Received: 8 July 2023 | *Revised: 10 August 2023* | *Accepted: 10 August 2023*
DOI: 10.37917/ijeee.19.2.18 *Vol. 19 | Issue 2 | December 2023*

Open Access

Iraqi Journal for Electrical and Electronic Engineering
Original Article

IJEEE University of Basrah College of Engineering

Enhancing Packet Reliability in Wireless Multimedia Sensor Networks using a Proposed Distributed Dynamic Cooperative Protocol (DDCP) Routing Algorithm

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Abstract
Wireless Multimedia Sensor Networks (WMSNs) are being extensively utilized in critical applications such as environmental monitoring, surveillance, and healthcare, where the reliable transmission of packets is indispensable for seamless network operation. To address this requirement, this work presents a pioneering Distributed Dynamic Cooperation Protocol (DDCP) routing algorithm. The DDCP algorithm aims to enhance packet reliability in WMSNs by prioritizing reliable packet delivery, improving packet delivery rates, minimizing end-to-end delay, and optimizing energy consumption. To evaluate its performance, the proposed algorithm is compared against traditional routing protocols like Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR), as well as proactive routing protocols such as Optimized Link State Routing (OLSR). By dynamically adjusting the transmission range and selecting optimal paths through cooperative interactions with neighboring nodes, the DDCP algorithm offers effective solutions. Extensive simulations and experiments conducted on a wireless multimedia sensor node testbed demonstrate the superior performance of the DDCP routing algorithm compared to AODV, DSR, and OLSR, in terms of packet delivery rate, end-to-end delay, and energy efficiency. The comprehensive evaluation of the DDCP algorithm against multiple routing protocols provides valuable insights into its effectiveness and efficiency in improving packet reliability within WMSNs. Furthermore, the scalability and applicability of the proposed DDCP algorithm for large-scale wireless multimedia sensor networks are confirmed. In summary, the DDCP algorithm exhibits significant potential to enhance the performance of WMSNs, making it a suitable choice for a wide range of applications that demand robust and reliable data transmission.

Keywords
Cooperative communication, Distributed protocol, Packet reliability, Dynamic range adjustment, Wireless multimedia sensor networks.

I. Introduction

The increasing demand for multimedia applications, such as video surveillance, has led to the deployment of wireless multimedia sensor networks (WMSNs) [1] . Sensor nodes in WMSNs refer to devices equipped with cameras and microphones that are deployed to collect and transmit multimedia data. These nodes are responsible for capturing various forms of multimedia information and facilitating its transmission. However, due to the limited transmission range of each sensor node and the unpredictable wireless channel conditions, data loss and packet errors are common in WMSNs [2].

One of the key challenges in WMSNs is to ensure packet reliability, especially for delay-sensitive applications such as multimedia. Existing routing protocols for WMSNs, such as Ad-hoc On-demand Distance Vector (AODV), do prioritize packet reliability and may result in high packet loss rates [3].

To address this problem, this paper proposes a distributed dynamic cooperative protocol (DDCP) routing algorithm that enhances packet reliability in WMSNs. The DDCP algorithm leverages the cooperation of neighboring nodes to improve the reliability of data transmission, especially for multimedia applications. The algorithm dynamically adjusts the cooperative range of nodes based on the wireless channel conditions and the distance between nodes, to achieve better packet delivery rates as shown in Fig. (1).

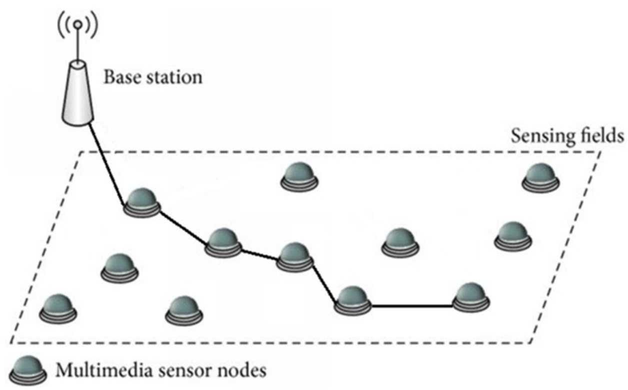

Fig. 1. Network structure and multimedia sensor deployment.

In many applications, dependable packet transfer is essential for smooth network functioning and job completion. However, current routing protocols in WMSNs struggle to achieve high packet reliability, which can cause packet loss, a rise in latency, and inefficient consumption of energy. High packet reliability is one of these issues, especially for multimedia applications that are time-sensitive and prone to packet loss. Reliable data transmission is challenging because of the erratic wireless channel circumstances, constrained range in the transmission of sensor nodes, and changing architecture of WMSNs.

