INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

Cluster Based Energy Efficient Routing Protocol using SA-LEACH to Wireless Sensor Networks

Sudhakar Chekuri[1]*, **B N Bhandari**[2]

1 Research Scholar, Department of Electronics and Communication Engineering, Jawaharlal Nehru Technological University Hyderabad, Hyderabad, India

2 Professor, Department of Electronics and Communication Engineering, Jawaharlal Nehru Technological University Hyderabad, Hyderabad, India

Check for updates

OPEN ACCESS

Received: 06-03-2022

Accepted: 19-01-2023

Published: 21-02-2023

Citation: Chekuri S, Bhandari BN (2023) Cluster Based Energy Efficient Routing Protocol using SA-LEACH to Wireless Sensor Networks. Indian Journal of Science and Technology 16(7): 492-500. https://doi.org/10.17485/IJST/v16i7.425

* **Corresponding author**.

sudhakar452@gmail.com

Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Abstract

Objectives: To develop an energy efficient routing protocol using SA-LEACH to Wireless Sensor Networks (WSN). **Methods:** The Simulated Annealing (SA) and LEACH algorithms are used to optimize the energy and maximize the active period of the network nodes. Here, initially the selection of the cluster head will be chosen by LEACH protocol; however, it is further investigated by SA algorithm to get better neighboring node (if exist) when compared with the selected one cluster head. **Findings:** There is an improvement in the throughput by 5.25%, 30% when compared with EE-LEACH and LEACH algorithms respectively. Also, energy is improved by 11.11% and 23.07% when compared to EE-LEACH and LEACH respectively. The performance of the designed algorithm has well suited for Coal mine industry, in which large number of sensor nodes is deployed to monitor the situation of the coal mine, continuously. **Novelty:** The designed algorithm is simple and effective. Furthermore, the proposed approach can enhance the rural healthcare monitoring system.

Keywords: WSNs; Energy Optimization; LEACH Protocol; SA; Routing; MATLAB

1 Introduction

Wireless Sensor Networks (WSNs) are the most promising technology due to its wide applications in real time applications such as health care monitoring systems, Coal mine industry, defense applications etc. The diversity of applications of such a network deflects the mindset of the research community to precede the work on this era. Many theories and models have been proposed to improve the performance of the network system, however still the network system need further enhancement in energy and routing parameters. Radhika et al [(1)] presented a model in which the authors tried to improve the lifetime of the node using Fuzzy Based Clustering and Machine Learning Based Data Reduction, no doubt the proposed approach improved the lifetime of the node but maximizes the delay and reduces the overall throughput of the network system. In [(2,3)] the authors improved the lifetime and energy of the nodes in Wireless Sensor Networks, but the design of the proposed approaches are too complex and may not be the optimum solution for real time applications.

Here the study focuses on the LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol, which is one of the algorithms based on the clustering approach. In this protocol the selection of 'CH' is performed randomly without considering the geographical location and residual energy of the node[4]. So sensor nodes whose energies and lifetime are very close to die out can be chosen as cluster head 'CH' in data transmission cycles and degrades the performance of the network. Furthermore different optimization methods have been proposed to select the most suitable CHs and clusters of the network in WSNs using the LEACH-based protocol[5], the BEE-WSN developed honey bee algorithm to select the 'CH'. In this method, a number of network parameters is used to test the selection process and showed high performance compared to the current LEACH protocol. Yadav et al.[6] aimed to extend the lifetime of the cluster head (CH) by using the Particle Swarm Optimization (PSO) technique. In another study, Mehra et al.[7] presented an energy-conscious fuzzy clustering protocol called fuzzy-based enhanced cluster header selection (FBECS), which calculates the fitness index of the sensor node used to select the CHs. In the designed FBECS model, 42.02% more data was transmitted than the LEACH protocol[8]. Sivakumar and Radhika[9] compared the performance of the Genetic Algorithm-based Hierarchical routing protocol LEACH-GA developed with the LEACH protocol. In the comparative analysis the initial energy and cluster head probabilities in a network, i.e. LEACH-GA increased the network lifetime by 54% compared to the LEACH protocol. Mohammed Moyed et al[10] proposed a method in which the authors tried to monitor landslides in real time applications; however, the authors did not put any attention for the enhancement of energy, hence may not be the optimum solution to real time applications.

