Evaluation of Energy-Efficient Routing Strategies Based on Multi-Hop Clustering in Heterogeneous Wireless Sensor Networks

Dattatray B. Kamble[1] Prof. Dr. Ajitsinh N. Jadhav[2]
[1]Research Scholar [2]Professor
[1,2]Department of Electronics and Telecommunication Engineering
[1,2]D Y Patil College of Engineering and Technology, Kolhapur, India

Abstract — A wireless sensor network (WSN) comprises numerous energy-efficient devices that use routing protocols for prolonged operation. Recent cluster-based protocols focus on enhancing energy efficiency, throughput, and network longevity, yet often neglect crucial factors like node-to-Base Station (BS) distance when selecting cluster heads. This oversight can lead to suboptimal battery usage due to high energy demands in distant data reporting. The implementation of blanket coverage in heterogeneous WSNs aims to address this. This study evaluates the Low Energy Adaptive Clustering Hierarchy (LEACH), Energy Aware Multi-hop Routing (EAMR), and the newly proposed Distributed Energy Efficient Clustering (DEEC) protocol across various scenarios. DEEC optimizes cluster head selection by factoring in residual energy and distances from both the BS and neighboring nodes, aiming to minimize energy dissipation. Results indicate that DEEC significantly improves energy consumption, throughput, and network lifetime compared to LEACH and EAMR.

Keywords: WSN, LEACH, EAMR, DEEC, Base Station (BS), Cluster

I. INTRODUCTION

WSNs are essential for real-time, cost-effective, and flexible data collection across various fields such as healthcare, industry, environmental monitoring, and smart cities. They can be deployed in challenging locations, providing wireless data collection that enhances efficiency, safety, and decision-making. WSNs facilitate large-scale monitoring and self-organization, making them invaluable where wired networks are impractical, and they offer a scalable solution by eliminating the need for expensive cabling.

A. *Wireless Sensor Networks*

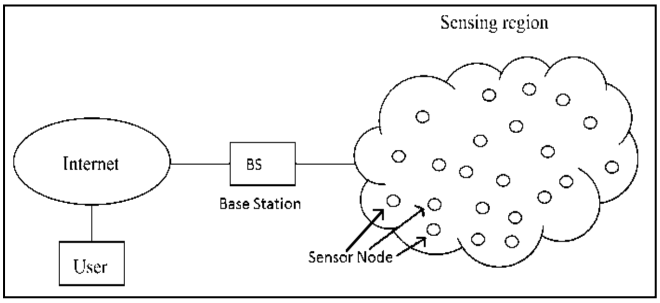

Fig. 1: Simple WSN

WSNs consist of small, dispersed devices equipped with various sensors. They enhance communication, data collection, and monitoring across multiple fields such as smart cities, industrial automation, healthcare, environmental monitoring, and military applications. These nodes communicate wirelessly and collaborate to transmit data to a central processing unit for analysis.

Technological advancements in wireless communication and micro-sensor technologies have led to the development of WSNs, which emerged from military research in the 1980s and 1990s. WSNs utilize multiple sensor nodes to autonomously collect and transmit data for applications in smart cities, healthcare, and environmental monitoring. However, they encounter challenges such as energy efficiency, especially since battery-powered nodes are often in difficult-to-access locations. Research is focused on extending network lifetime, ensuring communication reliability, improving scalability, enhancing reliability against node failures, and bolstering security against wireless communication vulnerabilities.

B. *Communication in WSNs*

The devices in WSNs utilize a multi-hop structure for communication, transferring data from node to node until reaching the central hub or sink. This approach conserves energy by reducing power requirements for transmissions, balancing energy consumption, and prolonging operational life. The sink, or base station, collects, processes, and transmits data. Key components of WSNs include sensor nodes, communication infrastructure, and the sink itself, comprising four critical subsystems: a sensing unit for measuring physical events, a processing unit typically managed by a microcontroller, a communication unit for data exchange via a wireless transceiver, and a power unit, which is often battery-operated or supplemented by energy-harvesting devices like solar panels.

C. *Routing Protocols*

Determining the best path for data transmission from origin to destination requires a routing protocol, which must overcome obstacles caused by network type, channel characteristics, and performance indicators. Wireless sensor networks (WSN) connect the sensor network to other networks, such as the internet, for data collection and analysis by sending data from sensor nodes to a base station.

Single-hop communication takes place in small sensor networks with nearby base stations and motes. However, since many sensor nodes are too far from the sink node to interact directly with the base station, multi-hop communication is necessary in most WSN applications with vast coverage regions. Direct communication is defined as single-hop communication, and indirect communication is defined as multi-hop communication.

In multi-hop communication, sensor nodes facilitate connections between other nodes and the base station while producing figuring out the best route from the source node to and transmitting their own data. In this situation, routing which entails the destination node is the main function of the network layer.

