

Dual step hybrid routing protocol for network lifetime enhancement in WSN-IoT environment

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ABSTRACT

Recent development in internet of things (IoT) has been generating huge data due to the large number of nodes deployed and utilized for different applications. In addition, these applications utilize big data and require a more efficient mechanism for data sensing and data transmission. This research work proposes dual step hybrid routing (DSHR) protocol for efficient cluster-based routing. It comprises a two-phase algorithm, which aims at finding the optimal path considering clustering. It further comprises several processes such as cluster head selection, optimal path construction, integrating of nodes to cluster head and sensing range optimization. DSHR is evaluated considering the network lifetime; thereafter model is compared with the existing low energy adaptive clustering hierarchy (LEACH) protocol to prove the efficiency.

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1. INTRODUCTION

In the internet of things (IoT) environment, data load has been increasing enormously due to its heterogeneous nature. Furthermore, big data is utilized for various applications such as smart agriculture, smart homes, smart city, and smart healthcare. In all these applications, wireless sensor network (WSN) has been one of the key components of IoT as it helps in data propagation in the network [1]–[3]. In IoT, WSN are used for processing, storage, mining and data analysis, which is helpful in monitoring application of IoT. Hence, WSN has been widely researched at industry level and academia level.

In a typical WSN scenario, the sensor nodes are widely distributed across where data collection or observation of data and transferred to the sink. The information gathered from the multi-hop transmission is crucial for transmission to the base station (BS), which is situated behind the transmission that supplies the sensor node and determines the best path to the sink [4]. The essential application for WSN's nodes consists of minimal energy that is not efficiently charged upon further deployment. The energy dissipation for routing, in addition to maintaining the remaining energy residual. Depending on the number of intermediary nodes, the energy dissipation concentrates on the distance between these nodes. The WSN routing path with the fewest hops over the shortest distance. The remaining energy is associated with each node to avoid the drain capacity for network segmentation. These procedures enhance network lifetime because the energy is transferred amongst all the nodes [4], [5]. Figure 1 shows the typical WSN-IoT architecture that comprises sensing layer, transport layer and application layer. In sensing layer, data are sensed and sent to transport layer, which is integrated with IoT platform and further connected to application layer where the data are stored and available for end user.

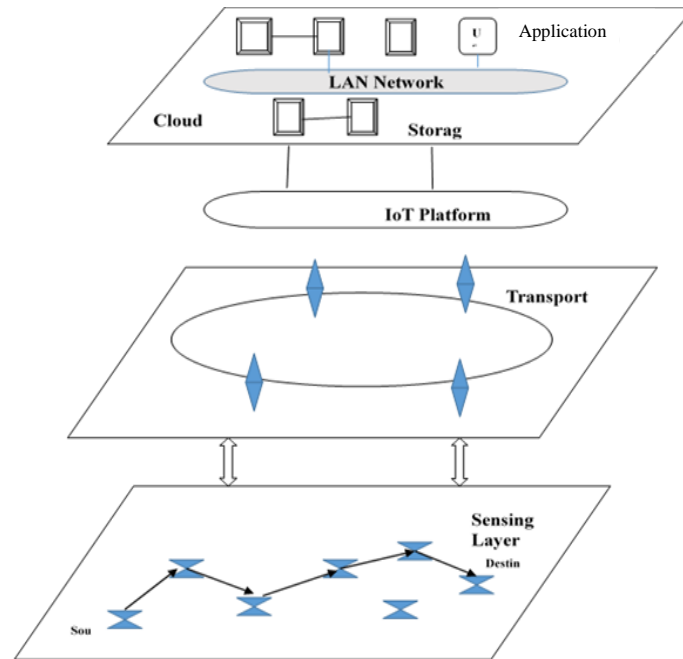


Figure 1. Typical WSN-IoT architecture

In a limited area, the node is responsible to transmit the packets to the BS, and over a wide area, the packet transmission with several intermediate nodes. In a wide WSN area, there exist three major challenges: i) area division; and ii) splitting into sub-divisions through the whole region, effective routing, and intermediate energy nodes.

