International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
IJISAE
ISSN:2147-6799 www.ijisae.org Original Research Paper

Optimizing Network Efficiency and Stability through Increased Sectorization Enhanced Protocol (ISEP) in Wireless Networks

Nishant Tripathi[1], Charanjeet Singh*[2], Kamal Kumar Sharma[3]

Submitted: 13/12/2023 **Revised**: 25/01/2024 **Accepted**: 04/02/2024

Abstract Wireless sensor networks (WSNs) play a pivotal role in a myriad of applications ranging from environmental monitoring to industrial automation. Clustering sensor nodes is a critical technique to enhance network efficiency, prolong network lifetime, and reduce energy consumption. However, existing clustering protocols often face challenges in achieving high throughput and stability, especially in environments characterized by increased levels of heterogeneity. In this paper, we propose a novel clustering scheme named Increased Sectorization Enhanced Protocol (ISEP) tailored to address these challenges. Through rigorous simulations and real-world experimentation, we demonstrate that ISEP outperforms existing schemes in terms of throughput and stability, making it a promising solution for diverse WSN deployments.

Keywords: *Clustering, Wireless Networks, Stability, Optimization*

1. Introduction

Wireless Sensor Networks (WSNs) have emerged as a pivotal technology for a wide range of applications, spanning from environmental monitoring to healthcare and industrial automation. The effectiveness of WSNs relies heavily on the efficient management and utilization of sensor nodes. Clustering, a fundamental technique in WSNs, organizes nodes into groups or clusters to reduce communication overhead, prolong network lifetime, and enhance scalability. However, the performance of clustering protocols is often hindered by the inherent heterogeneity in sensor nodes, which manifests in variations in processing capabilities, energy levels, and communication ranges. Existing clustering protocols, while effective in homogeneous environments, face significant challenges in heterogeneous settings, limiting their applicability in real-world scenarios. As the demand for WSNs in complex and diverse environments continues to grow, it is imperative to develop clustering schemes that can operate effectively under increased levels of heterogeneity. In response to this challenge, we propose a novel clustering protocol, the Increased Sectorization Enhanced Protocol (ISEP), designed to address the limitations of existing schemes. ISEP leverages increased sectorization to dynamically adapt to varying node characteristics and environmental conditions, thereby achieving higher throughput and stability compared to conventional protocols. Through extensive simulations and real-world experiments, we evaluate the performance of ISEP across a range of scenarios and demonstrate its superiority in terms of throughput and stability.

In this paper, we present the design principles, algorithmic details, and comprehensive performance evaluation of ISEP.

We compare the proposed protocol with state-of-the-art clustering schemes, highlighting its advantages in scenarios characterized by increased heterogeneity. The results of our study underscore the potential of ISEP as a robust and versatile clustering solution for modern WSN deployments.

2. Clustering

Clustering in wireless networks is a pivotal technique that involves organizing nodes into groups or clusters to facilitate efficient communication and resource management. This approach is indispensable in addressing the inherent challenges of wireless networks, such as limited bandwidth, energy constraints, and dynamic network topologies.

2.1. Need for Clustering

The primary motivation for employing clustering in wireless networks lies in its ability to enhance network performance and scalability. In a traditional flat network structure, every node communicates directly with all other nodes, leading to significant overhead due to the increased number of connections. Clustering, on the other hand,

[1] *ECE Department, SEEE, Lovely Professional University, Phagwara, Punjab, India*
[1]*ECE Department, Pranveer Singh Institute of Technology Kanpur, UP India. ORCID ID : 0000-0002-3366-7739*
[2] *[*]ECE Department, SEEE, Lovely Professional University, Phagwara, Punjab ORCID ID : 0000-0001-9799-1418*
[3] *Ambala College of Engineering and Applied Research Devsthali, Ambala Cantt – Jagadhari Road, P.O. Sambhalkha Ambala, Haryana, India ORCID ID : 0000-0002-6294-0829*
** Corresponding Author Email: *[2]rcharanjeet@gmail.com , [1]phd.nishant17@gmail.com*

reduces this complexity by dividing the network into manageable groups. This not only minimizes the overhead but also improves the overall network efficiency, as nodes within a cluster can communicate more effectively.

2.2. Advantages of Clustering

Energy conservation stands out as a primary benefit of clustering. In situations involving nodes powered by batteries or constrained energy sources, clustering introduces hierarchical structures, where only a specific subset of nodes, designated as cluster heads, engages in communication with the base station or other clusters. This strategic approach significantly diminishes the energy consumption of individual nodes, leading to an extended lifespan for the network. Furthermore, clustering fosters load balancing and enhances network stability. By distributing tasks and responsibilities across cluster heads, the network gains the ability to handle a larger number of nodes and traffic without overwhelming individual devices. Additionally, clustering contributes to improved fault tolerance, as the failure of a single node or cluster does not necessarily disrupt the entire network.

2.3. Disadvantages of Clustering

Despite its advantages, clustering does come with some drawbacks. One notable disadvantage is the potential for increased latency, as messages may need to traverse multiple nodes within a cluster before reaching their destination. This additional hop can introduce delays, which may be critical in real-time applications.