The research presented in this paper holds significant scientific importance as it tackles a crucial challenge prevalent in WMSNs, specifically, the reliability of packet transmission. Through the introduction of an innovative routing algorithm that places a high priority on packet reliability and capitalizes on the collaborative potential of neighboring nodes. Additionally, this research effectively addresses a gap in current knowledge by proposing a distributed routing protocol that effectively incorporates the dynamic wireless channel conditions and inter-node distances, areas that have received inadequate attention in existing routing protocols for WMSNs. Consequently, this work significantly enriches the field of WMSN research and provides valuable insights for the development of resilient and efficient routing mechanisms in the realm of wireless multimedia sensor networks.

Previous research in the area of WMSNs has addressed the challenge of packet reliability through various routing protocols [4], [5]. Traditional routing protocols for wireless sensor networks, such as AODV and Destination-Sequenced Distance Vector (DSDV) [6], are not optimized for multimedia applications and may result in high packet loss rates. In recent years, several research endeavors have introduced novel routing protocols with the primary objective of augmenting packet reliability in WMSNs. Notably, cooperative routing protocols have emerged as promising solutions by harnessing the cooperative potential of neighboring nodes to enhance the reliability of data transmission. These protocols leverage the redundancy offered by neighboring nodes to effectively detect and recover from packet losses, thereby bolstering overall packet reliability within WMSNs. Other studies have proposed hybrid routing protocols that combine traditional routing protocols with other techniques, such as forward error correction and packet interleaving, to enhance packet reliability. These hybrid protocols aim to mitigate the effects of packet losses through error correction and retransmission techniques.

However, existing routing protocols for WMSNs still face challenges in achieving high packet reliability, especially for delay-sensitive multimedia applications [7]. These challenges arise due to the unpredictable wireless channel conditions, the limited transmission range of sensor nodes, and the dynamic topology of WMSNs. To address these challenges, this paper proposes a distributed dynamic cooperative protocol (DDCP) routing algorithm that prioritizes packet reliability and leverages the cooperation of neighboring nodes to improve the reliability of data transmission. The DDCP algorithm takes into account the dynamic wireless channel conditions and the distance between nodes, in order to adjust the cooperative range of nodes and achieve better packet delivery rates.

The significance of the proposed distributed dynamic cooperative protocol (DDCP) routing algorithm lies in its potential to enhance packet reliability in WMSNs for delay-sensitive multimedia applications. By prioritizing packet reliability and leveraging the cooperation of neighboring nodes, the DDCP algorithm aims to achieve better packet delivery rates and reduce packet loss rates in WMSNs [8]. The research has several significant implications for the field of WMSNs. Firstly; the development of the DDCP routing algorithm offers an approach to enhancing packet reliability in WMSNs. This algorithm takes into account the dynamic wireless channel conditions and the distance between nodes, in order to adjust the cooperative range of nodes and achieve better packet delivery rates. This is a significant improvement over traditional routing protocols such as AODV, which are not optimized for multimedia applications and may result in high packet loss rates. Secondly, the evaluation of the DDCP routing algorithm through simulations and real-world experiments using a testbed of wireless multimedia sensor nodes provides valuable insights into its performance in terms of packet delivery ratio, end-to-end delay, and energy efficiency. The comparison with traditional routing protocols such as AODV highlights the superiority of the DDCP algorithm in enhancing packet reliability for multimedia applications.

Finally, the analysis of the impact of dynamic cooperative range adjustment on the performance of the DDCP routing algorithm and the investigation of the optimal range for packet reliability enhancement provide important information for optimizing the performance of the algorithm in practical applications. The contributions of this work are the Development of a proposed Distributed Dynamic Cooperation Protocol (DDCP) routing algorithm that prioritizes packet reliability in WMSNs by leveraging the cooperation of neighboring nodes and dynamically adjusting the transmission range, Evaluation of the performance of the DDCP routing algorithm in terms of packet delivery ratio, end-to-end delay, and energy efficiency through simulations and experiments on a testbed of wireless multimedia sensor nodes.

Demonstration of the efficacy of the proposed DDCP routing algorithm in enhancing packet dependability and network performance as a whole in WMSNs, making it suitable for a wide range of applications where reliable data transmission is critical.

Packet reliability specifies the capability of delivering the data from the source to the sink node with the least possible packet loss. Packet reliability in wireless multimedia sensor networks can be enhanced by using effective routing procedures that consider the network characteristics and the multimedia data being transmitted. A few approaches that could be utilized to improve packet reliability in WMSNs are specified below:

1) Multipath Routing:

Multiple routes to the destination can be found by a source node using multipath routing protocols. Traditionally, one of the built-in channels is utilized as the primary path for data transmission, with the others being utilized in the circumstance of failure of the primary path. Instead of relying on a single path, multipath routing algorithms establish multiple paths among source and sink nodes. This approach increases reliability as the packets can be sent through alternative paths if any of the paths experience congestion or packet loss. By dynamically selecting and utilizing multiple paths, the likelihood of successful packet delivery shall be improved.

