Enhancing WSN Lifespan Based on Efficient-Energy Management Approach for Cluster Head Selection in IoT Application

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Abstract. *Wireless sensor networks (WSNs) are one of the most important components in the connected world i.e. Internet of Things (IoT). WSN is a network of distributed sensor nodes that communicate wirelessly to transmit and receive real-time data. These sensor nodes play a crucial role in monitoring various environments, enabling smarter decision-making and improving efficiency across numerous applications. This paper presents an energy-efficient protocol based on low energy adaptive clustering hierarchy (LEACH) for improving the lifetime of WSN. The proposed method modifies the basic LEACH protocol and incorporates the factors of residual energy of the network, number of neighbor nodes, average energy of the network, and threshold distance between the nodes and base station. The proposed work compares the result with the existing methods and has shown the improvement in the network performance parameter metrics. The simulation results show an improvement in the network lifetime due to better energy management, thus increasing the number of data packet transfers.The proposed method has shown improvement by 13% over the first dead (FD) node of EEBC-LEACH, 5% improvement over half dead (HD) node of PEGASIS, and 3% improvement over all dead (AD) nodes of FBCR-LEACH.*

Keywords

Internet of Things (IoT), wireless sensor network (WSN), LEACH, cluster head (CH) selection, proximity, network energy

1. Introduction

Wireless sensor networks (WSN) play an important role in the Internet of Things (IoT) world. WSN has many applications in smart communities, such as smart hospitals, buildings, agriculture, military, civil services, etc [1]. The WSN enables a reliable and controlled monitoring of these areas. Gartner's research report has suggested a massive rise in number of IoT-enabled networked devices. The IoT has transformed traditional way of living and working into high-tech areas through the integration of intelligent device applications and technologies that enable automation and offer various user services. The state-of-the-art (SOTA) in IoT refers to the cutting-edge technologies and latest advancements. The SOTA in IoT has wide spectrum of technologies and applications that may include:

- 5G and 6G communication,
- AI and edge computing,
- Blockchain for security,
- Digital twins,
- Low-power IoT devices etc.

The above technologies have various IoT applications in smart urban cities, connected automobiles, wearables, smart grids, industrial internet, smart supply chain, etc., and shall utilize the potential of IoT to its fullest. This will need an efficient energy management approach for enhanced WSN lifetime. For developing the smart systems, low-cost sensor-based embedded devices (sensor nodes) are used. Using these embedded devices creates a wireless network and these network systems are deployed in any application-specific area that wants to be controlled and monitored [2].

Nodes deployed in the WSN area communicate real-time information to the base station (BS). The sensor nodes may transmit information in many ways. If sensor nodes communicate directly, then they will consume more energy, which will decrease the life-cycle of the network. On the other hand, one can use some energy-efficient WSN protocol, which enhances the life-cycle of the network. It is observed that much of the research is done and also going on to achieve better performance of WSN by improving the energy efficiency of the systems [3]. The term energy efficiency is directly or indirectly related to many aspects of smart IoT systems. To improve the performance of the systems, various experiments were performed on various key aspects such as quality of service parameters, routing techniques, wireless communication device, security methods, wireless communication protocols, [4] etc.

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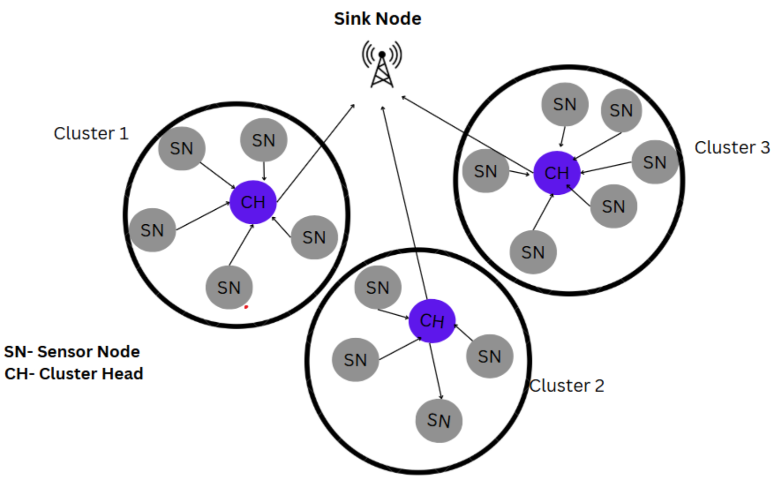

Fig. 1. Basic LEACH architecture.

The clustering is one of the primitive approaches in hierarchical routine protocol. The approach divides the network into several disjoint clusters. Each cluster has a cluster head (CH), which acts as a gateway between its member sensor nodes (SN) and sink node or base station (BS). For effective clustering, CHs must be uniformly distributed throughout the network. If CHs are assigned too close or too far apart, the protocol may not be energy efficient. Using the low-energy adaptive cluster head (LEACH) technique increases the lifespan of the wireless sensor network, the basic architecture of LEACH protocol is shown in Fig. 1. However, the LEACH exhibits poor energy management due to its random CH selection approach. The network life cycle of WSN is directly related to the energy or power consumption of the network because a more energetic system has more life. In the WSN generally, the tiny sensor nodes with limited energy capability are deployed randomly in particular application-specific areas. These sensor nodes send the information to the sink node (base station) for monitoring and controlling the application through wireless communication technologies like Bluetooth, Zigbee, Wi-Fi, [5] etc.

