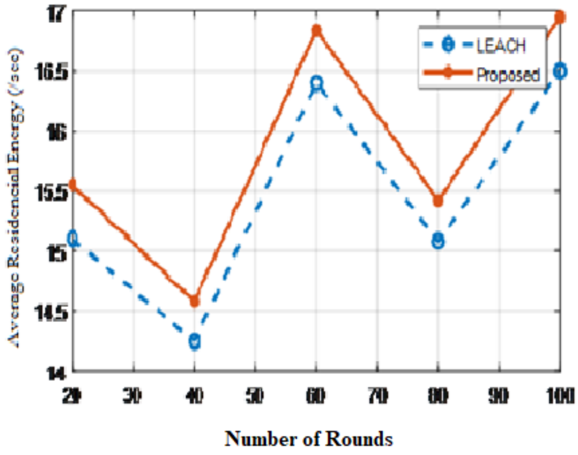

Figure 8. Number of Rounds Vs Average Residual Energy

The existing LEACH protocol accepts the identical energy for every round which leads to an ineffective CH selection and increases the consumption of resources. However, CLEES-LEACH selects the cluster head based on remaining energy and average distance among nodes and cluster head. From the investigation of both existence of alive nodes and remaining energy, the proposed method shows efficient usage of energy better than the existing protocol. The total alive nodes present in the network for both proposed and existing are provided in the below table.

Table 5. Comparison of Average Residual Energy Present for Various Rounds

Number of Rounds	LEACH	CLEES-LEACH
20	15.1	15.55
40	14.25	14.58
60	16.4	16.84
80	15.08	15.42
100	16.5	16.95

The comparison graph for efficient usage of energy based on total alive nodes exists and average residual energy is shown in Figure 8.

The total number of rounds executed is 100 and a new cluster head is chosen for each round. More consumption of energy arises during CH selection. Therefore, it is improved in CLEES-LEACH method and thus the graph in Figure 8 shows the proposed work is better comparing to the existing systems.

The initial energy of the nodes is set as 2 Joules. While performing numerous tasks related to transmission, the residual energy starts diminishing over time and finally reaches zero. The exhausted state specifies the termination of the simulation. The average remaining energy for each round is calculated by the total of the entire alive node's residual energy divided by the total alive nodes present in a specific round.

8.3 Scalability

CLEES-LEACH follows cross layer approach which helps in supporting scalability through the intermediate node and cluster member node. Figure 9 shows the successful packet delivery of the network.

8.3.1 Number of nodes versus Delivered packets (for 100 nodes)

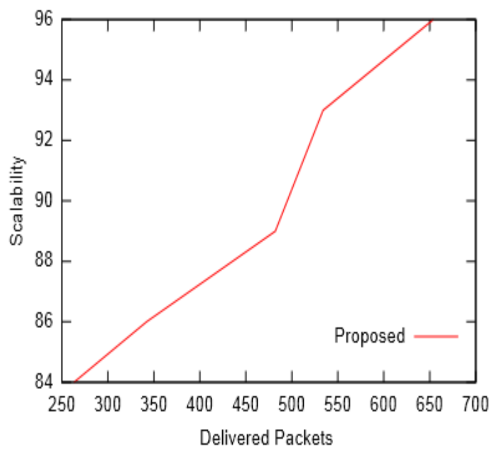

Figure 9. Data Packets Delivered for 100 Nodes

The progression of scalability for the system depends on the nodes considered in each round and intermediary node. By using these values, packets are delivered to the destination with a data rate of 128 bps. Figure 9 shows that the data packets reached the destination using CLEES-LEACH and thus are significantly much better than LEACH.

8.3.2 Number of nodes versus Delivered packets (for 200 nodes)

In Figure 10, scalability evolution is done for 200 nodes. The packets received by the sink node for the proposed CLEES-LEACH are higher than LEACH protocol.