2.4. Types of Clustering in Wireless Network

There are several types of clustering techniques used in wireless networks, each with its own unique characteristics. Some common types include Single-Cluster, Multi-Cluster, and Hybrid Clustering. Single-Cluster involves the entire network forming a single cluster, which is suitable for small-scale deployments. Multi-Cluster, on the other hand, divides the network into multiple non-overlapping clusters, providing scalability for larger networks. Hybrid Clustering combines elements of both single and multi-cluster approaches, offering a flexible solution for networks with diverse requirements. Clustering plays a crucial role in optimizing the performance of wireless networks. By mitigating issues related to energy consumption, network stability, and scalability, clustering proves to be an indispensable tool in the design and management of wireless communication systems. Despite some inherent drawbacks, the benefits of clustering far outweigh its limitations, making it an essential technique in the field of wireless networking.

3. Increased Sectorization Enhanced Protocol (ISEP) in Wireless Networks

3.1 Hypothesis Algorithms 1

- Initialization and Parameters:

1. `clear; ` - Clears all variables from the workspace.

2. Setting various parameters like field dimensions, sink coordinates, number of nodes, election probabilities, energy model values, heterogeneity parameters, and maximum number of rounds.

3. `do=sqrt($E_{fs}/E_{mp}$);` - Calculates a threshold distance based on energy parameters.

4. Randomly initializes node positions, energy levels, and types (Normal or Advanced).

5. Initializes the sink node.

3.2 Cluster Head Election (Round Loop):

1. `for r=0:1: rmax` - Loop over rounds.

2. Election Probabilities for Normal and Advanced Nodes are computed based on the current round (`r`) and the set parameters.

3. `if(mod(r, round(1/pnrm) )==0)` and `if(mod(r, round(1/$p_{adv}$) )==0)` - Operations for heterogeneity and sub-epochs.

4. Loop through nodes to check for dead nodes, update node types, and count the number of dead nodes.

5. Calculate the minimum distance between nodes and the sink.

6. Election of Cluster Heads based on energy and probability calculations.

7. Update node types and energy levels based on cluster head elections.

8. Update counters for transmitted packets and energy consumption.

3.3 Results and Visualization:

1. Track and visualize statistics like dead nodes, alive nodes, cluster heads, etc., over the rounds.

2. Plot the sensor network, cluster heads, and sink node positions.

3.4 Hypothesis Algorithm 2

Input and Output

- Input: M x N Dimension Wireless Sensor Networks

- Output: Clustered Network with Cluster Heads

Algorithm Steps

1. Initialization

- Initialize an empty list 'clusters' to store cluster information.

- Define a parameter 'radius_threshold' to determine the maximum distance for a node to join a cluster.

- Set 'cluster_heads' as an empty list to store cluster head information.

2. Node Selection

- Select a node 'myCH' from the network as the first cluster head (e.g., based on energy or location).

3. Cluster Formation

- Create a new cluster with 'myCH' as the initial cluster head.

- Add 'myCH' to 'cluster_heads'.

- Iterate through all nodes in the network:

- For each node 'node_i':

- Calculate the distance between 'node_i' and the current cluster head 'myCH'.

- If the distance is less than or equal to 'radius_threshold':

- Add 'node_i' to the current cluster.

- If the distance is greater than 'radius_threshold':

- Mark 'node_i' as a potential cluster head candidate.

4. Cluster Head Election

- From the potential cluster head candidates:

- Select a candidate node 'candidate' based on certain criteria (e.g., highest energy, highest remaining energy).

- Set 'myCH' to the selected 'candidate'.

- Add 'myCH' to 'cluster_heads'.

- Repeat the cluster formation process using the new 'myCH'.

5. Cluster Finalization

- Repeat the cluster formation and head election process until all nodes are part of a cluster.

- Store the information of each cluster, including the cluster head and its members, in the 'clusters' list.

6. Output

- The 'clusters' list now contains information about all the formed clusters in the network, including their respective cluster heads and members.

The ISEP algorithm is designed to equitably distribute energy consumption across sensors within the network through the deliberate selection of steadfast cluster heads. The computation of the Zone Stability Factor (ZSF) constitutes a pivotal component of the ISEP formula, as it governs the likelihood of a sensor node assuming the role of a cluster head, contingent upon considerations of its remaining energy reserves and proximity to the base station.

The ZSF formula in ISEP is typically defined as follows:

$$\textbf{ZSF} = \frac{\textit{Residual Energy}}{\textit{Threshold Energy} + (\alpha \times \textit{Distance to Base Station})}$$

In this formula:

Residual Energy: The remaining energy of the sensor node.

Threshold Energy: A predefined threshold value, which represents the minimum energy required for a sensor node to be eligible as a cluster head.

α: A parameter that controls the impact of distance on the probability. It can be adjusted to balance the trade-off between energy and distance factors.

