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CLT-CRP : A CROSS LAYER TECHNIQUE FOR CLUSTER BASED ROUTING PROTOCOL IN MOBILE WIRELESS SENSOR NETWORK

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ABSTRACT

The Wireless Sensor Network(WSN)s attains tremendous changes in the field of communication networks. Due to the nature of ubiquitous capability of WSN, used in different applications such as monitoring of environment, surveillance in military and health care applications. The innovations in WSN are widely used in data transmission applications. Basically the WSN consists of sensor nodes and clusters. The sensor nodes can move from one cluster to another cluster uniformly and randomly. The phenomenon leads to high energy consumption and data loss in the network. The field of WSN attracts many researchers to work with different routing protocols. However, the previous routing protocols were unable to reduce energy consumption and data loss. Many issues in data transmission with the sensor nodes and nature of resource constrained. To address the limitations of WSN, in this research paper proposed a Cross Layer Technique for Cluster Routing Protocol (CLT-CRP) for Mobile Wireless Sensor Network(MWSN). The proposed protocol is designed with a combination of MAC layer and Network layer configurations. The implementation of the proposed CLT-CRP is made using the NS2 simulator. The proposed protocol outperforms with the comparison of LEACH, CRPD protocols in terms of residual energy, delay, throughput and packet delivery ratio. The results revealed that the proposed protocol improves the performance of WSN.

Keywords - *Wireless Sensor Network, Cluster Head, Energy Consumption, Data Transmission*

1. INTRODUCTION

A cluster-based routing protocol is a commonly employed approach in Wireless Sensor Networks (WSNs) to enhance energy conservation and expand the network's lifespan. In this protocol, nodes are grouped into clusters, with a designated cluster head responsible for overseeing and coordinating the activities of the other sensor nodes within the cluster. The primary benefit of employing a cluster-based routing protocol lies in its ability to reduce energy consumption and communication overhead, thus extending the network's longevity. This is accomplished by restricting the number of nodes that need to communicate directly with the base station, thereby minimizing overall energy consumption[1][7].

Numerous WSN routing protocols are built on the cluster technique, including notable examples like the Low Energy Adaptive Clustering Hierarchy (LEACH), the Network Condition-Aware Geographical Routing Protocol (NCARP), and the Threshold-Sensitive Energy-Efficient Network (TEEN). Each of these protocols possesses unique features and advantages[2]. In WSNs, these protocols collectively work towards minimizing energy utilization and improving the network's overall coverage. In general, cluster-based routing protocols divide the network into clusters, each of which is overseen by a cluster head responsible for managing and coordinating the activities of the other nodes within the cluster[6][9].

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The selection of the cluster head is typically based on criteria such as the node's energy level, its location within the network, or its communication capabilities. After the clusters are formed, the nodes within each cluster can communicate with one another using various routing methods, including direct communication, multi-hop communication, or data aggregation. The cluster head assumes the responsibility of forwarding data to either the destination node or other cluster heads, depending on the chosen routing protocol. Employing a cluster-based routing protocol is an effective means of conserving energy and extending the operational life of a WSN. By organizing nodes into clusters and restricting communication to only a select few nodes, the network can function for extended durations without the need for frequent recharging or replacement[3].

This research makes a significant contribution to the field of Wireless Sensor Networks (WSNs) by proposing a novel solution to address key challenges associated with energy consumption and data loss. The introduction of the Cross Layer Technique for Cluster Routing Protocol (CLT-CRP) for Mobile Wireless Sensor Networks (MWSNs) represents an innovative approach. Unlike previous routing protocols, CLT-CRP integrates both MAC layer and Network layer configurations, providing a comprehensive strategy to enhance energy efficiency and reduce data loss in the network.

The primary objectives of this research were to mitigate the issues of high energy consumption and data loss in WSNs, particularly in the context of sensor nodes moving uniformly and randomly between clusters. The proposed CLT-CRP successfully achieves these objectives by introducing a cross-layer technique that optimizes both the Medium Access Control (MAC) layer and the Network layer. The implementation of CLT-CRP, carried out using the NS2 simulator, demonstrates superior performance compared to existing protocols (LEACH and CRPD) in terms of residual energy, delay, throughput, and packet delivery ratio. The positive results affirm the success of CLT-CRP in significantly improving the overall performance of WSNs, thereby validating the achievement of the stated research objectives.

