

Enhancing Data Rate And Network Reliability Through Multi-Stage Cluster Head Delegation

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Abstract: In wireless sensor networks (WSNs), the reliance on irreplaceable sensor nodes (SNs) and limited power sources restricts network lifetime, reliability, and sustainable throughput. This paper presents an algorithm for cluster routing that focuses on sensible bunching and cluster head (CH) variety for different numbers of SNs. The proposed routing model incorporates multipath propagation to reduce residual energy and compares its performance with existing clustering approaches regarding network lifetime, energy efficiency, and throughput sustainability. Moreover, a multi-hop-multi-hop network routing protocol (MMNRP) is proposed for statistics communication between SNs, CHs, and the base station (BS). The energy usage of MMNRP is compared with other existing techniques. This work provides insights into selecting an optimal approach to lessen energy consumption in WSNs through simulation studies. The proposed model is evaluated in different deployment scenarios considering other numbers of SNs and other base station locations. The consequences of the proposed model exhibit superior performance in relation to network endurance, power ingesting, and system throughput compared to conventional approaches.

Keywords: Sensor node, Routing protocols, Residual energy, Homogeneous Network, Cluster-Based Architecture, Cluster Head Rotation, LEACH.

1 Introduction

In rural, urban or any live locations in this era the existence of a wireless sensor network (WSN) is imperative. With advancement in semiconductor and communication, the size and performance of sensor nodes used in WSN has improved substantially [1]. Self-configured microsensors are positioned for traffic tracking, agricultural monitoring, military observation operations, calamity prediction, industrial automation, health care, structural health monitoring, underground water monitoring etc. [2], [3]. Sensor nodes are positioned mostly in remote and distant places reliant on the applications [4]. To have an energy-efficient consumption of sensor nodes and improvement in the throughput of WSN, researchers are exploring several techniques [5], [6]. Several routing protocols in WSN are proposed with their confines. WSN comprises many sensor nodes each having an integral power source, processor, memory and so on where several constraints limit the operation of network routing effectively [7], [8]. The structure of WSN routing has two operatives: Flat and Hierarchical routing. Enhanced

performance and scalability are optimum in hierarchical routing. Node clustering and multi-hopping are used to reduce energy consumption and maximise throughput. WSN is segmented into clusters where each cluster has its own base station (BS) (i.e.) cluster head (CH) which is a gateway of BS and member nodes (MN) [7], [9]. MN senses data and sends it to CH in the allotted slot they are idle. Data are aggregated by CH and are sent to BS [8]. The election of the CH node must be effective and uniformly distributed throughout the network for better performance [10]. In a clustering-based algorithm, the election of CH and formation of a cluster can be resolved by the balanced cluster formation, balanced distribution of CH, balanced load, and CH election optimum [11], [12]. Several protocols, algorithms, and models have been proposed by several researchers to improve the throughput of the WSN. The impartial of this article is to design a WSN model with a sustainable throughput where the BS locations are different.

In this paper, the introduction to WSN is presented in section 1 and the literature review is in section 2 and then followed by the Description of our proposed model after that the article, describe the experimental results and discussion. And the lastly a brief discussion of the proposed model and the conclusion followed by references.

2 Literature survey of proposed model

In low energy adaptive clustering protocol (LEACH) [13], for CH election, each sensor node having residual energy $[(R)]_E > \text{average energy } [(A)]_E$ create a random value and threshold value; if (random value < threshold), then it becomes CH [14]. Drawback in LEACH is that, any node can be CH by selecting the lower random value [11]. Algorithm for clustering "LEACH-C", where centralized election of CH is done by BS on the information received from nodes consisting their location and R_E [4]. Outline for evaluating the performance an algorithm reliant on amount and total energy Consummation per packet delivered was proposed [16]. S-LEACH [17] proposed a secure extension for LEACH. To create an efficient protocol, it was separated in phases with cryptographic operations to each part. In DEEC [18], CHs are elected on the probability of the ratio between R_E of each node and A_E of WSN. Nodes with higher R_E are eligible for electing as a CH. S. D. Kadu et al. [19] considered throughput vital parameter as nearer node from BS gets overloaded and with time passing its throughput reduces. N. Amini et al. [20] proposed a distance-based segmentation technique using different clustering policies to reduce the energy consumption [21]. Energy efficient multipath routing protocol increases the lifetime through balanced energy consumption across nodes [22]. Area throughput is the volume of samples per unit of time effectively transmitted to BS for an area, which depends on density of nodes and query interval [23]. Bo-Chao Cheng et al. [24] proposed a high energy first clustering algorithm [25], for an optimal clustering under idle conditions. Energy efficient routing algorithm elects sensor as CH having higher R_E [26], large number of neighbor nodes, and less distance from the BS [27]. Depending upon sensor nodes, data rate and energy level MAC algorithm has been designed to establish the relation between throughput and energy consumption [28]. Mehdi T. et al. [29] proposed an appropriated SEECH dependent on adaptable energy effective clustering hierarchy which elects CHs and transfers information independently [30]. Dependent on LEACH protocol, researcher has proposed two new clustering routing protocols based on geographical distance between nodes and BS [31]. Enhanced Mod-LEACH [32] in homogeneous network instigated the impression of efficient cluster structure and dual transmission power. O. N. Koyi et