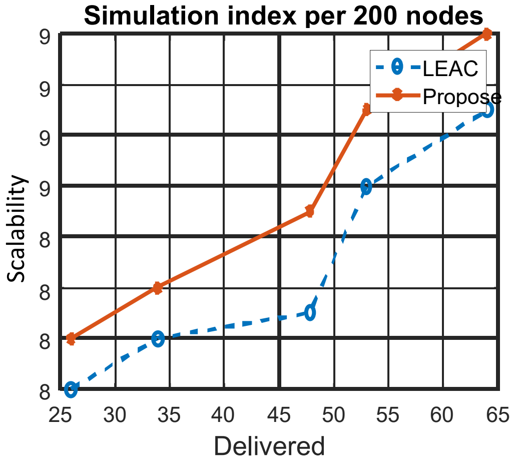

Figure 10. Data Packets Delivered for 200 Nodes

In Figure 11, Scalability for existing protocol LEACH, CL-LEACH and the proposed CLEES-LEACH are shown.

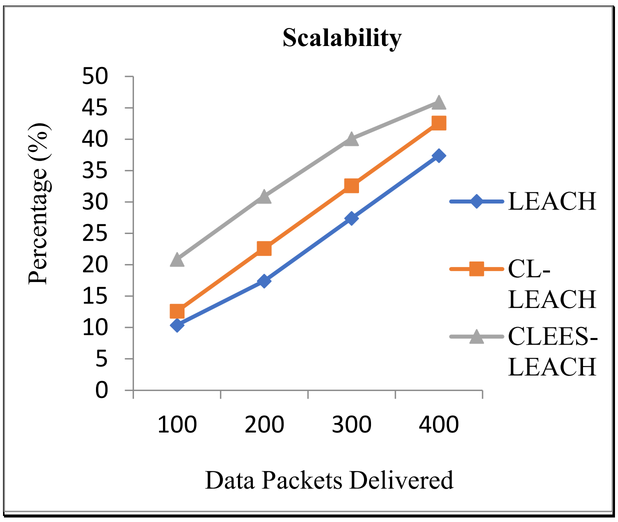

Figure 11. Scalability for existing protocol LEACH, CL-LEACH and proposed CLEES-LEACH

8.4 Throughput

Figure 12 depicts that the proposed algorithm maximizes the throughput for the higher density network. It is observed that the solutions show the maximization of throughput with higher network density. When wireless sensor networks increase their energy consumption, the number of active nodes present in the entire network is reduced. Thus, network connectivity is reduced and it is difficult to forward packets only by the cluster heads to the base station. However, the sensor nodes present in the network can forward the packets in the proposed routing algorithm using cross layer approach. So, this algorithm is more helpful when the number of nodes in wireless sensor networks is insufficient.

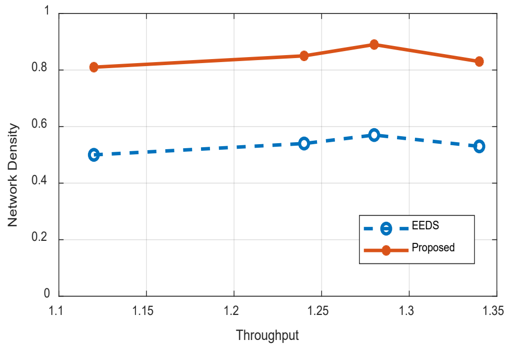

Figure 12. Network Density Versus Throughput

Table 6 shows the Comparison values for Throughput for EEDS, ILP, and CLESS-LEACH protocols.

Table 6. Comparison Table for Throughput VS Network Density

Methods	Throughput (kbps)	1.0	1.5	2.0	2.5
EEDS	Network Density	0.5	0.7	0.79	0.82
ILP		0.7	0.5	0.4	0.89
CLEES-LEACH		0.8	0.82	0.84	0.92

Figure 13 shows the Comparison graph values for Throughput for EEDS, ILP and CLESS-LEACH protocols.