2. RELATED WORK

Muhammed Ali Aydin and his team have introduced and investigated two algorithms with the aim of enhancing energy utilization in Wireless Sensor Networks (WSNs). One effective strategy for extending the lifespan of WSNs is referred to as "sensor clustering." In this approach, sensor nodes in WSNs exhibit random mobility and self-organize into clusters based on proximity to one another. The selection of the cluster head is determined by evaluating the remaining energy of sensor nodes within each cluster. To achieve this, a combination of Artificial Neural Networks (ANN) and a Greedy Approach is employed. Furthermore, they employ a mobile sink to reduce the energy consumption of cluster heads. The mobile sink's route is determined using a genetic algorithm that takes into account the route information. It moves through clusters and initiates the data collection process for each one. The proposed models are evaluated based on two criteria: the round at which all sensor nodes deplete their energy and the overall energy consumption of the network per round. The empirical results indicate that these proposed models significantly enhance energy efficiency and prolong the network's operational lifetime[2].

In addressing energy efficiency issues in Wireless Sensor Networks (WSN), Shaha Al-Otaibi and colleagues have introduced a novel protocol that leverages advanced routing and clustering methods. These issues often involve optimization problems categorized as Non-deterministic Polynomial (NP)-hard problems, and to tackle them, metaheuristic algorithms are employed to seek the most effective solutions. Motivated by this, the authors have developed a hybridized metaheuristic cluster-based routing method for WSN, referred to as HMBCR. The initial step in the HMBCR method involves a brainstorm optimization process using levy distribution (BSO-LD) for clustering. This process considers four parameters, namely energy, distance to neighbors, distance to the base station, and network load. Subsequently, a routing process based on hill-climbing and water wave optimization (WWO-HC) is used to determine the optimal route. To ensure the energy efficiency and network lifetime performance of the HMBCR technique, extensive experimental analysis is conducted. The results of these experiments demonstrate that the HMBCR method outperforms other approaches in various aspects[4][8].

Sehar Umbreen and her team highlight the resource constraints faced by wireless sensor networks (WSNs) and the development of various clustering protocols aimed at extending their operational lifespan. Nevertheless, these protocols are plagued by shortcomings such as inadequate cluster head selection criteria, fixed clustering, and static rounds, which result in elevated energy consumption. To tackle these challenges, there is a need for an adaptive clustering strategy that offers improved cluster head selection and load balancing. This study introduces an energy-efficient mobility-based mechanism for selecting cluster heads, taking into account crucial parameters that significantly influence sensor energy consumption. The node's weight is determined based on factors like mobility level, residual energy, proximity to the sink, and neighbor density. Inter-cluster communication can employ single-hop or multi-hop techniques, and MATLAB is employed for simulation purposes. The outcomes of this research reveal that the proposed approach, known as EEMCS, surpasses existing algorithms such as CRPD, LEACH, and MODLEACH in various aspects, including load balancing, network stability, energy depletion, and throughput. EEMCS also demonstrates superior energy efficiency, resulting in extended network lifetimes when compared to other existing protocols[5].

3. PROPOSED METHODOLOGY

3.1 Problem Statement

The Wireless Sensor Network(WSN) is a self-infrastructure network with a huge amount of sensor nodes. The distributed sensor nodes communicate with others. In WSN the sensor nodes collect the information and transfer it to the base station. The WSN is deployed in many applications such as healthcare systems, secure military applications, and monitoring applications. But the WSN has inherent limitations of energy and data transmission. Achievement of energy efficiency is essential for WSN. Many researchers have focused on enhancing communication performance and extending the network lifetime. The traditional design of WSN has sensor nodes, cluster head(CH) and base station(BS). The communication of sensor nodes using the traditional design consumes high energy, increases delay and reduces network performance. To address the limitation of the present state of the system, in this research work proposed Cross Layer Technique for Cluster Routing Protocol (CLT-CRP) for Mobile Wireless Sensor Network(MWSN).

3.2 CLT-CRP

In proposed methodology introduced CLT-CRP, to address the limitation of traditional sensor networks. The proposed protocol utilize cluster formation for simplification of network. The cross layer technique applied for optimal data transmission in the network. The physical layer techniques improved network transmission range and received power. Using the MAC layer technique for clearance of node busy tones in the network. So the combination of cross layer technique utilize for fair data transmission in mobile wireless sensor networks. The proposed protocol performance is evaluated with network simulation version 2.

