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Reducing Transmission Signal Collisions on Optimized Link State Routing Protocol Using Dynamic Power Transmission

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ABSTRACT

Many devices connected to a network inevitably result in clashes between communication signals. These collisions are an important factor that causes a decrease in network performance, especially affecting Quality of Service (QoS) like throughput, Packet Delivery Ratio (PDR), and end-to-end delay, which has a direct impact on the success of data transmission by potentially causing data loss or damage. The aim of this research is to integrate the Dynamic Power Transmission (DPT) algorithm into the Optimized Link State Routing (OLSR) routing protocol to regulate the communication signal strength range. The DPT algorithm dynamically adapts the signal coverage distance based on the density of neighboring nodes to reduce signal collisions. In our protocol, the basic mechanism of a DPT algorithm includes four steps. The Hello message structure of OLSR has been modified to incorporate the "x-y position" coordinate field data. Nodes calculate distances to neighbors using these coordinates, which is crucial for route discovery, where all nearby nodes can process route requests. The results of this research are that DPT-OLSR improves network efficiency in busy areas. In particular, the DPT-OLSR routing protocol achieves an average throughput enhancement of 0.93%, a 94.79% rise in PDR, and reduces end-to-end delay by 45.69% across various variations in node density. The implication of this research result is that the algorithm proposed automatically adapts the transmission power of individual nodes to control the number of neighboring nodes within a defined range. This effectively avoids unwanted interference, unnecessary overhearing, and excessive processing by other nodes, ultimately boosting the network's overall throughput.

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1. INTRODUCTION

Currently, data communication in mobile devices has become the backbone of modern connectivity, providing wireless access that enables the exchange of information between devices without requiring physical cables. The wireless network model where a set of network devices move freely in all directions and communicate with each other to forward data packets is called a Mobile Ad Hoc Network (MANET) [1]. When desiring to communicate, network devices or nodes within MANET will emit signals to reach their neighboring nodes. If two nodes are within each other's signal range, it means they can communicate with each other [2]. The most common communication is communication during the route discovery towards the destination node before the data packet transmission process occurs. This route discovery process is called routing, which functions to determine the best route from the sender node to the destination node. The routing process requires a routing protocol responsible for determining the best route based on the algorithm used by that routing protocol. OLSR is one of the proactive routing protocols where this routing protocol continuously communicates with other nodes to exchange routing table information periodically because the update of routing table information must be constantly performed to ensure all route information in the network is available [3, 4]. All nodes utilizing the OLSR routing protocol will frequently communicate to update the routing tables, consequently leading to collisions of communication signals [5]. The problem that arises due to the collision of communication signals is: 1) The transmitted data becomes corrupted or lost. Signal collisions can cause signal distortion, where the original signal waveform is disrupted, which can alter the bit values within data packets; 2) Decreased throughput and bandwidth. Communication signal collisions can lead to a decrease in signal strength, requiring a network device to retransmit, which affects a decrease in throughput and bandwidth; 3) Increased latency. Latency is the time required to transmit data from one network device to another. Signal collisions can cause an increase in latency because the transmitted data needs to be resent [6].

There have been several studies discussing communication signal collisions. In [7] authors optimize throughput in a Flying Ad Hoc Network (FANET) when all nodes communicate with each other, resulting in signal collisions. Optimization is achieved by selecting reliable links and allocating signal strength when signal collisions occur. Bamhdi et al. [8] proposed a method by adapting the standard Ad hoc On-Demand Distance Vector (AODV) protocol to dynamically adjust transmission power usage, called Dynamic Power-Ad Hoc On-Demand Distance Vector (DP-AODV). DP-AODV increases network throughput while reducing node interference in a dense region. Ardiani et al. [9] optimize the performance of the Destination Sequenced Distance Vector (DSDV) routing protocol by implementing the DPT method to reduce signal communication collisions based on node density. The proposed routing protocol can improve throughput, packet delivery ratio (PDR), and reduce delay compared to the standard DSDV routing protocol. In [10] author enhances the PDR by optimizing the adaptive usage of the communication signal range applied to the DSDV routing protocol. The adaptive communication signal range ranges from 20 meters to 250 meters with node densities of 25 nodes, 50 nodes, and 100 nodes in network areas of 250 m^2 and 500 m^2. The proposed method can improve the PDR value. In [11] authors proposed a method with various communication signal ranges using the Dynamic Source Routing (DSR), AODV, and DSDV routing protocols. The variations in communication signal range from 100 meters to 550 meters with a node density of 50 nodes in a network area of 1000 m^2. The proposed method results indicate that the AODV and DSR routing protocols can provide good throughput and PDR values with the maximum communication signal range. Meanwhile, the DSDV routing protocol offers better end-to-end delay values.

In [12], the authors analyzed the standard OLSR routing protocol against variations in node density starting from low to high density, namely 20, 40, 60, 80, and 100 nodes in a 1000×1000 m^2 network area. The communication signal range used by each node is fixed at 250 meters. The performance of the OLSR routing protocol is measured from delay, throughput, and PDR parameters. The results show that the higher the node densities, the decrease in the throughput and PDR values, while the delay value increases. In [13], the author compares the performance of three routing protocols, namely AODV, DSR, and OLSR, if given a simulation environment with a variation in the number of nodes of 20, 40, 60, 80, 100, 120, and 140 in a 1500×1500 m^2 network area. The communication signal range used by each node is fixed at 250 meters. The performance of the three routing protocols is measured by delay and throughput parameters. The results show that the OLSR routing protocol has inconsistent throughput and delay values against variations in node density. In [14], the author modifies the standard OLSR routing protocol and then compares the performance of the modified routing protocol with the standard OLSR routing protocol tested in a simulated environment with a variation in node density of 50, 100, 150, and 200 in a 1216×768 m^2 network area. The communication signal range used by each node is fixed at 250 meters. The performance of the OLSR routing protocol is measured from delay, throughput, and PDR parameters. The results show that the OLSR routing protocol has inconsistent throughput and PDR values against variations in the number of node densities. At a density of 50 nodes, the throughput value increases, but at a density of 100 nodes, the throughput value decreases. In comparison, the PDR value at a density of 50 and 150 nodes is higher than that of 100 and 200 nodes.