3.5 Cluster Head Selection Process

In the cluster head selection process,

$$P_i = \begin{Bmatrix} 0 \quad \text{if } E_i > E_{max} \\ or \\ \frac{1}{\sum_j \left(W_e E_j + W_d \frac{1}{D_j} + W_c CE_j \right)} \left(W_e E_i + W_d \frac{1}{D_i} + W_c CE_i \right) \end{Bmatrix} \quad (1)$$

- E_i: Residual energy of node i.
- D_i: Distance of node i to the base station.
- CE_i: Cumulative energy of neighbouring nodes of node i.
- W_e,W_d, W_c: Weights assigned to residual energy, distance, and cumulative energy respectively.
- Emax: Maximum allowable energy for a node to be eligible for cluster head selection.
- D_{max}: Maximum distance of a node to the base station for it to be eligible for cluster head selection.
- CE_{max}: Maximum allowable cumulative energy of neighboring nodes for a node to be eligible for cluster head selection.

4. Simulation cases for Optimizing the set-up

4.1. Case 1 :- For rmax=8000 with x_m=100; y_m=100; n=100; while b=0.5 is an intermediate energy level let's say , the energy is β times more than normal ones, and less than the advanced nodes energy (α) where β = α/2. (α=0.2)

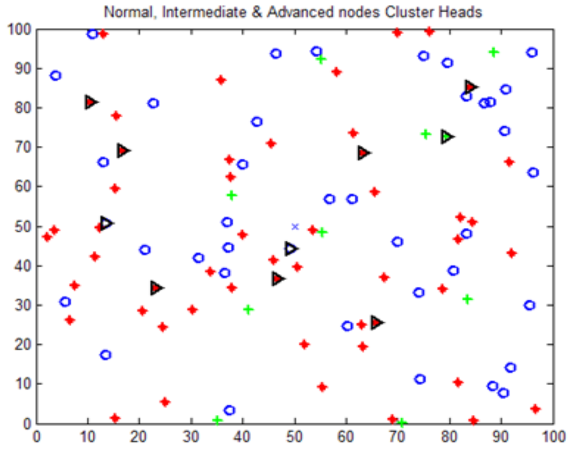


Fig 1 Wireless Sensor Network Set-up
Blue: Normal Nodes;

Red: Intermediate Nodes;

Green: Advanced Nodes;

Black Triangle: Cluster head

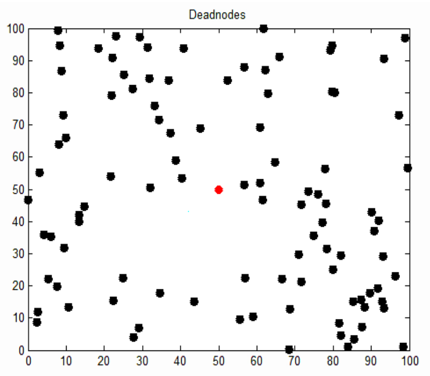
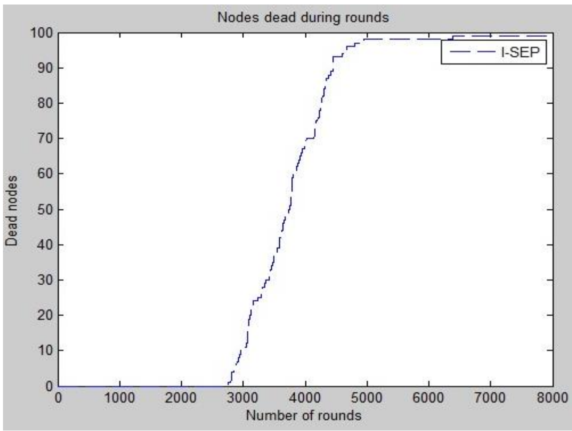


Fig 2. Wireless Sensor Network set Up in MATLAB showing all dead MSN

- In optimizing energy usage within a network, the allocation of energy differs between active or sensing nodes and non-sensing nodes, referred to as dead nodes. Energy is primarily directed towards active or sensing nodes, leaving non-sensing nodes with depleted energy, rendering them inactive. This strategy serves to conserve energy effectively. Notably, advanced nodes receive the highest energy levels, resulting in a lower occurrence of dead nodes compared to intermediate and normal nodes. Over time, normal nodes experience a faster depletion rate, leading to the prominence of intermediate and advanced nodes in the election process for Cluster Heads (CH). This selection of intermediate and advanced nodes as CH extends the network's lifespan across numerous rounds and contributes to an increased count of Cluster Heads.