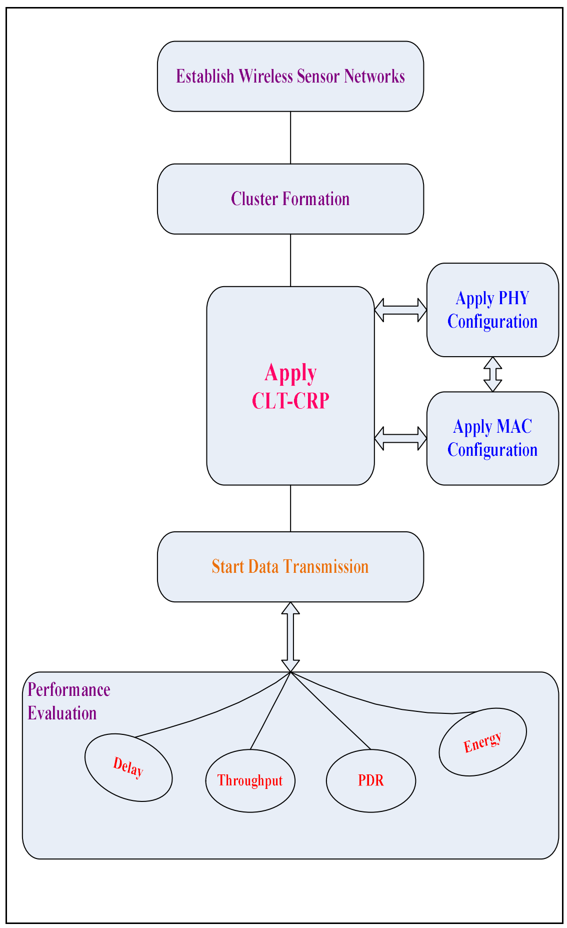

Figure 1- Proposed CLT-CRP Architecture

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In MWSN, clustering is a common technique used for efficient data aggregation and communication. Cross Layer Technique Cluster-Based algorithms in MWSN combine the advantages of cross-layer communication and clustering for improved network performance. The cross-layer technique allows communication between different layers of the network protocol stack, enabling the exchange of information that can be used to optimize network performance.

The CLT-CRP algorithm 1 designed using cross-layer techniques as follows: Initialization: The network is initialized with different number of nodes, each node selecting a random mobility to form Clusters.

Cluster Formation: In WSN cluster node broadcasts a message to all nodes in its range, inviting them to join its cluster. Nodes that receive this message calculate their distance from the cluster and determine their cluster membership based on a distance.

Cluster Head Selection: The MWSN values of all nodes are updated based on the energy consumed and other parameters. A sensor node which have high energy and capacity value becomes the cluster head for the next round.

Cross-Layer Optimization: The cluster head and member nodes exchange information about their energy levels, signal strengths, and other parameters using cross-layer techniques. This information is used to optimize network performance by adjusting parameters such as transmission power, data rate, and routing paths.

Data Transmission: The CH collects data from its other sensor nodes, aggregates it, and sends it to the destination node.

Algorithm 1 CLT-CRP Algorithm
Input - Source Node SN, Destination Node DN, Node Energy NE, Node Capacity CN, Cluster Head CH
Output - Quality of Service Metrics

1. Start
2. Establish WSN
3. Apply Node Mobility
4. Form Clusters
5. If(NE >= Threshold && NC>=Threshold)
6. {
7. Select CH
8. }
9. Apply CLT-CRP
10. Configure PHY parameters
11. Configure MAC parameters
12. Initiate Data Transmission
13. SN sends packets to DN
14. Evaluate Performance Metrics
15. Calculate Energy, PDR, Throughput, Delay
16. End

This algorithm improves the network's energy efficiency and extends the network lifetime by reducing the number of transmissions and increasing the nodes' sleep time. Cross-layer techniques enables the network to optimize its performance based on real-time information, improving the network's reliability and scalability.

4. RESULT ANALYSIS

The implementation of proposed CLT-CRP is made using Network Simulation(NS) version 2.35. The proposed CLT-CRP achieved high performance, the empirical results given below.