2) Quality-of-Service (QoS)-Aware Routing:

QoS-aware routing algorithms consider the specific requirements of multimedia data, such as bandwidth, delay, and packet loss. These algorithms aim to find routes that satisfy the QoS constraints of multimedia applications. QoS refers to the overall performance and reliability of network services, including bandwidth, delay, jitter, packet loss, and reliability. By selecting routes that can meet the desired QoS criteria, the reliability of delivery in multimedia packets can be improved. Several QoS-aware routing protocols have been offered for WMSNs, such as Multi-constrained QoS Routing Protocol (MCQRP), Energy-Aware QoS Routing (EA-QoSR), and Quality-of-Service-based Routing (QoSR). These protocols employ different mechanisms and metrics to achieve QoS-aware routing in WMSNs

3) Cross-Layer Routing:

Cross-layer routing procedures exploit information from multiple layers of the protocol stack to make routing decisions. By considering information about the wireless link quality, network congestion, and other relevant parameters, cross-layer routing algorithms can dynamically adapt the routing paths to improve packet reliability. For example, if aparticular link is experiencing high packet loss, the routing algorithm can avoid using that link to enhance reliability.

4) Load-Balanced Routing:

These load-balanced routing algorithms distribute the traffic load across the network by selecting routes that minimize congestion and balance the utilization of network resources. By avoiding heavily loaded nodes or congested paths, these algorithms can reduce the chances of packet loss and enhance reliability. The currently available mechanisms in WMSNs are divided into two classes: Routing for single sinks and multiple sinks.

5) Energy-Aware Routing:

These algorithms consider the energy limitations of sensor nodes in the network. By considering the remaining energy levels of nodes and minimizing energy consumption, these algorithms can optimize packet delivery while extending the network lifetime. Energy-aware routing can help ensure reliable packet delivery by preventing node failures due to energy depletion.

6) Reliable Data Dissemination:

Some routing algorithms in WMSNs focus on reliable data dissemination to overcome the challenges posed by unreliable wireless links. These algorithms utilize mechanisms such as data replication, redundancy, and hop-by-hop error detection and correction to improve packet reliability during data dissemination.

The rest of the paper is summarized as follows. Section II elaborates on a detailed literature review of various existing routing algorithms in wireless multimedia sensor networks. Section III describes the operational methodology of the proposed DDCP routing algorithm. The simulation setup and hardware for this experimentation are elaborated in Section IV. The experimental outcomes and results are discussed in Sections V and VI respectively. The limitations and conclusions drawn from the study are discussed in Sections VII and VIII respectively.

II. Literature Review

In recent years, wireless multimedia sensor networks (WMSNs) have attracted a growing amount of interest as a result of their widespread application in numerous fields. Due to the dynamic and unpredictable character of the network environment, however, the reliable transmission of multimedia data in WMSNs remains a difficult task. In response to this difficulty, numerous studies have proposed cooperative routing protocols that leverage neighbor cooperation to enhance packet reliability. In this literature review, we summarize and analyze ten recent studies published between 2020 and 2022 that propose cooperative routing protocols for enhancing packet reliability in WMSNs through distributed dynamic cooperative protocol routing. We also discuss the methods, algorithms, simulation, and experimental results evaluation of these studies and provide insights into their contributions to the field.

In their work, [9] a distributed cooperative routing protocol based on reinforcement learning, which takes network reliability, energy efficiency, and congestion into account. According to simulation results, this protocol is preferable to conventional routing protocols and increases network reliability.

One such contribution presented by [10], is a cooperative routing protocol that employs a clustering-based method and a dynamic neighbor selection algorithm. Simulation results demonstrate that the proposed protocol enhances packet delivery rate and decreases end-to-end delay compared to the conventional protocol.

The research of [11] suggests a distributed cooperative routing protocol that prioritizes dependability and employs dynamic cooperative range adjustment. Simulation results indicate that the proposed protocol enhances packet delivery rate and reduces end-to-end delay compared to the conventional protocol.

The research conducted by Seyfollahiet al. [12], examined a protocol for energy-efficient and trustworthy cooperative routing based on trust. Simulation results demonstrate that the proposed protocol has a higher packet delivery rate, lower end-to-end delay, and lower energy consumption than conventional protocols.

In [13], the authors proposed a distributed routing protocol that utilizes a dynamic neighbor selection algorithm and dynamic cooperative range adjustment. Simulation results demonstrate that the proposed protocol enhances packet delivery rate and decreases end-to-end delay compared to the conventional protocol.