Sometimes, the sensor nodes may be deployed in hazardous environments. So, replacing or recharging the batteries is challenging. To address these shortcomings, researchers have prioritized the effective utilization of sensor nodes battery energy when creating hardware architectures and protocols. Consequently, many protocols have been proposed to increase the lifecycle of sensor networks [6].

The main goal of this research is to improve the lifetime of WSN by using the hierarchal routing method. A novel energy-efficient protocol is developed by modifying the low energy adaptive clustering hierarchy (LEACH). For enhancing the network lifetime, the proposed method take into account the important network parameters like initial energy, remaining energy of sensor nodes, an optimal number of CH in the network, and distance between the neighbor nodes.

The contribution of the proposed work could be briefed as follows:

- To propose an effective clustering algorithm for finding most suitable CHs based on node energy and distance between the neighboring sensor nodes.
- To decide an appropriate number of nodes in each cluster for every round.
- To enhance the WSN life-time and improve throughput.

The rest of the document is organized as follows: Section 2 discusses the related work. Section 3 describes the basic system model of network and energy dissipation. Section 4 discusses the proposed method. Section 5 addresses the simulation parameters and implementation process. The network performance evaluation and results are mentioned in Sec. 6. Finally, conclusions are drawn in Sec. 7.

2. Related Work

In IoT, a large number of sensor nodes are deployed to collect and transmit data in real-time. These nodes play a crucial role in monitoring various environments, enabling smarter decision-making, and improving efficiency across numerous applications. One of the major challenges in IoT is to manage these sensor nodes in terms of access, energy consumption, security, and maintenance [7]. These sensor nodes are low-power devices that often rely on limited battery life, thus requires efficient energy management, which is essential, and efficient use of the sensor nodes is necessary to address these challenges [8]. Researchers are exploring various approaches that can enhance the reliability and lifetime of WSN. Numerous routing protocols have been proposed to address the limitations imposed by WSNs, improving energy efficiency and extending network lifetime [9–11].

In recent years, researchers have focused a lot of attention on the cross-layer cluster-based routing protocol. The number of clustering protocols works in two sections: one is the setup phase another is the steady state phase. During the setup phase, a CH is chosen using centralized, hybrid, or distributed criteria, efficiently creating several clusters within

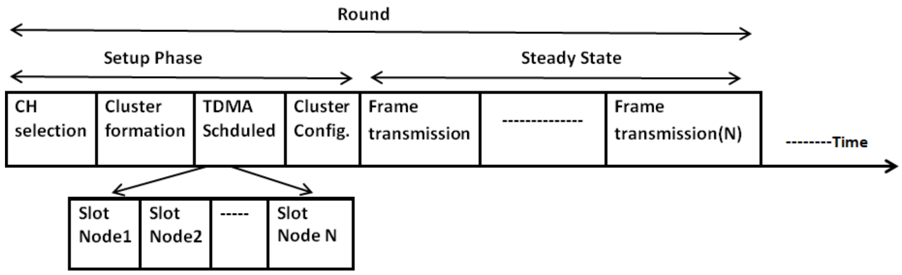

Fig. 2. LEACH operation.

Method	Year	Features	Weakness
LEACH [12]	2000	Distributed, CH value rotate, low energy saving	Random, single hope, uneven CH distribution
LEACH-C [13]	2002	Evenly distributed cluster using simulated annealing	Random, single hop
PEGASIS [23]	2002	Distributed, energy efficient, high scalability	Chain based selection, single hop
HEED [24]	2004	Distributed, topology-based, multi-hope	complexity high
TL-LEACH [25]	2005	Distributed, high energy efficiency, hybrid	Low scalability
LEACH-L [26]	2008	Distributed, high scalability, energy efficient, hybrid	Complexity high
I-LEACH [16]	2013	Distributed, improved CH value, energy efficient	Random, single hop
EE-LEACH [27]	2015	Distributed, energy efficient, multihop	Complexity high
IEE-LEACH [28]	2019	Distributed, energy efficient, hybrid	Complexity high
EADCR-LEACH [29]	2020	Centralize distribution, improve energy efficiency	Moderate Complexity, single hop
EACR-LEACH [30]	2022	Distributed, improve energy efficiency	Moderate Complexity, single hop
EES-LEACH [31]	2023	Distributed, improve CH selection	Moderate Complexity, single hop
FBCR-LEACH [32]	2023	Distributed, fuzzy based CH selection	Moderate Complexity, single hop
Proposed method	2025	Distributed, energy efficient, improve CH selection	Moderate Complexity, single hop, less scalability

Tab. 1. Clustering-based routing protocols.

the network. During the steady-state phase, each cluster's member nodes transmit sensor data to the CH node in each of the TDMA slots that the CH allocated them during the setup phase. After gathering all of the data, the CH compiles it and forwards it to the base station (BS).

