

Particle Competitive Swarm Optimizer (PCSO), an Energy Efficient Algorithm to Enhance the Network Lifetime in Heterogeneous Wireless Sensor Network

Mandar K Mokashi¹, Dr. Pooja Sharma², Dr. Vishal Puri³, Dr. Vinayak G. Kottawar⁴

¹Research Scholar, School of Engineering and Technology, D.Y.Patil University Pune-Ambi (India) and Assistant Professor, Department of Information Technology, Vishwakarma Institute of Information Technology, Pune (India)

²Associate Professor, Department of Computer Engineering, School of Engineering and Technology, D.Y.Patil University Pune-Ambi (India)

³Associate Professor, Department of Computer Engineering, School of Engineering and Technology, D.Y.Patil University Pune-Ambi (India)

⁴Associate Professor, Department of Artificial Intelligence and Data Science, D.Y.Patil College of Engineering, Akurdi, Pune (India)

Abstract. Heterogeneous wireless sensor network (HWSN) consist of sensor nodes having varied capabilities, like distinct computational ability, distinct initial energy, sensing and communication area in comparison with homogeneous WSN. The placement of nodes and topologies are very difficult in heterogeneous WSN. HWSN is more effective, scalable and flexible with reduced deployment cost, energy consumption, and improved communication and coverage performance. However, energy consumption remains a major concern for HWSNs. As, routing techniques play a crucial role in energy conservation, this paper provides – 1. comprehensive survey of various routing techniques in WSN. 2. Novel optimization enabled routing with Particle competitive swarm optimization algorithm (PCSO). 3. Discussion on results and simulation setup.

Keywords: Wireless Sensor network, Deep Learning, Heterogeneous sensor, energy prediction, routing in HWSN.

Introduction

Heterogeneous WSN is a network of multiple sensors consisting of multiple types and functions of sensor nodes. In a WSN, judicious usage of heterogeneous nodes may increase application ability and extend longevity. The heterogeneous WSN has a wide range of usefulness in industrial, military, medical, commercial, environmental, and other important settings, as well as family life. Because it has a durable energy, network resources and does not require frequent replacement, the heterogeneous node in a HWSN can support complex communication tasks. Furthermore, heterogeneous nodes have significantly greater communications and data processing capacity than common nodes. [12].

1.1 Formation of A heterogeneous sensor network (HWSN):

A HWSN may be constructed that extends the lifespan of WSNs. Such design is even affordable in critical environments it, is also the current WSN design trend. For example, if a network is being operated since a long time, new sensors can be

added to achieve an extension of network lifetime. The recently inserted nodes currently possess sample energy than older nodes. But costs of heterogeneous node is comparatively high. Due to this, heterogeneous nodes are difficult to be freely incorporated in WSN. [13][14]. Energy in HWSN with varied initial energy has a direct and practical effect on network energy reduction.

The network maintains virtual hierarchical architectures such as mesh, tree, cluster, ring, and others, where sensor nodes must perform many dynamic functions to effectively manage the mobility of sinks in hierarchical routing protocols. When a sink moves, it only informs a few higher-level sensor nodes of its new location, rather than broadcasting to the entire network. Only upper-level nodes in the network are responsible for storing the current location of the movable sink, lower-level nodes transmit requests to the superior nodes to know the location of the sink so that they can transmit their detected information to the sink. This multi-level node responsibility structure minimizes flooding and facilitates balancing of

network energy consumption [6]. Focusing only on energy efficiency will reduce energy use.

1.2 Energy consumption balancing (ECB) :

This is an important function to maximise community longevity, as in a perfect world, all sensor nodes would use up enough energy to expire simultaneously. In WSNs, multi-hop communication is frequently utilised to ensure short-range communications while conserving energy. While, since multi-hop communication paths create an uneven data transmission load for sensors, especially sensors closer to the media, this communication style can cause energy imbalance in the WSN. As a result, to maximize the lifespan of WSN, in addition to minimizing the distances transmitted through multi-hop communication channels, it becomes absolutely essential to balance the energy consumption of WSN. Hence, energy dissipation schemes and algorithms which make sure there is uniform energy loss.