Here in this study, the performance of the Simulated Annealing (SA) algorithm, which is one of the stochastic global search algorithms, was tested on the LEACH protocol. The Annealing Simulation method is an iterative meta-heuristic method for the solution of linear and non-convex optimization problems[11]. It is used in the fields of science and engineering related to single and multi-objective, constrained, or unconstrained optimization problems. In this study, a WSN environment with 100 sensor nodes has been chosen as an optimization problem. The developed LEACH-SA method affects the overall performance of the WSN. Energy consumption during the data transmission, active/dead node numbers on the network, and average energy per sensor were examined on the WSN model. The presented approach is validated using MATLAB R2015b. The rest of the paper is organized as follows in section 2 background and motivation of the proposed approach is presented, section 3 explains about the proposed approach, In section 4 we discussed our results and finally we conclude our paper in section 5

1.1 Background and Motivation

The art of work models which have been compared with the presented approach i.e. LEACH, EE-LEACH protocol, and Simulation Annealing algorithms (SA) are described below:

1.1.1 LEACH Protocol

LEACH is a hierarchical routing protocol[12] (Figure 1) which takes place in two phases: the setup phase, and the steady state phase. In the setup phase, one of the sensor nodes acts as the CH receiving messages from the SN node and transmits these messages to all sensor nodes. Clusters are created from sensor nodes then; CH is selected from among the nodes in the cluster.

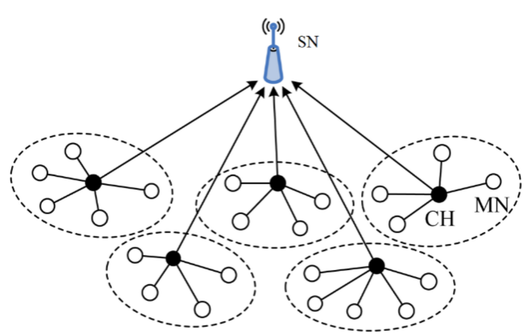

Fig 1. LEACH protocol model

In the steady state phase, the sensor nodes in the cluster send the data to the CH. CH sends these collected data to SN. CH selection is performed randomly, regardless of the geographical location and residual energy of the node. When selecting a node as CH, the node generates a random number between 0 and 1. The generated number threshold is obtained from Equation (1) and is represented as (S). After getting the value, the node will be considered as a cluster head (CH).

$$T(S)=\begin{cases}\dfrac{P}{1-P*\left(r\bmod\left(\dfrac{1}{p}\right)\right)} & \text{if } n\in G\\ 0 & \text{otherwise}\end{cases} \tag{1}$$

Here 'p', the probability of being selected per cluster, and 'r' is the number of cycles in which data transmission is performed.

The energy consumption model is based on the primary radio propagation model. Radio energy propagation between the receiver and sender nodes is given in the energy consumption model and can is represented in Equation (2)[13]. Here H is the number of bits to be transmitted, E_{TX} The energy consumed by a node while transmitting data to a neighbor of a sensing node, ε_{fs} is energy loss in space, E_{amp} is the amplifier coefficient for energy dissipation, E_{elec} is the energy consumed per bit to operate the transmitter or receiver circuits and free space energy,d is the transmission distance. It is calculated based on the Euclidean distance. d^2 is the power loss in vacuum, d^4 is the multipath fading power loss.

$$E_{TX}(m,d)=\begin{cases} mE_{\text{elec}}+m\varepsilon_{fs}d^2 & d<d_0\\ mE_{\text{elec}}+m\varepsilon_{mp}d^4 & d\geq d_0\end{cases} \tag{2}$$

Where 'd_0' is the distance between the receiver and the transmitter and is can be calculated as

$$d_0=\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \tag{3}$$

1.1.2 EE-LEACH Protocol

Energy Efficient LEACH (EE-LEACH) protocol is the improved version of the LEACH protocol in which the lifetime of the sensor network and coverage probability is derived with respect to the Gaussian Distribution, list of neighbor nodes is obtained by sorting algorithm based on the residual energy of the neighboring nodes. Data collection is done with aggregation to save energy, while the clusters are formed in a relatively small area when the sink node is at a distance comparably large. Cluster head CH election is carried out by taking account of the concentration degree of the member nodes and their residual energy[14].