al. [33] has discussed the WSN with different dynamic locations of BS and its performance. An energy efficient protocol used few sensor nodes as a relay node to avoid the long distance in which the election procedure for relay node was complex. Sukh K. Kaur et al. [34] examined the situation of BS in WSN, where number of nodes fluctuated and execution was assessed for packets gathering proportion, average latency, and average energy. Vidya T. et al. [35] proposed to maximize network lifetime and rate of transferring packets to BS. Jerew, O et al. [36] Implement dynamic clustering strategies where nodes are grouped into clusters based totally on proximity or different criteria. Cluster heads may be answerable for aggregating and forwarding statistics from their member nodes, allowing for electricity-green communication inside the cluster [37], considering BS inside the WSN area. A weight (w_v) for the election of CH considering residual energy(R_E), number of neighbor nodes ($n_{\text{neighbour}}$) and distance to BS($d_{\text{to BS}}$) [38].

$$w_v = w_1 n_{\text{neighbour}} + w_2 R_E + w_3 d_{\text{to BS}} \quad (1)$$

All sensor node computes w_v and sends to all $n_{\text{neighbour}}$ where node with higher w_v is elected as CH. Exchange of messages among all nodes consumes energy, reducing the throughput and lifetime. Fuzzy logic based model using R_E , location suitability, distribution density, compacting, and $d_{\text{to BS}}$ an algorithm for CH election was proposed [39]. BS is considered outside WSN area and $w = 0.1$ then

$$w_v = w n_{\text{neighbour}} + R_E \quad (2)$$

Each node calculates radius (r) and sends acknowledgement message to find the n_{neighbor} . Then each node sends information of R_E and n_{neighbor} to the BS, where BS calculates w_v for all node and elects the CH having highest value of w_v . Hybrid Algorithm [40] Is the concept of dragon fly and firefly calculation. The firefly supplanted position refreshes in dragonfly and is assessed regarding number of alive nodes, network energy, and delay. Liu et al. [40, 41] build the model of CH election, cluster formation, and path routing based on differential evolution algorithm which improved the overall performance by way of lowering the calculation in WSN area making Power consumption uniform.

3 Proposed Model

The proposed homogeneous routing protocol model comprises of uniform cluster. Load distribution among all sensor nodes in network area is uniform having sufficient energy to communicate with BS. Energy is expended when BS is away from the detecting region. Position of BS affects energy consumption, expands throughput, and decreases latency. Therefore, in this proposed homogeneous routing protocol model we will elucidate the effect of position of BS on WSN lifetime, energy consumption, and throughput sustainability for different number of sensors.

3.1 States of the Proposed Homogeneous Routing Protocol Model

Here, Wide variability of sensor nodes “N” is having single BS of unlimited energy and after the deployment of nodes the network is entirely considered as static with assumptions:

- All nodes are deployed with same energy, unique ID, identified location, data transmission rate equal
- Data computation and aggregation is done by CH and transmitted to BS

- BS with unlimited power energy, conscious of number of nodes, enough memory device, durable processor, and computational device

As shown in Fig. 1, 2 the long data transmission between MN to CH and CH to BS is avoided and multipath hopping is used to Limit the scope of the CH election system to a nearby community of nodes. This reduces the verbal exchange overhead and strength intake associated with international CH elections, as only close by nodes take part within the election method [42]. The sensor nodes are sharing information of ID, location, RE , and depending on E_V value BS counts and elect CH if higher resulting energy consumption of sensor nodes reduced. EEBC [10] nodes share "HELLO" message with the nodes residing within r and computes $n_{neighbor}$ and sends to BS which counts the weight for CH election. Here direct communication of nodes with BS consumes more power reduces the lifetime of WSN.

