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Modified Distance based Energy Efficient Reinforcement Learning Routing Protocol for Scalable WSN: EE-MD-RLP

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Abstract. Huge sensing devices have recently been developed for keeping track of in the patient health in healthcare sector. Designs of low cost tiny Wireless sensors are used by the HealthCare (HC) Internet of Things (IOT) to send huge information about patients and everyday hospital operations on network every day. This is a serious concern of future to manage the energy efficient (EE) data transfer considering the highly dense deployment in large area WSN. The major concern in the paper is to design the Reinforced Learning (RL) based EE large area sensor network routing protocol (EELA-RLP) for highly dense deployment. For extremely dense IOT networks, improvement in performance is achieved based on learning and optimal selection of energy enhancement parameters. In this paper it is proposed to adapt optimal transmission range (R), node density (n), and larger area of the network and employed RLfor protocol improvement. The sink node s adapted to default center location according to network scaling. The keeping network density constant the existing EE-RL protocols performance is compared with proposed modified distance based routing EE-MD-RLP the network size is kept fixed to standard. By adjusting design parameters to improve longevity and subsequently EE, and network scaling it is possible to analyses the effectiveness of the recommended protocol for better routing decisions. Modern RL based EE routing technologies claims to further improve performance.

Keywords: Healthcare,Large Area WSN, Reinforcement Learning,Node Density,Network Lifetime, Energy Consumption,

1 Introduction

In Wireless sensors networks (WSN) are now frequently employed to gather field data and save it on servers or the clouds. Because, the supply power capacity of sensors limits the lifespan of networks. Recently as a revolution Artificial intelligence (AI) and reinforcement learning (RL) are essential for improving WSN routing protocols. Innovative methods such as the Hybrid Deep Marine RL (H-DMRL) method [1], the Least-Square Policy Iteration (LSPI) [4], the Reliable Multi-Agent RL-based Routing Protocol (RRP) [2], and the Deep RL (DRL) algorithms [5] are proposed in a number of researches. In WSNs, these methods seek to maximize energy, network lifetime, as well as routing effectiveness. Large state spaces and learning episodes are issues that RL models, such Q-learning and LSPI, solve. This improves convergence speed along with energy efficiency (EE). Furthermore, AI-based routing protocols such as RRP prioritize designs that are lightweight, resilient to assaults, and customized to meet particular WSN needs, guaranteeing resilience against security breaches. These protocols provide promising ways to improve the efficiency and dependability of WSN routing in a range of applications by utilizing RL and AI.

Even yet, in the current WSN environment, the lifespan improvement remains a major issue that needs to be resolved.A sensor node acts as a switch in the network, therefore making sure the routing is appropriate is essential to boosting EE. As a result, increasing the energy consumption efficiency of such WSN systems is crucial. There're certain distance based approaches which may be usefully optimize the energy uses of the network The purpose of this manuscript is to design modified distance based WSN routing importance and issues for the futuristic networks.

Table 1Abbriviations used

HC	HealthCare
IOT	Internet of Things
ML	Machine Learning
EE	Energy Efficient
RL	Reinforced Learning
WSN	Wireless Sensor Network
CH	Cluster head
LA	Large Area
MIS	Mobile Information System
EELA-RLP	EE – LA RL protocol
AI	Artificial Intelligence
BS	Base Station
PDR	Packet-delivery-Ration

A WSN is composed of a vast number of tiny terminals, or nodes, which act as switches in these kinds of networks. Those nodes have limited energy sources since they cannot be quickly replaced or charged. Expanding nodes' scalability within the network architecture through widespread WSN adoption contributes to energy conservation in WSN networks.Because of this, energy consumption is a crucial topic for WSN research. Of recent times, machine learning (ML) has become a crucial element of smart sensor networks. This work attempted to investigate reinforcement learning (RL) as a means of addressing WSN routing problems. WSN's computational capacity is limited by the limited memory and power of IOT devices.

The creation of a modified distance centered WSN protocol is essential to improving network reliability and EE. Numerous studies highlight how crucial it is to optimize routing protocols within dense WSN deployments in order to increase performance and network longevity [11] [12] [13]. As an example, the recommended Modified-DEEC (M-DEEC) protocol uses energy-aware adaptable clustering to effectively distribute energy across nodes in order to increase network lifetime [14]. Furthermore, to improve energy efficiency in WSN-based Internet of Things applications, the Enhanced The threshold Sensitivity Distributed EE Clustering (ETSDEEC) protocol provides both hard and soft thresholds, exceeding previous protocols with regard to of network lifetime as well as energy dissipation [15]. These results highlight how important it is to create and put into practice improved distance-based routing protocols in order to address issues with EE and enhance WSN effectiveness in general. contributions is to enhance the energy performance of the current RL-based WSN routing protocol in order to examine the network effectiveness under the scalable WSN. Papers analyze the effect of the optimal modified measure of distance on the network routing performance. Comparing the effectiveness of current protocols with suggested routes is also necessary.