4.1 WSN Parameters

Table 1 presents the environment for network simulation for the empirical study.

Table 1: Simulation Environment

S NO	Network Parameter	Network Value
1	Type of Channel	WirelessChannel
2	Radio-Propagation	Propagation/TwoRay Ground
3	Network Interface	WirelessPhy
4	Interface Queue Type	DropTail
5	Model of Antenna	OmniAntenna
6	Length of Queue	50
7	Routing Protocol	AODV
8	Number of Nodes	100
9	Data Rate	2MB
10	Basic Rate	1MB
11	Total Simulation Time	50

The CLT-CRP simulation design incorporates Table 1, which offers a detailed set of network parameters. The Wireless Sensor Network (WSN) deployment is based on the two-ray ground radio propagation model. Various performance metrics, including delay, throughput, packet delivery ratio, and energy consumption, are employed to assess the effectiveness of the proposed mechanisms. In the subsequent section, we conduct a comparative analysis of CLT-CRP against previously established protocols, namely the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol for WSN and the Cluster-based Routing Protocol for Dynamic Wireless Sensor Networks (CRPD-WSN). This assessment is based on the predefined metrics.

4.2 Metric Comparative Analysis

The definition of QoS metrices with equation discussed in sub sections. Also given comparative analysis of CLT-CRP.

4.2.1 Packet Delivery Ratio

The ratio between the number of packets sent and number of packets received at receiver node. The formula given in Eq(1).

$$\text{Packet Delivery Ratio} = \frac{\sum_{i=1}^{n} RPi}{\sum_{i=1}^{n} SPi} \text{ ------------ Eq(1)}$$

In Table 2 demonstrate the empirical results of PDR performance of CLT-CRP.

Simulation Time	Performance of PDR		
	CLT-CRP	LEACH-WSN	CRPD-WSN
0	0	0	0
10	8	5	2
20	28	16	9
30	50	32	19
40	74	56	35
50	97	79	60

Table 2: PDR Performance Results

In Figure 2 given graphical representation on PDR with respective simulation time. It shown the comparative results between proposed protocol and existing WSN protocols.

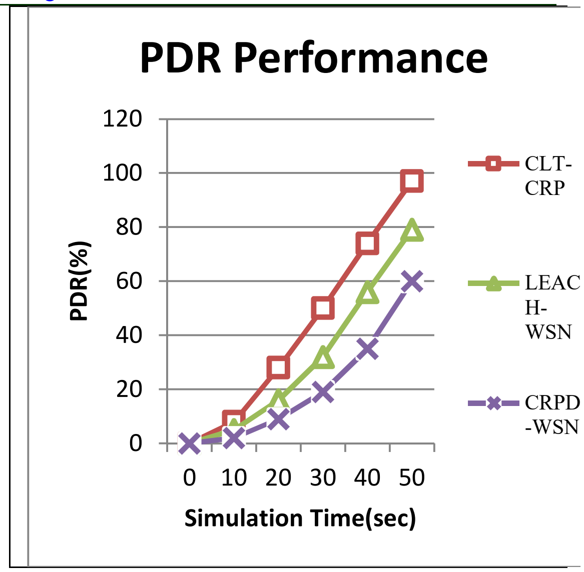

Figure 2 - PDR Performance Comparison

The empirical findings of the CLT-CRP, as well as the established CRPD-WSN and LEACH-WSN mechanisms, are visually presented in Figure 2. The X-Axis corresponds to the simulation time, spanning from 0 to 50 seconds, while the Y-Axis illustrates the Percentage of Packet Delivery Ratio (PDR). It's evident that as the simulation time progresses, the PDR of the CLT-CRP network exhibits improvement. A similar trend is observed in the case of the existing mechanisms; however, the performance results distinctly reveal that the CLT-CRP protocol surpasses the CRPD-WSN and LEACH-WSN mechanisms.

4.2.2 Throughput

Throughput calculate with received bytes rate at destination node with respective simulation time. The formula given in Eq(2).

$$\text{Throughput} = \sum_{i=1}^{n} \frac{Pi}{Time} * 8 \text{ -- Eq(2)}$$

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In Table 3 demonstrate the Throughput performance of CLT-CRP results.