Fig. 1 WSN model scenario (BS at border)

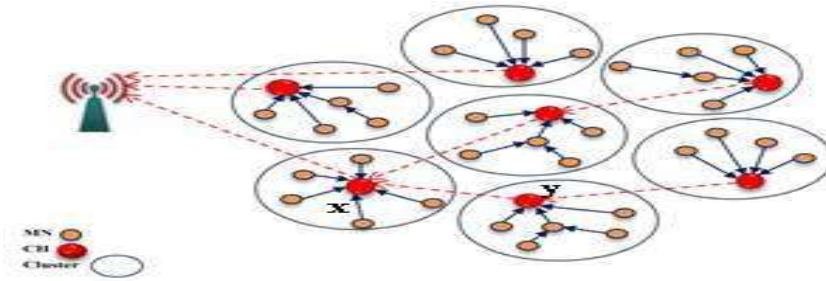
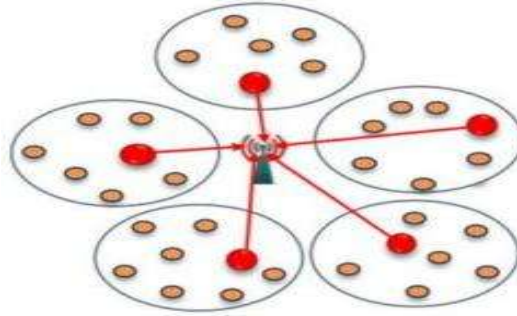


Fig. 2 WSN model scenario (BS at centre)



3.2 Radio energy consumption

Strength utilization in l-bits of data transmission as in line with radio energy version is shown in Fig. 3, the energy of transmitting nodes depends upon the threshold distance, path loss. Therefore, the amount of energy required for transmitting and receiving data of a single bit is expressed as:

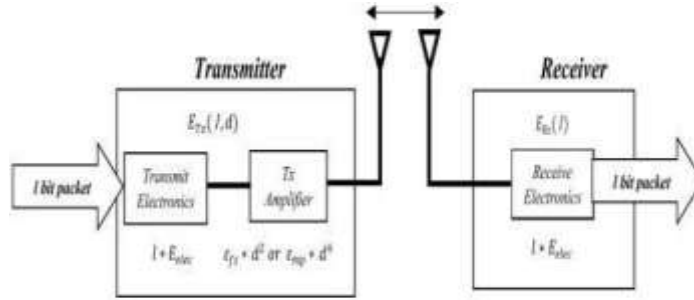
$$E_{Tx}(l, d) = \begin{cases} l * E_{elec} + l * \epsilon_{fs} * d^2; & \text{if } d \leq d_0 \\ l * E_{elec} + l * \epsilon_{mp} * d^4; & \text{if } d > d_0 \end{cases} \quad (3)$$

Where;

d_0 is threshold distance, ε_{mp} or ε_{fs} path loss, E_{elec} Radio energy dissipation and "d" is the gap between transmitter and receiver node. Same energy also consumed by the receiving node is

$$E_{Rx}(l) = l * E_{elec} \quad (4)$$

Fig. 3 Radio energy consumption model



Several researchers are working with low energy model for that several conventions considered for the radio signal transmission such as energy ingesting during data communication and reception. In Fig. 3 we have considered simple radio model in which dissipation of radio energy for transmission and reception is $E_{elec} = 50nJ/bit$.

3.3 Explanation of the Proposed Model

The proposed model in this research is a centralized clustering network routing protocol, where all decisions regarding the election of cluster heads (CHs) are made by the base station (BS) [43]. The BS acts as a central controller with sufficient resources such as memory, power, efficient processors, and computing devices [44]. Each sensor node (SN) communicates directly with the BS, and the BS has access to the geographical information of the nodes through GPS [45]. The CH election process consists of three phases: Pre-Setup Phase, Setup Phase, and Steady State [46]. In the Pre-Setup Phase, after the random deployment of SNs, the BS broadcasts a message, and each SN connects to the BS and calculates its distance to the BS (d_{toBS}) based on their geographical information [46]. Each SN broadcasts a Hello message in the Pre-Setup Phase before every round, sharing location and unique ID information with nearby SNs. Based on the received signal intensity, each node calculates an effective value (Ev) [47].

This is a distributed model depending upon $R_E, n_{neighbour}$, and the d_{toBS} results an improved performance, higher throughput with extra lifetime of WSN. On the basis of received data from each node ($n \in N$) SN will compute the $r, n_{neighbour}$ within the radius based on location, where radius (r) of each SN deployed in WSN area is calculated by Equation 5

$$r = \sqrt{A/\pi k} \quad (5)$$

A is the area of WSN, k is number of optimum clusters

$$k = \sqrt{\frac{N}{2\pi} \frac{\epsilon_{fs}}{\epsilon_{mp}} \frac{A}{d_{to BS}}} \quad (6)$$

k depends upon path losses ϵ_{mp} and ϵ_{fs} .