The purpose of the paper is to design distance based WSN routing method for HC fields. The utilization of sensor-based monitoring and management systems has increased significantly in the IOT collaborations for HC [16]. The WSN has positioned a number of sensors in the HC fields. In current scenario it is important to note that which sensor was most frequently used during the post COVID-19 pandemic HC sectors as illustrated in Figure 1.

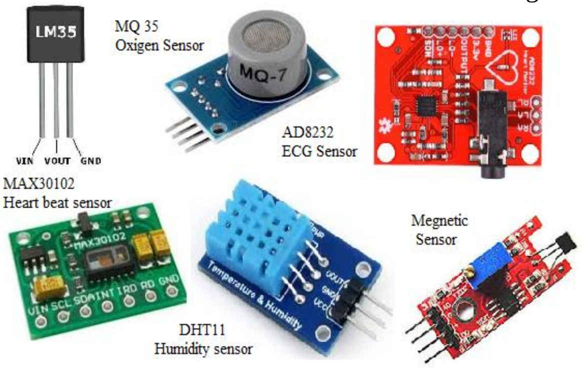


Figure 1 sensors used for HC sector suing IOT

2. Research Problems and Motivation

In order to extend the lifespan of the WSN network, it is necessary to lower the numbers of overflow packets that can be broadcast. The effectiveness of the sensor network may be improved by increasing clustering efficiency. The following technical difficulties are listed.

- Limited hardware: Due to low energy requirements and indeed the limited bandwidth, each node within the network has a restricted capacity for transmitting, processing, including storing data.
- Limited networking supports: The nodes inside a WSN are interconnected peer-to-peer using a mesh network, which has an unreliable communication and a self-motivated interconnection. No fundamental register technologies or standards are available everywhere.
- Limited supports to software development: WSN network uses dynamic node identification, are enormously disseminated in real-time, and must be able to handle demanding situations.

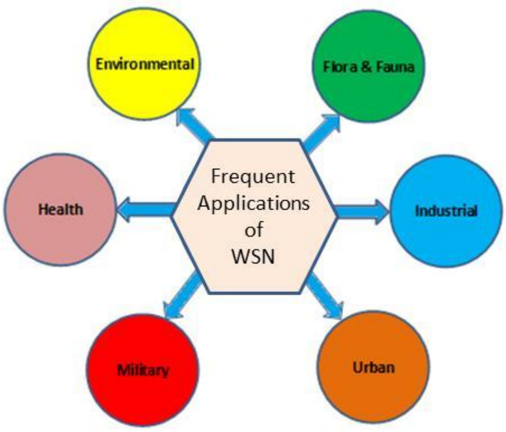


Figure 2 Frequent applications of the WSN designs

- Scalability: The major challenge is the constant scalability of network which is the prime reason to limit the energy and bandwidth of the communication.

Wide Range of Uses: Consequently, sizable quantities of sensor nodes were updated enabling various WSN application evaluations in the industry, Military and healthcare. The Health Care uses are based on internet of Things (IOT) uses wearable sensors to store patient and healthcare administrative data on a web server the most frequent applications of the WSN are illustrated in the Figure 2.

3. RL as Solution to WSN design

Researchers provide a way of rewarding desired actions and penalizing undesirable behaviors in reinforcement learning. In order to motivate the agent, this technique distributes positive values towards desired acts and negative values toward undesirable behaviors. This trains the agent to pursue long-term as well as maximum actual advantage in order to arrive at the best possible outcome. Even though RL has gained a great deal of attention in the field of machine learning, its implementation and use in the physical world are still severely constrained. Despite these, there have been number of research papers on speculative applications, in addition to certain real-world use cases. Reinforcement learning (RL), as depicted in Figure 3, enables equipment to respond to unpredictable network configuration, such as movement and energy density, therefore produce good routing knowledge. The design as well as assessment of a energy-efficient (EE) routing employing reinforcement learning is suggested in this paper (RL). RL learning does not include possessing supervision; it merely has reward signals or actual values. Making timely, relevant decisions is made easier by employing the deep learning model.

