International Journal of Scientific Research in Computer Science and Engineering
Vol.**12**, Issue.**2**, pp.**01-07**, April **2024**
E-ISSN: 2320-7639
Available online at: www.isroset.org

Research Article

Energy-efficient modified LEACH protocol for Wireless Sensor Networks (WSN)

Vivek Kumar[1*], Ruchika Malhotra[2], M. Yousuf Ansari[3]

[1,3]Defense Scientific Information & Documentation Centre DRDO, Metcalfe House Delhi, India
[2]University (DTU), Delhi, India

**Corresponding Author: vivekkumar.desidoc@gov.in*

Received: 23/Feb/2024; **Accepted**: 25/Mar/2024; **Published**: 30/Apr/2024. | **DOI**: https://doi.org/10.26438/ijsrcse/v12i2.17

Abstract— Numerous researches have been done for minimization of the consumption of energy on wireless sensor networks (WSNs). The reason behind such research is because of a large number of applications in this field. We have proposed a method for the same in our paper. We have implemented various approaches to minimize the energy consumption and based on various results which are calculation of cluster count, Communication between the packets and lifetime matrices which are number of alive and dead nodes. The techniques implemented in the system are simple leach, I-leach, modified I-Leach and the Multi-Hop Clustering Routing method in Leach. On comparing all the techniques, it is found how the suggested technique performs which is Multi-Hop Clustering Routing is better in network lifetime as well as in terms of stability period.

Keywords— Leach protocol; Multi- hop clustering; WSN.

1. Introduction

WSNs are micro sensor-equipped communication networks made up of a large number of geographically dispersed nodes. By collaborating and sensing data from that area, these tiny devices work together to collect and process data from a specific location. After that, the data is delivered into base station. WSN have been around for years, but now are an integral part of IoT-based assets[1]. They are critical in a number of applications. Smart cities[4], monitoring of the environment as well as Health care[2], are just a few examples of possible IoT application scenarios. Compared to ad-hoc networks, the total quantity, nodes in sensory network could be many orders which have high magnitude. Although sensor nodes are widely distributed, their power, computing capabilities, and memory are restricted[6]. One of the most pressing concerns in WSNs is the development of energy-efficient routing algorithms. Sensor nodes cannot be changed once they have been installed in the network[5].

As a result, network function is inextricably linked to the proper use and regulation of node power. In WSNs, the most energy efficient routing protocols are hierarchical routing protocols. They have grown in popularity in recent years. Split the network in bits, each of which has a (CH) that connects cluster nodes (known as member nodes) to BS. The CH takes in high amount of energy in the collection because it retrieves data, compiles it, and distributes it to BS by a method to minimize total power consumption.

The oldest hierarchically built system that uses clustering to route information is the LEACH[1]. Data is transferred directly from the CHs to the BS via a one-hop routing mechanism. However, it does have some limitations. To begin with, CHs that are farther from the BS, expend more energy than those which are nearer. Because of this, clusters that are further apart have a higher chance of dying than clusters that are closer together. Because LEACH's direct transmission technique interferes with distribution load balancing and reduces the network's working lifetime, it does not work efficiently for wide scale networks. Moreover, the data transfer frequency which varies from node to node, depending on the value of the data present at each and every node. Highly active nodes die sooner than those with medium activity as a result of this differentiation, resulting in an energy imbalance between network nodes.

The sensor nodes, which are battery-powered and have bounded power, must perform intensive processing and computing in order to extract meaningful data from a large volume of data. As a result, WSN is inhibited in terms of processing, power as well as some other factors[1]. On the contrary, the IOTs links a large number of devices in order to collect metadata that can later be analyzed. This will waste available energy and have an adverse effect on network's longevity. For the optimization of the network lifespan in a WSN, the data packet routing pathways must be chosen in such a way that the total energy spent on the path is reduced.