In the Setup Phase, each SN computes the effective value (E_v) of each node based on received signal strength [48]. If its own E_v is the highest and there are no elected neighbours within radius r , it elects itself as a CH; otherwise, it works as a member node (MN). The CHs broadcast a message, and the MNs join the CHs based on received signal strength, forming clusters. The CHs generate a time-division multiple access (TDMA) schedule and send it to the MNs [49]. According to the TDMA schedule, each MN can only send its sensed data to the CH in the allotted time slot, reducing energy consumption and improving system longevity and efficiency. If an MN is far away from the CH, it transmits its data via another MN available in the path of the CH, enabling multi-hop data transmission [50]. In the Steady-State Phase, the CH aggregates and fuses the received data from all MNs and sends it to the BS. This model employs a multi-hopping routing approach, where if the distance between a CH and the BS is longer, the data transmission occurs in multipath through other CHs in the path to the BS, avoiding direct communication with the BS [51].

The research includes an algorithm for the election of CHs considering different positions of the BS in the WSN area. The proposed model aims to enhance the performance, energy efficiency, and longevity of the WSN by utilizing centralized clustering, multi-hop data transmission, and efficient CH selection based on received signal strength and geographical information [52].

An algorithm for the election of CH is illustrated considering BS located at different position in both proposed scenarios in WSN area.

Algorithm for CH election	
1.	Randomly deployment of all SNs
2.	BS $\rightarrow$ Broadcast a Message
3.	SNs get connected with BS Also get d_{toBS}
4.	$n \in N$ do
5.	$n \rightarrow$ Hello Message
6.	$nID, location \rightarrow$ Broadcast n counts number of neighbour nodes ($n_{neighbou}$) within the r n counts E_v for strength of signal received by each node
7.	SORT (E_v)
8.	For $n = 1$ to N do
9.	If E_v of n is highest then
10.	$n \rightarrow$ CH else
11.	$n \rightarrow$ MN end if end for

4 Experimental Analyses

Performance of proposed WSN is evaluated with different locations of BS (at boundary and at centre) and different number of SNs deployed over the WSN area lifetime, energy consumption, and throughput are calculated and validated with the existing models. In this WSN model, for $A = 200 * 200$ and $N = 50, 100, 200$ randomly deployed the BS is placed at boundary location (100, 200) and at centre location (100, 100) respectively. Simulation model using Matlab® is used for the proposed WSN conditions showing the location of nodes deployed randomly in Fig. 4, 5. Notations and simulation parameters considered [43] for the proposed network model are given in Table 1 and Table 2.

Fig. 4 100 node with BS at boundary (100, 200)

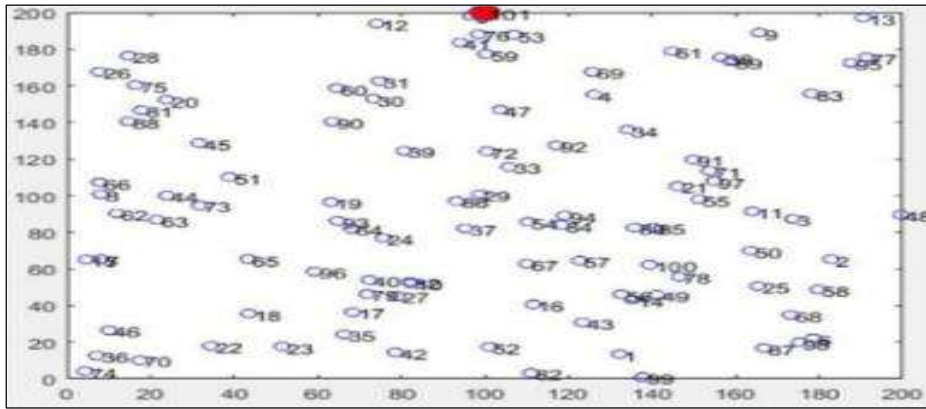


Fig. 5 100 SNs with BS at centre (100, 100)