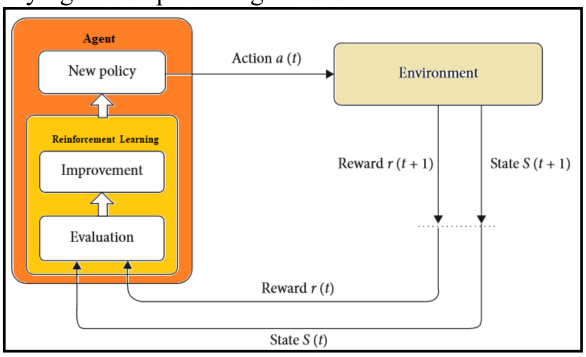


Figure 3 RL based learning model used in this study

The RL, a subclass of the ML, uses the bike path method which is based on incentives assignment as depicted in Figure 3 [1] to enhance productivity in uncharted territory. In IOT networks, RL may be employed to handle problems such unpredictable changes in the network architecture brought on by mobile device usage, energy usage, and other communication factors like signal intensity, distance, as well as bandwidth that could change over time and effect network performance.

4. Contribution of Work:

Energy conservation may significantly extend the networking's lifespan. This book addresses the primary issues related to lifetime enhancement in WSN routing architectures. Improving the model of energy consumption of network nodes is the primary goal of study. Through the application of optimal distance measure standards associated with increased network energy, this approach primarily enhances network life, throughput, and packet delay consumption. The distance between nodes and Cluster Heads (CH) varied with absolute scale, which is a major contributing factor.

Enhancing the EE depending on the RL protocol for routing scalable WSN is the work's primary contribution. The network nodes stability time is directly correlated with the EE. Improving lifetime is a major issue in large area networks because to the growing node density. Maintaining a working network for as long as possible requires energy efficiency.In this study, a technique based on reinforcement learning using modified distance is suggested for effective node development within clusters and CH selection. RL is supported by the dense nodes system (DNS). Performance of lifetime is validated and compared for state of art methods and the improvement in terms of speed and life is compared with proposed RL approach.

4 Literature Review

Figure 4 depicts the broad classification of the several invented WSN routing techniques for enabling EE interacting.

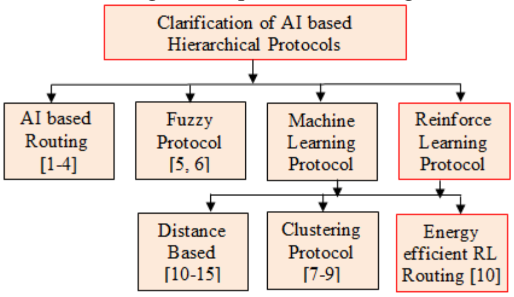


Figure4classification of advanced learning based WSN routing protocols

M. S., Ananth Kumar et al proposed to extend the network's lifetime under the WSN paradigm, a novel environmentally friendly mixed protocol for routing is proposed in this research. Using the chosen route, this protocol achieves the most efficient data transfer. A longer time frame for the entire structure depends on the effectiveness of the cluster strategy used to disperse WSN nodes. The entirety of the network is clustered using the Fuzz Dynamic Peak Clusters (FDPC) Method, dividing it into many clusters. To enhance node availability inside a cluster and enable effective transfer of information to the sinking node via the selected cluster heads (CH), the cluster head choice procedure also has to be carefully considered. The method of Adapting Donkey Theory Optimization (ADTO) is employed to determine the CH required for efficient data transport. using the selected CH, the information is transmitted to the node that sinks using an effective Hybrids Deep Marine reinforced learning (H-DMRL) method.

M. S. Hajar et al proposed a dependable reinforcement learning, multi-agent inspired routing method (RRP) is proposed in this research. Lightweight and robust to assaults, RRP is a routing protocol created specifically to fulfil WMSN criteria. It employs a cutting-edge qualitative learning model to minimize resource use together with a strong trust management mechanism to ward off different types of packet-dropping assaults. The thinness of RRP or its resilience to assaults such as cave, selective shipping, black hole, and complex on-off operations are demonstrated by results of experiments.

3. M.S. HAJAR et al In order to counter well-known drops assaults, the incentive component has been redefined as a penalty and combined with the suggested trust control mechanism. In addition, we used double qualitative learning to conquer the positive prejudice of utilizing just one estimation in order to address the inherent underestimation issue faced by Q-learning-based routing algorithms. To extend network lifetime and maintain system balance of energy, a framework for energy is used with the function of rewards. To circumvent resource constraints and safety concerns associated with sharing energy data, the suggested energy architecture exclusively utilizes local data.