In the sub-division, the entire region is split into smaller areas termed clusters. In these clusters, one node is picked as the cluster head for data reception from the remaining sensor nodes of the cluster and transfers it to the parallel node or BS. In the WSN environment, various protocols for clustering purposes were previously used for low energy adaptive clustering hierarchy (LEACH), multi-hop LEACH protocol (M-LEACH), and stable election protocol (SEP) [3]–[6]. Through these protocols, the network lifetime is prolonged for efficient energy dissipation is accomplished upon selecting the cluster head node. For routing there are two types of tasks; one is flat routing and the other is hierarchical routing. Flat routing involves the routing from the sensor to the BS is traversed; whereas in hierarchical routing, the sensor nodes are responsible for the transmission of data toward the cluster head, and this further transfers it to the adjacent node [7]–[9].

The route becomes vacant when the intermediate nodes consist of high energy for packets received and parallel transmission to the subsequent node; relaying and intermediate nodes for multi-hop transmission communication. The nodes consist of minimal energy for relaying purposes, as the transmission descends. The nodes adjacent to the sink node or BS are simultaneously used for relaying and the outcome of these results in energy dissipation. Accordingly, the nodes are dead, and this region is deployed adjacent to the BS, termed a warm hole region [8], [10]. Choosing an optimized route is essential for selecting a prime aspect for WSN design. The motivation behind deploying the WSN is as: i) to find an optimal energy consumption routing for packet transmission via multi-hop WSN; ii) to enhance the packet delivery to the BS; iii) to increase the network lifetime to minimize the energy consumed by the node; iv) to make use of the maximum available network capacity; and v) to reduce the warm hole problem for multi-hop WSN.

Further, the research contribution is given as: i) this research work develops a dual step hybrid routing (DSHR) protocol, which aims at finding the optimal path for data packet transmission; ii) at first, the model develops a novel cluster head selection concerning large sensor nodes and later designs the optimal path construction concerning the same; iii) further, connecting nodes to clusters with respect and sensing range is optimized and iv) DSHR is evaluated for network lifetime enhancement; model efficiency is proved by comparing it with the existing LEACH protocol.

This research is organized as follows: the first section starts with background IoT and WSN, along with the importance of the development of a routing mechanism. Furthermore, in second section, few existing routing protocols are discussed along with their shortcoming, section ends with motivation and

contribution of research work. The third section presents the mathematical modelling of the DSHR protocol and the same is evaluated in the fourth section.

2. RELATED WORK

According to Alami and Najid [11], an enhanced clustering hierarchy approach (ECH) uses a sleeping-waking mechanism for overlapping and nearby nodes to achieve energy efficiency in WSNs. Reduced data redundancy and maximum network longevity are both achieved. The efficiency of rule-based fuzzy routing is improved in Sert and Yazici [12] by applying a modified clonal selection method called CLONALG-M to choose the proper functional form for the output membership function. The fuzzy technique is effective and well formed with a variety of methodologies and distinct borders between poorly defined clusters. A successful conclusion to the iterative experiment using the membership function.

An effective energy-efficient network for the deep belief network (DBN) based on routing protocol is implemented, this establishes efficient data transmission via the path selected thereby enhancing the packet delivery ratio (PDR) is enhanced [13]–[15]. In the framework initially, the nodes in the entire network are clustered by using a reinforcement algorithm, which allocates a reward for the nodes assigned to a specific cluster. The cluster head is required for efficient data transmission by selecting a mantaray foraging optimization (MRFO) algorithm. In several studies [16]–[18], this is an energy clustering protocol based on Voronoi dividing known as the energy-saving cluster for Voronoi adaptive routing (ESCVAD) protocol [19]. The procedure built on ESCVAD protocol resulted in an adaptive clustering algorithm for Voronoi dividing as well as cluster head election optimization algorithm resulting in energy comprehensive weighting [20]–[22]. The energy efficiency and network quality-of-service by incorporating reward function including the required metrics. The agent gets the reward for action-based reward, while the software-defined wireless sensor network (SDWSN) improvises the routing path on the experience. In Gamal *et al.* [23], a technique that uses less energy to improve the performance of a SDWSN. A mixed integer linear programming (MILP) issue is combined with an energy-optimized multi-constrained sustainable routing (EOMCSR) model to improve the SDWSN's network resource-based energy consumption [24].