1.3 HWSN Routing protocols :

In the conventional networks, various routing protocols are developed to extend the network performance with regard to delivery of information and delay in network. Different WSNs' routing paths are mutually independent, which means that, each WSN routes its own packets through its own routing paths and sensors. WSNs primarily focus on advancements in power conservation at the same time minimising communication costs [16][2]. Routing algorithm must adjust to the nodes' available and needed resources. I How to design a network topology for resource nodes with varied requirements for resources and a variety of application activities (ii) The distribution of network traffic while the network is in use [17]. Scalability, low cost, accuracy, stability and durability are the main striking features of WSN applications compared to traditional network technologies [18][2]. Energy usage is a scarce resource in WSN scenarios [19][2] because it is limited and must be intelligently managed to improve network lifetime and routing efficiency. Due to changing behavior of sensor nodes, conventional and mono-level routing techniques are not very reasonable in applications based on sensors. As a result, several researchers [20][2] have recently focused on building adaptive and resilient routing protocols to improve energy efficiency and find optimal routes to endpoints

[2]. Alternative methods for supporting effective discovery of route and efficiency of energy for WSNs are hierarchical-based routing protocols [21][2]. In general, such methods are beneficial in situations where scalability to hundreds and thousands of users is required.

2. Literature Review

Multiple sensor nodes are deployed throughout an area forms a wireless sensor networks (WSNs) It accumulates statistics from surroundings and forwards it to base station (BS). In WSNs, node's energy is constrained. Reducing its energy consumption, which subsequently increases network lifetime, is a major concern in WSN. Energy-efficient routing is one way to lower the energy consumption in WSNs. To conserve the energy of nodes, data is transmitted to sink in energy-efficient routing. Two-level routing system based on clusters was suggested which is based on clustering, backup cluster heads (BCH), stacking cluster heads (CH), and breaking each cluster into four portions to increase packet delivery rate and decrease energy usage. There are two stages of the process. In the first stage, clustering of nodes is done based on the residual energy, proximity to the BS, and centrality. CHs and BCHs are also chosen. Every cluster is split into four sections for the purpose of performing inner group routing, allowing nodes to transmit information towards CH directly or via the best node within their section. Based on their proximity to the BS, CHs are layered for inter-cluster routing. As cluster heads are stacked, the source cluster head decides which CH in the top layer to use for the following hop depending on its leftover energy and proximity to the base station.

One of the recently developed homogeneous routing protocols that can more effectively reduce the power usage of remote nodes is the gateway-based Energy-Aware Multi-Hop Routing Protocol (MGEAR). During a longer use of the protocol, it was found to have a high power consumption, a shorter stability period and a worse information transfer to the sink node.

A modified Energy-Aware Multi-Hop Routing Protocol (HMGEAR) based on heterogeneous gateway is discussed in this paper. The added heterogeneous nodes, head selection based on

remaining energy, multi-hop communication implemented across the network, and energy hole elimination methods are the foundations of the suggested routing method. These strategies are all meant to save energy and prolong the network lifetime. The findings shows the suggested routing technique out performsthe other two in view of throughput, remaining energy, and network life.

The gateway-based multi-hop routing protocol is examined in this work in an upgraded form. In homogeneous wireless sensor networks, MGEAR protocol, primarily used to increase network longevity. In this situation, the proposed method intends to increase this protocol's throughput and extend the network lifetime for HWSNs. MGEAR is separated in various fields, and the first field's sensor nodes are directly connected to base station. The gateway performs data integration, spreading the information to base station after receiving data from the network's central sensors. The remaining nodes are split into two equally sized areas, and the sensor nodes within each region are organised. When a major node serves as the cluster head in a cluster. The most important part of the strategy is choosing the cluster heads based on the ratio between the residual energy of each sensor node and the average energy of the region to which it belongs. To balance the load and lengthen the life of the sensors, the cluster-head election probability is determined for each round based on the residual energy of each sensor node. The simulation study demonstrates that, when dealing with 2-level heterogeneity, this model outperformed HCR, ERP, ModLEACH, D-MSEP, and DDEEC protocols in terms of throughput and lifetime by 130%, 151%, 167%, 171%, and 215%, respectively. In the case of 3-level heterogeneity, the network life increases by 123%, 150%, 163%, and 218% compared to HCP, ModLEACH, hetSEP[3].