Obi E et al focused on the main applications of Q-education was used in the field of reinforcement learning, also known as RL, for determining the best route Router in wireless networked sensors (WSNs). However, because learning the most effective routing path requires an extensive number of training seasons, the standard Q-learning used for implementing centralized RL-based protocol routing that have considerable space for states and action space experiences degradation in integration speed, network lifespan, and system consumption of energy. Least-Square Policy Iterations (LSPI), an effective model-free RL-based method, is suggested to get beyond these restrictions and maximize the lifetime and consumption of energy in WSNs. A Centralized Router Method for Longevity and Energy optimization with a GA (Genetic Algorithm) and LSPI (CRPLEOGALSPI) is the final constructed technique.

S. Regilan et al stated that protocols for routing play a critical role in IOT of Things powered wireless sensor networks (WSNs), due to the significance of several system characteristics, including energy efficiency, data transmission rate, overall system capacity, and from end-to-end latency. Consequently, in comparison with various networks in the network, the sensors may negatively impact the power endurance and dependability of the navigation method. The wide-field use cases for IoT-enabled WSNs thus require an autonomous energy route planning protocol. Recently an intelligent method of routing with tremendous possibilities for energy saving and system efficiency above the generally realized aim has been developed with the help of the reinforced learning (RL) technique.

Arafat Habib et al stated that in recent years, algorithms for routing in WSNs (wireless sensor networks) have been designed using RL (reinforcement learning) methods. This work surveys the salient characteristics of the RL-based protocols for routing and compares them with one another. There is also discussion of difficult research issues related to creating RL-based routing methods in WSNs. K. Anitha et al have proposed WSN to sense and gather environmental data in order to monitor the surroundings. Explaining the design difficulties that require relevant both software and hardware supports is getting harder and harder as a result of the emergence of several application-specific routing standards. The in-depth analysis of protocol stacks specifically designed for connected sensors is a significant portion of sensors network studies. This paper suggests an overview of the Reward Learning strategy for routing algorithm optimization in wireless sensors.

KhuramKhalida et al estimated the probability that a node will be chosen as a suitable the carrier of a communication from the source to location, a fuzzy controller uses a node's Q values, honors value, and staying buffer room to be input variables. The article suggests an innovative sending system over Opp Nets dubbed Positive reinforcement Learning-based fuzzier Geofact The routing process Protocol (RLFGRP) for

Opp Nets. The suggested RLFGRP rules is demonstrated as being better in terms of expenses ratio, shipment proportion, and typical delays than the developed Geofact Fuzzy-Based Check-and-Spray sending (FCSG) [4] or the fuzzier logic-based qualitative learning the routing (FQLRP) [9] procedures through exercises employing real accessibility tracks.Gaidhani AR et al solved a difficult problem that WIFI sensor networks (WSNs) face is how to extend the duration of the network. There was an extensive amount of work done in this field lately to increase the quantity of services (QoS) and prolong the useful life of the internet connection. The wireless sensor network (WSN) consists of independent, scattered nodes with sensors that use wireless communications to collect and send information to a centralized hub, or "the foundation Station," in the absence of a centralized administrator. Mr. Ankit B. Pate et al worked open mobile sensor networks has seen a rise in attention in recent years. In wireless networks of sensors, nodes that send signals have limited energy. Thus, minimizing the number of resources spent at each sensor node is one of the main design difficulties in WSNs. As a result, several routing techniques are created to effectively utilize the sensing nodes' limited power. The most well-known hierarchy protocol for routing is those that promote environmental sustainability.

P. K. Goyal et al discussed advantages and disadvantages of the clustering strategy have a direct impact on the final cluster division outcome in the clustered transportation algorithm. In order to address the shortcomings of group head randomized elections and unbalanced cluster in the conventional LEACH procedure clustered method in WSN, a procedure for choosing cluster members using nodes distributed intensity and assigning leftover nodes is suggested in this study. The method's ability to quickly choose the heads of and divide groupings, which is beneficial for cluster grouping and helps to balance energy usage, is demonstrated by testing. K., Sakthivel et al aimed to transport data by extending the system's lifespan, productivity, and the cluster head (CH) count. We compare the suggested M-DEEC architecture, particularly allow for optimizing the network's lifespan and minimized the power expenditure of the terminals in the connection, with the DEEC method. An improved energy allocation technique called M-DEEC employs an economy-aware reactive grouping procedure in heterogeneity wireless sensor networks. Every node in the network will retain some energy, which may be utilized as a benchmark to extend its lifespan.NoureddineMoussa et al studied an application-specific Networking Policy that uses reinforced learning (RL) for WSN identification of forest fires (RPLS) facilitated by software-defined networking (SDN) is proposed. In order to preserve energy, we first created a clustering method that maintains an identical architecture over multiple rounds. In contrast to previous research, our approach reduces the cluster radius by taking into account both the power variables and the link reliability. Following network aggregation, the SDN controller capability is leveraged to proactively design, using reinforcement learning, the ideal pathways for the monitoring nodes, therefore reducing the demand for these limited nodes.