D. Clustering routing protocols

By grouping nodes into clusters, clustering routing techniques improve energy efficiency in WSNs by lowering long-distance transmissions and extending network lifetime. Additionally, this technique reduces unnecessary data transfer and saves energy by facilitating data aggregation.

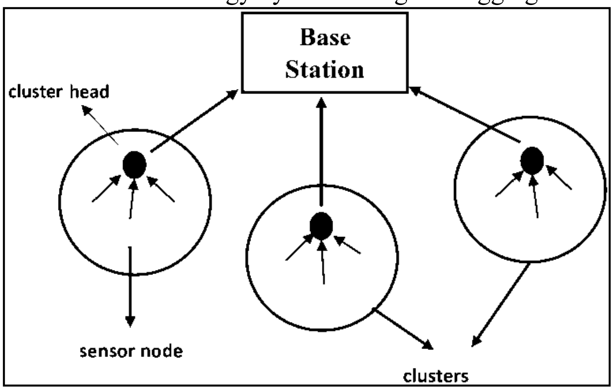

Fig. 2: Clustering routing protocol schematic in WSN

In WSNs, clustering routing techniques establish logical groups known as clusters, with a Cluster Head (CH) overseeing data gathering and transmission to the base station (BS). By reducing long-distance data transmission, they aim to improve energy efficiency, balance the network load, and prolong the network's lifespan. LEACH (Low-Energy Adaptive Clustering Hierarchy), DEEC (Distributed Energy Efficient Clustering), and EAMR (Energy Aware Multi-hop Routing) are notable examples.

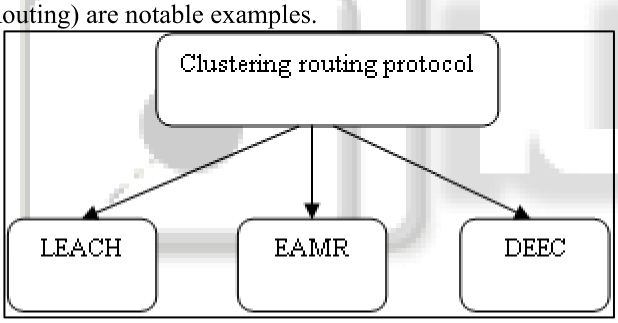

Fig. 3: Clustering routing protocol Considered

By organizing nodes into clusters, each overseen by a specific Cluster Head (CH), clustering routing methods improve the effectiveness and longevity of wireless sensor networks. This organization minimizes long-distance transmissions, balances the load with specialized CHs, enhances scalability and robustness, and uses data aggregation to reduce energy usage.

E. Motivation

Recent advancements in Wireless Sensor Networks (WSNs) highlight their applications in areas such as environmental monitoring, healthcare, military surveillance, and smart cities. A key challenge remains the limited energy resources of sensor nodes, which affects network longevity due to high communication overheads. Clustering-based routing protocols offer a solution by grouping nodes into clusters, allowing cluster heads to manage data aggregation and reduce redundant transmissions. However, in heterogeneous WSNs with varying energy capacities and computational abilities, balancing energy consumption becomes intricate. Employing multi-hop communication can further enhance performance by minimizing the transmission distance between cluster heads and base stations, thereby conserving energy. This study aims to evaluate and optimize energy-efficient multi-hop clustering protocols to ensure reliable communication, scalability, and extended lifespan of heterogeneous WSNs.

F. Problem Statement

In heterogeneous wireless sensor networks, variations in energy levels, processing capabilities, and communication ranges among sensor nodes can lead to unbalanced energy consumption and reduced network lifetime. Traditional routing protocols and clustering mechanisms do not effectively address these disparities, causing energy holes and network performance degradation. Multi-hop clustering-based protocols have been developed to improve energy efficiency and load balancing. However, there is a critical need to analyze and compare the performance of these protocols under heterogeneous conditions with respect to energy consumption, network lifetime, packet delivery ratio, and throughput to optimize energy usage and enhance data transmission reliability.

G. Objectives

1) This study compares the energy efficiency and load distribution of multi-hop clustering protocols in heterogeneous WSNs.
2) It measures network lifetime across various heterogeneity ratios and node densities.
3) When data is transferred multi-hop to the Base Station (BS), performance parameters like throughput, packet delivery ratio, and end-to-end delay are assessed.
4) The analysis identifies the strengths and weaknesses of each protocol and suggests suitable use cases.