2. Literature Review

i. Gurjot, Himanshu, Lavish, and Rajan Miglani (2016). "WSN I-LEACH Protocol." IJMUE, 11, 279-292. WSNs are important for marine engineering, human tissue research, and animal life research. WSN is limited when replacing the node's small battery is impractical. This research paper helps. LEACH, an early WSN energy-saving technique, inspired this work. This protocol must accommodate node fabrication. I-LEACH outlasts MOD-LEACH, an analysis shows (a variant of LEACH). Compared to MOD-LEACH, network lifetime increased by 54%, ensuring reliability.

ii. International Journal of Computer Applications in Technology 60(3):267 published MPF-LEACH. They improved LEACH's Cluster Head election probability function (thresholds). Former CHs can run again. CH residual energy prolongs network life. The new threshold increases CH probability above 0. New research improved LEACH. Throughput and durability are improved. Encouraging reselection of an expired CH with insufficient residual energy. Our proposed MPF-LEACH procedure was tested extensively. Network resilience and throughput have improved. We raised LEACH's election threshold using CH residual energy. A CH's re-election increases the network's lifespan.

iii. In 2018, IET published "Energy-efficient modified LEACH for IoT." Wi-Fi sensor networks are versatile (WSNs). IoT connects devices and objects. Unlike mobile ad-hoc networks, WSN battery life affects network durability. Wireless sensor network energy consumption is studied. Clustering reduces WSN power. This study changes cluster head selection thresholds and node power levels. Enhanced LEACH increases WSN life by 1,750 rounds per round. Node density, size, and energy consumption beat energy-efficient protocols.

3. Modelling of The System

LEACH is a TDMA-based MAC system that uses a combination approach to distribute power to provide balance between network sensors. Nerve notes process data before sending it to BS via CH. CH is a cluster sensor node that can only communicate with BS [9]. The data is then made available to the end user in the online context. The LEACH method is divided into circles, each with two main stages: setting and solid state.

During the first setup phase, clusters are formed as well as a selection of CH node is being done. For the selection of CH, a random number among 0 and 1 is assigned and every node participates in this process. Selected as CH if the number of member nodes is below the limit of T. (n). Group Head even assigns TDMA schedules for group members.

Where p is taken as the required amount of the sensor nodes which may be CH, r current round, along with the G node group don't participate in selection of CH in previous 1 / p round. Because the selected CH area in cycle r isn't permitted to be voted in next 1 / p rounds, every sensor of the group has an equal probability of being CH. As a result, power dissipation in the network is evenly distributed between the sensor nodes.

In between of intensity, cluster nodes use TDMA schedule for transfering sensory data into appropriate nodes. Any node can transmit data while all nodes are asleep. Internal conflict in the group can be avoided in this way[16]. The protocol's main goal is to improve energy efficiency by selecting random numbers depending on rotation.

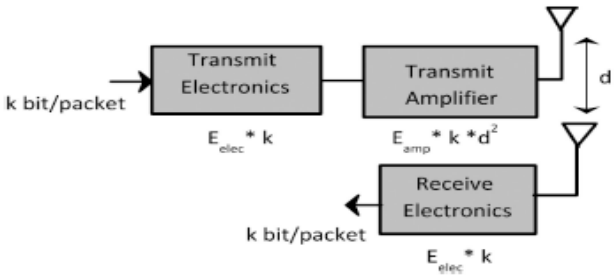

Figure 1. LEACH Protocol Phases

In our modified protocol[17], we communicate using the first-order radio energy concept, as represented by Figure. 1.

Radio model of first-order can be separated in two types that are classified into the distance among the sensing as well as the receiving nodes: free space as well as the multi-path fading[18]. Communication channel is expected of being symmetrical, amount of energy that is wasted when bits are being sent to a node hundreds of meters distant by the sensor nodes may be calculated using the formula[19].

$$E_{\mathrm{Tx}}(k,d) = E_{\mathrm{Tx\_elec}}(k) + E_{\mathrm{Tx}}\mathrm{amp}^{\mathrm{amp}}(k)$$

$$E_{\mathrm{Tx}}(k,d) = \begin{cases} E_{\mathrm{elec}} * k + E_{\mathrm{fs}} * k * d^2, & d \le d_0 \\ E_{\mathrm{elec}} * k + E_{\mathrm{amp}} * k * d^4, & d > d_0 \end{cases}$$

Likely, energy taken in by a sensor node to receive packets is represented by

$$E_{\mathrm{Rx}}(k) = E_{\mathrm{Rx\,elec}}(k) + kE_{\mathrm{elec}}$$

Where E_{elec} is transmitter's or receiver's energy consumed for every bit, E_{amp} and E_{fs} are transmission amplifier parameters for the multi-path fading as well as for the free-space models, respectively. Every packet includes data as well as overhead. The overhead bits contain information about packets, such as the coding scheme used to transmit date securely, the encryption mechanism used for the security purpose, and the basis and end point addresses. Regardless of packet size, the overhead is the same. As a result, the overhead spectrum as well as the energy usage may be negligible, lowering wireless sensor network energy efficiency as well as the spectral. Furthermore, the obtained output has amplified.