- **Case.2. For rmax=8000, xm=100; ym=100; n=100; b=0.5 in an intermediate energy level, which is β times more than normal ones, and less than the advanced nodes energy (α) while β = α/2.**



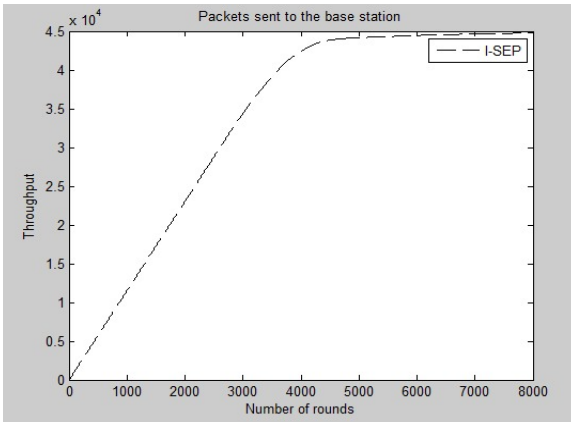
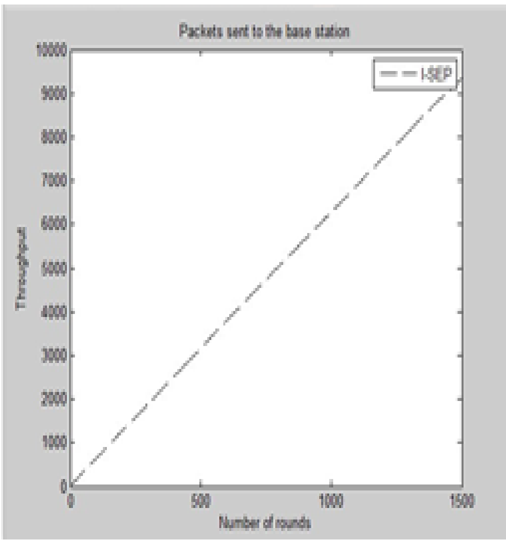


Fig 3, 4 Throughput vs Rounds, dead nodes vs rounds respectively using the algorithms proposed for case 1

Throughput: For n=50; x=y=100; R=rmax=4000:- At once all the nodes became dead at r=1300 since we limited the ability of the advanced nodes become a CH if E<0.5



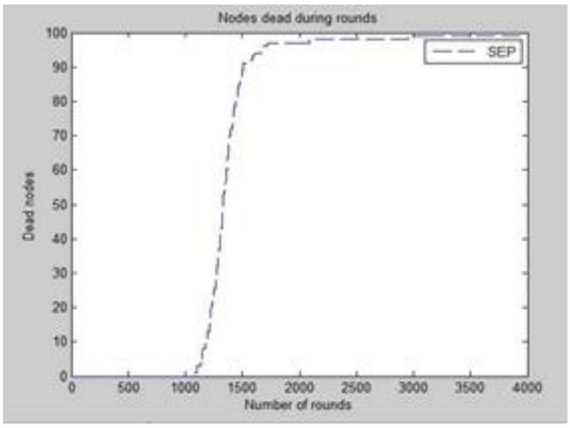
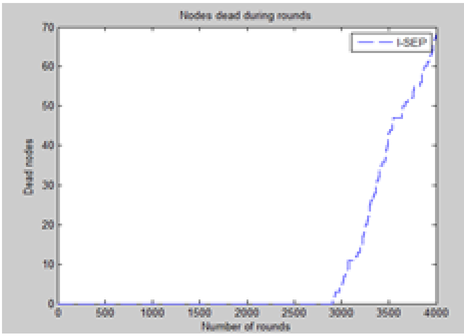
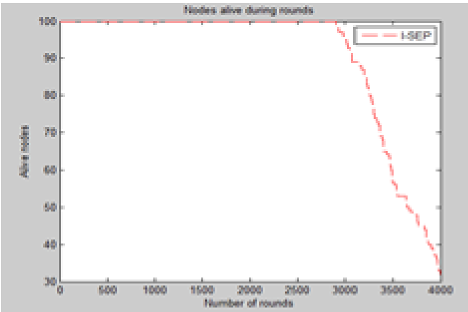


Fig 5, 6 Throughput vs Rounds, dead nodes vs rounds respectively using the algorithms proposed for case 2

4.2. Case 3. In I-SEP , for n=100; x=y=100; β =0.3; α=1; R=rmax=4000, By calculating the residual energy and if the cluster head is there with the residual energy greater than the threshold value, then the same cluster head is continued to remain as the cluster head thereby we energy consumption is reduced. So, when compared to the previous values, the dead nodes are seen at the round 2900. Which makes our network stable.