II. LITERATURE SURVEY

1) Wireless Sensor Networks (WSNs), which emphasize energy conservation due to sensor node battery restrictions, are essential for applications like environmental monitoring and the Internet of Things. Although it has difficulties in dynamic contexts, the Enhanced Distributed Energy-Efficient Clustering (DEEC) protocol increases energy efficiency by choosing cluster heads depending on residual energy. In order to solve these problems, this study presents a modular DEEC solution that supports heterogeneous nodes, load balancing, dynamic cluster head selection, and realistic energy models. When compared to traditional DEEC, MATLAB simulations demonstrate that this improved protocol dramatically boosts energy economy, nearly doubles network lifetime, and improves stability, making it a reliable alternative for contemporary WSN and IoT applications.
2) Affordable sensor nodes are used in wireless sensor networks (WSNs) to gather environmental data and send it via multi-hop communication to a base station (BS). Maintaining battery-operated nodes is difficult, which emphasizes the need for energy conservation to increase network longevity. The upgraded Snake Optimizer (SO) and Golden Jackal Optimization (GJO) techniques are combined in this study to create the ESO-GJO multi-hop routing protocol. In order to produce a fitness function for the best cluster head selection, it uses a Brownian

motion function during exploitation and incorporates a number of variables, including cluster head energy consumption, node degree, and distance to the BS. The routing path from cluster heads to the BS is subsequently established using the GJO technique. According to simulations, ESO-GJO performs better than LSA, LEACH-IACA, and LEACH-ANT in terms of reducing energy consumption and prolonging network lifetime.

3) To increase device longevity, WSN depends on energy-efficient routing techniques. Critical parameters like the distance between nodes and the Base Station (BS) are not taken into account in recent improvements in cluster-based routing protocols, which concentrate on improving energy efficiency, throughput, and network longevity. The Distributed Energy Efficient Clustering (DEEC) protocol made this constraint clear. The Distance-DEEC (D-DEEC) protocol, which takes into account residual energy and node-to-BS distances while choosing Cluster Heads (CHs), was developed to address these problems. This innovative approach uses a sleep and awake strategy to maximize energy dissipation in addition to selecting CHs with high energy levels closer to the BS. Performance evaluations using MatLab R2018a demonstrated that D-DEEC outperforms TDEEC in energy consumption, throughput, and network lifetime.
4) Wireless Sensor Networks (WSNs) represent a significant advancement in wireless communication, facing various challenges particularly in routing protocols. This paper outlines the types of sensors used for data transmission, discusses issues related to network testing, and analyzes protocols that prioritize data transfer based on features rather than direct sensor node interaction. Key elements include energy recovery through boundary service and optimal group head selection to minimize energy use. The study also explores interventions in flooding algorithms and assesses performance amidst node failures using MATLAB tools, comparing traditional WSN protocols like LEACH, TEEN, and APTEEN across various metrics such as energy efficiency and scalability. This research holds implications for communication analysts and WSN application developers.
5) With the rise of Wireless Sensor Networks (WSN), the use of heterogeneous sensor nodes (SNs) has enhanced convenience through wireless connections. These SNs utilize clustering algorithms and routing protocols for effective data transmission by aggregating and eliminating redundant packets. This paper introduces a dynamic, multi-hop clustering routing protocol that optimizes routing paths based on distance and energy, addressing a gap in environmental behavior analysis. The new Multi-hop Deterministic Energy Efficient Routing protocol (MDR) significantly improves network lifetime, data aggregation, and throughput compared to existing protocols such as LEACH, O-LEACH, EEE-LEACH, and ZSEP.
6) Our research focuses on Wireless Sensor Networks (WSNs), which are made up of energy-constrained sensor nodes that send data to a Base Station (BS). We use effective data communication techniques to increase battery life and lessen the difficulties associated with battery replacement. Blanket coverage for heterogeneous sensor networks in the Internet of Things is a result of the increased reliance on nodes nearer the base station. Distributed Energy Efficient Clustering (DEEC), Developed DEEC (DDEEC), Enhanced DEEC (EDEEC), Threshold DEEC (TDEEC), and Improved DEEC Protocol (IDEEC) are among the protocols we assess. Throughput, network longevity, and stability duration are used to evaluate performance. When it comes to network longevity, both EDEEC and TDEEC perform well in heterogeneous circumstances, with TDEEC taking the lead in stability period. IDEEC outperforms DDEEC in terms of overhead, but TDEEC is still the best option. Variations in network heterogeneity characteristics have a substantial impact on DEEC and DDEEC performance.
7) WSN nodes are low-power devices, and effective routing protocols should conserve energy and extend network lifetime. This paper introduces a modified grey wolf optimizer-based routing protocol (HMGWO) for heterogeneous WSNs (HWSNs), addressing energy imbalance issues. The protocol identifies initial clusters using fitness functions tailored for nodes with varying energy levels. These initial fitness values serve as weights in the grey wolf optimizer, which dynamically adjusts based on node distances and coefficients, thereby optimizing cluster head selection. According to experimental data, HMGWO improves power consumption and network throughput while increasing network lifetime by 55.7%, 31.9%, 46.3%, and 27.0% over SEP, DEEC, M-SEP, and FIGWO protocols, respectively.