TheN_{data} data bits in packet as well asN_{overhead} the overhead bits are E_{data} and E_{overhead} respectively, if the energy related

to every data bit and overhead bit is. The overall energy of the packets is calculated using the following formula:

$$E_{\text{Packet}} = N_{\text{data}} \times E_{\text{data}} + N_{\text{overhead}} \times E_{\text{overhead}}$$

A system's efficiency is determined by

$$\eta = \frac{N_{\text{data}} \times E_{\text{data}}}{E_{\text{packet}}} \times 100$$

The efficiency will be nearly identical when the value of is large. The amount of energy spent in each round must be determined in order to create a threshold limit for selection. We estimate this energy threshold value using our suggested method in order to conserve energy and extend network longevity.

4. Proposed Techniques

i. Simple Leach
ii. I-Leach
iii. Modified I-leach (random Probability Function)
iv. Multi-hop clustering routing-method in LEACH

i) Simple Leach

Based on TDMA, the Leach protocol is a MAC protocol. The primary objective of this protocol is to extend the lifespan of wireless sensor networks by reducing their energy consumption. It consists of a setup phase and a steady phase. The "round" is the unit of the Leach protocol. Each "round" consists of a "cluster setup phase" and a "steady state storage phase." This is done to reduce unnecessary energy expenditures.

ii) I-leach

Wireless Sensor Networks can only exist so long as the nodes continue to function. Sensor Nodes are miniature, battery-powered modules. Consequently, constant power consumption depletes the battery and kills the node. The network continues to function as long as the nodes remain alive. Utilizing I-LEACH significantly increases the number of nodes that are still alive.

iii) Modified I-leach (random probability function)

In this paper, the Cluster Head (CH) election probability function is modified to improve LEACH. A CH who had previously held office was more likely to be re-elected. The intention is to utilize CH's excess energy to keep the network operational for longer[24]. As a means to raise the election probability threshold, the Probability Function for LEACH Protocol (MPF-LEACH) was proposed. We propose that the MPF-LEACH method utilize the CH residual energy to increase the WSN's lifetime and data transmission rate[7].

iv) Multi-hop clustering routing-method in the LEACH

In the LEACH-based phase, the multi-hop clustering strategy seeks to improve the delivery of selected facts to connect with others on the multi-hop approach to BS. That's why the network data transmission efficiency should be maintained at all times while the network is operating[8]. In most cases, WSN sensors are used randomly, no matter how far away from the network, and use a high amount of power to transmit data. In this case, the power of the sensor node will expire. This issue arises from Leach such that the protocol accepts that every participant transmits the data to the BS directly. This has an impact on network longevity as well as coverage region, as sensor nodes positioned distant from the BS will rapidly deplete their energy supply.

The routing table must be set up at this stage, which is the most important. An announcement message in the routing table is used to calculate the distance between the furthest zone and the zone closest to BS. It can take one of four routes, with the amount of energy expended varying depending on which one is chosen.

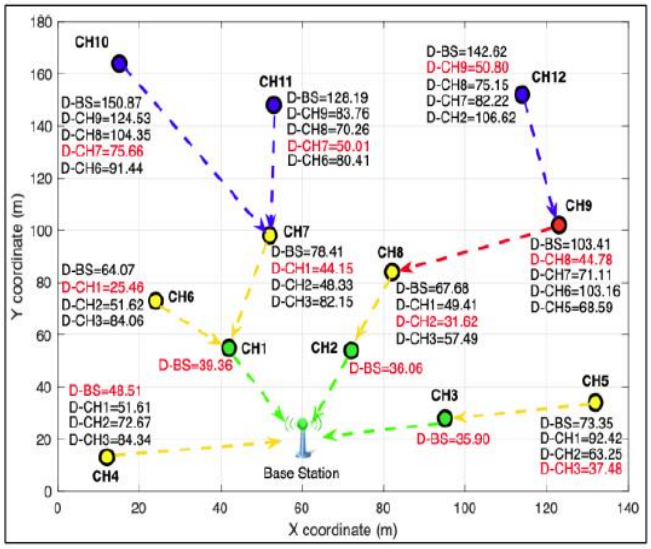

Figure 2. Routing Phase in Multi-hop clustering routing method

- Case 1: If the CH is in Zone 1 or $CH_{d-BS} < d'$, the data is immediately forwarded to the BS. The following equation is used to calculate the transmission energy:

$$E_{Tx}(k) = k\left(E_{\text{elec}} + \varepsilon_{fs} CH_{d-BS}{}^{2}\right)$$

- Case 2: Data is forwarded to an in Zone 2 with a minimum distance value if the CHs of Zone 2 or the CHs $(CH_{d-BS} \geq d')$ and $(\text{CH}_{d-BS} < 2d')$, in transmit data to an in Zone 2 with a least value of distance.

$$E_{Tx}(k) = k\left(E_{\text{elec}} + \varepsilon_{fs} CH_{d-Z1}^{2}\right)$$

When CH_{d-Z1} the distance between them is sufficient, the data in Zone 2 is transmitted to everyone in the Zone 2.