The hierarchical protocols, such as the LEACH protocol, are among the earlier reported most efficient approaches. The LEACH was proposed to enhance the efficiency of WSN by dividing the network into clusters, and through a random CH selection (Fig. 1). In the steady state phase data is communicated from node to base station via cluster head. The LEACH is the first hierarchical routing protocol that uses clustering and MAC protocol based on the time division multiple access (TDMA) technique. The LEACH process is divided into two phases: one is the set-up phase followed by the steady-state phase. The set-up phase, randomly selects the clustether head (CH) and CH forms a cluster then creates a TDMA scheduled for the sensor nodes. During the steady state phase, the data is collected from sensor nodes in cluster and sent to base station through the cluster head, with data aggregation occurring at CH level. The process is shown in Fig. 2 [12]. The LEACH is a distributive cluster formation algorithm. In this protocol, CH counts are not fixed, and even the number of nodes assigned to the clusters also vary [13]. This results in poor energy management of the network thereby reducing lifetime.

To overcome the drawback of LEACH, a central control algorithm is proposed, where nodes send their information on energy level and position to the base station. On the basis of node information base, the station selects the CH and steady-state phase is the same as LEACH. In this research, the central control algorithm considers residual energy and distance between the nodes for the selection of CH [14]. Several residual and distance-based CH selection techniques, such as enhanced centralized (EC-LEACH) [15], Improved-LEACH [16], energy-efficient balanced cluster (EEBC-LEACH) [17], and low energy adaptive clustering with deterministic cluster-head selection (LEACH-DCS) [18] have been developed in previous works. In this study, the author suggested that the CH election algorithm uses the minimum and maximum distance [19]. The Balance Residual Energy LEACH (BRE-LEACH) further enhanced the LEACH algorithm to extend the network lifetime through energy consumption optimization. Three criteria form the basis of this protocol operation viz multi-hop, residual energy, and distance to the base station (BS) [20]. Some works, elect the best-suited node as the cluster head considering the remaining energy and its distance from the other nodes [21], [22].

Table 1 illustrates the few descendants of LEACH in relation to a few factors. From the surveys, it is observed that CH selection is an important parameter used in various research to enhance the life of WSN. In the entire process of CH selection, energy management and the number of cluster heads in the network play an important role.A comparison of salient feature and weakness of few popular algorithms along with the proposed approach presented in Tab. 1

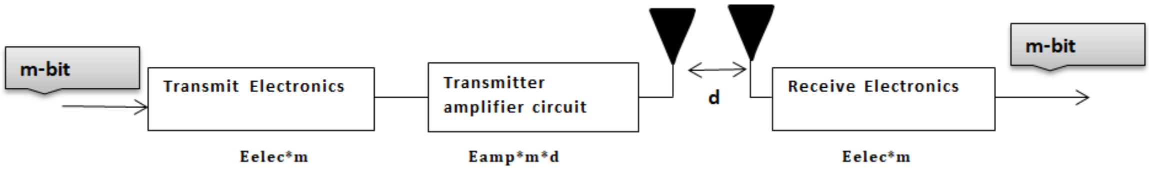

Fig. 3. Radio energy dissipation model.

3. Basic System Model

3.1 Energy Dissipation Model for Radio Signal

The energy consumed by sensor nodes during various phases of operation, particularly for communication and data aggregation, can be estimated by first-order model. The radio energy dissipation model consists of a transmitter circuit (radio-electronic and power amplifier) and receiver circuit (radio-electronic), as shown in Fig. 3, and its energy consumption is given (1) and (2), respectively.

$$E_{\mathrm{TX}} = \begin{cases} m \cdot E_{\mathrm{elec}} + m \cdot E_{\mathrm{fs}} \cdot d^2 & \text{if } d \le d_0, \\ m \cdot E_{\mathrm{elec}} + m \cdot E_{\mathrm{mp}} \cdot d^4 & \text{if } d > d_0, \end{cases} \tag{1}$$

$$E_{\mathrm{RX}} = m \cdot E_{\mathrm{elec}}, \tag{2}$$

$$d_0 = \sqrt{\frac{E_{\mathrm{fs}}}{E_{\mathrm{mp}}}}. \tag{3}$$

The E_{TX} and E_{RX} are the energy consumed at the transmitter and receiver respectively, d_0 is threshold distance (3). The energy consumption depends on the distance between the transmitter and the receiver d, data packet length m, energy consumed in the transmitter and receiver electronics E_{elec}, multi-path energy E_{mp}, and free space energy E_{fs}, n is the number of nodes. The threshold $T(n)$ is computed using the probability p for a node to be a candidate for CH.

$$T(n) = \begin{cases} \frac{p}{1-p\cdot\left(r \mod \frac{1}{p}\right)}, & \text{if } n \in G \\ 0, & \text{otherwise}, \end{cases} \tag{4}$$

where G is the collection of the nodes that have not yet been CH in the last $1/p$ rounds.