The literature on several existing strategies in heterogeneous WSNs based on energy aware routing these research articles on energy conscious routing in heterogeneous WSN were selected and reviewed based on the most recent published years. TEAR (Traffic and Energy Aware Routing) was developed by Deepak Sharma and Amol P Bhonekar [4] to improve the stability period in heterogeneous WSNs. This strategy took into account a node's traffic as well as its priliminary

and residual energy. In multi-heterogeneous scenario, TEAR outperformed many current techniquesconsideringlastingness. Although this strategy showed effective performance in the face of traffic heterogeneity, it is computationally difficult. The number of living nodes achieved by the suggested technique is 80, according to simulation data.

Khalid Haseeb., et al. [5] proposed the Reliable Cluster-based Energy-aware Routing (RCER) protocol to extend network lifespan while lowering computational costs. There were two main phases to this strategy. To attain more energy-efficiency of the network, the network field was initially divided into geographical clusters. Then, using the remaining energy, count of hops, and weighted value of RTT (Round Trip Time) parameters, RCER performed optimal routing to improvise the choosing of next hop. The data delivery performance was increased thanks to this protocol. However, this protocol was unable to assess the RCER protocol's effectiveness on mobile sensors. The simulation results revealed that the RCER protocol had a 92.5 percent packet delivery ratio (PDR).

SunitiDutt., et al. [6] proposed a Cluster-head Restricted Energy Efficient Protocol (CREEP) to increase network lifespan in a multi-level heterogeneous WSN by altering cluster head election thresholds. This approach increased the network's longevity, but it failed to enhance energy efficiency when applied to more than two degrees of heterogeneity. The proposed technique achieved a higher throughput value of 160000 for the round 6395, according to simulation findings.

To accomplish effective routing in heterogeneous WSNs, Sai Krishna Mothku and Rashmi Ranjan Rout [7] devised a Fuzzy-based delay and energy-aware intelligent routing technique. The fuzzy input variables were residual energy, free buffer, channel quality and closeness of node. Furthermore, the network's performance was assessed using various fuzzy input variables. Proposed routing technique lowered dropping the package rates, resulting in less latency and lower energy use. This approach, however, has a considerable computational cost. The suggested technique achieved effective performance related to network stability with values of 853.0, according to simulation findings.

Sanjay K. Malik, et al. [8] suggested the improved ant-based Quality of Service-aware routing protocol for HWSN (EAQHSeN), which divided all traffic into control and data streams. Data traffic was further divided into multimedia and scalar traffic, and routing decisions were made based on the traffic type as well as the traffic type's Quality of Service (QoS) restrictions, resulting in a performance boost. This strategy decreased delay overhead issues, however the main challenge is to compare the proposed methodology to existing Ant Colony based Optimization (ACO) solutions for optimal performance. According to simulation findings, the proposed technique achieves a minimum remaining value of 99 percent.

Densely distributed large heterogeneous WSNs, Sonam Maurya, et al [9] proposed a Delay aware energy efficient reliable routing (DA-EERR). During the data transmission phase, By selecting the lowered distance energy-efficient later-hop sensor, the suggested DA-EERR technique established a good compromise between power consumption and end point latency.

This strategy ensured that time-sensitive data was delivered on time. However, in order to provide effective results, this method must be used in several mobile sink networks. According to the simulation findings, the suggested DA-EERR approach reaching an average endpoint of a latency value of 0.10 seconds.

Raja Al-Kiyumi, et al. [10] developed a Distributed Energy-aware Fuzzy Logic-based routing algorithm (DEFL) that solved both power stability and power balancing issues at the same time. For the shortest path calculation, this algorithm used relevant energy measures to capture network health and mapped them into cost values. Furthermore, to incorporate human logic, a fuzzy logic technique was used for mapping operations. This technology considerably improved energy balancing performance, but it did so at the expense of increasing network communication complexity, which degraded network performance. The proposed DEFL approach demonstrated effective network life time performance with a value of 998 seconds, according to the simulation findings.