3. PROPOSED METHOD

In WSN based IoT environment, clustering and routing has one of the important roles to play for efficient data transmission, the main objective of this research is to enhance the network lifetime. Thus, this research utilizes the clustering and routing to develop a novel hybrid protocol for improvisation in network lifetime. The proposed approach consists of two phases: consists of clustering and routing. The main task of clustering is to choose the cluster head nodes by utilizing the local information for the sensor nodes with relevant parameters to build a routing mechanism for data collection. Figure 2 shows the proposed workflow, at first optimal cluster head selection concerning a large number of sensor nodes. Furthermore, optimal path construction for the data transmission module is designed. Sensor nodes are connected to the *clus_head*; at last sensing, range optimization is designed for the data sensing.

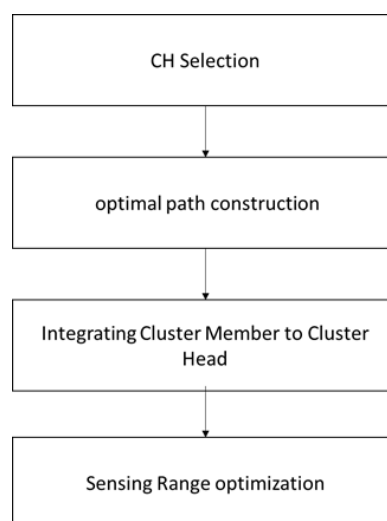


Figure 2. DSHR workflow

3.1. Cluster head selection

The distance estimated from the BS to the initial point of the neglected region where the BS is presumed to be adjacent to the monitored area, a BS is assumed adjacent to the monitored area. Initially, the BS at the breaking point transmits *BS_Init_msg* while the competition range D that initializes clustering. The top layer nodes receive *BS_Init_msg* to know the distance to a BS and are involved in the cluster head competition. Here each node in the top level broadcasts the *start_msg*($x, dis_{x-BS}, R_x^{out}, R_x^{EP}(u+1)$) to accommodate the distance $\frac{w}{2}$ that swap the information along with cluster head selection, where x indicates the reference id of the node, dis_{x-BS} , f_x is the distance between the node f_x and BS, R_x^{out} is the remaining energy for the node f_x during the prediction given by $(u+1)$. Once the local information is gathered from the adjacent nodes, each node evaluates its weight election for cluster head selection using (1).

$$RG_x = Y_1 \times \frac{R_x^{out}}{R_x^{EP}} + Y_2 \times \left[1 - \frac{dis_{x-BS} - \min(dis_{x-BS})}{\max(dis_{x-BS}) - \min(dis_{x-BS})} \right] + Y_3 \times \frac{R_x^{EP}(u+1)}{\max(R_x^{EP})} \quad (1)$$

Here Y_1, Y_2, Y_3 is the constant value between 0 and 1 whereas $Y_1 + Y_2 + Y_3 = 1$. Various solutions handle the dimensions of min-max normalization, where the largest value is normalized. The maximum value is utilized in the min-max normalization process. An improved choice for the cluster head with a higher weight is a node with greater energy, a shorter distance for BS, and high prediction energy. When a cluster head is chosen for each level of the entire network area, the cluster head updates the distance from the BS to each level when the cluster head is chosen for each level of the entire network area dis_{CH-BS} . Here dis_{CH-BS} is the first-level cluster head nodes the Euclidean distance is the distance to BS for low-level cluster head nodes. By exchanging local information with nearby nodes, each of which has an adjacency degree z_x^{adj} and signal-to-noise ratio snr_x . The degree of the node is the number of neighbors evaluated by the recipient *start_msg*() messages. snr_x is evaluated as (2).