3.2 Assumption for Network Model

In this section, consider a WSN model with n number of nodes and L×L area in which nodes are randomly distributed. The basic network architecture of the WSN is illustrated in Fig. 1. It shows clusters with some nodes in each cluster, and each cluster has a cluster head (CH). The CH node gathers data from other nodes, processes it, and then communicates it to the base station. The position of the randomly distributed sensor nodes and the base station are shown in Fig. 4. The following assumptions are made during the wireless sensor network area deployment & distribution of sensor nodes.

- All sensor nodes are stationary and randomly placed.
- Each node has a finite amount of energy and have similar energy consumption, computational power, and storage capabilities (homogeneous).
- The base station is located at the center of the sensing area, and is static with unlimited energy.
- The node inside the cluster sends its data through the cluster head and other remaining nodes (not part of any cluster) send data directly to the base station.
- The nodes are unaware of their precise location or those of neighboring nodes.
- The nodes are autonomous. Therefore, it is self-organized and does not require supervision after distribution.
- Every node is capable of acting as the cluster head.
- The nodes are not harvesting energy.

The simulation with the above assumption may hold good with real-world scenarios like smart buildings, agriculture, hospitals, etc. To an extent, the results from the simulation models with given assumptions may replicate the real-world scenario. However, the actual results and performance may differ due to many factors affecting the outcome. The deviation in results may be due to the facts that in real-world scenario, the sensing area may not be geometrically symmetric, the sensing nodes energy depletion rate may not be identical, the sensing area may be affected by strong EM interference etc.

4. Proposed Method

In order to extend the network's lifetime, the proposed method modifies the basic LEACH protocol and incorporates the factors of the residual energy of the network, average energy, the number of neighbor nodes, and the threshold distance. The use of these controlling factors results in better energy management of the network.

4.1 Optimal Number of Cluster Selection

An efficient network can be achieved by getting an optimal selection of a number of clusters. The cluster heads of the clusters consume a major portion of energy in the data acquisition, aggregation, and transmission. Hence limited and optimal number of clusters will dissipate less energy.

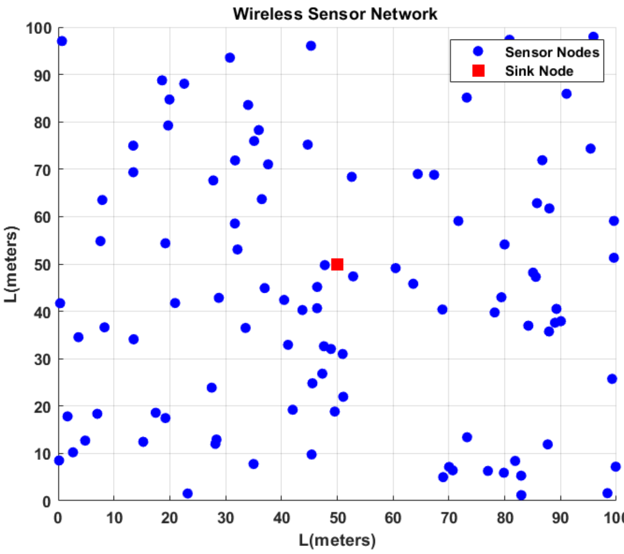

Fig. 4. Wireless sensor area network with distributed nodes.

In the basic LEACH method, non-uniform clusters head selection and formation occur, which leads to higher energy dissipation. So to achieve the optimal number of cluster heads, proper selection is necessary [33]. Therefore, carefully choosing cluster heads with network parameters such as residual energy, distance, and neighbor nodes that can create balanced clusters and fairly cover the entire sensing area. In this section, it is assumed that n sensor nodes are evenly scattered throughout a square area of L×L (Fig. 4).

4.2 Cluster Head Set-up Phase

In the set-up phase, each node's potential to become CH is decided based on residual energy, initial energy, average energy, and the number of neighboring nodes, and the threshold distance whether or not to become a cluster head for the current round. The selection also depends on decisions made by the nodes by choosing a random number between 0 and 1. If the number is less than threshold $T_1(n)$, also called as improved probability function (IPF), the node becomes cluster head for the current round. Otherwise, it acts as a normal node (NN). Equation (5) defines the total residual energy of the active nodes and Equation (6) shows the average energy of the network:

$$E_{\text{residual}} = \sum_{i=1}^{n} SN(i).E, \tag{5}$$

$$Avg.E = \frac{\sum_{i=1}^{n} SN(i).E}{n} \tag{6}$$

where E_{residual} is the residual energy of network and $SN(i).E$ is the current energy of the sensor node $SN(i)$. Based on the threshold $T(n)$ given by (4), a new threshold $T_1(n)$ is computed as shown in (7):

$$T_1(n) = \begin{cases} \frac{p}{1-p\cdot\left(r \mod \frac{1}{p}\right)} \times \frac{SN(i).E}{E_0}, & \text{if } n \in G, \\ 0, & \text{otherwise} \end{cases} \tag{7}$$

where p is the probability. E_0 is initial energy of node and r is the current round. The ratio E_{residual}/E_0 serves to favor the nodes of residual energy higher than the average residual energy of being CHs. The comparison of initial node energy with the average energy of the network suggests a potential candidate for cluster head (CH). Each sensor node also compares with a random number generated between 0 and 1. If this value is less than the threshold, the node is picked out for a CH selection process at the current round. Subsequently, the CHs broadcast the information to the other nodes. Depending on the strength of the received signal, each normal node determines the cluster to which it belongs. After determining the cluster, nodes send a confirmation message to their CHs. The cluster head setup phase is shown by the flow diagram in Fig. 5.