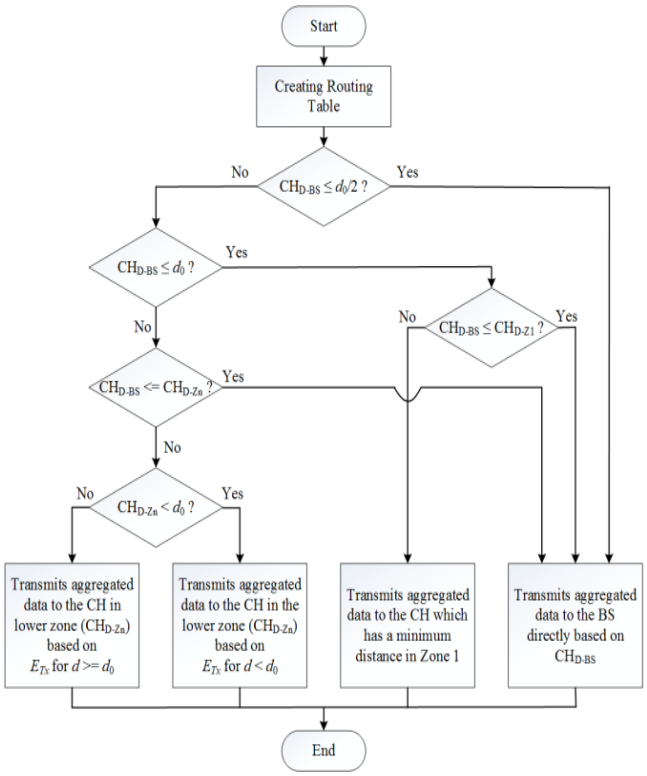

Figure 3. Multi-Hop Routing phase flow chart in LEACH.

- Case 3: The CHs of Zone 3 or in the $(\mathrm{CH}_{d-BS} \geq 2d')$ and $(\mathrm{CH}_{d-BS} < 3d')$ transmit data with least distance to Zone 3.

$$E_{Tx}(k) = k\left(E_{elec} + \varepsilon_{fs} CH_{d-Z2}{}^{2}\right)$$

When CH_{d-Z2} the distance between them is sufficient, the in Zone 3 broadcasts its data to the entire Zone 3.

- Case 4: If CHs are present in Zone 3 or its vicinity $(\mathrm{CH}_{d-BS} \geq 3d')$ and$(CH_{d-BS} < 4d')$.
- If$(\mathrm{CH}_{d-BS} \leq \mathrm{CH}_{d-Zn})$, is the case, the sends its data to the directly. The transmission energy is as follows:

$$E_{Tx}(k) = k\left(E_{\text{elec}} + \varepsilon_{mp} CH_{d-BS}{}^{4}\right)$$
$$\text{If}(CH_{d-BS} > CH_{d-Zn})$$

- If$(\mathrm{CH}_{d-Zn} < 2d')$, uses the free-space concept of energy transmission to send data to an over a short distance in the n-th zone.
- $E_{Tx}(k) = k\left(E_{elec} + \varepsilon_{mp} CH_{d-Zn}{}^{2}\right)$
Where $\mathrm{CH}_{d-\mathrm{Zn}}$ = the data from the zone is sent to all of the zones in zone n-1

Figure 3 can be used in the scenarios below. Figure 2 shows that, depending on the zone acquired, everyone chose the other for the next hop. For example, the closest to can send data directly to without having to go through another.

Other members of the same zone, on the other hand, can sort from zone 4 to zone 1 and send data to the other zone's nearest member. Additionally, it can transfer data to a zone that is not immediately adjacent to it if the distance to BS is close enough.

During the routing step, the technique is shown in Fig 3. The routing table is based on the shortest data transfer distance between the higher and lower zones. The combined data is transferred to the zone division is based on distance among BS as well as the CH. Data can be delivered directly to BS by nodes that are closer to it. Cases 1 through 4 will be followed by the selected CHs stationed further away.