Simulation Time	Performance of Throughput		
	CLT-CRP	LEACH-WSN	CRPD-WSN
0	0	0	0
10	74.81	48.61	39.2
20	66.5	42.67	34.32
30	70.65	39.31	28.79
40	82.39	37.25	24.4
50	82.39	34.62	21.93

Table 3: Throughput Performance

In Figure 3 shown graphical representation on performance of throughput Vs simulation time.

Figure 3 illustrates the throughput performance of the CLT-CRP mechanism. The X-axis depicts the simulation time, ranging from 0 to 50 seconds, while the Y-axis represents the amount of data received at the destination node in bytes. Notably, the CLT-CRP mechanism exhibits a significant enhancement in throughput performance, achieving 82.39 KBPS. In comparison, the existing mechanisms, CRPD-WSN and LEACH-WSN, achieve 34.62 KBPS and 21.93 KBPS, respectively.

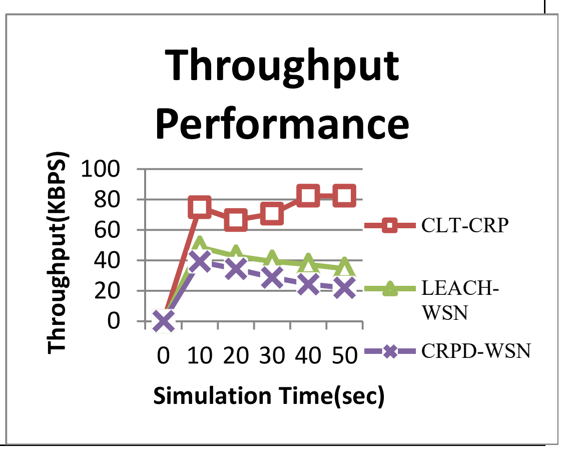

Figure 3 - Comparison On Throughput Performance

4.2.3 Delay

The delay calculate with the difference between the received packets time and sent packets time. The formula given in Eq(3).

$$\text{Delay}= \sum_{i=1}^{n} \text{PSTi} - \text{PRTi} \quad ----\text{Eq(3)}$$

In Table 4 demonstrate the CLT-CRP delay performance results.

Simulation Time	Delay Performance		
	CLT-CRP	LEACH-WSN	CRPD-WSN
0	0	0	0
10	0.1121	0.421	0.528
20	0.0606	0.305	0.398
30	0.0598	0.275	0.325
40	0.0439	0.235	0.295
50	0.0305	0.188	0.241

Table 4: Delay Performance

In figure 4 shown graphical representation on proposed CLT-CRP delay performance Vs Simulation Time.

In Figure 4, a comparison of network delay performance between the proposed mechanism and the current system state is presented. The X-axis denotes the simulation time in seconds, and the Y-axis represents the network delay in milliseconds. The empirical results highlight the superior performance of the proposed mechanism over the existing system, showing substantial improvements from 0 to 50 seconds.

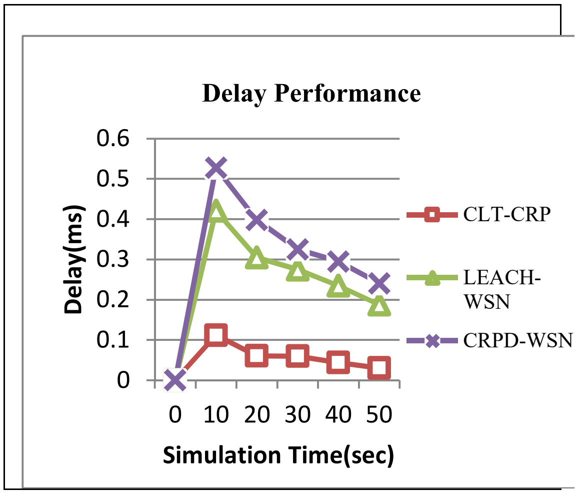

Figure 4 - Delay Performance Comparison Results

While the proposed mechanism initially experienced higher network delays, these delays gradually decreased and minimized over time.

4.2.4 Residual Energy

It represents total energy utilized by the sensor nodes in the network for data transmission. The formula given in Eq(4).

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$$\text{Energy} = \sum_{i=1}^{n} \text{NEi} \text{ -------- } \text{Eq}(4)$$

In Table 5 demonstrate the CLT-CRP Energy performance results.