1.2 Algorithms related to meta-heuristic

Meta-heuristic algorithms are algorithms designed to solve a problem faster when classical methods are too slow or to reach the closest solution under given conditions when a definite result cannot be reached. The point where meta-heuristic algorithms differ from mathematical optimization algorithms is that Meta heuristic algorithms look for the closest solution by approaching the solution set heuristically instead of scanning the entire solution set. Looking at the basis of heuristic algorithms, it is seen that it is a trial-and-error method. There are basic meta-heuristic algorithms that are generally accepted in the literature are the Genetic Algorithm, Particle Swarm Optimization, Artificial Bee Colony, and Gravity Algorithm[15].

It is seen in the literature that heuristic algorithms are used in solving many industrial and scientific problems. Meta-Heuristic search algorithms are used in determining the parameters that will increase the energy efficiency of geothermal power plants, defining PV cell parameters, and planar steel frame structures. It has been used in many different areas such as finding optimum design, graph coloring problems, and planning moving robot paths[13]. However, the wide acceptance of meta-heuristic algorithms has led to the development of different meta-heuristic algorithms in recent years.

1.3 Simulated Annealing

The Simulated Annealing (SA) method is a meta-heuristic method that basically imitates the atomic movements of solids during the annealing process. Annealing is a thermal process used to reach low energy levels in a material. In this process, the temperature is first raised to the melting temperature for a solid, and then the material is cooled. In the annealing process, if the cooling rate is sufficient to allow the atoms to be displaced, the atoms tend to move randomly to the lowest internal energy and highest stability state. These random fluctuations will allow the material to escape the local energy minimum and cool it structured with some residual energy characterizing the thermal stress in the material[16].Mathematically the annealing process is expressed using Monte Carlo probability mechanisms to find the lowest energy state associated with the optimum solutions. While the standard Monte Carlo algorithm only accepts motion to a low-energy state, the Metropolis procedure made it possible to accept a higher-energy state as well. Kirkpatrick et al. transformed this idea into an intuitive method for dealing with combinatorial optimization problems.

The Annealing Simulation algorithm can be expressed with six steps given in Figure 2. When we adopt this situation to problems, with a wide range of solutions, starting from the high temperature value, the search for a solution is started, the temperature is gradually reduced, and neighboring solutions are looked at randomly. The newly found neighbor solution is accepted if it is better than the previous objective function. If this is a minimization problem, the lowest value is looked at. The search continues, if a worse solution is found in the search process by looking at neighboring solutions, it is evaluated by looking at the acceptance probabilities of this solution. Once the acceptance of probabilities of the solutions is evaluated, the search for neighboring solutions can be calculated using equation 4 with gradually decreasing temperature. When the final temperature value is reached, the best solution found so far is accepted as the objective function[17].

$$X_{i+1} = \begin{cases} X_{\text{new}} & \exp\left(-\frac{\Delta f}{T}\right) > r \\ X_i & \text{otherwise} \end{cases} \tag{4}$$

The purpose of looking at acceptance probability is not to limit the solution to the first local minimum found. While searching for the minimum value of the objective function in the algorithm, the best value obtained locally is the local minimum solution. If the first local minimum value is accepted as the solution, the possibility of reaching the universal best solution, which is a better solution than this value, is prevented. It is not a case that the algorithm is always expected to reach the universal best solution. The best solution found by the algorithm in its search for the lowest temperature is accepted.