III. METHODOLOGY

Clustering routing protocol methodology involves dividing a network into clusters, with a cluster head (CH) elected to manage each one. The methodology uses a hierarchical structure where cluster members send data to their CH, which then aggregates the data and forwards it to a base station or another CH. This reduces routing overhead and conserves energy, improving the network's lifetime and stability.

In the proposed work mainly three protocols are considered,

1) Low Energy Adaptive Clustering Hierarchy (LEACH)
2) Energy Aware Multi-hop Routing (EAMR)
3) Distributed energy efficient clustering (DEEC)

A. Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH is a wireless sensor network routing protocol that employs clustering to reduce energy consumption. It functions in rounds, with each round comprising a setup phase for selecting cluster heads and creating clusters, followed by a steady-state phase for data transmission. To evenly distribute the energy load across the network and significantly extend its lifetime, nodes are chosen as cluster heads on a rotating and randomized basis.

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical, self-organizing, adaptive cluster-based routing algorithm for wireless sensor networks. The signal strength is used to create the clusters. The setup phase and the steady state phase are the two stages of the LEACH technique.

B. Energy Aware Multi-Hop Routing (EAMR)

A recently created homogenous routing strategy called the Gateway-based Energy-Aware Multi-hop Routing protocol aims to more effectively lower the energy consumption of remote nodes. Nevertheless, it has been found that the protocol displays a high energy consumption rate, a shorter stability period, and less efficient data transmission to the Base Station (BS) when it is deployed for extended periods of time.

Based on a predetermined threshold distance, the network divides the sensor nodes into four logical areas. The base station is outside the sensing field, while the gateway node is in the middle of the network. Regions 1 and 2 are assigned to nodes that are within a predetermined distance of the gateway node or base station, respectively. In this case, they use direct communication to transmit their data to the gateway node or base station. These are the homogenous nodes. However, they are assigned to region 3 if their distance is greater than the predetermined threshold and they are nearer the gateway node; if not, they are placed in region 4. These nodes exhibit heterogeneity.

C. Distributed energy efficient clustering (DEEC)

A hierarchical routing system called DEEC (Distributed Energy-Efficient Clustering) was created for wireless sensor networks (WSNs) in order to prolong the network's lifespan by distributing energy use. It increases the chance of selection for nodes with higher energy by selecting cluster heads based on a probability determined by a node's remaining energy. This allows for more energy-efficient cluster head elections, particularly in heterogeneous networks where nodes have different initial and residual energy levels.

The ratio of a node's residual energy to the average energy of the network is used to choose CHs. Several enhancements to DEEC have been proposed to address its inadequacies in heterogeneous situations. For instance, modifications intended to improve energy distribution and increase network longevity are implemented by the DDEEC and Enhanced DEEC (EDEEC) protocols. By adjusting the probability of nodes being chosen as cluster heads based on their energy levels, these protocols improve the stability and longevity of the network.

IV. IMPLEMENTATION

A. Simulation Setup

Simulation is carried on machine with Intel i3 Processor, 8 GB RAM, 40GB+ HDD Space. Using Fedora operating system in Network simulator version NS-2.35.

B. Simulation Parameters

Following are the parameters considered in an NS2 (Network Simulator 2) for simulation. These parameters are configured in the Tcl simulation script.

Parameter	Value
Sensor deployment area	50 x 50 m^2 and 100 x 100 m^2
Coordinates for Base station	(150,50)
Number of Nodes	50 and 100
Initial Energy of each node	2 Joules
Packet size for data	6400 bits
Packet size for control information	200 bits
Transceiver energy	50 nJ/bit/signal
Energy per bit	5 nJ/bit/signal
Threshold Value (Thv)	0.05J

Table 1: Simulation Parameter

C. Nodes Simulation

Figure 4 shows node deployment, Figure 5 shows cluster head selection for LEACH, Figure 5 shows cluster head selection for EAMR and Figure 6 shows cluster head selection for DEEC.