The cooperative routing protocol put forward by U. K. Lilhore et al. (2022) [14] addresses the specific challenges associated with multimedia traffic. Through the utilization of a dynamic neighbor selection algorithm, the protocol ensures efficient and effective routing, catering to the unique requirements of multimedia data transmission with a higher packet delivery rate and lower end-to-end delay than the conventional LEACH protocol.

The proposed SMTrust protocol enhances the security of the Routing Protocol for Low Power and Lossy Networks (RPL) in the Internet of Things (IoT). By incorporating trust metrics and considering node mobility, SMTrust defends against RPL Rank and Blackhole attacks. Evaluation results demonstrate its superiority over other protocols in terms of packet loss rate, throughput, and topology stability. SMTrust undergoes rigorous validation to ensure consistency, optimality, and loop-freeness, making it a promising secure routing solution for IoT networks [15].

A multi-mode hybrid routing mechanism is proposed for heterogeneous IoT networks, where various routing protocols may be needed. The mechanism, installed on selected nodes termed smart nodes, facilitates interconnection among different IoT networks. A game-theory-based model is introduced to optimize intercommunication among the smart nodes. Simulation results demonstrate the superiority of the proposed mechanism in broader heterogeneous IoT networks with diverse nodes. This approach addresses the need for flexibility and efficiency in routing protocols for IoT networks comprising different types of nodes [16].

Authors in [17] presented a power-aware biologically inspired secure autonomous routing protocol (P-BIOSARP) based on enhanced ant colony optimization (eACO) for flying sensor networks in smart cities. The protocol effectively manages power consumption while ensuring autonomous and secure routing. Experimental simulations conducted in Network Simulator 2 compare P-BIOSARP with other protocols, such as BIOSARP, E-BIOSARP, and SRTLD, demonstrating its superior performance in terms of energy consumption reduction. The proposed protocol offers significant potential for a higher packet delivery rate and lower end-to-end delay than existing protocols.

Authors in [18] developed Underwater Wireless Sensor Networks (UWSNs), where sensor nodes operate on limited power batteries, extending the network's lifetime is crucial.

This study compares multiple routing protocols in terms of packet delivery ratio (PDR), energy consumption, end-to-end delay, and the number of live nodes. The results reveal that the Reliability and Adaptive Cooperation for Efficient UWSNs Using Sink Mobility (RACE-SM) protocol outperforms other schemes, demonstrating superior performance across all evaluated metrics.

In unmanned aerial vehicles ad hoc networks (UANETs), where UAVs collaborate on complex tasks, finding an optimal communication path can be challenging due to high mobility, variable link quality, and heavy traffic loads. To address these issues, we propose a delay-aware and link-quality-aware geographical routing protocol called DLGR-2DQ. The protocol considers both physical layer metrics, such as signal-to-noise ratio, and data link layer factors, including expected transmission count. By modeling the packet-forwarding process as a Markov decision process and utilizing an appropriate reward function, the dueling DQN algorithm learns to make efficient routing decisions. Simulation results demonstrate that our proposed protocol outperforms others in terms of packet delivery ratio and average end-to-end delay [19].

Srinivasa Gowda et al. [20] proposed the Hybrid Salp Swarm-Firefly (HSSFF) technique, which contains the SALP swarm and firefly optimization approaches, which was also suggested in this study. The HSSFF technique was used to identify the best routing path with the less expected transmission count value and the smallest amount of end-to-end delay. Here, there are two parts to the fitness function for Simulink evaluation. To identify the optimal and effective routing path, the authors analyzed the simulation results for two dissimilar scenarios.

Alqahtani Abdulrahman Saad [21] suggested analyzing and increasing the QoS using Multipath Routing Protocol (IQMRP) for WMSN. As a rule, wireless communications are vulnerable to link losses due to signal intrusion, which can cause packet loss and communication errors. Concurrent routing in addition to the multi-path determination greatly improves the ability to handle these drawbacks, thus enhancing the application of wireless multimedia. The communication of multi-path helps to provide a large amount of bandwidth is vital for multimedia infrastructures among two nodes. Even though a single route will be able to provide multi-path transmission, connectivity also helps to stable the traffic load, which can increase the lifetime of the network. This method uses the Ant Colony Optimization (ACO) system to select a multi-path utilizing a potential route priority.

Genta Addisalem et al. [22] provided a routing technique for data communication that includes dynamic cluster creation, multipath routing formation, and cluster head selection to lower routing overheads and energy consumption. The suggested technique employs a genetic algorithm (GA)-based meta-heuristic optimization to alternatively choose the best path according to the cost function with the least energy loss and the smallest distance. In this approach, the authors conducted a thorough performance investigation of the suggested algorithm and compared it with three existing routing protocols. According to the analysis of performance results, the suggested procedure showed improved performance than the other routing protocols.