4.3 Cluster Formation Process

All sensor nodes are randomly distributed in the monitoring area. Each node has a unique ID and is aware of its residual energy. Non-CH nodes select CH based on energy and proximity. The node informs its chosen CH by sending a join request message. Each CH maintains a list of its cluster members. The CH defines the TDMA schedule according to the number of cluster nodes and their proximity. All cluster members' time slots are included in the TDMA schedule, which the nodes use to send data to the CH. During the transmission only the transmitting node remains active, and other nodes will be in sleep mode thus process saving the energy of nodes. When all the nodes have sent their data to the cluster head, the cluster head starts processing the received data: aggregation, reduction of redundant data, and compression of the data for fair bandwidth utilization. The CH nodes transmit data to the sink node/base node using single-hop communication. Nodes closer to the base station send data directly to the base station instead of routing it through any nearby cluster head.

5. Simulation Parameters

A randomly distributed WSN area of 100 m × 100 m with a total randomly distributed 100 sensor nodes with similar initial energy are used for network simulation in the MATLAB environment. With assumptions made in Sec. 3.2, the simulation parameters listed in Tab. 2 are used in the experiment. The homogeneous wireless sensor network model is used for simulation. The position of the base station is kept in the center 50 m × 50 m [34]. So, maximum distance between the sensor node to base station is $50\sqrt{2}$ (about 70.71 m) as shown in Fig. 4. The simulation is conducted for 3000 rounds and tested on MATLAB 2018a. The source code can be made available on request.

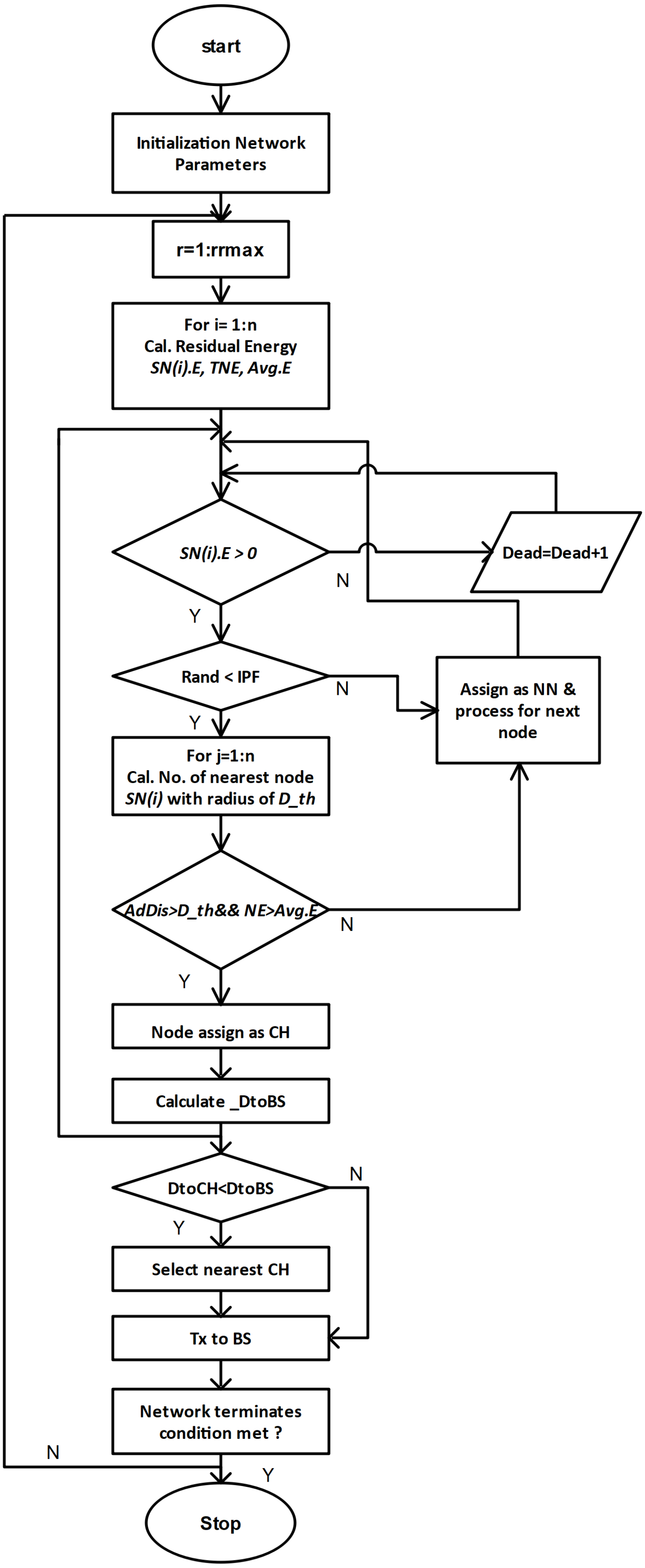

Fig. 5. Flow diagram of proposed method.