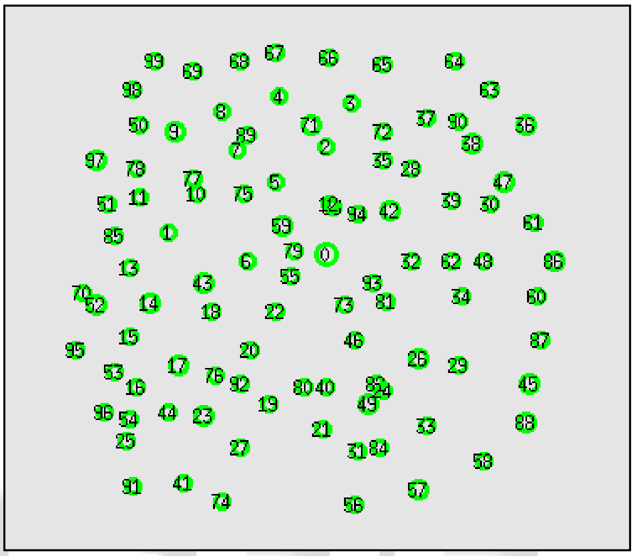

Fig. 4: 100 Nodes Deployment

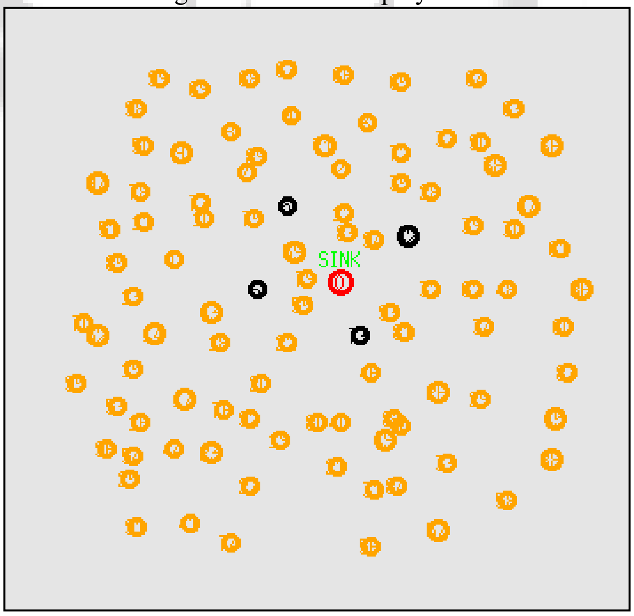

Fig. 5: LEACH Cluster head selection

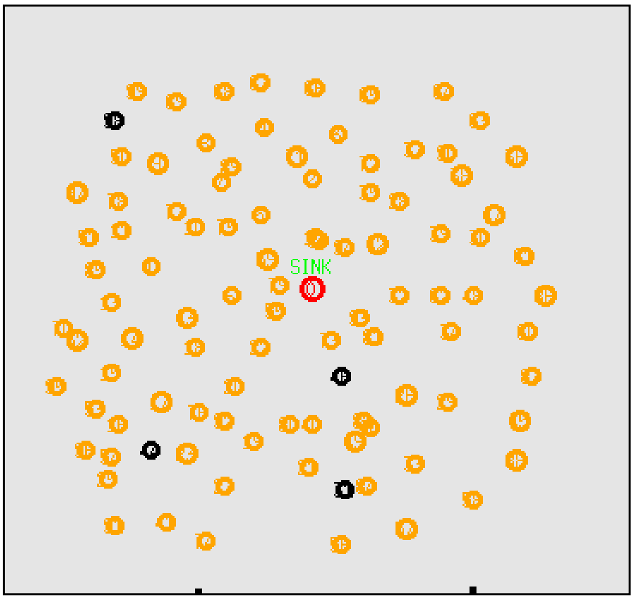

Fig. 6: EAMR Cluster head selection

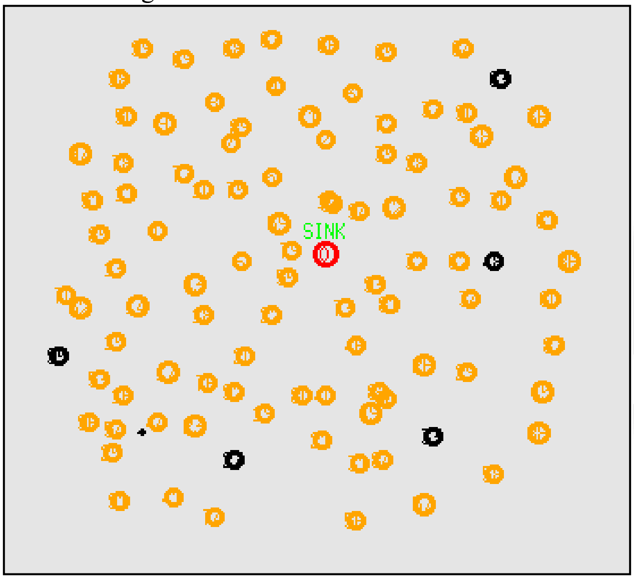

Fig. 7: DEEC Cluster head selection

V. RESULT AND ANALYSIS

Performance analysis is done by consider following metric, for 25, 50, 75 and 100 Nodes.