$$snr_x = 10 \log_{10} \left(\frac{I_x^{sig}}{I_x^{noise}} \right) \quad (2)$$

Here I_x^{sig} and I_x^{noise} depicts effective signal power and effective noise. A node is picked as the cluster head continues to broadcast the *clushead_msg*($\sum_{CHU}, \sum_{relay-vc}$) whereas P indicates lower-level competition, where \sum_{CHU} indicates the information of present and top-level cluster head nodes and $\sum_{relay-vc}$ indicates the information of the top and present level relay vc nodes. A relay node consists of the high-energy consumption of the vc nodes in the adjacent cluster group consisting of the cluster head node. The parameters involved are *clushead_msg* that contains the reference of the node, distance transmitted to BS, the remaining energy, adjacency value, the energy predicted and SNR value. For example, the *clushead_msg* is stated as the *clushead_msg*($j_{CHU}, dis_{clushead_{BS}}, R_{clushead}^{out}, z_{clushead}^{adj}, R_{clushead}^{EP}(u+1), snr_{clushead}$) for the present level *clushead* node, the *clushead* and vc node at each level cluster holds the routing table for top-level *clushead* node and vc node is responsible for transmitting data by incorporating adaptive transmission power modification. The broadcasting of the *clushead_msg*() where each *clushead* node determines the information series for top-level *clusheads*, the vc node determines the information of the relay nodes for data transmission. The relevant information of all the nodes *clushead* node and vc node of the top level is forwarded in a systematic manner to the *clushead* node and vc node selected for low-level transmission. All nodes in q_x , that participate in the *clushead* incorporate the following features. It consists of $clushead_x$ as the top-level *clushead*, the distance $clushead_x$ is minimal in terms of the radius and the remaining energy is higher than the *energy - peak*.

$$q_u = \{q_y / clushead_x \in clushead_{q_y}^{hl}, q_y \in adj clushead_{in P}, R_y^{out}\} \quad (3)$$

$R_{l-peak}, q_y.state$ not equal to the VC of $clushead_x$,

$$dis_{clushead_x-BS} < dis_{y-BS}$$

All the nodes that compete may receive an acknowledgement as $clushead_x$ from the top-level *clushead* nodes. Here BS is defined as (4).

$$dis_{y-BS} = \min\{dis_{clushead_x-BS}, + dis_{clushead_x-y}\} \quad (4)$$

That is the Euclidean distance from the node q_y , to BS. Consequently, every node q_y , broadcasts the $start_msg(x, dis_{y-BS}, R_y^{out}, R_y^{EP}(u+1))$ in the range to swap the information with the neighbours for $clushead$ selection. This $clushead$ is repeated for the entire area.

3.2. Optimal path selection

In the routing phase, the routing-table necessary for data transmission is built consecutively for the $clushead$ selection. Each present level in $clushead$ chooses the next task to be performed according to $clushead_msg$ from the top-level $clusheads$, however, the top-level $clushead$ having the lowest cost is estimated by a formula which is subsequently selected as the next hop.

$$UL_x = \beta_1 \times \frac{R_{clushead}^{out}}{R_{clushead}^{rc}} + \beta_2 \times \frac{\max(R_{clushead}^{EP} - R_{clushead}^{EP}(u+1))}{\max(R_{clushead}^{EP})} + \beta_3 \times \frac{dis_{clushead-BS}}{\max(dis_{clushead-BS})} + \beta_4 \frac{\alpha_{clushead}^{adj}}{\alpha_{clushead}^{adj}} + \beta_5 \frac{(snr_{clushead}) - snr_{clushead}}{(snr_{clushead})} \quad (5)$$