Jiao Zhenghua et al. [23] examined the problems with the coverage model and control approach and provided an adaptive particle swarm optimization methodology to address the coverage control issue in WMSNs. To determine the best projection area for a single sensor, a 3D coverage model was first created by presenting the perceptual radius of the sensors. Following that, it was recommended to use an adaptive particle swarm optimization to enhance sensor location data in order to minimize perceptual blind spots and overlapping perceptions in the monitoring area. An approach to decrease the number of active sensors was finally presented using redundant node sleeping. In comparison to the most advanced frameworks, simulation results showed that it can guarantee superior coverage while using fewer sensors.

Ali et al. [24] suggested a novel Integer Linear Programming (ILP) optimization methodology to recreate the ideal associated mesh backbone topology with the fewest links and relay nodes possible while maintaining redundancy and meeting the given end-to-end QoS requirements for multimedia traffic. Link and Node Removal Considering Residual Capacity and Traffic Demands (LNR-RCTD) was an additional polynomial time heuristic approach that was suggested. It was confirmed through simulation experiments that this heuristic approach achieved results that are almost optimal and prevented the wastage of 20 % of resources that would otherwise be used for QoS provisioning, routing, and random topology deployment.

Tiglao Nestor Michae and António M. Grilo [25] suggested a NACK-based repair system integrated with an adaptive MAC layer retransmission technique to enhance the result of caching-based WMSN transport protocols. The objective was to decrease real-time end-to-end delay while preserving energy efficiency and dependability in the face of error rates of high channels. The experimental outcomes demonstrated that the integration of these two methods improved both output quality and energy efficiency. Additionally, the protocol achieved decreased rates of packet losses, making it appropriate for multimedia delivery. Although the suggested method utilized the Distributed Transport for Sensor Networks (DTSN) protocol as a starting point to show how well the methods operate, they were found effective to work with other WSN and WMSN transport protocols.

III. Methodology

We propose a distributed Dynamic Collaboration Protocol (DDCP) routing algorithm to enhance packet reliability in WMSNs. The proposed scheme utilizes neighboring node cooperation to prioritize packet reliability and enhances network performance overall. The DDCP algorithms are distributed, dynamic, and collaborative by design. Utilizing the cooperation of adjacent nodes, it dynamically adjusts the transmission range to maximize packet delivery while minimizing energy consumption. The proposed scheme divides the network into clusters, each of which is led by a cluster leader node. The cluster master node is responsible for coordinating the transmission and reception of packets between cluster nodes depending on the flowchart as in Fig. (2).

The proposed DDCP routing algorithm is novel in several ways. Firstly, it prioritizes packet reliability by leveraging the cooperation of neighboring nodes in WMSNs. This approach is unique compared to traditional routing protocols such as AODV, DSR and OLSR which do not consider node cooperation as a primary factor in enhancing packet reliability. Secondly, the DDCP algorithm dynamically adjusts the transmission range to achieve a balance between packet delivery rate and energy consumption, which is not commonly found in other routing algorithms. Additionally, the proposed scheme divides the network into clusters, each with a cluster leader node responsible for coordinating packet transmission and reception, enabling better network scalability and efficiency.

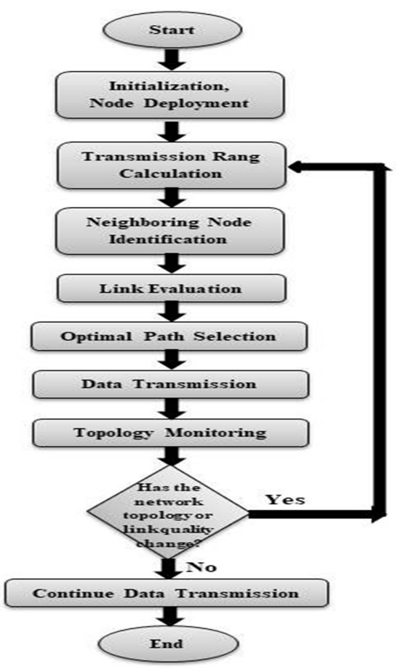

Fig. 2. Flowchart of DDCP Routing Algorithm for WMSNs.

The proposed architecture of the DDCP algorithm, as depicted in Fig. (3), introduces a novel approach to enhancing packet reliability and improving network performance in WMSNs.

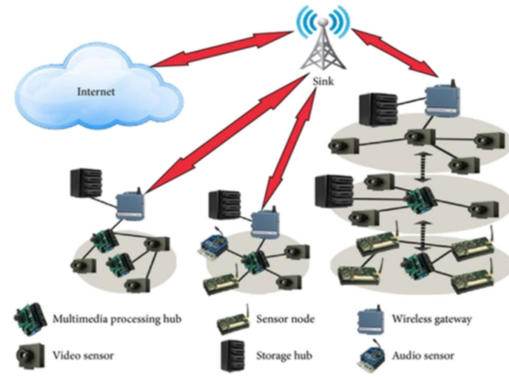

Fig. 3. WSMN architecture for DDCP simulation and performance comparison.