5. Discussion and Results of the Simulation

Table 1. Parameters for simulation

Symbol	Description	Value
X_m	X-axis Distance	400 m
Y_m	Y-axis Distance	400 m
N	total sensor nodes	100 nodes
P_{Tx}, P_{Rx}	Total network energy	0.5 J
E_{mp}	energy dissipation: receiving	0.0013/pJ/bit /m^4
E_{fs}	energy dissipation: free space model	10/pJ/bit/m^2
E_{amp}	energy dissipation: power amplifier	100/pJ/bit/m^2
E_{DA}	Energy dissipation: aggregation	5/nJ/bit
d_0	reference distance	87 m
I	packet size	4000bits

The proposed technique is used to produce the results simulated based on parameters that are listed in the table 1. Table to create distinct visualizations, a simulation in MATLAB is run for 2000 rounds of iterations. The packet size in this study is 4000 bytes, which is a reasonable size. As a result, in comparison to the total packet energy, the overhead energy is negligible, and it can be overlooked. As a result, throughout the simulation, the proposed Multi-hop clustering routing mechanism in LEACH. CH protocol has been compared to many current energy-efficient protocols, while ignoring the energy associated with packet overheads.

On many metrics, such as count, durability of the network, residual energy as well as the throughout, simulation findings clearly show that the Multi-hop clustering routing technique in the LEACH protocol outperforms all three strategies mentioned above, namely I-LEACH, LEACH, and Modified I-LEACH protocol.

When the LEACH protocol is changed to include a threshold power level for replacement criterion, the number of CHs for the multi-hop clustering routing strategy increases to 1903 rounds, compared only 850 rounds for the inefficient replacement method as well as to 1750 rounds for I-Leach depicted in Figure 4.

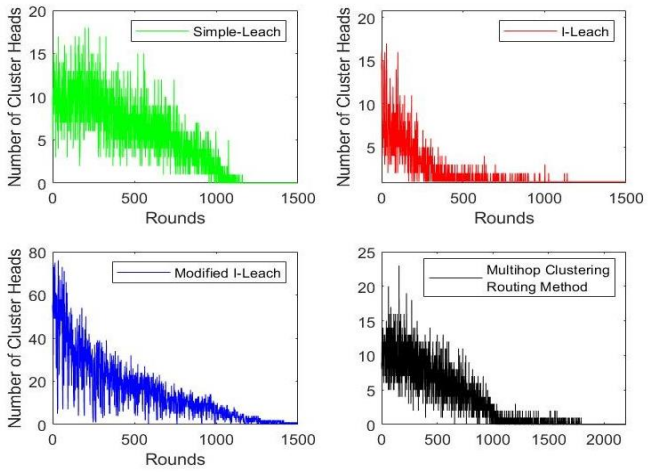

Figure 4. Cluster Counts in Simple Leach, I-Leach, Modified I-Leach and Multi-hop Clustering Routing Method in Leach

The sensor node's energy depletes as number of the rounds rises, until it dies. Quantity of the alive as well as dead nodes, respectively, represent the network lifespan in Fig 5. and fig 6. The number of active nodes drops to zero after about 750 rounds, but with I-LEACH, some nodes can stay active for up to 1500 rounds. In our suggested strategy, the multi-hop clustering routing mechanism in Leach keeps a large number of nodes alive until 1900 rounds. As a result, a complete scene to maximize longevity of the network emerges, including allocating various power levels for several types of network communication.