This equation transforms into a $clushead$ node with more remaining energy, energy prediction rate, and minimal distance to BS, low adjacency degree, and high signal-to-noise ratio of chances to be selected as the next $clushead$. A $clushead$ takes less energy for transmission amid the clusters which are why a $clushead$ with low value has high priority amongst several other $clusheads$. Accordingly, a $clushead$ is positioned in a sparse area with remaining energy, minimal distance to BS, low adjacency degree, and high signal-to-noise ratio of chances to be selected as the next $clushead$. The routing table is built from top-level minimal distance to BS, low adjacency degree, the high signal-to-noise ratio of likelihood to be a selection of as the next $clushead$ to low-level minimal distance to BS, low adjacency degree, high signal to noise ratio of chances to be selected as the next $clushead$, each $clushead$ has its routing tree from itself to BS.

3.3. Network lifetime enhancement transmission

Once the cluster head selection and routing process are done, in the first phase the nodes do not receive any message and elect themselves as the cluster head, whereas vc picks a cluster head along the smallest join shown by the formula as its cluster head and joins it.

$$NC = \delta_1 \times \frac{R_{clushead}^{rc} - R_{clushead}^{out}}{R_{clushead}^{max}} + \delta_2 \times \frac{\max(R_{clushead}^{EP} - R_{clushead}^{EP}(u+1))}{\max(R_{clushead}^{EP})} + \delta_3 \times \left(p \times \frac{dis_{clushead-x}}{\max(dis_{clushead-x})} + Y \times \frac{\max(dis_{clushead-BS}) - dis_{clushead-BS}}{\max(dis_{clushead-BS})} + \delta_4 \times \frac{\alpha_{clushead}^{adj}}{\max(\alpha_{clushead}^{adj})} + \delta_5 \times \frac{\max(snr_{clushead}) - snr_{clushead}}{\max(snr_{clushead})} \right) \quad (6)$$

Here $p, Y, \delta_1, \delta_2, \delta_3, \delta_4, \delta_5$ are the constants in the range 0 to 1 and $p + Y = 1, \delta_1 + \delta_2 + \delta_3 + \delta_4 + \delta_5 = 1$. In (6), the vc joins the $clushead$ node with more remaining energy, energy prediction rate, minimal distance to BS, low adjacency degree, and high signal-to-noise ratio. The nearest the BS to $clusheads$ the more data is transmitted. Henceforth they have a heavy relay load in between the clusters. This problem is handled by making the vc closer to the $clushead$ if the distance is less than vc should join it.

This results in a high chance of vc to being able to join $clushead$ from the BS. The overhead is balanced in between the $clushead$ in inter-cluster and intra-cluster communication. Here one vc picks the $clushead$ along, then it transmits the $closure_msg(x, x_{clushead}, dis_{x-clushead}, R_x, sar_x)$ for the $clushead$ and completes the cluster, where $x_{clushead}$ is the reference of the cluster head and sar_x denotes the sampling rate.

Algorithm 1 and Algorithm 2 present two-step DSHR developed. Algorithm 1 is first step of DSHR. Moreover, sensing range optimization is carried out with respect to big data sensing for large deployment of sensor nodes and data gathering through above two-phase hybrid model.

Algorithm 1. First step cluster-based routing (phase 1)

Step 1: BS communicates the BS_Init_msg in the radius R
 Step 2: for(every node q_x) do
 Step 3: If(node q_x received BS_Init_msg then
 Step 4: Compute dis_{x-BS} according to the standard
 Step 5: Communicate $start_msg$ in R/2 to swap the information;
 Step 6: Fetch the nodes adjacency degree
 Step 7: Compute the signal-to-noise ratio snr_x
 Step 8: Evaluate its UL_x
 Step 9: Comparison with the adjacent nodes
 Step 10: If UL_x is largest then
 Step 11: Change its state to $clushead$;
 Step 12: Choose BS as the parent node;
 Step 13: Communicate $clushead - msg()$ in R;
 Step 14: else
 Step 15: Change its state to vc ;
 Step 16: end if
 Step 17: end if
 Step 18: end for