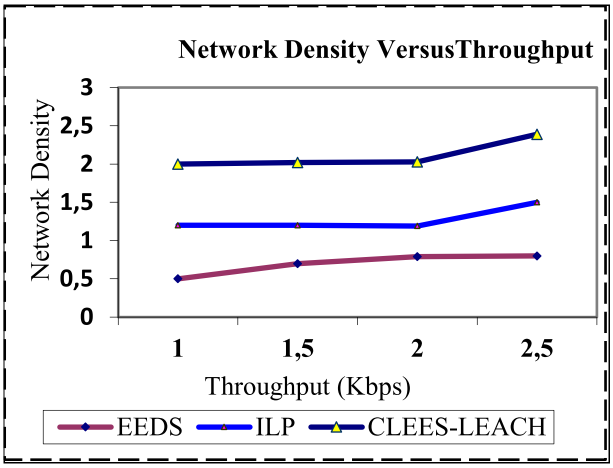

Figure 13. Comparison Graph for Throughput for Existing

Protocols Vs CLEES-LEACH Proposed Protocol

8.5 Latency

The Combined design of scheduling and CLEES routing model is used to minimize the Latency. The graph shows that latency has been reduced in the CLEES-LEACH model which is much better than the existing EEDS model. Regarding the performance of the proposed routing protocol, it is clearly shown that the proposed work is much better in terms of energy efficiency, scalability, latency, and throughput. The Figure 14 shows the graph of latency vs network density for EEDS and CLESS-LEACH protocols. Table 7 shows the Comparison values for Latency for EEDS, ILP, and CLESS-LEACH protocols.

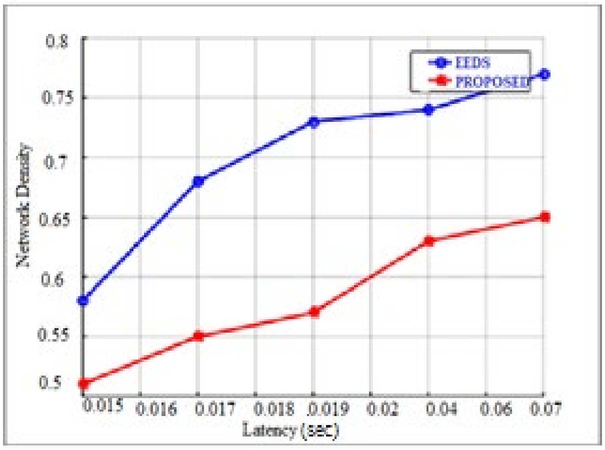

Figure 14. Network Density versus Latency

Table 7. Comparison Values of Latency

Methods	Latency
EEDS	48%
ILP	35%
CLEES-LEACH	25%

Figure 15 indicates the comparison values of Latency with the existing and the proposed routing mechanism.

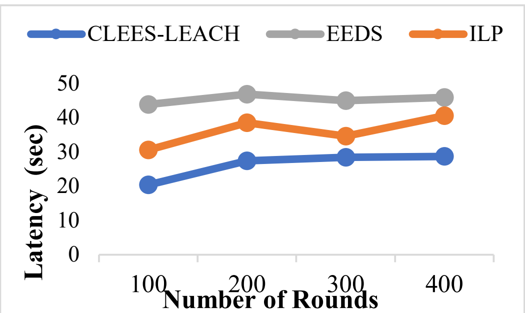

Figure 15. Latency Comparison Graph of CLEES-LEACH and Existing Protocols

8.6 Delay

To minimize delay, the Combined design of scheduling and CLEES LEACH Routing model (CSCR) is used. By the usage of both scheduling and linking route, delay can be reduced. The graph shows that lower delay has been raised in the proposed CLESS-LEACH Combine design of scheduling and Routing model (CSCR) which is much better than existing EEDS and ILP protocol.
Figure 16 shows the Comparison graph values for Delay for the Existing EEDS Protocol and the Proposed CLEES-LEACH protocol using NS3 simulation.