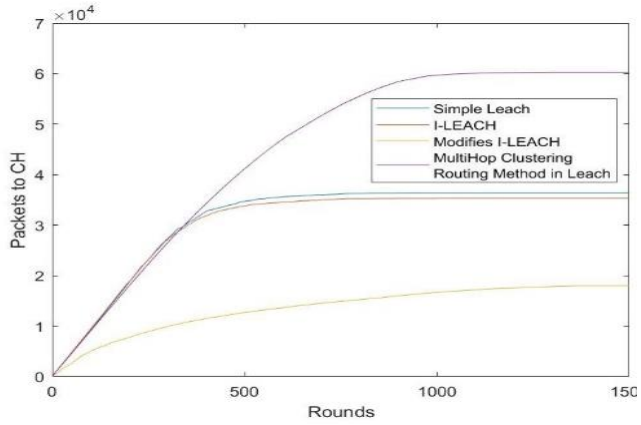

Figure 5. Life Metrices: Alive Nodes

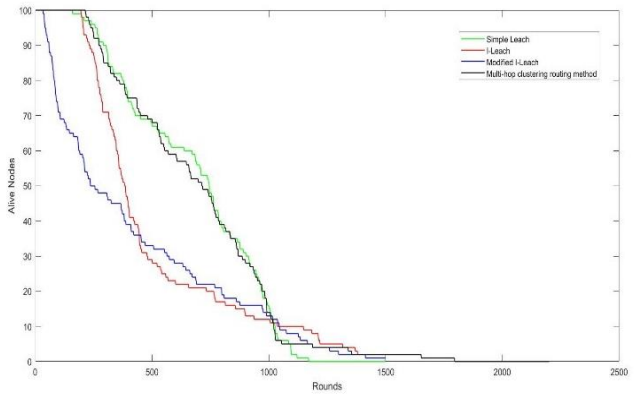

Figure 6. Life Metrices: Dead Nodes

The quantity of the data bits sent to in LEACH is limited to 2.7×10^4, but this number rises to 3.0×10^4 in I-LEACH, and to in the multi-hop clustering routing strategy, as shown in Figure 7.

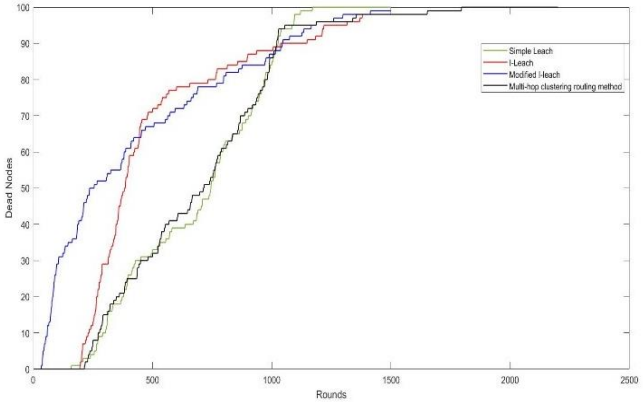

Figure 7. Packets Communicated to CH

The quantity of the data bits delivered to the BS determines efficiency of any routing strategy. The algorithm improves as the throughput increases. The throughput of the multi-hop clustering-routing technique has been significantly higher than the other protocols studied, as shown in Figure 8.

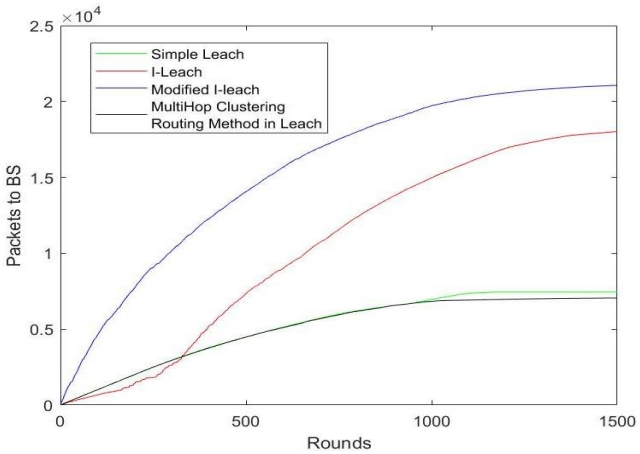

Figure 8. Packets Communicated to BS

We may improve several aspects of non-wired network of sensors well-matched for IoT devices by selecting a verge value in start-up phase for the replacement of CH as well as forming cluster process for the LEACH protocol, as seen in the above comparison.

6. Conclusion and Future Scope

The LEACH technique has proven to be popular among WSN researchers, demonstrating its importance. For various applications, different LEACH descendants have been developed. This is something we have discussed in this paper. We have implemented various approaches to minimize the energy consumption and based on various results which are calculation of cluster count, Communication between the packets and lifetime matrices which are number of alive and dead node.

The techniques implemented in the system are simple leach, I-leach, modified I-Leach and the Multi-Hop Clustering Routing method in Leach. On comparing all the techniques, it is found that the proposed technique which is Multi-Hop Clustering Routing technique works better in terms of the network lifetime, Fig 8, as well as stability period. The protocol has been improved to allow for the switching of multiple power levels at the same time as well as efficient CH selection.

The protocol increases network's life due to consumption of the energy decrease in a dispersed method. When associated with the different techniques of the low-energy, the suggested protocol was found to be the best fit for a variety of applications with varying quantity of nodes, energy as well as area. We can even expand the study to look at various routing protocols and see what results they produce.