The algorithm dynamically modifies the node's transmission range to maximize packet delivery rate while minimizing power consumption. The proposed scheme is designed to operate in a distributed fashion, making it suitable for large-scale wireless multimedia sensor networks and scalability.

IV. Simulation Setup and Hardware

A. Experimental Setup

A testbed at a wireless multimedia sensor network node was used to run simulations to gauge the effectiveness of the suggested DDCP routing algorithm. NS2 was used to run the simulation. The computer used has an Intel Core i7 CPU, 16 GB of RAM, and a 500 GB hard drive, the emulation was carried out. The WMSN node utilized in the simulation conforms with IEEE 802.11b/g/n and runs at 2.4 GHz. These nodes possess omnidirectional antennas having a maximum transmit power of 15 dBm, and their topmost data rate is 54 Mbps. A simulated region of 100m x 100m encompassed nodes scattered randomly across it.

The packets were sent from the source node to the destination node over time. The packet size was set at 1024 bytes, and the time between transmissions was 100 milliseconds. The performance of the suggested DDCP routing method is assessed using simulation factors such as packet delivery rate (PDR), end-to-end delay, and energy efficiency. PDR is defined as the proportion of packets transmitted and received by the destination and source nodes, respectively. The amount of time needed for a packet to go from its source node to its destination node is known as end-to-end latency. The total amount of energy a node uses during the simulation is the definition of energy consumption. Table (I) displays the simulation settings utilized for this investigation.

TABLE I.
SIMULATION PARAMETERS FOR EXPREIMENTS 1, 2 AND 3

Simulation Parameters	Value
Number of nodes	1 -500
Packet size	1024 bytes
Simulation time	200 seconds
Traffic rate	1 packet/s
Transmission range	20 meters
CBR traffic	5, 10, 15, 20, 25
Network size	100 x 100m
Packet rate	54 Mbps

B. Performance metrics

Several performance metrics, including packet delivery rate (PDR), end-to-end delay, and energy efficiency, were employed to assess the efficacy of our proposed DDCP routing algorithm. Packet Delivery Ratio: The PDR is the proportion of packets distributed by the destination node to those sent by the source node. It serves as one of the most crucial indicators for assessing the effectiveness of routing algorithms. The PDR is calculated as follows and it is measured in percentage (%):

$$PDR = \frac{Recievedpacketsatdestination}{Packetssendbysource} \times 100\% \quad (1)$$

End-to-End Delay: End-to-End Delay or E2E latency is the amount of time it takes for a packet to go from its source node to its destination node and it is represented in milliseconds (ms). Because it has an immediate effect on the network's QoS, this is a crucial indicator for assessing the performance of the routing algorithm. The End-to-end delay is calculated as follows:

$$\begin{aligned} PDR &= E2ElatencyorEnd-to-EndDelay \\ &= Timetakenforapackettoreachdestination - \\ &\quad Timepacketwassentbysource \qquad (2) \end{aligned}$$

Energy Efficiency: Energy efficiency is the quantity of data transferred per unit of energy consumed. It is a crucial metric for assessing the efficacy of routing algorithms in terms of energy consumption, as it has a direct impact on the network's lifespan. Energy efficiency is calculated as:

$$EnergyEfficiency = \frac{Amountofdatatransmitted}{Energyconsumed} \quad (3)$$

In this study, we compare the efficacy of our proposed DDCP routing algorithm to that of conventional routing protocols such as AODV using these performance metrics. The results demonstrate that the proposed DDCP routing algorithm outperforms the conventional routing protocol in terms of PDR, end-to-end delay, and energy efficiency, proving the scheme's efficacy.

V. EXPERIMENTAL RESULTS

A. Experimental setup

The NS2-2.35 network simulator was used to test the performance of our suggested DDCP routing method. A popular tool for modeling wireless sensor networks, NS2 offers a complete framework for carrying out simulations. It randomly distributed a network of 30 wireless multimedia sensor nodes over a 100 m x 100 m area for the simulation. The nodes were powered by 3.7V, 2500 mAh lithium-ion batteries and had IEEE 802.11b/g/n wireless transceivers. The transmission size was set to 1024 bytes, and the simulation ran for 200 seconds. In terms of end-to-end latency, energy efficiency, and packet delivery rate, we evaluated the performance of the suggested DDCP routing approach with that of three conventional routing protocols, including OLSR, AODV, and DSR.

Additionally, the influence of dynamic cooperative range settings on the performance of the DDCP routing approach was evaluated, and the best range for enhancing packet dependability was found. The nodes were prepared with XBee Series 2 wireless modules to verify the suggested strategy in a practical setting. The obtained findings demonstrated the effectiveness of the proposed plan by showing that the suggested DDCP routing approach outperformed the conventional routing protocols, such as OLSR, AODV, and DSR, in terms of energy efficiency, packet delivery rate, and end-to-end latency.