Algorithm 2. Second step cluster-based routing (phase 2)

Step 1: Initialize $l = 2$; l is the level
 Step 2: While(node which is not clustered)
 Step 3: for(every node q_x) do
 Step 4: if (node q_y received $clushead - msg$ from $clushead_x$ and $R_y^{out} > R_{low-peak}, q_y.state \neq vc$ of $clushead_x, dis_{clushead-BS}$ then
 Step 5: Evaluate $dis_{y-BS} = \min\{dis_{clushead x-BS} + dis_{clushead x-y}\}$;
 Step 6: Communicate $start - msg()$ in R/2 to swap local information;
 Step 7: Fetch the nodes adjacency degree
 Step 8: Compute the signal-to-noise ratio snr_x
 Step 9: Evaluate its UL_x
 Step 10: Comparison with the adjacent nodes
 Step 11: If UL_x is largest then
 Step 12: Change its state to $clushead$;
 Step 13: for (each $l - 1$ level $clushead$)do;
 Step 14: estimate the forwarding cost;
 Step 15: end for
 Step 16: Choose $clushead$ with the lowest forwarding cost as the $clushead$
 Step 17: Update the distance to BS;
 Step 18: Communicate $clushead - msg$;
 Step 19: else
 Step 20: Change its state to vc ;
 Step 21: end if
 Step 22: $l = l + 1$;
 Step 23: end for
 Step 24: end while
 Step 25: for(each vc_y) do
 Step 26: for(each $clushead | dis_{clushead-y} < R$)do
 Step 27: evaluate joining cost
 Step 28: end for
 Step 29: Choose $clushead$ with the lowest joining cost as its parent node;
 Step 30: end for
 Step 31: for(each node q_x) do
 Step 32: If $R_x^{out} < R_{low-peak}$, then node q_x switches to an idle state
 Step 34: else
 Step 35: end if
 Step 36: end for

4. PERFORMANCE EVALUATION

WSN has various range of application, which produces enormous amount of data; hence, this research work adopts the sensoria simulator [25] for large WSN scenario that allows the deployment of any number of sensor nodes. Furthermore, in this section, our proposed algorithm DSHR is evaluated by considering the parameters like network lifetime, communication overhead and the number of active nodes for 1,000 nodes, 1,500 nodes and 2,000 nodes. The system configuration used in developing our proposed model is the research carried out through the Windows 11 operating system (OS) with the quad-core processor, 2 GB NVIDIA graphics packed with 16 GB of RAM. The framework used is the .NET simulator known as the sensoria simulator, which functions in the C # programming language. Moreover, comparison is carried out with existing LEACH protocol. Table 1 shows the parameter selected to carry out the simulation.

Table 1. Parameter details

Network parameter	Value
Network size selected	50mx50m
Nodes considered for simulation	1,000, 1,500, and 2,000
Nodes initial energy	0.2J
Number of base station	1
Nodes initial energy	0.2J
Simulator	Sensoria

4.1. Network lifetime

Generally, a network depicts the time duration during which the network is functional. This is an essential parameter for performing the task. The more the network lifetime the better the performance of the model. Figure 3 shows the network lifetime for 1,000 nodes. The comparative analysis of the existing system with the proposed system is carried out; a graph is plotted by comparing the network lifetime for 1,000 nodes we can see that in the existing system it lasts for a short period whereas in the proposed system we can see the network lifetime is increased and lasts longer for 1,000 nodes. ES represents the existing approach as well as PS represents the proposed approach.