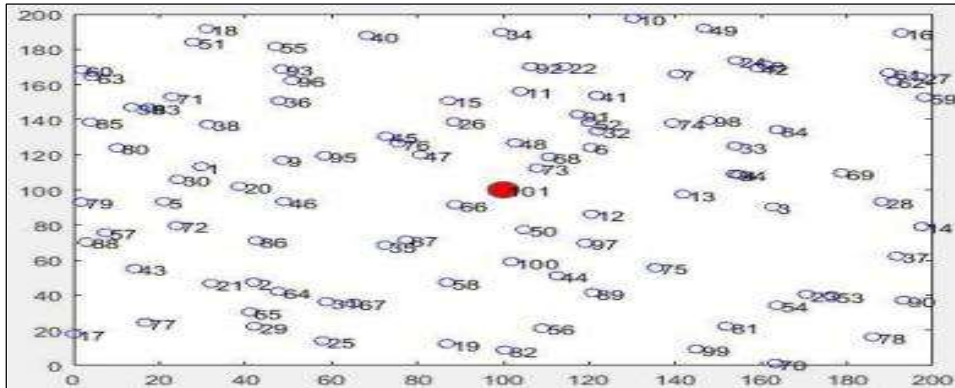


Table 1 Notation of Parameters used in experimental setup

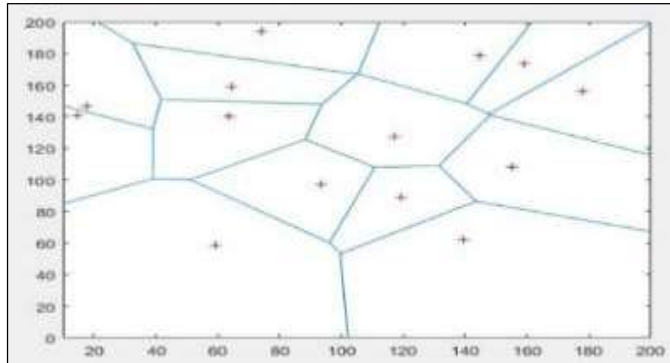
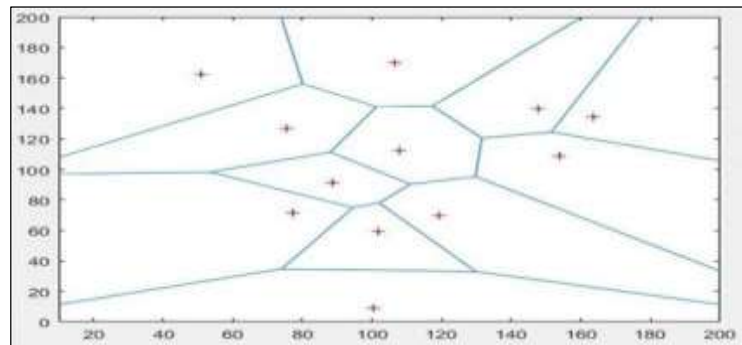
Parameter	Notations
Total energy of sensor node	E_i
Distance to BS	$d_{to\ BS}$
Distance of MN to CH	$d_{to\ CH}$
Residual Energy	R_E
Area of WSN	A
Radius of cluster	r
No. of neighbour count	$n_{neighbour}$
No. of CHs	k

Table 2 Experimental value of Parameters used in model

Parameter	Data
No. of sensor node (N)	50, 100, 200
Area of WSN ($A = X_m * Y_m$)	$200 * 200$
l (No. of bits transferred)	2000
E_0 (Initial energy of sensor)	0.5 J
$Sink * x$	$0.5 * X_m$
$Sink * y$	$1.0 * Y_m, 0.5 * Y_m$
Transmitted/Received energy	$50 * 10^{-9} J$
Free space path loss (ϵ_{fs})	10 pJ
Multi space path loss (ϵ_{mp})	0.0013 pJ
Data aggregation energy (E_{DA})	$5 * 10^{-9} J$
Probability percentage (p)	0.05

4.1 Sensor Dead Node

In terms of sustainability, the proposed protocol model exhibits balanced cluster and CH election, increasing the lifetime more efficiently. CH elected in proposed WSN model for $A = 200 * 200$ with BS at boundary (100, 200) and BS at centre (100, 100) is shown in Fig. 6, 7 using voronoi diagram.

Fig. 6 No. of CH (+) elected in $A = 200 * 200$ with BS at boundary**Fig. 7 No. of CH (+) elected in $A = 200 * 200$ with BS at centre**

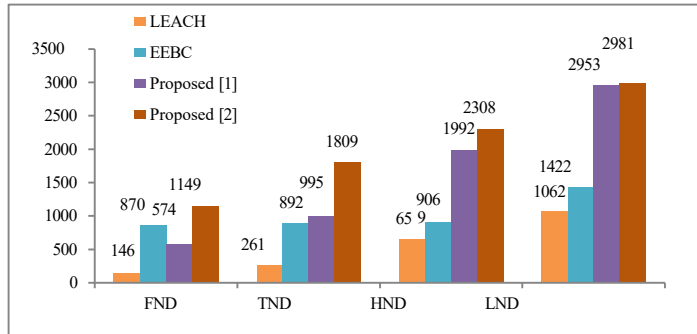
In proposed WSN model, for $A = 200 * 200$ and $N = 50, 100, 200$ the results for both scenarios are compared with existing models. The x-axis abbreviations for FND: First Node Died, TND: Tenth Node Died, HND: Half Node Died, LND: Last

Node Died.