Yadav, A.K et al have used an adaptable routing strategies constructed using reinforcement learning with Q-learning methods to offer a quantitative assessment of energy usage. Evaluations were conducted between the effectiveness of multiple routing methods and several system parameters, including distribution rate, usage of energy, and speed of flow, packet corruption rate, and longevity.Chourey, Priyanka et al have suggested designing an effective routing technique, HSO-SAA, for WSN systems by analyzing and evaluating many cutting-edge WSN routing algorithms. The distribution protocol's energy consumption is increased by employing the best parameterization choosing technique. To assess how well the suggested optimal design functioned in conjunction with the already in use clustering-based methods, several experiments have been carried out. Network characteristics such as life duration, alive the nodes, latencies as FND, and the quantity of messages delivered are used for comparing effectiveness. The suggested electricity model is adequate overall to enhance WSN's energy use. Finally Y, K.C., et al designed a cluster-based router performance technique known as Improved DSHR (Dual Stage Hybrids Router) is presented in this paper. It is a two-step process meant to find the optimal path while accounting for clustering. It also includes choosing the cluster head, creating the best possible path, integrating nodes onto the group head, & optimizing sensor range. Moreover, an effective data transfer. After evaluating the makeshift DSHR with consideration for network lifespan, communication overhead, no operational node locations, and path width, it's efficacy is shown by comparing it to the present Leach method..

5 Proposed EELA-RLP Protocol Design

The evaluation process for the suggested RL-based scalable routing algorithm is shown in steps in Figure 5.

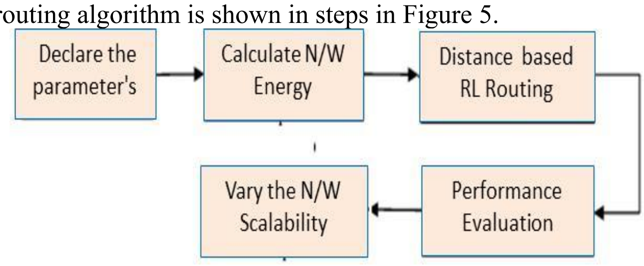


Figure 5 block diagram of proposed distance based RL routing for scalable WSN

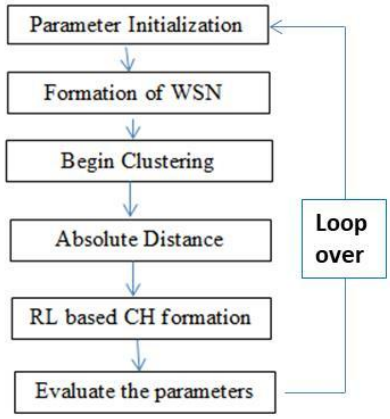


Figure 6 Flow chart of the

To evaluate the routing performance of the RL under network node distributions in this research it is proposed to use the modified distance (MD) measures advised to employ impact of CHelection. The RL decides who will serve as the network's Cluster Head (CH) using MD concept makes if faster. Overall, it is anticipated that the suggested solution will increase the network's energy efficiency.

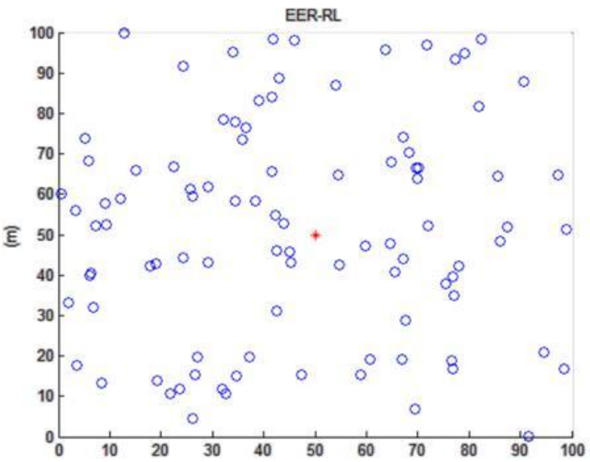
It is clear from the Figure 6 that paper proposed to vary the CH election distance measure. The Euclidian distance is replaced by the absolute difference error (ADE),the node density in ratio of the fixed network area (FNA) of field is varied. And simulation is carried out for the every time for center sink location. Overall the node density is increased to 2:3:4 times and considered as 225000 m sq.