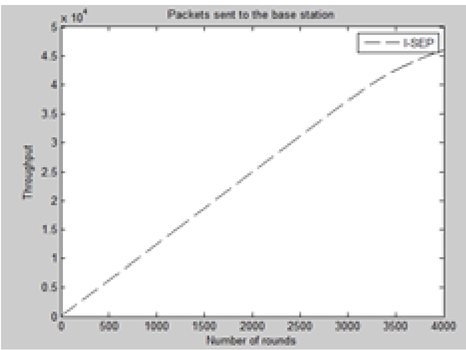
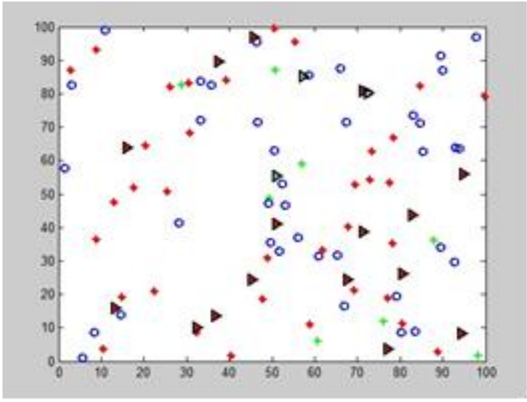
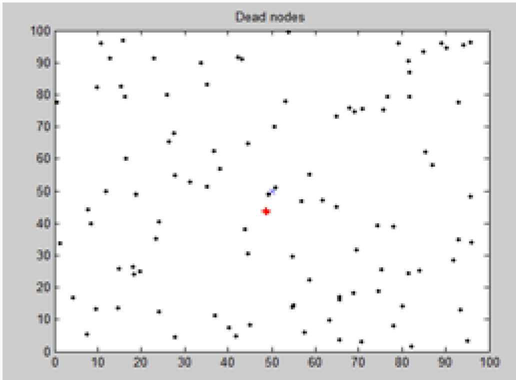
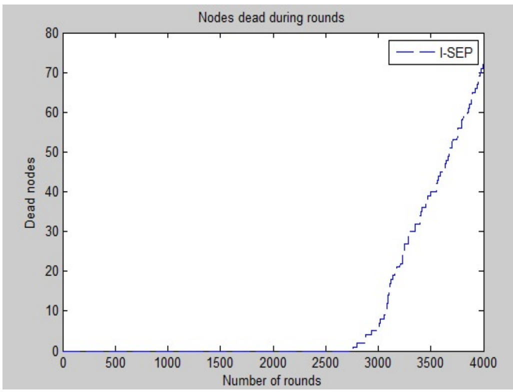


Figure 7, 8 Throughput vs Rounds, dead nodes vs rounds respectively using the algorithms proposed for case 3

4.3. Case.4 I-SEP for rmax=4000: (maximum number of rounds); xm=100; ym=100; n=100; β =0.5







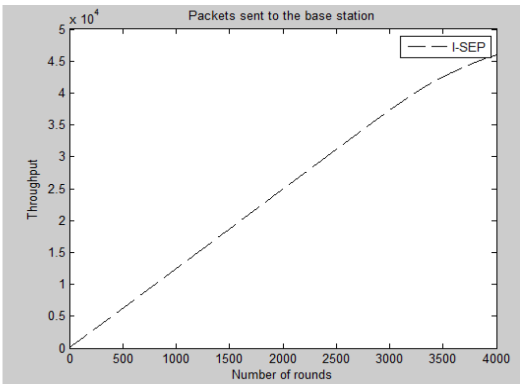
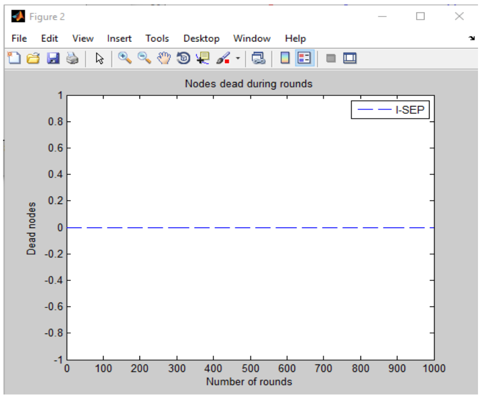


Figure 9, 10, 11, 12 Throughput vs Rounds, dead nodes vs rounds respectively using the algorithms proposed for case 4

4.4. Case.5. N=100; Rmax=r=1000; I-SEP , If we take the number of rounds less that is 1000, the graph is as below where, the dead nodes are not available



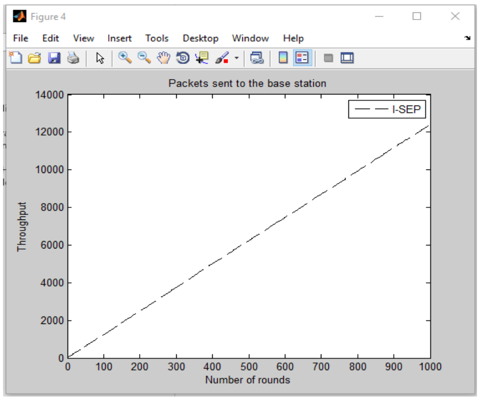
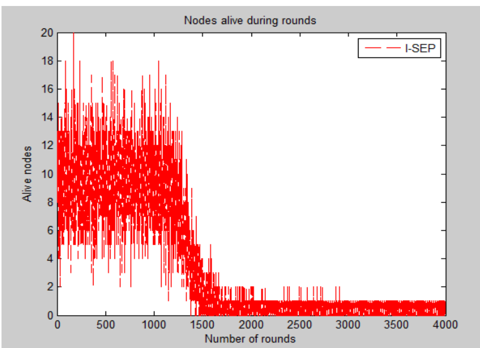
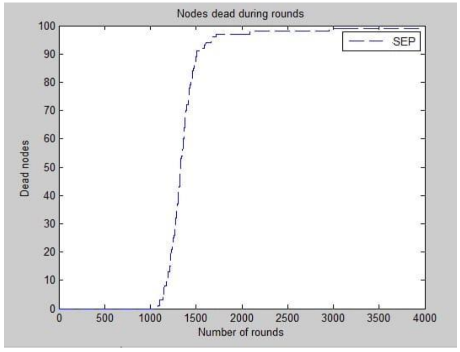
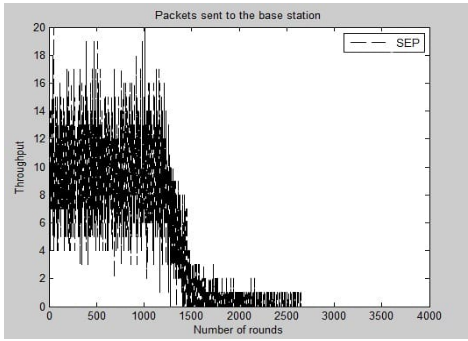