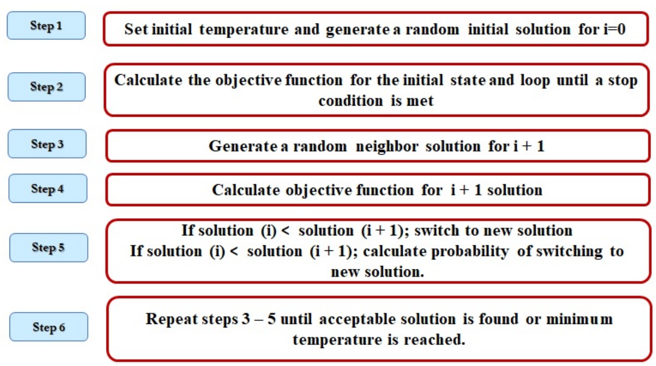

Fig 2. Steps of the Simulated Annealing Algorithm

2 Methodology

2.1 SA-LEACH Algorithm (Proposed Approach)

In the study, first of all the LEACH routing protocol is modeled using MATLAB R2015b software based on a graphical user interface for a 100-node WSN. In the model, the sensor nodes are randomly distributed in an area of 100m x 100m. In addition, a device that acts as a gateway is placed at a central point in the model. The network model created in which clusters are formed according to the LEACH protocol for one data transfer cycle. This clustering process is rebuilt in each cycle and the most suitable cluster head node is selected according to LEACH protocol procedures. As an example, 11 clusters were created during the clustering phase. The sensor nodes included in the cluster transmit their data to the CH, and then the CHs send these collected data to the centrally located Sink node SN. Thus, the first data transfer cycle is completed and the network is ready for the new cycle. The parameters and initial values used in the calculation of the energy consumption experienced in each data transmission cycle in the prepared WSN test model are given in Table 1.

So after finalizing the CH, further investigation is carried out to optimize energy efficiency using SA algorithm. Therefore, called a LEACH-SA Method, the LEACH protocol performs the task of selecting the number of CH and nodes selected in each round, while the SA algorithm replaces these selected nodes with better nodes that will provide the least energy consumption for that data transfer. The objective function of the study is the total energy remaining in the sensors after each data transfer cycle can be calculated using equation 5

Table 1. First Order Radio Model Simulation Parameters

Parameter	Value
Initial Energy (E_0)	0.5 J/node
Energy for Transmitter Electronic (E_{elec})	50 nJ/bit
Energy for Receiver Electronic (E_{elec})	50 nJ/bit
Data Pack Size (h)	4000 bits
Energy Transfer Coefficient (E_{fs}) for d<d_0	10 pJ/bit/m^2
Energy Loss in Void (E_{amp}) for d>d_0	0.0013 pJ/bit/m^4
Cluster ratio (p)	0.1

$$f(x_i) = f(x_{i-1}) - \sum_{i=1}^{CHn} E_{TX(Si \rightarrow CHn)}(m,d) + \sum_{i=1}^{CHn} E_{CHi} + E_{TX(CHn \rightarrow SN)}(m,d) + \sum_{i=1}^{c} E_{TX(Si \rightarrow SN)}(m,d) \quad (5)$$

Here CHn the number of cluster heads, $E_{TX(Si \rightarrow CHn)}$ the energy consumed while sending data to the CH from the sensor node $'i'.E_{CHi}$ is the energy consumed by the CH while receiving the data, $E_{TX}(CHn \rightarrow SN)$ is the energy spent in sending data from cluster head to sink node energy, C sensors not included in any cluster, $E_{TX(Si \rightarrow SN)}$ refers to the energy consumed during data transmission from the sensor node to the SN.

The constraints used when optimizing energy efficiency in WSN with the simulated annealing (SA) algorithm are given below.

• Node CH is a member of set N (CH ∈ N), where N is a set of sensor nodes.

• New CH cannot be a member of the set M, where M is the set of previously selected nodes CH ($CH_{new} \notin$ M) M set every r. (M=∅) for (r mod CH reset = 0)

• The selected sensor node energy must be greater than 0 (E > 0)

Annealing Similarity parameters and values used in the LEACH-SA method are represented in Table 2.