6. Simulation Results of Proposed EE-MD-RLP

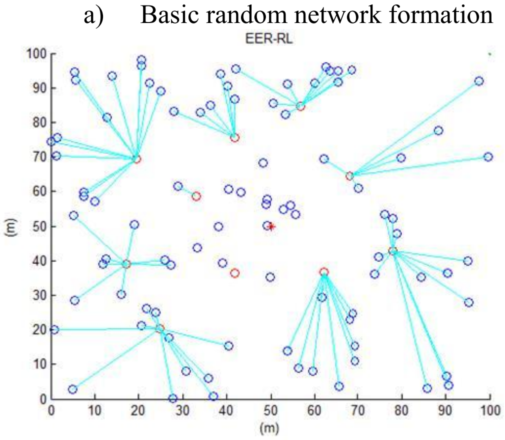
In this research, the fundamental simulation findings for the currently in use RL-based WSN protocols is first validated. The usual field area of 100x100 with 100 nodes is taken into consideration for simulation during validation...

6.1 Validation of EER-RL WSN protocol

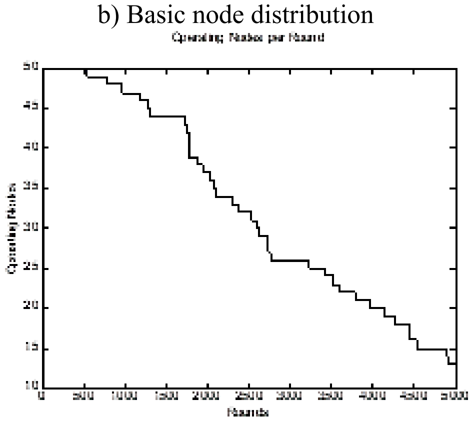
The basic validation results for the number of alive operational nodes and the energy consumptions are plotted in the Figure 7.



a) Basic random network formation



b) Basic node distribution



c) validation of EE-MD-RLP Routing protocol.
Figure 7 Validation of CH formations for EE- RL routing

. The validation process uses 100 nodes and 100 m x 100 m area with sink at the center of the network. The CH are connected to their neighbor nodes for data collection and forwarding on the networkFigure 7 c) have represents the validations of the live nodes in the network with rounds for the 50 nodes and it can be observed that it is required to improve the stability time of the network and overall life too for the validated EE-MD-RLP protocol.

6.2 Result of the proposed EE-MD-RLP Protocol

This section presented the results of the proposed modified distance based EE-MD-RLP routing protocol. The initial results have compared the live nodes for 100x100 m standard area with and without MD measure. The comparison is shown in the Figure 8.

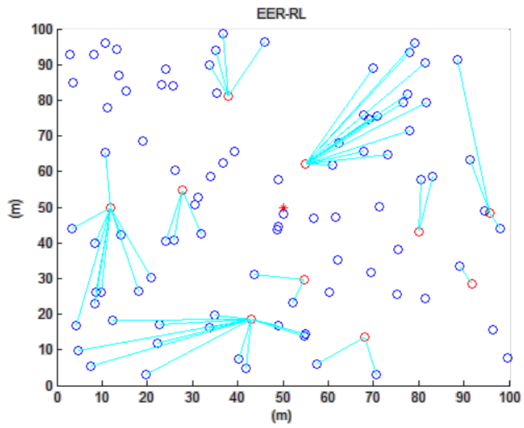


Figure 8 Node cluster formation for EE-MD-RLP protocol

Experiment 2 Results of proposed EE-MD-RLP

The performance of the existing EE-RL routing protocol is compared with the proposed modified distance based routing the performance comparison is based on lifetime, stability, number of dead nodes and energy consumption during clustering and routing. During the experiment the number of nodes is set to the 50 and the network area is set to 100x100 m. the sink location is kept content to center. The Figure 9, Figure 10 and Figure 11 respectively compares the performance for standard and proposed modified distance based RL based routing performance for the energy, dead nodes count and finally live nodes counts,

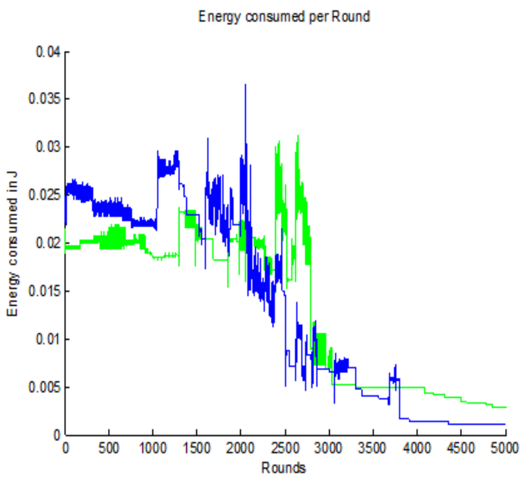


Figure 9 comparisons of Energy consumption with and without MD RL protocol.