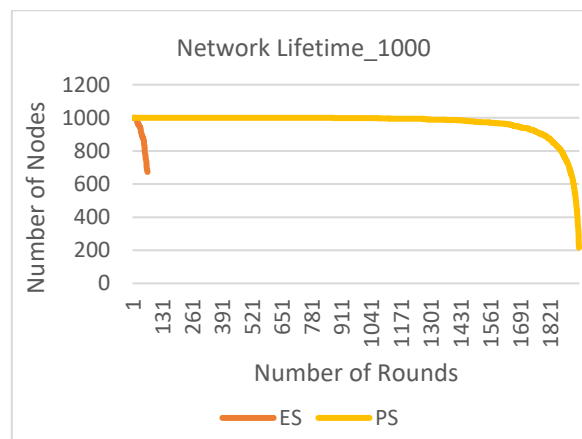


Figure 3. Network lifetime for 1,000 nodes

Figure 4 shows the network lifetime for 1,500 nodes. The comparative analysis of the existing system with the proposed system is carried out. A graph is plotted by comparing the network lifetime for 1,500 nodes we can see that in the existing system it lasts for a short period whereas in the proposed system we can see the network lifetime is increased and lasts longer for 1,500 nodes.

Figure 5 shows the network lifetime for 2,000 nodes. The comparative analysis of the existing system with the proposed system is carried out. A graph is plotted by comparing the network lifetime for 2,000 nodes we can see that in the existing system it lasts for short period whereas in the proposed system we can see the network lifetime is increased and lasts longer for 2,000 nodes.

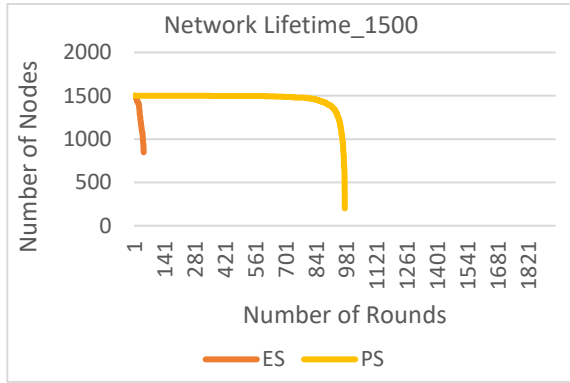


Figure 4. Network lifetime for 1,500 nodes

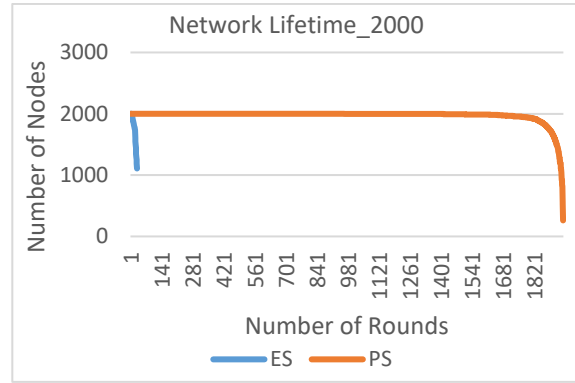


Figure 5. Network lifetime for 2,000 nodes

4.2. Comparative analysis

Table 2 shows the comparative analysis over the LEACH protocol over various nodes i.e. 1,000, 1,500 and 2,000. Here we see the improvisation % for different number of nodes. At 2,000 node we get the maximum improvisation.

Table 2. Improvisation over the existing model

Parameters	Network lifetime		
	1,000	1,500	2,000
No. of sensor nodes	1,000	1,500	2,000
Improvisation	2.7224%	16.421%	19.056%

5. CONCLUSION

The lifespan of a WSN might be impacted by the routing protocol's energy consumption because tiny sensor nodes are sometimes challenging to recharge after deployment. This research work develops a novel DSHR protocol, which helps in routing with respect to clustering. DSHR is evaluated considering the large number of nodes with 100, 1,500 and 2,000 in terms of network lifetime and model is proved to be marginally efficient than the existing LEACH protocol. DSHR solves the optimal routing mechanism; however, considering the scenario of big data in WSN, model would be evaluated further considering different parameter.





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