In a heterogeneous WSN situation, Nura Modi Shagari, et al [11] proposed the Energy and traffic aware sleep-awake (ETASA) technique to improve the energy efficiency and load balancing. To further refine the balanced energy usage, this technique uses an improved cluster head election method which chooses the higher power, reduced traffic, and nodes having a large count of pairs. By reducing redundant transmission from sensor nodes, this technique enhanced energy efficiency. However, in case of different zones in the same network, this technique failed to account for traffic heterogeneity. According to the simulation findings, the proposed approach produced a high network average remaining energy of 0.329.

m-BEENISH (Modified Balanced Energy Efficient Network Integrated Super Heterogeneous) Protocol is proposed in [26]. It provides four node classifications based on power levels. As energy levels and probability limits classification are increased better results and performance can be achieved. The m-BEENISH is a significant advance for heterogeneous WSNs, where a new method is adapted to ensure the feasibility of the current BEENISH protocol. Choosing a common cluster head, considering the node location and its energy capacity, is a proposed step forward. With this, improved efficiency, reliability and longer service life can be achieved.

3. Challenges

The challenges faced by the reviewed techniques based on energy aware routing in heterogeneous WSN are as follows -

- TEAR approach was devised for improving the stability period of the heterogeneous WSN. However, this approach failed to consider multiple levels of heterogeneity concept specially the traffic heterogeneity for realistic WSNs and IoT applications with heterogeneous sensing requirements [1].
- After the invention of multimedia systems, it is necessary to create mechanisms supporting variable bit rate (VBR) traffic consisting of burst packages in order to achieve improved performance results [3].

- Fuzzy-based delay and energy-aware intelligent routing mechanism was devised for selecting the efficient routes, but the biggest challenge is to implement the proposed mechanism in a power cycle based sensor operator network to achieve efficient routing. [4].
- In [6], DA-EERR was introduced for the densely deployed large heterogeneous WSNs. However, this approach did not develop energy-efficient routing for a large-scale and dense networks with several movable base stations in order to yield effective results.
- DEFL was developed for extending the lifetime in heterogeneous WSNs, but the major challenge lies in designing a routing protocol for the delay constrained WSN applications which can receive best compromise in increasing network span and reducing end-to-end latency in multi-hop networks. [7].

4. Proposed Approach

The primary intention of this research is to redesign and create an optimization-enabled routing system for heterogeneous WSNs using a deep recurrent neural network based energy prediction approach. The routing phase and the energy prediction phase are two of the overall phases involved in this technique. The heterogeneous WSN network will be simulated first, followed by the presentation of simulated heterogeneous WSN nodes to the routing phase. Routing will be done using a suggested optimization method called Particle Competitive Swarm Optimizer (PCSO), which will be a combination of particle swarm optimization and competitive swarm optimization techniques of optimizations. The PCSO will take into account several fitness variables such as anticipated energy, delay, distance (considering mobility), and link life time.

Deep Recurrent Neural Network (DRNN)[12] can be implemented to predict the remaining energy of nodes. Nodes are then selected for the routing on the basis of their predicted energy by the proposed PCSO algorithm.

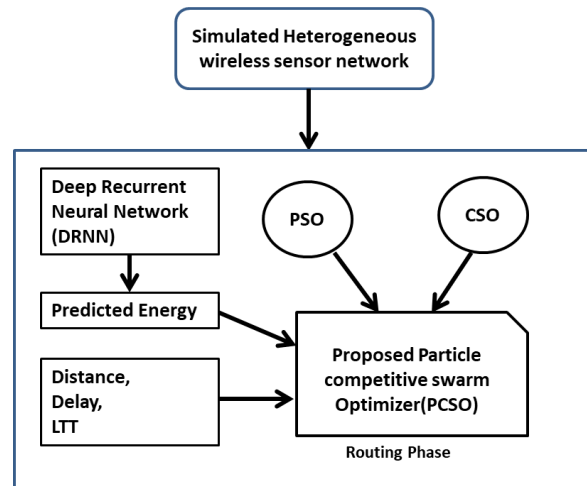


Figure 1. Schematic view of the proposed PCSO for energy prediction in heterogeneous WSN

4.1 Expected results and simulation setup.

Here, the expected results of the proposed PCSO protocol are elaborated. The proposed PCSO method, will be realised by simulation in the MATLAB tool. The proposed PCSO method's performance will be evaluated using four distinct evaluation metrics, including energy, delay, and link lifetime and throughput. The findings will be compared to those of other current studies [1], [2], [3] and [4] in order to disclose the new PCSO technique's efficiency. The block diagram of the suggested PCSO for energy prediction in a heterogeneous WSN environment is depicted in Figure 1.