Simulation Time	Performance of Energy		
	CLT-CRP	**LEACH-WSN**	**CRPD-WSN**
0	100	100	100
10	94	85	82
20	96	71	66
30	97	62	51
40	95	52	40
50	96	50	34

Table 5:Energy Performance

Figure 5 illustrates the energy consumption over time. The graph depicts the total energy consumed in each time interval, covering a simulation duration from 0 to 50 seconds. In the CLT-CRP network, each sensor node is initially allocated 100 Joules of energy. As the simulation time progresses, there is a gradual increase in energy consumption. However, in comparison to existing mechanisms, the proposed CLT-CRP approach demonstrates significantly lower energy consumption. By the end of the simulation, the CLT-CRP mechanism has consumed only 5 Joules, whereas the existing CRPD-WSN and LEACH-WSN mechanisms have consumed 30 Joules and 39 Joules, respectively[9][10].

The proposed CLT-CRP, implemented using the NS2 simulator, demonstrates significant superiority over the LEACH and CRPD protocols across key performance metrics in wireless sensor networks (WSN). Notably, CLT-CRP outperforms in terms of residual energy, delay, throughput, and packet delivery ratio. The superior residual energy implies enhanced energy efficiency, prolonging the operational lifespan of individual nodes. Lower delay indicates a more responsive protocol, making CLT-CRP suitable for applications with stringent timing requirements. Higher throughput suggests improved network efficiency and capacity, facilitating increased data transfer. The superior packet delivery ratio signifies enhanced reliability and reduced packet loss in CLT-CRP. Collectively, these improvements underscore the protocol's comprehensive enhancement of WSN performance, showcasing its potential to address critical aspects such as energy conservation, responsiveness, efficiency, and reliability compared to existing LEACH and CRPD protocols.

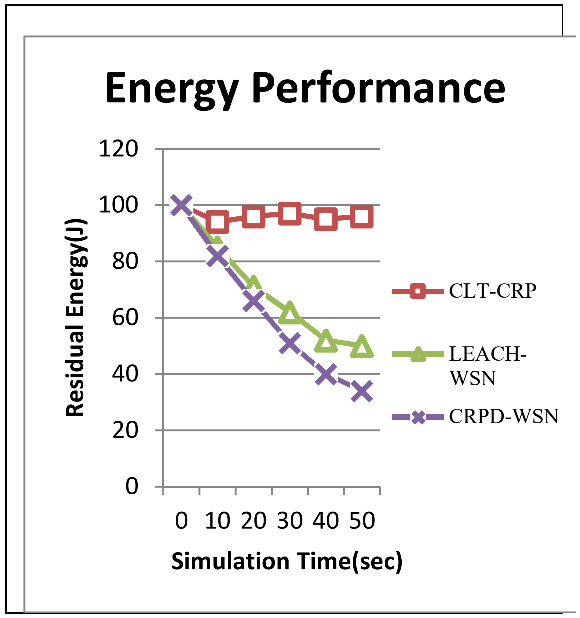

Figure 5 - Comparison on Energy Consumption

5. CONCLUSION

Wireless Sensor Network (WSN) is an emerging technology that has revolutionized the field of communication networks. The use of WSN in various applications such as monitoring of environment, surveillance in military and health care applications, has made it a ubiquitous capability. However, due to the nature of sensor nodes moving from one cluster to another cluster uniformly and randomly, energy consumption and data loss have been major challenges in WSN. In this research paper, a Cross Layer Technique for Cluster Routing Protocol (CLT-CRP) for Mobile Wireless Sensor Network was proposed, which is designed with a combination of MAC layer and Network layer configurations to reduce energy consumption and data loss. The results obtained from the NS2 simulator showed that the proposed protocol outperforms existing protocols such as LEACH, CRPD, in terms of energy consumption, delay, throughput and packet delivery ratio. Therefore, the proposed protocol can be used to improve the performance of MWSN in data transmission applications. The proposed protocol has contributed significantly to the field of MWSN by providing an

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innovative solution to address the limitations of existing routing protocols.

Future research should prioritize tackling node or link failure in Mobile Wireless Sensor Networks (MWSNs). It's crucial to concentrate on fortifying the Cross Layer Technique for Cluster Routing Protocol (CLT-CRP) with resilient mechanisms capable of adeptly managing and recuperating from these failures.

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