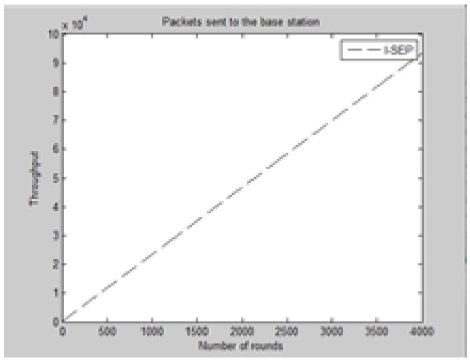
Figure 13, 14 Throughput vs Rounds, dead nodes vs rounds respectively using the algorithms proposed for case 5

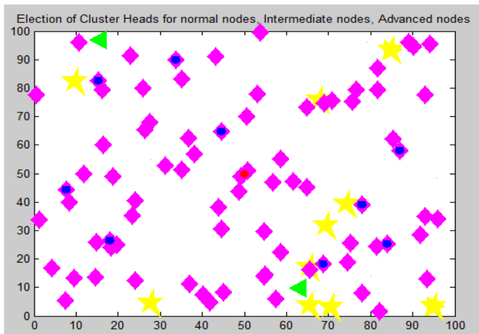
4.6 Case.6. Comparison of SEP with I-SEP results; For rmax=4000 in I-SEP; xm=100;; ym=100;; n=100; β =0.5 Pink : normal; Blue advanced nodes; Yellow: dead nodes











4.7 Case.7. R=rmax=4000; in I-SEP; n=150; α =3; β =0.2

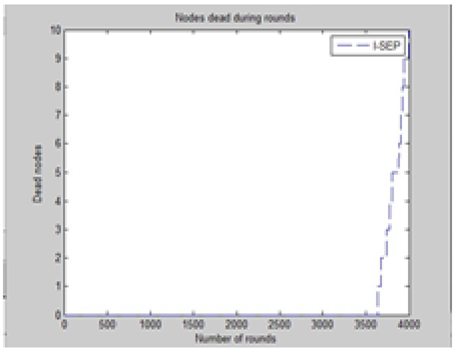


Figure 15,16,17,18 Throughput vs Rounds, dead nodes vs rounds respectively using the algorithms proposed for case 6,7.

5. Conclusion

The research presented in this study introduces a novel protocol, Increased Sectorization Enhanced Protocol (ISEP), which outperforms existing protocols such as LEACH, SEP, Z-SEP, and Mod-LEACH in terms of stability and throughput.

The ISEP protocol takes into consideration the energy levels and distances of Sensor members from the destination point, effectively conserving energy while maintaining a balanced energy dissipation across all MSNs. The introduction of an access collection node further contributes to energy conservation by preventing excessive transmission distances. Simulation results demonstrate significant enhancements in various performance metrics. Specifically, the ISEP protocol leads to a remarkable reduction in dead member sensors per round, increasing the lifespan of the WCS network by approximately 40% compared to SEP and nearly 125% more than LEACH. Throughput and efficiency also experience substantial improvements, surpassing existing protocols by approximately 56%, more for ISEP than SEP.

Moreover, the transition rate to inactive MSNs is considerably more favorable in our approach, with the stability significantly enhanced. The number of rounds required for the transition from 10% to 100% inactive MSNs is increased to 5,000-8,000 rounds in EZ-SE protocol compared to LEACH, which exhibits rapid inactivity within 3,000 rounds. The ISEP protocol further refines this stability. The transition to inactive MSNs between CH and BS in the simulation is estimated to take place over 3,500-8,500 rounds, depending on heterogeneity. Through rigorous MATLAB simulations and detailed graphical analyses, this research substantiates the substantial advancements in WCS network performance metrics. The protocol not only leads to increased throughput and enhanced network stability but also extends the lifespan of the network, presenting opportunities for better power optimization across a range of WCS network applications. This research provides a strong foundation for further refinements and enhancements to the existing protocol, paving the way for even more stable and efficient MSN deployments in larger WCS network setups through the incorporation of advanced mathematical or meta-heuristic approaches.

Author contributions

Nishant Tripathi[1]: Conceptualization, Methodology, Software, Field study, Simulation **Charanjeet Singh[2]:** Data curation, Writing-Original draft preparation, Validation., **Kamal Kumar Sharma[3] :**Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

References

[1] N. Tripathi and K. K. Sharma, "Analytical Review of Different Routing Methodologies and Clustering Techniques in WSN/WCSN leading to Cooperative Communication," 2020 IEEE International Conference for Innovation in Technology (INOCON), Bangluru, India, 2020, pp. 1-6, doi: 10.1109/INOCON50539.2020.9298208.