– Network Lifetime: Network lifetime in WSN is the duration from deployment until the network can no longer perform its intended function
– Number of dead nodes: In WSNs, "number of dead nodes" refers to the count of sensor nodes that have depleted their battery energy and ceased functioning.

$$\text{Number of Dead Nodes} = \text{Total Nodes} - \text{Alive Nodes}$$

– Energy Consumption: Energy consumption in a Wireless Sensor Network (WSN) is the total energy used by its battery-powered sensor nodes for sensing, data processing, and especially wireless communication (transmission/reception).
– Packet Delivery Ratio: In Wireless Sensor Networks (WSNs), Packet Delivery Ratio (PDR) is a key performance metric measuring the ratio of data packets successfully received at the destination (sink node) to the total number of packets sent from the source nodes, indicating network reliability and efficiency, with higher PDR signalling fewer packet losses.

$$E = (P_{tx} \times t_{tx}) + (P_{rx} \times t_{rx}) + (P_{idle} \times t_{idle})$$

- P_{tx}: Transmission Power (Watts)
- P_{rx}: Reception Power (Watts)
- P_{idle}: Idle Power (Watts)
- t: Time (seconds)

$$PDR = \frac{Total\ Packets\ Received}{Total\ Packets\ Sent}\ \%$$

Performance analysis of network area as 100 x100 m^2 in wireless sensor network (WSN) for 100.

In graph blue worm is LEACH, Green is EAMR and Red is DEEC.

1) Network life time

Time	LEACH	EAMR	DEEC
0	100	100	100
1	94	95	95
2	87	89	89
3	80	82	84
4	73	75	77
5	61	63	65
6	48	50	52
7	36	39	41
8	25	30	32
9	15	19	23
10	2	8	18

Table 2: Network life time

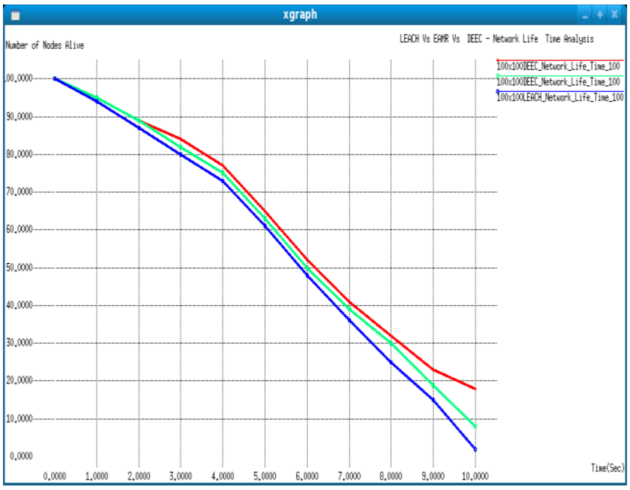

Fig. 8: Network life time Comparison

B. Network Dead Nodes

Time	LEACH	EAMR	DEEC
0	0	0	0
1	6	5	5
2	13	11	11
3	20	18	16
4	27	25	23
5	39	37	35
6	52	50	48
7	64	61	59
8	75	70	68
9	85	81	77
10	98	92	82

Table 3: Network Dead Nodes

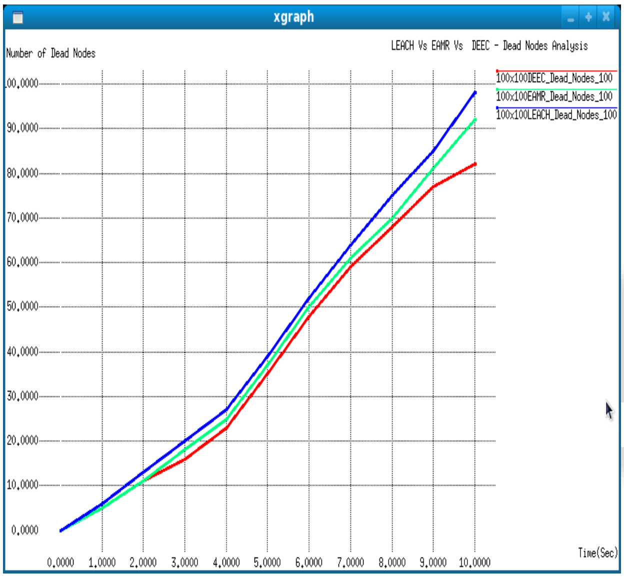

Fig. 9: Network Dead Nodes Comparison

1) Energy Consumption

Time	LEACH	EAMR	DEEC
0	0	0	0
1	7.2	7.9	7.2
2	23.4	22.3	21.5
3	33.1	31.8	29.4
4	46.3	44.2	37.1
5	51.2	49.3	45.1
6	57.9	55.7	49.7
7	66.2	60.2	56.2
8	72.4	69.2	61.2
9	79.2	74.9	69.1
10	85.2	81.2	75.5