It can be clearly observed from the Figure 9 that proposed method offers less energy consumption

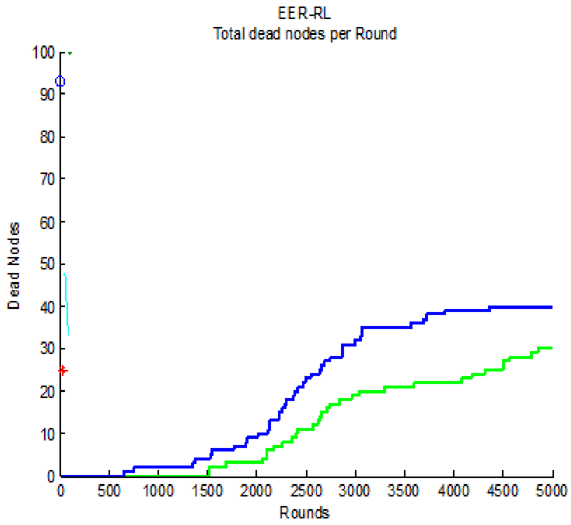


Figure 10 comparisons of dead nodes counts with and without MD RL protocol.

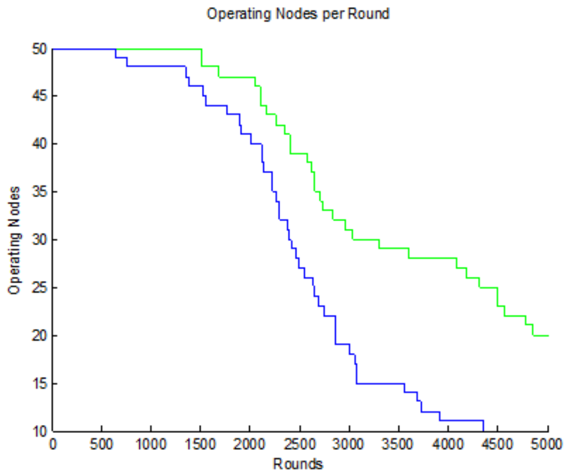


Figure 11 comparisons of allive nodes counts with and without MD RL protocol

. The more number of nodes are alive and the overall network lifetime is increased. Nearly 20% and more nodes are still alive even after the 5000 rounds with the proposed EE-MD RL routing protocol as clear from the Figure 11.

6.2 Parametric Optimization

Table 2 shows all of the best factors that were chosen and used in the simulation for this study's goal of enticing greater effectiveness levels.

Table 2 selection of optimal related simulation parameters

Parameter	**Explanation**	**Choice**
X, Y	WSN field area	100 m x 100 m
n	Nodes in the network	50
S_x, S_y	Sink coordinates	50, 50
E_{Tx}	Energy Transmitted	50×10^{-9} in J
E_{Tr}	Receiver Energy	$50 * 10^{-9}$ in J
E_{amp}	Energy of the Amplifier	$100 * 10^{-12}$ in J
E_{DA}	Aggregation Energy	$5 * 10^{-9}$ in J
R	Range of transmission	[20]
α	Learning rate	[0.5]
γ	Discount factor	0.95
p	Energy probability range	0.5
Q_{hc}	probability of hop counts	0.5

7 Conclusions and Future Prospects

The main goal of the paper is to build the EE large area sensor network routing protocol (EELA-RLP) for small area dense deployment using Reinforcement Learning (RL). Performance improvement for very dense IOT networks is contingent upon learning and choosing the best energy enhancement parameters. This research suggests using RL to optimize protocols by adjusting the ideal transmission range (R), node density (n), and network coverage area. Network scalability caused the sink nodes to adjust to their default center location. The performance of the current EE-RL protocols is compared to the suggested improved distance-based routing protocol, EE-MD-RLP, while maintaining a constant network density. The network size is also maintained at the standard level. By modifying design specifications to increase durability and, in turn, EE and network
Future energy and life efficiency improvements could be made using the adaptive learning rate-based routing system. The optimization techniques might result in further speed improvements in future.