[2] Tripathi, N., Sharma, K.K. (2022). Distributed and Hierarchical Clustering Techniques Comparison in Wireless Camera Sensor Networks. In: Kaiser, M.S., Bandyopadhyay, A., Ray, K., Singh, R., Nagar, V. (eds) Proceedings of Trends in Electronics and Health Informatics. Lecture Notes in Networks and Systems, vol 376. Springer, Singapore. https://doi.org/10.1007/978-981-16-8826-3_33

[3] Tripathi, N. ., Singh, C. ., & Sharma, K. K. . (2023). Enhancement of Performance Metrics of Heterogeneous Wireless Camera Sensor Network with Functionalization of Extensive Zonal Stable Election Protocol using Threshold Amplification and Residual Energy. International Journal on Recent and Innovation Trends in Computing and Communication, 11(8s), 657–669. https://doi.org/10.17762/ijritcc.v11i8s.7253

[4] D. Kandris, C. Nakas, D. Vomvas, G. Koulouras, Applications of wireless sensor networks: An up-to-date survey, Appl. Syst. Innov. 3 (1) (2020) 14.

[5] F. Fanian, M.K. Rafsanjani, Cluster-based routing protocols in wireless sensor networks: A survey based on methodology, J. Netw. Comput. Appl. 142 (2019) 111–142.

[6] S.M. Zin, N.B. Anuar, M.L.M. Kiah, A.-S.K. Pathan, Routing protocol design for secure WSN: Review and open research issues, J. Netw. Comput. Appl. 41 (2014) 517–530.

[7] K.A. Darabkh, S.M. Odetallah, Z. Al-qudah, K. Ala'F, M.M. Shurman, Energy-aware and density-based clustering and relaying protocol (EA-DB-CRP) for gathering data in wireless sensor networks, Appl. Soft Comput. 80 (2019) 154–166.

[8] L.K. Ketshabetswe, A.M. Zungeru, M. Mangwala, J.M. Chuma, B. Sigweni, Communication protocols for wireless sensor networks: A survey and comparison, Heliyon 5 (5) (2019) e01591.

[9] P. Maheshwari, A.K. Sharma, K. Verma, Energy efficient cluster based routing protocol for WSN using butterfly optimization algorithm and ant colony optimization, Ad Hoc Netw. 110 (2021) 102317.

[10] S. Zeadally, F.K. Shaikh, A. Talpur, Q.Z. Sheng, Design architectures for energy harvesting in the internet of things, Renew. Sustain. Energy Rev. 128 (2020) 109901.

[11] P. Rawat, S. Chauhan, Clustering protocols in wireless sensor network: A survey, classification, issues, and future directions, Comp. Sci. Rev. 40 (2021) 100396.

[12] D. Sharma, A. Ojha, A.P. Bhondekar, Heterogeneity consideration in wireless sensor networks routing algorithms: A review, J. Supercomput. 75 (5) (2019) 2341–2394.

[13] S. Arjunan, S. Pothula, A survey on unequal clustering protocols in wireless sensor networks, J. King Saud Univ.-Comput. Inf. Sci. 31 (3) (2019) 304–317.

[14] R.E. Mohamed, A.I. Saleh, M. Abdelrazzak, A.S. Samra, Survey on wireless sensor network applications and energy efficient routing protocols, Wirel. Pers. Commun. 101 (2) (2018) 1019–1055.

[15] S.K. Singh, P. Kumar, J.P. Singh, A survey on successors of LEACH protocol, Ieee Access 5 (2017) 4298–4328.

[16] W.R. Heinzelman, A. Chandrakasan, H. Balakrishnan, Energy-efficient communication protocol for wireless microsensor networks, in: Proceedings of the 33rd Annual Hawaii International Conference On System Sciences, IEEE, 2000, p. 10.

[17] W.B. Heinzelman, A.P. Chandrakasan, H. Balakrishnan, An application-specific protocol architecture for wireless microsensor networks, IEEE Trans. Wirel. Commun. 1 (4) (2002) 660–670.

[18] A. Shahraki, A. Taherkordi, Ø. Haugen, F. Eliassen, Clustering objectives in wireless sensor networks: A survey and research direction analysis, Comput. Netw. 180 (2020) 107376.

[19] D. Wohwe Sambo, B.O. Yenke, A. Förster, P. Dayang, Optimized clustering algorithms for large wireless sensor networks: A review, Sensors 19 (2) (2019) 322.

[20] L. Xu, R. Collier, G.M. O'Hare, A survey of clustering techniques in WSNs and consideration of the challenges of applying such to 5G IoT scenarios, IEEE Internet Things J. 4 (5) (2017) 1229–1249.

[21] M. Mukhtaruzzaman, M. Atiquzzaman, Clustering in vehicular ad hoc network: Algorithms and challenges, Comput. Electr. Eng. 88 (2020) 106851.