It is observed for 50 nodes from Fig. 8, that FND for proposed [1] the sustainability is trivial but as the number of rounds increases its lifetime increases whereas in proposed [2] it has better sustainability throughout the network life.

HND for LEACH [11] in 659th round and EEBC [9] in 906th round whereas for proposed [1] performs for 1992nd round and for proposed [2] it is 2308th round. LND for LEACH [11] in 1062th round and EEBC [9] in 1422nd round whereas for proposed [1] performs for 2953rd round and proposed [2] for 2981st round.

Fig. 8 Dead node for 50 nodes deployment



Similarly, for 100 and 200 nodes the proposed routing is compared and validated which confirms that the proposed routing is more efficient with the sustainable throughput as shown in Fig. 9, 10.

Fig. 9 Dead node for 100 nodes deployment

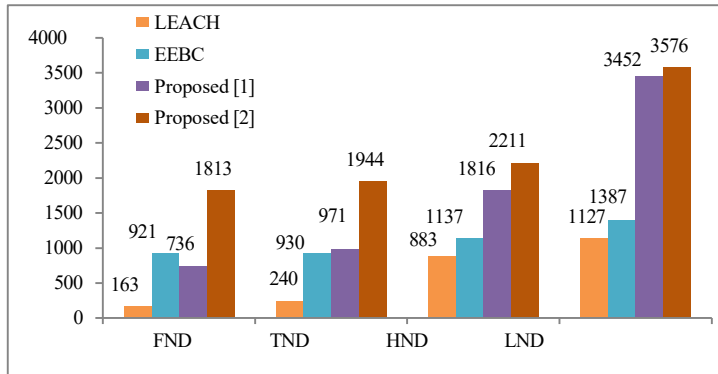
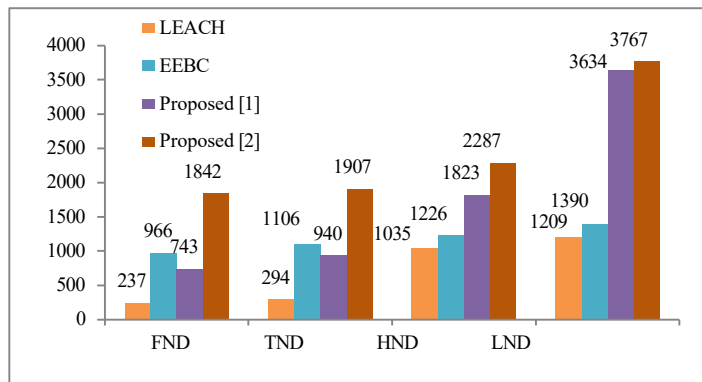


Fig. 10 Dead node for 200 nodes deployment



4.2 Residual Energy

Evaluation of R_E for the proposed model in WSN scenario for 50, 100, and 200 sensors are shown in Fig. 11, 12, 13 respectively.