References

[1] M. S., Ananth Kumar, “Hybrid deep marine reinforcement learning-based routing protocol in wireless sensor networks”, Proceedings of the SPIE, Volume 12616, id. 126160E 18 pp. (2023). doi: 10.1117/12.2675102

[2] M. S. Hajar, H. Kalutarage and M. O. Al-Kadri, "RRP: A Reliable Reinforcement Learning Based Routing Protocol for Wireless Medical Sensor Networks," 2023 IEEE 20th Consumer Communications & Networking Conference (CCNC), Las Vegas, NV, USA, 2023, pp. 781-789, doi: 10.1109/CCNC51644.2023.10060225.

[3] M.S.HAJAR 2022. ”A reliable trust-aware reinforcement learning based routing protocol for wireless medical sensor networks”. Robert Gordon University, PhD thesis. Hosted on OpenAIR [online]. Available from: https://doi.org/10.48526/rgu-wt-1987863

[4] Obi E, Mammeri Z, Ochia OE. A Centralized Routing for Lifetime and Energy Optimization in WSNs Using Genetic Algorithm and Least-Square Policy Iteration. MDPI Computers. 2023; 12(2):22. https://doi.org/10.3390/computers12020022

[5] S. Regilan and L. K. Hema, "A Comprehensive Study on Routing Protocol for IoT-enabled WSNs using Deep Reinforcement Learning Strategy," 2022 Fourth International Conference on Cognitive Computing and Information Processing (CCIP), Bengaluru, India, 2022, pp. 1-9, doi: 10.1109/CCIP57447.2022.10058657. .

[6] Arafat Habib, Yeasir Arafat and SangmanMoh, “A Survey on Reinforcement-Learning-Based Routing Protocols in Wireless Sensor Networks”, 2018, The 8th International Conference on Convergence Technology, https://www.researchgate.net/publication/325617283.

[7] K. Anitha, “A survey of optimization of routing protocol in wireless sessor network using reinforcement learning technique”, 2022, IJARIIE-ISSN(O)-2395-4396, Vol-8 Issue-3.

[8] KhuramKhalida, Isaac Woungang, Sanjay K. Dhurandher, Jagdeep Singh, “Reinforcement learning-based fuzzy geocast routing protocol for opportunistic networks”, 2021, ELSEVIER Internet of Things, https://doi.org/10.1016/j.iot.2021.100384.

[9] Gaidhani AR, Potgantwar AD. A Review of Machine Learning-Based Routing Protocols for Wireless Sensor Network Lifetime. Engineering Proceedings. 2023; 59(1):231. https://doi.org/10.3390/engproc2023059231
.

[10] Mr. Ankit B. Patel, Dr. Hitesh B. Shah, “Reinforcement Learning Framework for Energy Efficient Wireless Sensor Networks”, 2015, International Research Journal of Engineering and Technology (IRJET),Volume: 02 Issue: 02.

[11] P. K. Goyal and N. K. Gupta, "Design of the Modified D-LEACH based Routing Protocols for the Dense Deployment based WSN," 2022 Second International Conference on Advances in Electrical,

Computing, Communication and Sustainable Technologies (ICAECT), Bhilai, India, 2022, pp. 1-5, doi: 10.1109/ICAECT54875.2022.9807983.

[12] K., Sakthivel.,Rajkumar, Ganesan., Gayathri, T., Devi., M., Sowmya. (2022). Modified distributed energy efficient clustering protocol for lifetime maximization in wireless sensor networks. International Journal of Health Sciences (IJHS), doi: 10.53730/ijhs.v6ns6.12459

[13] NoureddineMoussa, Edmond Nurellari, KebiraAzbeg, AbdellahBoulouz, KarimAfdel, LahcenKoutti, Mohamed Ben Salah, Abdelbaki El Belrhiti El Alaoui, "A reinforcement learning based routing protocol for software-defined networking enabled wireless sensor network forest fire detection", Future Generation Computer Systems, Volume 149, 2023, Pages 478-493, https://doi.org/10.1016/j.future.2023.08.006.

[14] Yadav, A.K., Sharma, P. &Yadav, R.K. A novel algorithm for wireless sensor network routing protocols based on reinforcement learning. Int J SystAssurEngManag 13, 1198–1204 (2022). https://doi.org/10.1007/s13198-021-01414-2

[15] Chourey, Priyanka and Imran Ali Khan. “High Speed Optimum WSN Routing using Modified Distance Measure based Clustering: HSO-SAA.” International Journal of Computer Applications (2021): n. pag.

[16] Y, K.C., M, S.B. An improvised dual step hybrid routing protocol for network lifetime enhancement in WSN-IoT environment. Multimed Tools Appl 83, 59965–59984 (2024). https://doi.org/10.1007/s11042-023-17823-3