Data Availability

The data supporting findings of this study are all presented in the article.

Conflict of Interest

The authors declare no conflicts of interest.

Funding Source

There is no funding source for this paper.

Authors' Contributions

Author-1, Vivek Kumar, researched the literature, collected data and organized the study. Author 2 and 3 supervised the preparation of the study and gave final approval of the article for publication.

Acknowledgements

We appreciate and thank the International Journal of Scientific in Research in Computer Science and Engineering (isroset) for their assessment and suggestions to improve visibility and clarity. We would also like to sincerely thank all the teachers and software laboratory in-charge involved in our research.

References

[1] Lee I, Lee K the internet of things (IoT), "applications, investments, and challenges for enterprises", Bus Horizons Vol.**58,** Issue**.4,** pp**.431–440, 2015**

[2] Qiu T, Han M, Li M, Zhang Y "A self-recoverable time synchronization for sensor networks of healthcare IoT", Computer Networks **129,** pp**.481–492, 2017**

[3] Lazarescu MT, "Design of a WSN platform for long-term environmental monitoring for IoT applications", IEEE J Emerg Select Topics Circuit Syst, Vol.**3,** Issue.**1,** pp**.45–54, 2013**

[4] Ghayvat H, Mukhopadhyay S, Gui X, Suryadevara N, Ghayvat H, Mukhopadhyay S, Gui X, Suryadevara N, "WSN and IOT-based smart homes and their extension to smart buildings Sensors", Vol.**15,** Issue**.5,** pp**.10350–10379, 2015**

[5] S.Ramesh, R.Rajalakshmi, Jaiprakash N Dwivedi, S. Selvakanmani, "Optimization of LEACH Protocol in WSN using Machine Learning", Computational Intelligence Neurosciences, **2022.**

[6] Bhende M, Wagh SJ, Utpat A, "A quick survey on wireless sensor networks", Fourth international conference on communication systems and network technologies. Pp.**160–167, 2014**

[7] Bhukya Suresh, G Shyama Chandra Prasad, "An Energy Efficient Secure routing scheme using LEACH protocol in WSN for IOT Networks", Measurements: Sensor (Elsevier), **2023**

[8] Trupti Mayee Behera, Umesh Chandra Samal, Sushanta Kumar Mohapatra, "Energy-efficient modified LEACH protocol for IoT application", The Institution of Engineering and Technology, ISSN **2043-6386**, doi: **10.1049**/iet-wss.**2017.0099**, May. **2018**

[9] Hana Rhim, Karim Tamine, Ryma Abassi, Damien Sauveron and Sihem Guemara, "A multi-hop graph-based approach for an energy-efficient routing protocol in wireless sensor networks" Cent. Computer. Inf. Sci. **8:30, 2018**

[10] Yick, J., Mukherjee, B., Ghosal, D.: 'Wireless sensor network survey', Computer Networks, 52, (12), pp.**2292–2330, 2008**

[11] Kim, D.S., Chung, Y.J., "Self-organization routing protocol supporting mobile nodes for wireless sensor network', First Int. Multi-Symp. on Computer and Computational Sciences, IMSCCS '**06**, Hanzhou, Zhejiang, China, Vol.**2**, pp.**622–626, 2006**

[12] Akyildiz, I.F., Su, W., Sankarasubramaniam, Y., et al, "Wireless sensor networks: a survey", Comput. Netw., Vol.**38,** Issue**.4,** pp.**393–422, 2002.**

[13] Kumar, V., Jain, S., Tiwari, S., et al, "Energy efficient clustering algorithms in wireless sensor networks: a survey", Int. J. Comput. Sci. Issues, Vol.**8,** Issue**.5**, pp.**814–1694, 2011**

[14] Zorzi, M., Gluhak, A., Lange, S., et al. "From today's intranet of things to a future internet of things: a wireless-and mobility-related view", IEEE Wirel. Commun., Vol.**17,** Issue**.6,** pp.**44–51, 2010**

[15] Mahapatra, R.P., Yadav, R.K, "Descendant of LEACH based routing protocols in wireless sensor networks", Procedia Comput. Sci., **57**, pp.**1005–1014, 2015**

[16] Wu, W., Xiong, N., Wu, C., : 2015, "Improved clustering algorithm based on energy consumption in wireless sensor networks', IET Networls", Vol.**6,** Issue**.3,** pp.**47–53, 2017**