Table 2. Parameters of Simulated Annealing

S.No.	Parameters	Value
1	Initial Temperature (T_{start})	100,000
2	Final Temperature (T_{end})	0.1
3	Coefficient sk	0.99

The flow diagram of the SA-LEACH algorithm developed in the study is given in Figure 3. Process steps according to the flowchart;

1. Start the WSN run for the maximum number of rounds
2. Define Simulation Annealing parameters (T_{start}, T_{end}, sk) .
3. Save current status for WSN
4. Select CH nodes from N clusters based on percentage value from sensors that are not included in M cluster at the same time.
5. Clustering is performed according to the selected CHs
6. Calculate the energy consumption according to the objective function given in Equation 5
7. Consider the calculated value as the best value
8. With Simulation Annealing for $(i+1)$iteration, select a new neighboring node as CH and replace it with a CH from the existing list. Then distribute the nodes in the network to the clusters and calculate the energy consumption for the new situation.
9. If $E_{T(rem)}(i+1)$ is less than energy consumption value than $E_{T(rem)}$, save the energy consumption value, save the newly found value in the cluster head list, if not, to accept the new bad situation or not generate a random number$rs < exp(-\Delta E_{T(rem)}/T)$,if so, consider this situation as the new situation.
10. If the minimum temperature value is reached, exit the loop and update the WSN according to the least energy consumption you find. If the minimum temperature value is not reached, decrease T_{start} value by sc and go back to the loop.

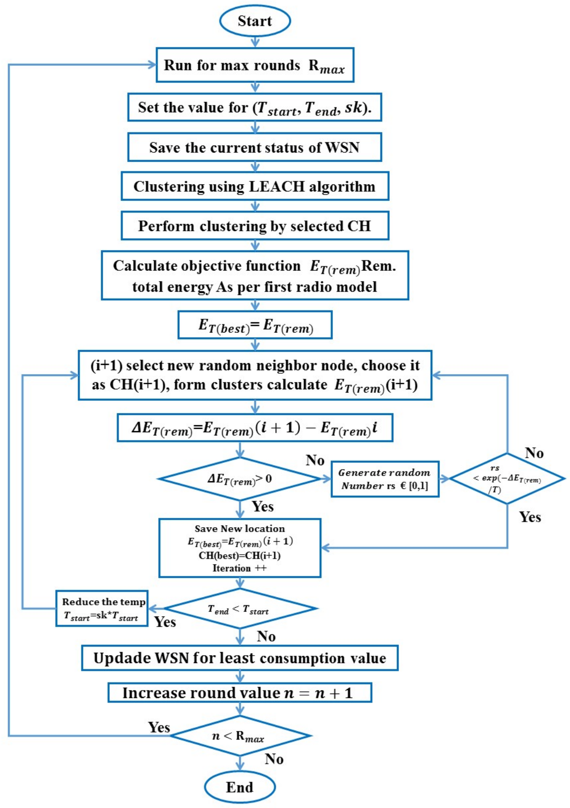

Fig 3. Energy Optimization Flow Chart with SA-LEACH

3 Results and Discussion

In Figure 4, optimization algorithm according to the designed WSN model is given graphically, in the search for the total amount of energy remaining in the network for a single data transfer cycle.

Network model used in the simulation is as follows, the initial energy of each sensor node is assumed to be 0.5J as given in Table 1. Accordingly, the total energy in the network for 100 nodes is 50J. However, this energy decreases with each data transfer cycle and eventually drops to 0. As depicted in the graph (Figure 4), the total energy of the network for the state before data transmission starts is 40.145J. What is desired here is that the clustering to be created should be designed to consume the least energy during data transfer. With the SA-LEACH algorithm developed for this purpose the objective function for neighboring cluster head groups is re- calculated in order to find the best value (local maximum) in 1500 iterations. As a result of the test x=311, it is recorded the highest energy state that will remain as a result of the data transfer cycle with Y=40.14 in the iteration. It is also seen in the graph that the annealing simulation algorithm, due to its nature, tends to get worse in some iteration. The main reason for this is that after a worse situation, a much better situation may emerge in the next iteration. In the test network model used, this process is repeated for each data transfer cycle and the best cluster that can be set up among the remaining nodes which will consume the least energy is selected. With 40.14, it recorded the highest energy state that will remain as a result of the data transfer cycle.