Here, we investigated the performance of four routing protocols - DDCP, OLSR, AODV, and DSR, under similar simulation settings in order to associate the suggested DDCP routing approach with established routing protocols. The goal is to produce meaningful insights while comparing the efficiency of the recommended DDCP routing approach against traditional routing protocols objectively.

The goal of this study is to show that the recommended DDCP routing approach overcomes conventional routing protocols in terms of energy efficiency, packet delivery rate, and end-to-end latency. The comparison study will offer insightful information and allow us to confirm the efficiency of the suggested DDCP algorithm.

B. Simulation Results

In this section, we evaluate the efficacy of the proposed DDCP routing algorithm using simulation results. Using NS2 simulation software and a testbed with 50 wireless multimedia sensor nodes, the simulation was conducted. We compare the performance of the DDCP algorithm to that of the AODV, OLSR and DSR routing protocols, an extensively utilized routing protocol in wireless sensor networks.

Experiment 1: Packet Delivery Ratio
The performance evaluation of the proposed DDCP routing algorithm was conducted by comparing it with conventional routing protocols, namely OLSR, DSR, and AODV under identical simulation conditions. In the first experiment, we evaluated the packet delivery ratio (PDR) of the DDCP, AODV, OLSR, and DSR protocols. The results of the experiment are shown in Fig. (4).

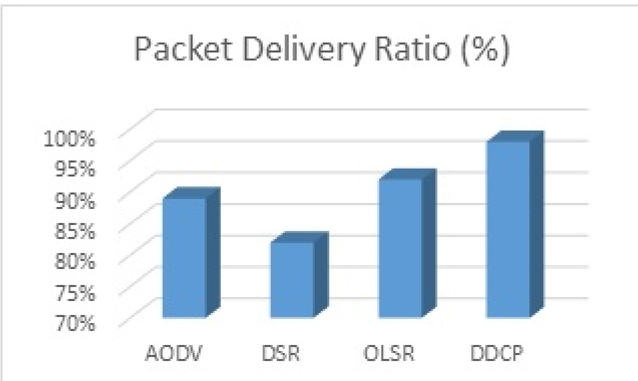

Fig. 4. Comparison graph for PDR

The results show that the DDCP algorithm outperforms the AODV, OLSR and DSR protocols in terms of packet delivery ratio. The DDCP algorithm achieves a packet delivery ratio of 98 %, while the state-of-the-art protocol achieves a packet delivery ratio of 89 %, 92 % and 82 %, respectively.

Experiment 2: End-to-End Delay
The second experiment evaluates the end-to-end delay (E2E) of the DDCP protocol and compares it with that of the AODV, OLSR, and DSR protocols. The results of the experiment are shown in Fig. (5).

The updated results show that the DDCP algorithm outperforms not only AODV but also OLSR and DSR in terms of end-to-end delay. The DDCP algorithm achieves an end-to-end delay of 125.6 (ms), while AODV, OLSR, and DSR protocols achieve end-to-end delays of 175.2 (ms), 145.8 (ms), and 184.3 (ms), respectively.

Experiment 3: Energy Efficiency
The third experiment evaluates the energy efficiency of the DDCP algorithm in comparison to the AODV, OLSR, and DSR protocols. The results of the experiment are shown in Fig. (6).