Parameter description	Symbol	Value
Number of Nodes	n	100
Probability	p	0.05
Initial node energy	E_0	0.5 J
Energy consumed by the amplifier to transmit at a short distance	E_{mp}	0.0013 pJ/bit/m^4
Energy consumed by the amplifier to transmit at a longer distance	E_{fs}	10 pJ/bit/m^2
Energy consumed in the electronics circuit to transmit or receive the signal	E_{elec}	50 pJ/bit
Data aggregation energy	EDA	5 nJ/bit
Data packet length	m	4000 bits
WSN area	L×L	100 m×100 m

Tab. 2. Simulation parameters.

5.1 Implementation of Proposed Method

The sensing area of 100 meters by 100 meters is initialized, and 100 sensor nodes are randomly scattered in the WSN area. The first round starts with assigning the same initial energy to all sensor nodes and setting up the variables. For each round, the total energy (TNE), average energy ($Avg.E$) and residual energy ($SN(i).E$) of all nodes are calculated. The residual energy of the node is calculated and checked if it is equal to 0, then that node is labeled and counted as dead node (Dead), otherwise, the node will continue to take part in the clustering and communication process. A random generated number (ranging between 0 to 1) is compared with the improved probability function (IPF) $T_1(n)$. If the IPF is less than the generated random number then the node is assigned as normal node (NN), otherwise this node is a fit candidate as CH. The number of nodes positioned within the threshold distance from this node are counted and stored in $AdDis$. The $AdDis$ count value is compared with the threshold node count value. If $AdDis$ is greater than the threshold node count value (D_th) and the node energy (NE) is greater than the average energy ($Avg.E$), then the node is elected as a cluster head (CH). Otherwise, it is assigned as a normal node (NN).

In the next phase of the current round, the distance between the nodes to cluster heads and the nodes to the base station is computed. All nodes nearer to the CH will be assigned to the cluster and will send the data to their assigned cluster head. Otherwise, the node will communicate directly with the base station. All these steps are repeated until all nodes are dead. All this process is shown in Fig. 5 flow diagram of the proposed method.

6. Network Performance and Results

The performance of the proposed algorithm is compared with three popular protocols, viz, LEACH [13], LEACH-C [14], and EEBC-LEACH [17]. Important network performance parameters, like the number of dead and alive nodes, total network energy, and throughput (number of packets transmitted) are taken into account.

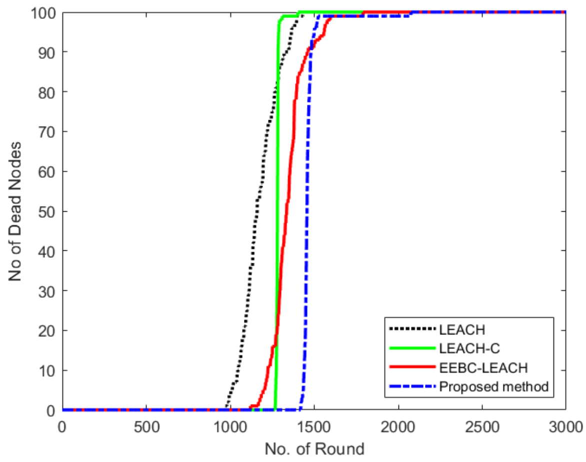

Fig. 6. Comparison of number of dead nodes over rounds.

Dead nodes	LEACH [13]	LEACH-C [14]	EEBC-LEACH [17]	Proposed method
FD	967	1280	1160	1388
HD	1052	1288	1238	1426
TD	1151	1298	1318	1440
AD	1394	1362	1841	1995

Tab. 3. Average dead nodes (in each case) in network vs rounds with base station is at 50 m×50 m.

6.1 Dead Nodes with Respect to Rounds

Figure 6 illustrates the number of dead nodes over multiple rounds for different clustering-based routing protocols in a wireless sensor network. The results indicate that the traditional LEACH protocol exhibits the shortest network lifespan, with nodes starting to die around 1000 rounds and all nodes depleting their energy soon after. LEACH-C demonstrates slightly improved performance due to its centralized cluster formation, but nodes still experience rapid energy depletion. The EEBC-LEACH protocol further extends the networks lifetime by introducing energy-efficient and balanced clustering mechanisms, delaying the onset of node deaths. However, the proposed method significantly enhances network longevity, with nodes starting to die around 1400 rounds and the complete depletion occurring much later compared to other protocols. This improvement is due to the incorporation of the metrics of residual energy, distance, and number of neighbor nodes. Therefore, the proposed approach has efficient energy consumption and enhances network management, thereby outperforming conventional clustering algorithms in prolonging the operational lifetime of WSNs.

The average of ten simulations is presented in Tab 3. The longevity of the network can be evaluated by three metrics: first dead (FD) node, half dead (HD) node, and all dead (AD) node. These parameters indicate the number of rounds after which the first node, half nodes, and all nodes of the networks have died i.e. fully depleted and can not take part in future rounds. It shows the better performance in terms of first dead (FD), ten dead (TD), half dead (HD), and all dead (AD) nodes to the number of rounds.