Three different setups will be used for the simulation, with the network size set as 200, 150, and 100 for analysis. Table 1 illustrates the simulation table and its parameters.

Simulation parameters	Values
dimension (x)	100
dimension (y)	100
Transfer of energy	50*10 ⁻⁸
Energy reception	50*10 ⁻⁸
Energy in gap	10*10 ⁻¹¹
Energy boost	0.0013*10 ⁻¹¹

Table 1. Simulation setup

The existing techniques to be considered for the performance analysis and evaluation of results of proposed technique are - i) TEAR [1], ii) RCER [2], iii)

CREEP [3] and iv) Fuzzy-based Energy-Aware Routing Mechanism (FEARM) [4].

The proposed PCSO technique will be compared with the existing four comparative techniques based on four factors such as residual energy, delay, throughput and Link Lifetime (LLT). The hybridization of PSO and CSO algorithms along with deep learning based energy prediction [12] can offer optimized results compared to available techniques.

Conclusion

This paper studies various routing techniques challenges and protocols for energy conservation and efficiency in WSN. The analysis of results shows, few of the protocols defeat the issues associated with power consumption. In m-BEENISH the choice of cluster head is primarily stands totally at the preliminary and residual power competencies of the sensors. Super nodes having high efficiency and capabilities has higher chances to become a cluster head. As per study, it is found that this protocol is quite efficient considering the stability and network lifetime, as it sends the packets to the BS more efficiently than other protocols. This paper also proposes, a novel PCSO routing algorithm which can be designed and implemented with high accuracy and efficiency along with the energy prediction system using deep recurrent neural network, which firstly calculates and predicts the energy contained in the node and based on that those nodes are considered for the routing phase. Results obtained from the suggested approach will be compared with the earlier techniques like - i) TEAR [1], ii) RCER [2], iii) CREEP [3] and iv) Fuzzy-based Energy-Aware Routing Mechanism (FEARM) [4] for the performance evaluation.

References

[1] Aram Mosavifard¹, Hamid Barati, "An energy-aware clustering and two-level routing method in wireless sensor networks", *Computing* (2020) 102:1653–1671 <https://doi.org/10.1007/s00607-020-00817-6>, May 2020.

[2] Fuseini Jibreel, Emmanuel Tuyishimire, and Mohammed Ibrahim Daabo, "An Enhanced Heterogeneous Gateway-Based Energy-Aware

Multi-Hop Routing Protocol for Wireless Sensor Networks", *Article-MDPI*, March 2022.

- [3] Abdelkader Benelhouri, Hafida Idrissi-Saba, Jilali Antari, "An Improved Gateway-Based Energy-Aware Multi-Hop Routing Protocol for Enhancing Lifetime and Throughput in Heterogeneous WSNs", *Elsevier*, January 2022.
- [4] Sharma D, Bhondekar AP., "Traffic and energy aware routing for heterogeneous wireless sensor networks", *IEEE Communications Letters*, vol.22, no.8, pp.1608-11, May 2018.
- [5] Haseeb K, Abbas N, Saleem MQ, Sheta OE, Awan K, Islam N, ur Rehman W, Salam T., "RCER: Reliable Cluster-based Energy-aware Routing protocol for heterogeneous Wireless Sensor Networks", vol.14, no.9, September 2019.
- [6] Dutt S, Agrawal S, Vig R., "Cluster-head restricted energy efficient protocol (CREEP) for routing in heterogeneous wireless sensor networks", *Wireless Personal Communications*, vol.100, no.4, pp.1477-97, June 2018.
- [7] Mothku SK, Rout RR., "Adaptive fuzzy-based energy and delay-aware routing protocol for a heterogeneous sensor network", *Journal of Computer Networks and Communications*, January 2019.
- [8] Malik SK, Dave M, Dhurandher SK, Woungang I, Barolli L., "An ant-based QoS-aware routing protocol for heterogeneous wireless sensor networks", *Soft computing*, vol.21, no.21, pp.6225-36., November 2017.
- [9] Maurya S, Jain VK, Chowdhury DR., "Delay aware energy efficient reliable routing for data transmission in heterogeneous mobile sink wireless sensor network", *Journal of Network and Computer Applications*, vol.144, pp.118-37, October 2019.
- [10] Al-Kiyumi RM, Foh CH, Vural S, Chatzimisios P, Tafazolli R., "Fuzzy logic-based routing algorithm for lifetime enhancement in heterogeneous wireless sensor networks", *IEEE Transactions on Green Communications and Networking*, vol.2, no.2, pp.517-32, January 2018.
- [11] Shagari NM, Idris MY, Salleh RB, Ahmedy I, Murtaza G, Shehadeh HA., "Heterogeneous energy and traffic aware sleep-awake cluster-