[22] F. Engmann, F.A. Katsriku, J.-D. Abdulai, K.S. Adu-Manu, F.K. Banaseka, Prolonging the lifetime of wireless sensor networks: A review of current techniques, Wirel. Commun. Mobile Comput. 2018 (2018).

[23] P.K. Mishra, S.K. Verma, A survey on clustering in wireless sensor network, in: 2020 11th International Conference On Computing, Communication and Networking Technologies (ICCCNT), IEEE, 2020, pp. 1–5.

[24] B.M. Sahoo, H.M. Pandey, T. Amgoth, GAPSO-H: A hybrid approach towards optimizing the cluster based routing in wireless sensor network, Swarm Evol. Comput. 60 (2021) 100772.

[25] A.S. Rostami, M. Badkoobe, F. Mohanna, A.A.R. Hosseinabadi, A.K. Sangaiah, et al., Survey on clustering in heterogeneous and homogeneous wireless sensor networks, J. Supercomput. 74 (1) (2018) 277–323.

[26] J. Liang, Z. Xu, Y. Xu, W. Zhou, C. Li, Adaptive cooperative routing transmission for energy heterogeneous wireless sensor networks, Phys. Commun. 49 (2021) 101460.

[27] P. Vadicherla, D. Vadlakonda, Study on energy efficient routing protocols scheme in heterogeneous wireless sensor networks (network & mobility), Mater. Today: Proc. (2021).

[28] G. Smaragdakis, I. Matta, A. Bestavros, SEP: A Stable Election Protocol for Clustered Heterogeneous Wireless Sensor Networks, Tech. rep., Boston University Computer Science Department, 2004.

[29] L. Qing, Q. Zhu, M. Wang, Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks, Comput. Commun. 29 (2006) 2230–2237.

[30] R. Khan, An efficient load balancing and performance optimization scheme for constraint oriented networks, Simul. Model. Pract. Theory 96 (2019) 101930.

[31] E. Niewiadomska-Szynkiewicz, a. Sikora, J. Kołodziej, P. Szynkiewicz, Modelling and simulation of

secure energy aware fog sensing systems, Simul. Model. Pract. Theory 101 (2020) 102011.

[32] S. Lindsey, C.S. Raghavendra, PEGASIS: Power-efficient gathering in sensor information systems, in: Proceedings, IEEE Aerospace Conference, Vol. 3, IEEE, 2002, p. 3.

[33] A. Manjeshwar, D.P. Agrawal, TEEN: Arouting protocol for enhanced efficiency in wireless sensor networks, in: Ipdps, Vol. 1, (2001) 2001, p. 189.

[34] O. Younis, S. Fahmy, HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks, IEEE Trans. Mobile Comput. 3 (4) (2004) 366–379.

[35] D. Mahmood, N. Javaid, S. Mahmood, S. Qureshi, A.M. Memon, T. Zaman, MODLEACH: A variant of LEACH for WSNs, in: 2013 Eighth International Conference On Broadband and Wireless Computing, Communication and Applications, IEEE, 2013, pp. 158–163.

[36] S. Dai, X. Jing, L. Li, Research and analysis on routing protocols for wireless sensor networks, in: Proceedings. 2005 International Conference On Communications, Circuits and Systems, 2005, Vol. 1, IEEE, 2005, pp. 407–411.

[37] S. Singh, A. Malik, hetSEP: Heterogeneous SEP protocol for increasing lifetime in WSNs, J. Inf. Optim. Sci. 38 (5) (2017) 721–743.

[38] D. Singh, C.K. Panda, Performance analysis of modified stable election protocol in heterogeneous wsn, in: Proceedings of the 2015 International Conference On Electrical, Electronics, Signals, Communication and Optimization (EESCO), Visakhapatnam, India, 2015, pp. 24–25.

[39] A. Singh, H.S. Saini, N. Kumar, D-MSEP: Distance incorporated modified stable election protocol in heterogeneous wireless sensor network, in: Proceedings Of 2nd International Conference On Communication, Computing and Networking, Springer, 2019, pp. 271–281.

[40] P. Saini, A.K. Sharma, Energy efficient scheme for clustering protocol prolonging the lifetime of heterogeneous wireless sensor networks, Int. J. Comput. Appl. 6 (2) (2010) 30–36.

[41] N. Javaid, T. Qureshi, A. Khan, A. Iqbal, E. Akhtar, M. Ishfaq, EDDEEC: Enhanced developed distributed energy-efficient clustering for heterogeneous wireless sensor networks, Procedia Comput. Sci. 19 (2013) 914–919.

[42] B. Elbhiri, R. Saadane, D. Aboutajdine, et al., Developed distributed energy-efficient clustering (DDEEC) for heterogeneous wireless sensor networks, in 2010 5th International Symposium On I/V Communications and Mobile Network, IEEE, 2010, pp. 1–4.

[43] S. Singh, A. Malik, R. Kumar, Energy efficient heterogeneous DEEC protocol for enhancing lifetime in WSNs, Eng. Sci. Technol. Int. J. 20 (1) (2017), 345–353.