The performance of the proposed SA-LEACH algorithm is simulated as per the simulation parameters given in the Table 1 and compared with the existing protocols, LEACH and EE-LEACH. The efficiency of the proposed protocol is evaluated using the criteria as follows, Throughput, Packet delivery ratio, Average Energy consumed and End-to-End delay.

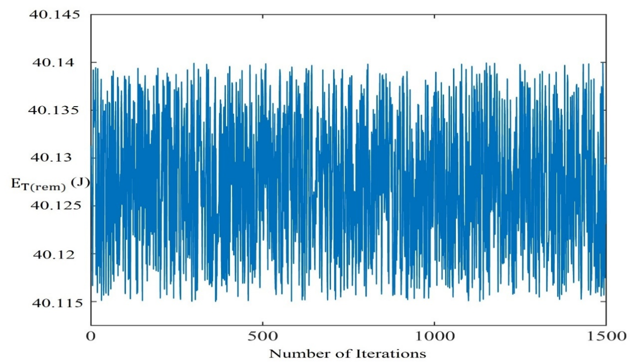

Fig 4. Search for the best situation with the SA-LEACH

3.1 Throughput

Figure 5 shows the throughput plot of the proposed SA-LEACH protocol compared with the existing LEACH and EE-LEACH protocol. From the results it is clear that the proposed protocol has improvement over the existing protocol, as it does the have uniform energy consumption over the clusters and successful data aggregation. Here in the proposed approach we observe that the throughput is increased by 5.25% when compared to EE-LEACH and 30% when compared to LEACH Algorithm.

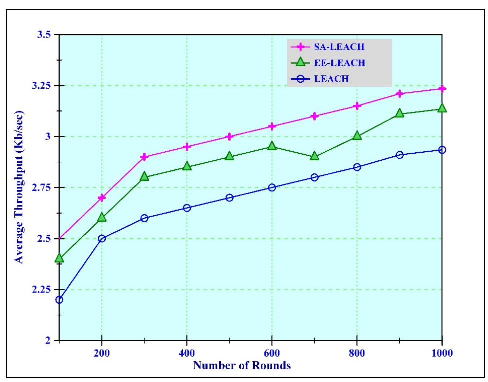

Fig 5. Throughput analysis of proposed protocol with the existing protocols

3.2 Average Energy Consumption

Figure 6 depicts the average energy consumed by the node in a WSN network, It is seen from the results, energy consumed by the nodes in our method protocol is better than the existing protocols i.e. LEACH and EE-LEACH, the reason being the optimum node selection using SA algorithm. Furthermore, simulation data shows average energy consumption reduced by 11.11% and 23.07% compared to EE-LEACH and LEACH respectively.

3.3 End to End Delay

Figure 7 shows the end-to-end delay of the proposed approach and the existing approaches i.e. SA-LEACH with the LEACH and EE-LEACH protocols. It is seen that the proposed protocol takes lesser time to forward the data to the sink node after aggregation compared to the existing protocols LEACH and EE-LEACH. As the optimum distance is selected using the link budget equation. There is improvement of 28.57% noticed compared to EE-LEACH, 300.1% improvement when compared to LEACH protocol.