- based routing protocol for wireless sensor network”, *IEEE Access*, vol.8, pp.12232-52, January 2020.
- [12] Inoue M, Inoue S, Nishida T., “Deep recurrent neural network for mobile human activity recognition with high throughput”, *Artificial Life and Robotics*, vol.23, no.2, pp.173-85, June 2018.
- [13] Wang D, Tan D, Liu L., “Particle swarm optimization algorithm: an overview”, *Soft Computing*, vol.22, no.2, pp.387-408, January 2018.
- [14] Cheng R, Jin Y., “A competitive swarm optimizer for large scale optimization”, *IEEE transactions on cybernetics*, vol.45, no.2, pp.191-204, May 2014.
- [15] Li, C., Bai, J., Gu, J., Yan, X. and Luo, Y., “Clustering routing based on mixed integer programming for heterogeneous wireless sensor networks”, *Ad Hoc Networks*, vol.72, pp.81-90, 2018.
- [16] An, J., Qi, L., Gui, X. and Peng, Z., “Joint design of hierarchical topology control and routing design for heterogeneous wireless sensor networks”, *Computer Standards & Interfaces*, vol.51, pp.63-70, 2017.
- [17] [17] Xiu-wu, Y.U., Hao, Y.U., Yong, L. and Ren-rong, X., “A clustering routing algorithm based on wolf pack algorithm for heterogeneous wireless sensor networks”, *Computer Networks*, vol.167, pp.106994, 2020.
- [18] Kong P, Fang G, He C, Liu Z., “Topology optimization of port wireless sensor network based on small-world network”, In *proceedings of International Conference on Circuits, System and Simulation (ICSS)*, pp.157-161, July 2017.
- [19] Yang, M., Li, Y., Jin, D., Zeng, L., Wu, X. and Vasilakos, “Software-defined and virtualized future mobile and wireless networks: A survey”, *Mobile Networks and Applications*, vol.20, no.1, pp.4-18, 2015.
- [20] Guo, J., Orlik, P. and Ishibashi, K., “Resource aware hierarchical routing in heterogeneous wireless IoT networks”, In *proceedings of Eighth International Conference on Ubiquitous and Future Networks (ICUFN)*, pp. 599-604, *IEEE access*, 2016.
- [21] Boukerche A, Turgut B, Aydin N, Ahmad MZ, Bo` lo` ni L, “Routing protocols in ad hoc networks: A survey”, *Computer networks*, vol.55, pp.3032–3080, 2011.
- [22] Song Y, Liu L, Ma H, Vasilakos AV, “A biology-based algorithm to minimal exposure problem of wireless sensor networks”, *Network and Service Management, IEEE Transactions on*, vol.11, pp. 417–430, 2014.
- [23] Hamid Z, Hussain FB, Pyun J-Y, “Delay and link utilization aware routing protocol for wireless multimedia sensor networks”, *Multimedia Tools and Applications*, vol.75, pp.8195–8216, 2016.
- [24] Dutta, T., Bhattacharyya, S., Dey, S. and Platos, J., “Border Collie Optimization”, *IEEE Access*, vol.8, pp.109177-109197, 2020.
- [25] T. N. Qureshi, N. Javaid, A.H. Khan, A. Iqbal, E. Akhtar, M. Ishfaq, “BEENISH: Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol for Wireless Sensor Networks”, *The 4th International Conference on Ambient Systems, Networks and Technologies (ANT 2013)*, Volume 19, 24 June 2013, Pages 920-925 12.
- [26] A. Preethi, E. Pravin, D. Sangeetha, “Modified Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol”, *2016 Fifth International Conference On Recent Trends In InformationTechnology*, © 2016 IEEE