Table 4: Energy Consumption

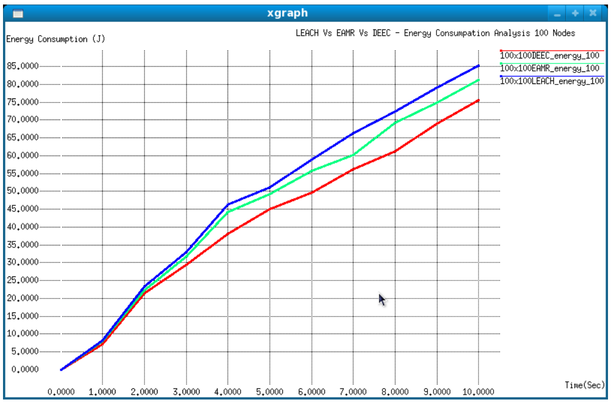

Fig. 10: Energy Consumption Comparison

2) Packet Delivery Ratio (PDR)

Time	LEACH	EAMR	DEEC
1	80.6	84.1	95.8
2	75.3	82.5	89.4
3	67.4	77.2	84.1
4	61.2	75.4	80.7
5	56.7	69.2	76.3
6	53.6	62.7	71.2
7	46.5	57.6	69.2
8	43.3	54.5	59.8
9	37.9	47.3	54.1
10	32.2	44.9	49.2

Table 5: Packet Delivery Ratio

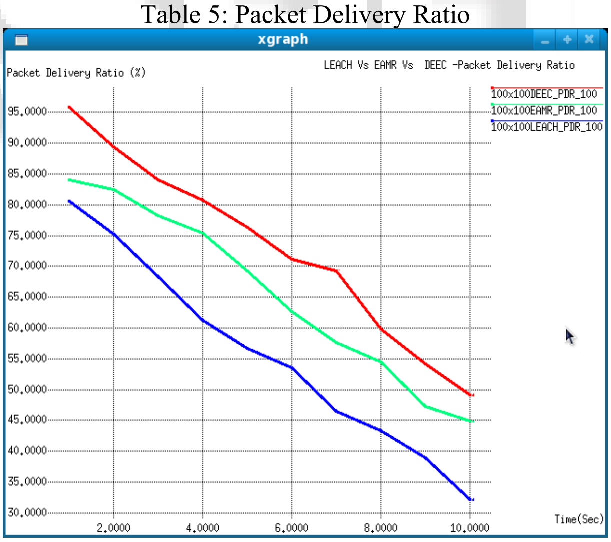

Fig. 11: Packet Delivery Ratio Comparison

VI. CONCLUSION

In wireless sensor networks (WSNs), routing protocols such as LEACH, EAMR, and DEEC aim to enhance energy efficiency and network longevity, each possessing unique advantages and drawbacks. LEACH, a foundational clustering protocol, utilizes random rotation of cluster heads but faces challenges with uneven energy depletion in larger or heterogeneous networks. EAMR advances LEACH by considering residual energy and employing multi-hop communication, thus reducing energy consumption and improving scalability. DEEC is tailored for heterogeneous

WSNs and chooses cluster heads based on both residual and average energy, leading to balanced energy usage and prolonging network stability and lifespan compared to LEACH and EAMR.

DEEC surpasses LEACH and EAMR in network lifetime, energy efficiency, and packet delivery stability, particularly in heterogeneous environments, while EAMR provides moderate improvements and LEACH is best suited for simple, homogeneous networks.

Network life time is 11% better than EAMR and 17% better than LEACH on average for a 50x50 network area; dead nodes are 11% better than EAMR and 17% better than LEACH; energy consumption is 12% better than EAMR and 15% better than LEACH; and packet delivery ratio is 11% better than EAMR and 15% better than LEACH.

Network life time is 8% better than EAMR and 12% better than LEACH for a 100x100 network area on average; dead nodes are 8% better than EAMR and 12% better than LEACH; energy consumption is 8% better than EAMR and 12% better than LEACH; and packet delivery ratio is 8% better than EAMR and 13% better than LEACH.

The reason for excellent performance of DEEC is the algorithm of DEEC. DEEC algorithm chooses the cluster head such that its energy is high and it almost equal distance from each cluster node and also at optimal distance from sink.

Bibliography

[1] Abdulla Juwaied, Lidia Jackowska-Strumillo and Michal Majchrowicz, "Enhanced Distributed Energy-Efficient Clustering (DEEC) Protocol for Wireless Sensor Networks: A Modular Implementation and Performance Analysis", Sensors 2025

[2] Zhen Wang, Jin Duan, And Pengzhan Xing, "Multi-Hop Clustering and Routing Protocol Based on Enhanced Snake Optimizer and Golden Jackal Optimization in WSNs", Sensors 2024

[3] F. Jibreel A, M. I. Daabo B And A. Abdul-Aziz A, "Distance-Distributed Energy Efficient Clustering (D-DEEC) Routing Protocol for Wireless Sensor Network", Asian Journal of Research in Computer Science, 2024.