[17] Rasheed, M.B., Javaid, N., Khan, Z.A., et al., "E-HORM: An energy-efficient hole removing mechanism in wireless sensor networks", 26th Annual IEEE Canadian Conf. on Electrical and Computer Engineering (CCECE), Regina, SK, Canada, pp.**1–4, 2013**

[18] Li, J., Mohapatra, P, "An analytical model for the energy hole problem in many-to-one sensor networks", IEEE Vehicular Technology Conf., Dallas, TX, USA, **1999**, Vol.**62**, pp.**2721, 2005.**

[19] Elbhiri, B., Saadane, R., Aboutajdine, D., et al, "Developed distributed energy-efficient clustering (DDEEC) for heterogeneous wireless sensor networks", 5th Int. Symp. on I/V Communications and Mobile Network (ISVC), Rabat, Morocco, pp.**1–4, 2010.**

[20] Perera, C., Zaslavsky, A., Christen, P., et al, "Sensing as a service model for smart cities supported by internet of things", Transaction Emerg. Telecommun. Technology, Vol.**25**, Issue.**1**, pp**.81–93, 2014**

[21] Gaba, Gurjot & Monga, Himanshu & Kansal, Lavish & Miglani, Rajan, "I-LEACH Protocol for Wireless Sensor Networks", International Journal of Multimedia and Ubiquitous Engineering. **11.** pp**.279-292, 2016**

[22] Nahar, Khalid & Ra, N.A. & Al-Khatib, Ra'ed M. & Barhoush, Malek & Abdul Halin, Alfian, "MPF-LEACH: modified probability function for cluster head election in LEACH protocol", International Journal of Computer Applications in Technology. **60. 267. 10.1504/IJCAT.2019.100295, 2019**

[23] Trupti Mayee Behera, Umesh Chandra Samal, Sushanta Kumar Mohapatra, "Energy-efficient modified LEACH protocol for IoT application", The Institution of Engineering and Technology, **2018**.

[24] Harneet Kaur, Omdev Dahiya, "A Modified LEACH Protocol in Wireless Sensor Network for Energy Efficient Routing Protocol", International Conference on Intelligent Engineering and Management (ICIEM) **2022**.

[25] Md. Ibrahim Abdullah, Md. Atiqur Rahman, Mohammad Alamgir Hossain, Md. Shohidul Islam, Md. Shamim Hossain, "To Identify the Untrustworthy Leader of a Hierarchical Wireless Sensor Network Using Received Signal Strength," *International Journal of*

Scientific Research in Computer Science and Engineering, Vol.**10**, Issue.**6**, pp.**30-39, 2022.**

[26] Musa Mojarad, Sayed Ebrahim Mousavipoor, Ali Kohan Mansourkhani, "Using of AODV Protocol to Develop Trust-Based Routing Algorithms in Wireless Sensor Networks," *International Journal of Scientific Research in Computer Science and Engineering*, Vol.**9**, Issue.**6**, pp.**13-19, 2021**

AUTHORS PROFILE

Vivek Kumar is a Scientist "E" at DESIDOC, DRDO, Delhi. He obtained his Bachelor's in Computer Science and Engineering from Motilal Nehru National Institute of Technology Allahabad, followed by an MBA from the esteemed Faculty of Management Studies at the University of Delhi and M.Tech from Delhi Technological University (DTU), formerly DCE. He has 18 years of research experience. He is proficient in a spectrum of areas including Requirements Analysis, Design and Development of Cryptosystems, Threat Modelling, Information Security Management, and Testing. His expertise also extends to project management, holding certification in this domain. Vivek is further recognized as an ISMS Lead Auditor, reflecting his proficiency in Information Security Management Systems.

Ruchika Malhotra currently working as Head of Department & Professor in Department of Software Engineering, Delhi Technological University (DTU), Delhi, India. She received a PhD from GGSIPU Delhi and Post Doc from Indiana University Purdue University Indianapolis, USA. She was among 2% scientists in the world for career long citation impact up until the end of 2019 and 2020. She has published more than 200 research papers in reputed international and national journals and conferences.

Mohd Yousuf Ansari received B.E. degree in Computer Science & Technology from University of Roorkee (Now IIT Roorkee), M.Tech degree in Software Systems from BITS, Pilani, and Ph.D. degree from Jamia Millia Islami (Central University). He is currently working as Scientist F at DESIDOC, DRDO. His research area includes knowledge discovery and data mining, cyber security, geographical information system, and software engineering.