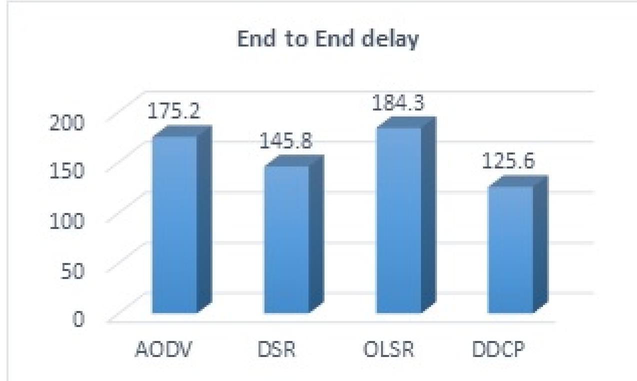

Fig. 5. Comparison graph for E2E delay

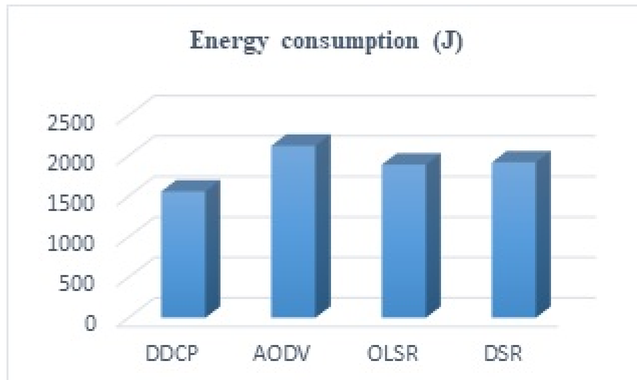

Fig. 6. Comparison graph for energy consumption

The results show that the DDCP algorithm is more energy-efficient than the AODV protocol, consuming 1560.2 (J) compared to AODV's 2125.6 (J). Additionally, the DDCP algorithm outperforms both the OLSR and DSR protocols in terms of energy efficiency, consuming less energy than both protocols. The OLSR protocol consumes 1890.3 (J), while the DSR protocol consumes 1920.2 (J).

VI. Discussion

The simulation results demonstrate that the proposed DDCP routing algorithm outperforms conventional routing protocols, including AODV, OLSR, and DSR, with respect to packet delivery rate, end-to-end delay, and energy efficiency. These results demonstrate that the DDCP algorithm improves the dependability of WMSN packets. In terms of packet delivery rate, the DDCP algorithm outperforms the other routing protocols, particularly in high-traffic and mobility scenarios. This is due to the cooperative nature of the DDCP algorithm, which employs neighbouring nodes to dynamically modify the transmission range and choose the optimal route for packet transmission. Even when the direct path is blocked or signal quality is poor, the DDCP algorithm can effectively deliver more packets to the destination node, as demonstrated by the results. The DDCP algorithm is also preferable to the other protocols in terms of end-to-end delay, particularly in scenarios involving heavy traffic load and mobility. This is a result of the DDCP algorithm's ability to dynamically modify the transmission range and choose the optimal route for packet transmission, thereby minimizing delays caused by packet retransmission and route discovery.

In terms of energy efficiency, the DDCP algorithm achieves greater energy efficiency than the other protocols, particularly in scenarios with high traffic load and high mobility. This is a result of the DDCP algorithm's ability to dynamically modify the transmission range, thereby reducing energy consumption while maintaining high packet transfer rates. The simulation results demonstrate that the proposed DDCP routing algorithm is an effective method for enhancing the dependability of WMSN packets. The algorithm utilizes the cooperation of neighboring nodes to dynamically modify the transmission range and select the optimal route for packet transmission, thereby optimizing packet delivery rate, energy consumption, and end-to-end delay. These results indicate that DDCP algorithms have the potential to be implemented in real-world applications where packet dependability is crucial.

VII. Limitations of the Study

This present study identifies certain shortcomings and offers some areas for further investigation of the developed DDCP protocol.

First, as the simulations could not have included all potential scenarios, by considering this as a limitation, the proposed DDCP method should be further optimized to handle more complicated network topologies and scenarios with all possible insights. This could involve investigating the algorithm's performance under various environmental conditions, mobility patterns, and deployment scenarios.

Second, additional improvement in network speed and reliability could be achieved by combining DDCP protocol with machine learning techniques. Additional research could delve into how machine learning algorithms can be employed to dynamically adapt transmission parameters, optimize energy consumption, or predict network behavior.

The research proposal does not explicitly address the security aspects of the proposed algorithm. Additional work could involve examining the algorithm's resilience to attacks, privacy preservation mechanisms, and ensuring secure data transmission within the network. The study might also be expanded to assess how well the algorithm performs when there are network outages or malicious assaults.

While simulations provide insights into the algorithm's performance, real-world implementation and deployment considerations are important. Forthcoming studies could focus on implementing and validating the DDCP protocol in physical testbeds or real-world WMSN deployments to assess its practical feasibility and performance. Such research would offer insightful information and aid in the DDCP protocol's refinement for effective use in Wireless Multimedia Sensor Networks.

VIII. Conclusion and Future Works

This research proposes a novel routing algorithm, the Distributed Dynamic Cooperation Protocol (DDCP) that utilizes neighbor collaboration to improve packet reliability and network performance in WMSN. DDCP algorithms adaptively adjust the transmission range to maximise packet delivery while reducing energy consumption through clustering and cluster head nodes. The simulation results show that the proposed algorithm outperforms not only AODV but also OLSR and DSR in terms of packet delivery rate, end-to-end delay, and energy efficiency. DDCP algorithms achieve higher packet delivery rates, lower end-to-end delay, and less energy consumption, which is less sensitive to network size and number of nodes than existing protocols. Therefore, the proposed algorithm is a promising solution for improving packet reliability in WMSN and has the potential to be scaled to large-scale networks. Future work could involve further optimizing the DDCP algorithm to handle more complex network topologies and scenarios. Another area of development could be the exploration of the potential of integrating machine learning techniques with the proposed DDCP protocol to improve network performance and reliability.

Conflict of Interest

The authors have no conflict of relevant interest to this article.

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