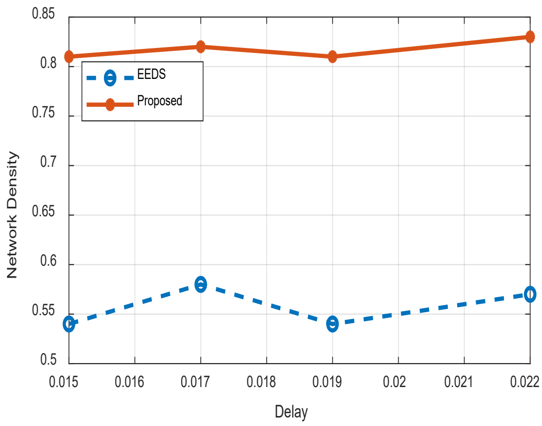

Figure 16. Network Density versus Delay

Table 8 shows the Comparison values for Delay for EEDS, ILP and CLESS-LEACH protocols.

Table 8. Comparison Values of Delay

Methods	Delay
EEDS	37%
ILP	26%
CLEES-LEACH	22%

Figure 17 shows the Comparison graph values for Delay for EEDS, ILP and CLESS-LEACH protocols.

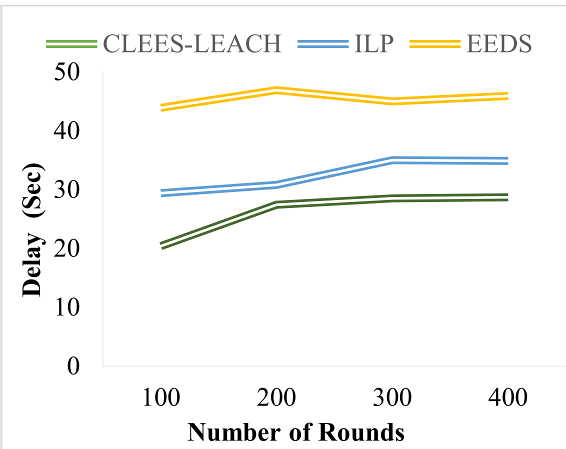

Figure 17. Delay Comparison Graph of CLEES-LEACH and existing EEDS, and ILP protocols

Figure 18 shows the Energy Consumption for existing protocols and proposed Protocol. In the proposed CLEES-LEACH Protocol, energy consumption is reduced to 20% compared to existing protocols.

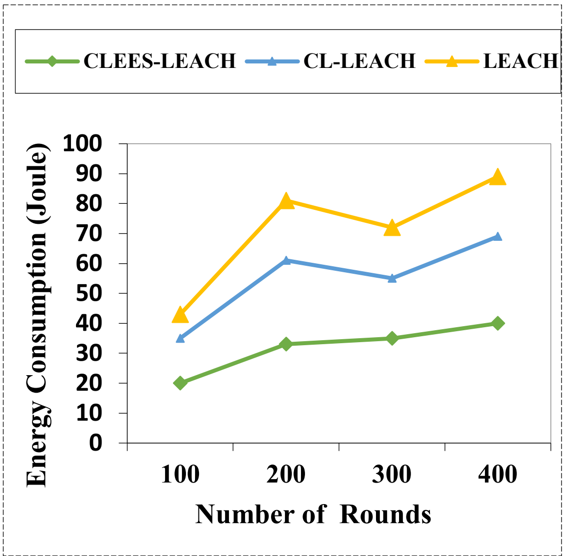

Figure 18. Graph of Energy Consumption for existing protocols and proposed Protocols.

9. Conclusion

In this paper, the efficiency of the proposed Cross Layer Energy Efficient with Scalability LEACH (CLEES-LEACH) is analysed based on average residual energy and active condition of sensor nodes in each round. The proposed model enhances energy efficiency along with QoS parameters. The QoS parameters, Latency is reduced to 25% and throughput is increased to 20% than the existing protocols EEDS and ILP. Energy consumption is reduced to 20% and scalability is improved to 10% compared to the existing protocols LEACH and CL-LEACH.

In the future, other QoS parameters such as reliability and bandwidth can be enhanced using CLEES-LEACH routing protocol.

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