The proposed method improved all dead rounds by 30%, 32%, and 8% in comparison to the LEACH [13], LEACH-C [14], and EEBC-LEACH [17] methods, respectively.

6.2 Alive Nodes with Respect to Rounds

Figure 7 presents the number of alive nodes as a function of the number of rounds for different clustering-based routing protocols in a wireless sensor network. The graph illustrates the network lifetime and the rate at which nodes deplete their energy over time. The traditional LEACH protocol shows the shortest lifetime, with nodes starting to die around 1000 rounds and complete depletion occurring soon after. LEACH-C exhibits a slightly improved performance due to its centralized clustering approach, but node deaths still occur rapidly. EEBC-LEACH extends the network lifespan by employing energy-efficient clustering and load-balancing mechanisms, delaying the first node death beyond 1100 rounds. The proposed method significantly outperforms the other protocols, with nodes remaining alive for a much longer duration, and complete depletion occurring only after 1500 rounds. This demonstrates the effectiveness of the proposed approach in reducing energy consumption and enhancing network longevity, making it a more suitable option for prolonging the lifetime of WSN.

In another experiment, simulation was performed on 100 m×100 m area with 100 sensing nodes and the base station positioned outside of the sensing area at 50 m×175 m. In the case of PEGASIS, the base station is positioned at 50 m×300 m. The performances of the proposed method are compared with other recent approaches like HEED [24], [35], fuzzy-based FBCR LEACH [13] and EEBC LEACH [17]. The proposed method demonstrates higher value across all three metrics (FD, HD, AD),indicating an improvement in the network longevity shown in Tab. 4.

Method	FD	HD	AD
LEACH [13]	987	1138	1417
LEACH-C [14]	1275	1288	1418
HEED [24], [35]	690	1301	1609
PEGASIS* [23]	675	1362	1544
EEBC-LEACH [17]	1189	1323	1816
FBCR-LEACH [32]	835	1195	1850
Proposed method	1381	1434	1924

Tab. 4. Value of FD, HD, and AD measures for each method over multiple rounds with base station is at 50 m×175 m.

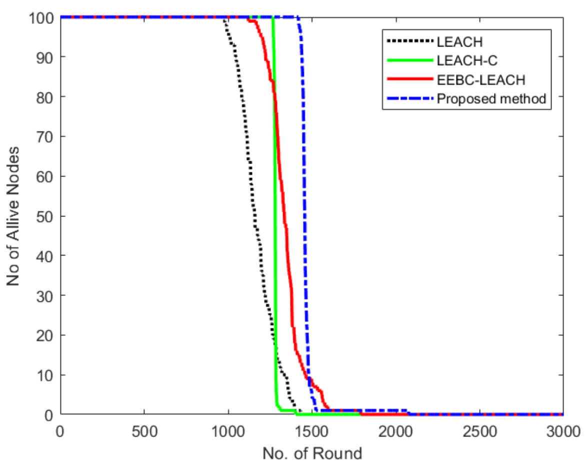

Fig. 7. Comparison of number of alive nodes over rounds.

6.3 Energy Dissipation vs Rounds

Figure 8 illustrates the total energy consumption of a wireless sensor network over multiple rounds for different clustering protocols, including LEACH [13], LEACH-C [14], EEBC-LEACH [17], and the proposed method. The results indicate that the proposed method maintains energy efficiency over a more extended period compared to the other approaches. The LEACH protocol exhibits the fastest energy depletion, followed by LEACH-C and EEBC-LEACH. The proposed method demonstrates superior energy efficiency, prolonging network lifetime by sustaining energy levels for more rounds. This finding highlights the effectiveness of the proposed approach in efficiently energy utilization and enhancing network longevity in wireless sensor networks.

Table 5 presents an average of ten simulations of the overall network's remaining energy at different rounds. Compared to the proposed method, 87%, 68%, and 45% of the energy is drained from existing LEACH [13], LEACH-C [14], and EEBC-LEACH [17], respectively, at the similar 1250 rounds.At the 2000 round, the first two methods were fully depleted, the third one had 0.0045 J residual energy, and the proposed method had 0.0151 J energy showing better energy management.

No. of round	LEACH [13]	LEACH-C [14]	EEBC-LEACH [17]	Proposed
1000	7.7720	11.2575	11.1317	11.7786
1250	0.6689	1.6344	2.8494	5.2274
1500	0.0000	0.0000	0.1623	0.0907
2000	0.0000	0.0000	0.0045	0.0151
2500	0.0000	0.0000	0.0000	0.0000

Tab. 5. Average energy (in each case) in network vs rounds.

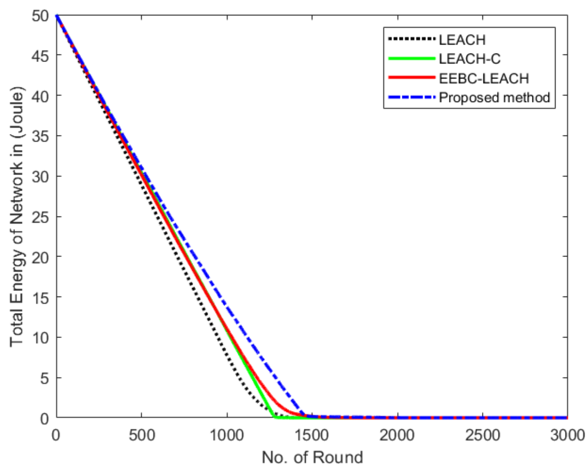

Fig. 8. Comparison of total energy available in the system.