[4] Mohan Kumar B N, Shivashankar, Manjunath R, Sumanth V,Manohar Koli, Nandeeswar S B, "Wireless Sensor Network Routing Protocols,Challenging Issues and Performance Comparison", Journal of Theoretical and Applied Information Technology, 2023.

[5] Subhash Chandra Gupta, Mohammad Amjad, "MDR-Multi-hop Deterministic Energy efficient Routing Protocol for Wireless Sensor Network". International Journal of Engineering Trends and Technology 2021.

[6] Hamdy H. El-Sayed, Zainab Mostafa Hashem. "Comparisons Of Distributed Energy Efficient Clustering (DEEC) And Its Variation for WSN To the Internet of Things Applications", Int. J. Advanced Networking and Applications (2021).

[7] Xiaoqiang Zhao, Shaoya Ren, Heng Quan and Qiang Gao, "Routing Protocol for Heterogeneous Wireless Sensor Networks Based on a Modified GreyWolf Optimizer", Sensors February 2020.

[8] Reena Kumari, Rishabh Bhardwaj, Vikas Nandal, "Performance Generation of Routing Protocol for WSN", International Journal of Engineering Research & Technology (IJERT) April-2019.

[9] Navneet Kaur, Dr. Sahil Verma, Dr. Kavita, "A Survey of Routing Protocols in Wireless Sensor Networks", International Journal of Engineering & Technology, 7 (4.12) (2018) 20-25.

[10] 10. Nabajyoti Mazumdar, Hari Om, "Distributed Energy-efficient Clustering Algorithm for mobile-sink based wireless sensor networks", IEEE 2017.

[11] Walid Abushiba, Princy Johnson, Saad Alharthi, Colin Wright, "An Energy Efficient and Adaptive Clustering for Wireless Sensor Network (CH-leach) using Leach Protocol", IEEE 2017.

[12] Maddali M.V.M. Kumar, Dr. Aparna Chaparala, "Dynamic Energy Efficient Distance Aware Protocol for the Cluster Head Selection in the Wireless Sensor Networks", 2017 2nd IEEE International Conference on Recent Trends in Electronics Information & Communication Technology (RTEICT), May 19-20, 2017, India

[13] K. Cengiz, Member, IEEE, and T. Dag, Member, IEEE, "Energy Aware Multi-Hop Routing Protocol for WSNs", 2169-3536 (c) 2017 IEEE.

[14] Saad A. Alharthi, Princy A. Johnson, "Threshold Sensitive Heterogeneous LEACH Protocol for Wireless Sensor Networks", 24th Telecommunications Forum TELFOR 2016.

[15] Shahrzad Dehghani, Mohammad Pourzaferani, Behrang Barekatain, "Comparison on energy-efficient cluster-based routing algorithms in wireless sensor network", Elsevier B.V 2015.

[16] Santar Pal Singha, S. C. Sharmab, "A Survey on Cluster Based Routing Protocols in Wireless Sensor Networks", International Conference on Advanced Computing Technologies and Applications (ICACTA- 2015).

[17] Junling Li, Danpu Liu "An Energy Aware Distributed Clustering Routing Protocol for Energy Harvesting Wireless Sensor Networks", IEEE 2014.

[18] Kajal V. Shukla. "Research on Energy Efficient Routing Protocol LEACH for Wireless Sensor Networks", International Journal of Engineering Research & Technology (IJERT) 2013.

[19] Ankit Solanki, Prof. Niteen B. Patel, "LEACH-SCH: An Innovative Routing Protocol for Wireless Sensor Network", ICCCNT - 2013 July 4 - 6, 2013, Tiruchengode, India

[20] V.Chandrasekaran, K.Lalitha , S.Anitha , "Secure Energy Aware Multi-Hop Routing Protocol for Wireless Sensor Networks", International Journal of Advanced Research in Computer Science March-April- 2013.

[21] N. Javaid, T. N. Qureshi, A.H. Khan, A. Iqbal, E. Akhtar, M. Ishfaq, "EDDEEC: Enhanced Developed Distributed Energy-Efficient Clustering for HeterogeneousWireless Sensor Networks", International Workshop on Body Area Sensor Networks (BASNet-2013) EDDEEC: - 2013.

[22] Brahim Elbhiri, Saadane Rachid, Sanaa El fkihi, Driss Aboutajdine. "Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks", IEEE -2010.