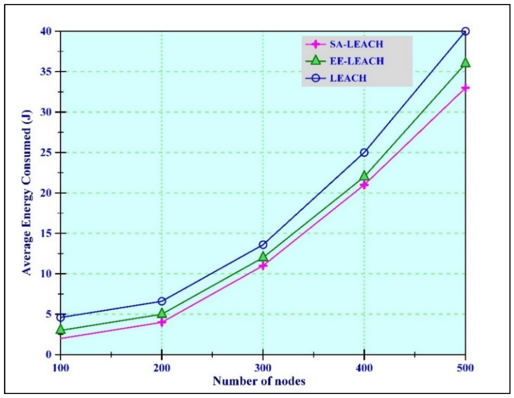

Fig 6. Average energy consumption for SA-LEACH with LEACH & EE-LEACH

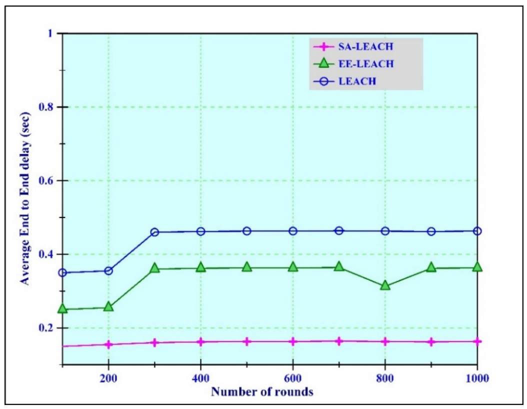

Fig 7. Analysis ofEnd-to-End delay for SA-LEACH, LEACH & EE-LEACH

3.4 Packet delivery Ratio

It is number of successful data delivered to sink node. Figure 8 represents the comparative analysis of the PDR of proposed protocol (i.e. SA-LEACH) and the existing protocols. From the figure it has been observed that the proposed one is more efficiently delivers the packets compared to the existing ones, as the optimum links chosen along the path of CH to sink node SN in the proposed SA-LEACH protocol, furthermore the Proposed protocol delivers more data i.e. 2.08% compared to EE-LEACH and 3.15% compared to LEACH.

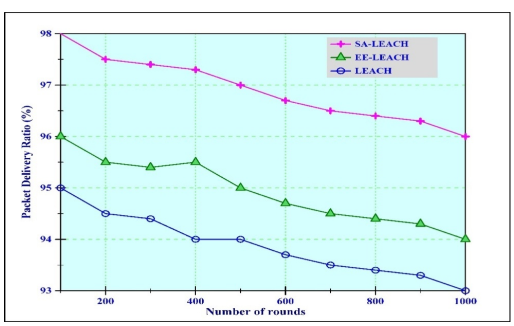

Fig 8. Packet Delivery Ratio analysis for SA-LEACH, LEACH & EE-LEACH

4 Conclusion

For balanced energy consumption to improve the energy efficiency of WSN, a method based on the Simulation Annealing algorithm, which is a meta-heuristic, has been developed for optimizing cluster head node selection process integrating with LEACH protocol. In the developed protocol SA-LEACH, the cluster head nodes from their member nodes will perform the task of collecting data during each cycle and are selected through the LEACH protocol, and then the neighborhoods of these nodes are examined and optimized by the Simulation Annealing method to replace the Cluster Head for low energy consumption. According to the test results, the SA-LEACH Protocol displays improved Energy consumption, End-to-End delay, Packet Delivery Ratio, and Throughput when compared to LEACH and EE-LEACH protocols. As in LEACH randomly generating cluster heads may lead to the unbalanced distribution of cluster heads, whereas the coverage probability is derived with respect to the Gaussian distribution in EE-LEACH gives better results for the small-scale networks. In large-scale networks, SA-LEACH proved to give better results with scalability, as the selection of CH node is done through the SA algorithm and replaces these selected nodes with better nodes that will provide the least energy consumption for the data transfer. The Average energy consumption is about 11.11% less compared to EE-LEACH, and 23.07% less compared to LEACH, whereas improvement in the Throughput is 5.25% over EE-LEACH, and 30% over LEACH protocol.