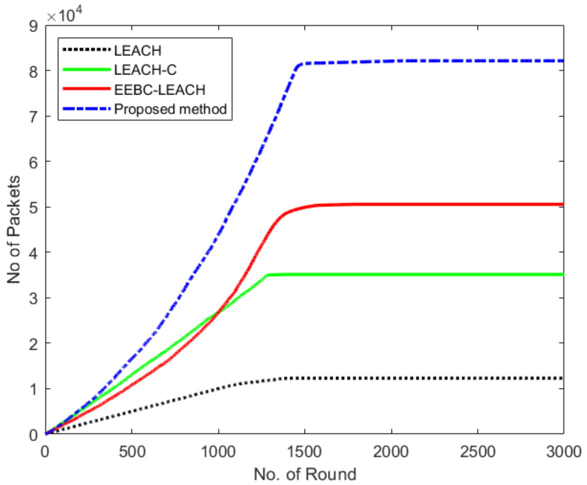

Fig. 9. Comparison of number of packets sent to sink node.

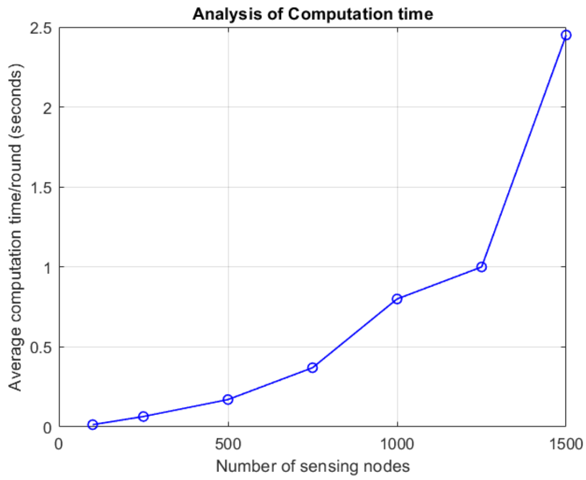

Fig. 10. Network computation per round time with respect to number of nodes.

6.4 Throughput

Throughput is the actual number of data packets successfully transmitted over a network from a cluster head node to a sink node in rounds. It is a key performance metric in data communication and network performance, and measurement. Higher throughput means better network efficiency and faster data transmission. As presented in Fig. 9, the number of packets successfully transmitted over multiple rounds for different clustering protocols, including LEACH [13], LEACH-C [14], EEBC-LEACH [17], and the proposed method. Figure 9 clearly shows that the proposed method significantly outperforms the other protocols in terms of packet transmission, achieving the highest number of successfully delivered packets. The EEBC-LEACH performs better than LEACH-C and LEACH. The proposed method's steep rise in packet transmission suggests enhanced network stability and prolonged lifetime, making it more efficient in data delivery.

This improvement underscores the effectiveness of the proposed approach in improving network performance by increasing data throughput while maintaining energy efficiency. The network throughput of the proposed method is much higher than the existing LEACH, LEACH-C, and EEBC-LEACH methods, which reflect in percent of 87%, 62%, and 37% respectively.

6.5 Network Computation Time

The trend in the graph of Fig. 10 shows an almost exponential rise in computation time with increases in the number of nodes. However, it can be brought to manageable level by using the high-speed processor, faster and larger storage etc.

In this section, the performance of the proposed method is compared with existing recent methods, and results are tabled above. It is evident that the proposed method improves the lifetime of the WSN network by 8% with the recent approach EEBC-LEACH [17]. The improvement is achieved by using (5)–(7), which regulated the energy dissipation of the sensing nodes. These equations are collectively used in the proposed algorithm for the selection of cluster heads that have a longer life span. Further, to support the enhancement of WSN lifetime, two other vital parameters, viz. threshold distance value and the node degree value (number of nodes in a CH) are used. The threshold distance value ensures that the sensing nodes affiliated to the cluster are at a short distance, thereby reducing the energy consumption needed for data packet transmission. The node degree value prescribe the candidates for being CH located in the area where the numbers of neighbouring sensing nodes are high. These three parameters incorporated in the proposed algorithm improved the overall lifetime of the WSN, which is a desired parameter for the IoT applications.

7. Conclusion

Selection of energy-efficient WSN is a challenging process, while designing the WSN routing protocol for IoT applications. The network energy and lifetime both are important factors, and a lot of research has been done to improve these factors. The suggested method modifies the cluster heads selection by considering the average energy of the network, residual energy, and node proximity. This improvisation has enhanced the network life and network throughput, which is one of the major demanding factors in any IoT application. The proposed method is suitable for a moderate number of sensing nodes in the sensing area. The suggested work can further be extended by applying some metaheuristic algorithms to optimize the proximity and cluster head selection criteria.

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