Fig. 11 Residual energy for 50 nodes

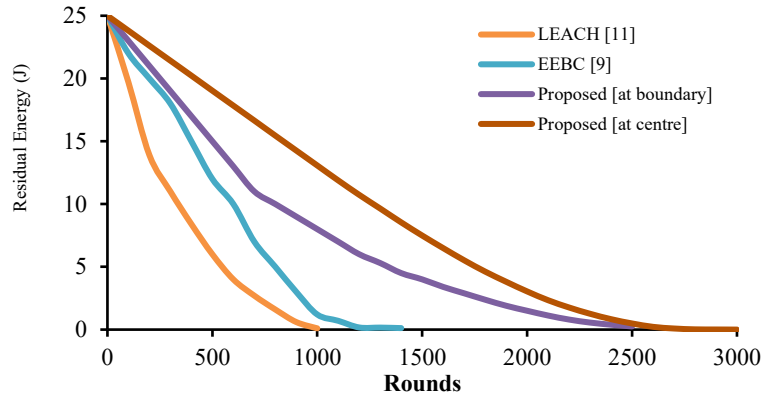


Fig. 12 Residual energy for 100 nodes

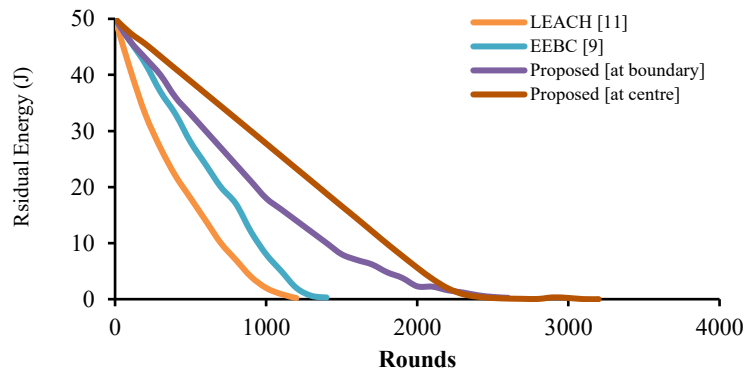
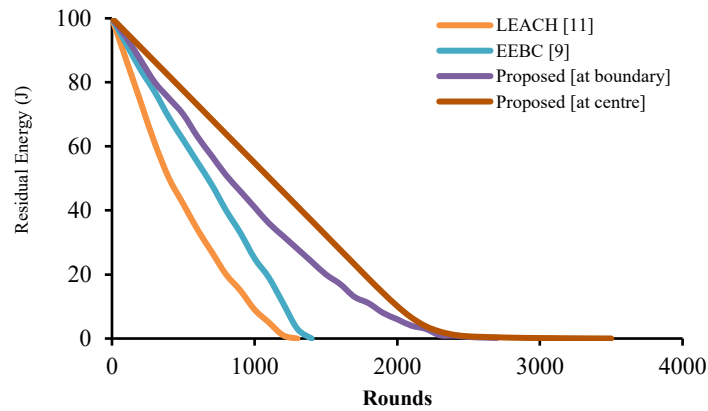


Fig. 13 Residual energy for 200 nodes



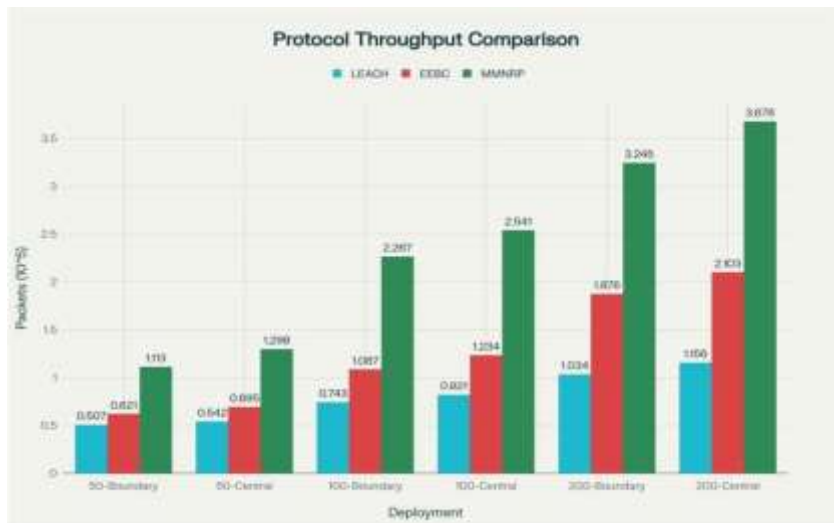
It is observed that for node 50 and 100 up to 1500 rounds the proposed model R_E is higher compared to existing routing protocol model (i.e.) the proposed model

significantly outperforms. The low energy consumption model proposed with two locations of BS (100, 200) and (100, 100) reduces the RE using proper cluster formation and CH election. As the RE is higher for the proposed model it improves the longevity of the WSN.

4.3 Throughput

Throughput is the number of data packets transmitted to BS (i.e.) a greater number of packets transmitted will result in improved performance and accuracy. Increasing the throughput of the network by reducing RE is a major contest. Substantial traffic load at first throughput increments with the load at BS and after certain point it reduces so throughput improves the execution of WSN. Network throughput is much higher of the proposed model in both cases in all scenarios (50, 100, 200 nodes) considered. It is due to the balanced election of CH with an adaptive communication model. For 50 nodes scenario the proposed protocol [1] sends $0.808 * 10^5$ and proposed [2] sends $1.113 * 10^5$ data packets whereas for existing it is $0.507 * 10^5$ [11] and $0.621 * 10^5$ [10]. Similarly, in case of 100 nodes deployment both proposed models send $1.524 * 10^5$ and $2.267 * 10^5$ data packets which is higher than the compared model as shown in Fig. 14.