References

1) Radhika S, Rangarajan P. On improving the lifespan of wireless sensor networks with fuzzy based clustering and machine learning based data reduction. *Applied Soft Computing*. 2019;83:105610. Available from: https://doi.org/10.1016/j.asoc.2019.105610.
2) Jagan GC, Jayarin PJ. Wireless Sensor Network Cluster Head Selection and Short Routing Using Energy Efficient ElectroStatic Discharge Algorithm. *Journal of Engineering*. 2022;2022:1–10. Available from: https://doi.org/10.1155/2022/8429285.
3) Satyanarayana P, Mahalakshmi T, Rao PRK, Sheeba A, Ravi J, Rao JN. Enhancement of Energy Efficiency and Network Lifetime Using Modified MPCT Algorithm in Wireless Sensor Networks. *Journal of Interconnection Networks*. 2022;22:2144012. Available from: https://doi.org/10.1142/S0219265921440126.
4) Mohan P, Subramani N, Alotaibi Y, Alghamdi S, Khalaf OI, Ulaganathan S. Improved Metaheuristics-Based Clustering with Multihop Routing Protocol for Underwater Wireless Sensor Networks. *Sensors*. 1618;22(4):1618. Available from: https://doi.org/10.3390/s22041618.
5) Subramani N, Mohan P, Alotaibi Y, Alghamdi S, Khalaf OI. An Efficient Metaheuristic-Based Clustering with Routing Protocol for Underwater Wireless Sensor Networks. *Sensors*. 2022;22(2):415–415. Available from: https://doi.org/10.3390/s22020415.
6) Yadav A, Kumar S, Vijendra S. Network Life Time Analysis of WSNs Using Particle Swarm Optimization. *Procedia Computer Science*. 2018;132:805–815. Available from: https://doi.org/10.1016/j.procs.2018.05.092.
7) Mehra PS, Doja MN, Alam B. Fuzzy based enhanced cluster head selection (FBECS) for WSN. *Journal of King Saud University - Science*. 2020;32(1):390–401. Available from: https://doi.org/10.1016/j.jksus.2018.04.031.
8) Karabekir B, Aydin MA, Zaim AH. Energy-Efficient Clustering-Based Mobile Routing Algorithm For Wireless Sensor Networks. *Electrica*. 2021;21(1):41–49. Available from: https://doi.org/10.5152/electrica.2021.20035.
9) Sivakumar P, Radhika MP. Performance Analysis of LEACH-GA over LEACH and LEACH-C in WSN. *Procedia Computer Science*. 2018;125:248–256. Available from: https://doi.org/10.1016/j.procs.2017.12.034.
10) Ahmed MM, Pothalaiah S, Rao DS. Real-time monitoring of partially stable slopes for Landslide prediction by using Wireless Sensor Networks. *2016 Online International Conference on Green Engineering and Technologies (IC-GET)*. 2016;p. 17–18. Available from: http://hobbydocbox.com/Radio/82416359-2016-online-international-conference-on-green-engineering-and-technologies-ic-get-2016.html.
11) Subramani N, Mohan P, Alotaibi Y, Alghamdi S, Khalaf OI. An Efficient Metaheuristic-Based Clustering with Routing Protocol for Underwater Wireless Sensor Networks. *Sensors*. 2022;22(2):415. Available from: https://doi.org/10.3390/s22020415.
12) Jasim AA, Idris MYI, Azzuhri SRB, Issa NR, Rahman MT, Khyasudeen MFB. Energy-Efficient Wireless Sensor Network with an Unequal Clustering Protocol Based on a Balanced Energy Method (EEUCB). *Sensors*. 2021;21(3):784. Available from: https://doi.org/10.3390/s21030784.
13) Jibreel F, Gbolagade KA, Daabo MI. Servant-LEACH Energy Efficient Cluster-Based Routing Protocol for Large Scale Wireless Sensor Network. *International Journal of Engineering Research and Technology*. 2020;9(05). Available from: http://doi.org/10.17577/IJERTV9IS050170.
14) Arshad M. A three-tier cluster-based routing protocol for mobile wireless sensor networks. *Indian Journal of Science and Technology*. 2020;13(33):3409–3424. Available from: https://doi.org/10.17485/IJST/v13i33.951.
15) Kendall G. AI methods simulated annealing. . Available from: http://www.cs.nott.ac.uk/~pszgxk/aim/notes/simulatedannealing.doc.
16) Rere LMR, Fanany MI, Arymurthy AM. Simulated Annealing Algorithm for Deep Learning. *Procedia Computer Science*. 2015;72:137–144. Available from: https://doi.org/10.1016/j.procs.2015.12.114.
17) Ahmad SJ, Ahmed MM, Unissa I. Optimization of Environmental Data to Improve Safety in Coal Mine using Wireless Sensor Networks. *Indian Journal of Science and Technology*. 2022;15(19):956–964. Available from: https://doi.org/10.17485/IJST/v15i19.686.