Fig. 14 Data Throughput Performance: Total Packets Successfully Transmitted to Base Station



5 Result and Discussions

The research paper focuses on a low energy consumption model for wireless sensor networks (WSNs) with two different positions of the base station (BS): (100, 200) and (100, 100). The model aims to reduce the energy consumption (RE) by employing correct balanced cluster progress and cluster head (CH) election [43,45,46]. Figures 1 and 2 illustrate that the proposed model avoids long-distance data transmission in a single path between member nodes (MN) and CHs, as well as between CHs and the BS. Instead, multipath hopping is utilized to reduce energy consumption. By employing this approach, the model effectively reduces the overall energy expenditure during data transmission. The CH election process involves nodes sharing their information such as ID, location, and RE . Based on the received signal strength, each sensor node (SN) calculates an effective value (Ev) [46]. The nodes then shortlist the Ev values in descending order and elect themselves as CHs

if their own E_v is the highest among the SNs [52]. This process ensures that CHs are selected based on their strong signal strength and reduces the energy consumption of the nodes. In contrast, the existing approach involves nodes sharing "HELLO" messages and calculating the number of neighboring nodes ($n_{neighbor}$) within a certain radius (r). The SNs then send the values of $n_{neighbor}$ and RE to the BS, which calculates the weight for CH selection. In this process, direct communication between SNs and the BS is required to share the messages, resulting in higher energy consumption compared to the proposed model. In EEBC, transmitting data based on single-hop-multi-hop network routing protocol in which, MN to CH data transmission done in a single-hop whereas CH to BS it is in multi-hop. But in our proposed model long route data transmission is avoided by using multi-hop between MN to CH and CH to BS both, so that it is very efficient for the large network area.

In both scenarios of our proposed model, we observed that the performance of our proposed model is better performance having maximized throughput. The proposed model reduces energy consumption by avoiding long-distance single-path data transmission and utilizing multipath hopping [50,52]. Additionally, the CH election process based on E_v values reduces energy consumption compared to the existing EEBC approach that involves direct communication between SNs and the BS. The research demonstrates the effectiveness of the proposed model in achieving energy efficiency in WSNs [52,53].

6 Conclusions

The research paper primarily focuses on improving the performance, lifetime, and sustainable quantity of wireless sensor networks (WSNs) by modifying the existing EEBC (Energy-Efficient Balanced Cluster) model [54]. Over the past two decades, researchers have made various advancements in WSNs, aiming to enhance their lifespan and performance. The first model in this field was LEACH (Low Energy Adaptive Clustering Hierarchy), which introduced a distributed system approach. The proposed model builds upon previous research and incorporates various factors such as the position of the base station (BS) [54], clustering techniques, residual energy (RE), and the number of neighbouring nodes ($n_{neighbor}$) to achieve better performance and a longer lifespan for the WSN. The model focuses on proper cluster head (CH) selection methodology, appropriate cluster formation, RE management, $n_{neighbor}$ determination within the cluster, and the distance to the BS ($dtoBS$). These considerations contribute to the model's suitability for large WSN areas. The proposed model significantly enhances inter-cluster and intra-cluster communication by avoiding long-distance data transmission between member nodes (MN) and CHs, as well as between CHs and the BS. This optimization leads to increased throughput, improved longevity of the WSN, and reduced data transmission delay. To evaluate the performance of the proposed model, the researchers employ a MATLAB emulator and comparison the results with the LEACH model, The first Low Energy Adaptive Clustering Hierarchy (LEACH) model, and the EEBC protocol, one of the recently proposed clustering protocols [53]. The comparative results demonstrate that the proposed model outperforms the previously recommended clustering techniques. This progress is achieved through a balanced selection of CHs and the utilization of a multi-hop communication technique for inter-cluster and intra-cluster data transmission. The proposed protocol is compared to the low energy adaptive clustering model (LEACH) and the EEBC clustering protocol using the MATLAB simulator. [54]. All results explained

above show that the performance of the proposed model is better than the previously recommended clustering techniques. This progress is accomplished using a well-adjusted assortment of CHs and using a multi-hop in inter-cluster and intra-cluster communication technique.

The research paper presents a modified model that improves the performance, lifetime, and sustainable throughput of WSNs. By addressing various aspects such as CH selection, cluster formation, RE management, and efficient communication techniques, the proposed model demonstrates superior performance compared to existing clustering techniques. The research contributes to advancing the field of WSNs and can assist as an origin for further revisions, including the implementation of dynamic BS positions for more efficient and effective network communication.

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