There are gaps that have not been resolved by previous research, in [7, 11] uses fixed range of communication signal strength that are unable to adapt to changes in node density on the network. This can cause a decrease in performance in the event of a high node density due to interference and cause delay when the node density is low so that data packet delivery can be disrupted. In [8–10] have used range of communication signal strength that can adapt to the network environment but has not been applied to the OLSR routing protocol framework. The difference between this research and the previous one is that we propose to manage the range of communication signal strength in the OLSR routing protocol using the DPT algorithm. The range of communication signals will dynamically adjust based on the density level of neighboring nodes to reduce signal collisions. The proposed method is called DPT-OLSR. DPT-OLSR will adjust the communication signal range by calculating the density level of neighboring nodes divided into three levels. In Figure 1, if the density level of neighboring nodes is below 7 nodes (Level 1), the communication signal range is automatically set to 250 meters. For a density level of neighboring nodes between 7 and 15 nodes (Level 2), if the required communication signal range to reach the destination node is already strong enough, then the use of a higher communication signal range is not necessary. Meanwhile, if the density level of neighboring nodes exceeds 15 nodes (Level 3), the communication signal range will be adjusted to 170 meters. Each node broadcasts information about the links it sees to its neighbors and picks a subset of its neighbors as Multipoint Relays (MPRs). By collecting link-state information from neighbors and MPRs, each node builds a complete picture of the network's topology. This allows them to calculate the shortest path to any destination. With dynamic communication signals based on node density applied to the standard OLSR routing protocol, DPT-OLSR can provide better performance and consistent results compared to the research results in [12–14]. The rest of the paper is organized as follows: In Section 2, we describe our proposed method, describe the operation of the standard OLSR routing protocol, describe the signal strength model, and describe the signal collisions. In Section 3, we show simulation results and analysis for evaluating the proposed method. Section 4 shows conclusion and the future work.

2. RESEARCH METHOD

2.1. Dynamic Power OLSR

As our proposal is based on an OLSR routing protocol, the fundamental mechanism of data packet handling is the same. However, in our protocol, the basic mechanism of a neighbor-based Variable-Power Transmission includes four steps. The Hello message structure of OLSR has been altered to include the ”x-y position” coordinate field data (Figure 1). This modification enables the routing protocol to acquire precise location details of a node, which is essential for route determination. Upon receiving the hello message, a node computes the distances to its neighbors using the embedded coordinates. The distance to neighboring nodes is crucial during route discovery, as all nodes within the coverage area of a particular node can receive and process route request messages.

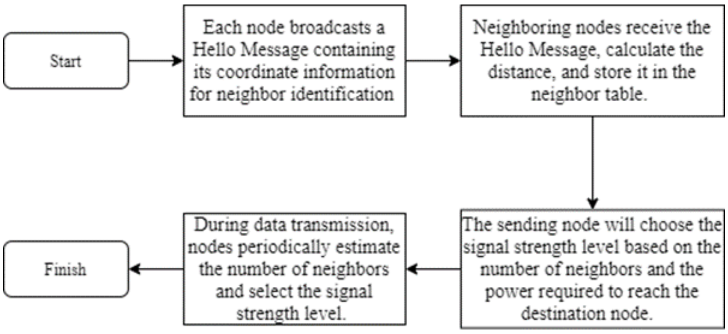
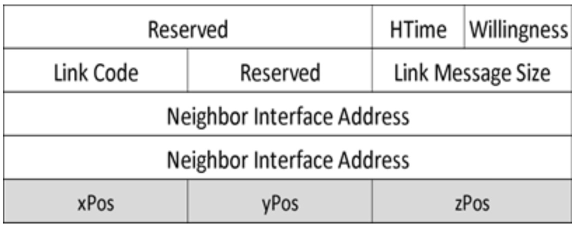


Figure 1. Dynamic Power OLSR Mechanism

Figure 1 is the process of adjusting the communication signal distance in the OLSR routing protocol. The following is an explanation of each step: 1. Each node transmits a Hello Message containing coordinate information to identify neighbors. The OLSR routing protocol sends Hello packets at regular intervals for neighbor identification. Figure 2 illustrates the structure of the OLSR routing protocol Hello packet message, with the grey section representing the additional coordinate parameter included in the OLSR Hello packet. 2. Upon receiving the Hello Message, neighbor nodes compute the distance and store it in the neighbor table. The distance calculation can be performed using the formula provided in Equation 1, where $x = (x_2 - x_1)^2$ and $y = (y_2 - y_1)^2$. The distance is calculated using the Euclidean equation based on the coordinates of the nodes received via Hello packets. The nodes transmit and update their location through the reply message of the Hello packet. When the node knows its distance, the communication signal strength level can be selected. 3. The sending node will choose the signal strength level based on the number of neighbors and the power required to reach the destination node. When sending packets to the destination node, the node will choose the communication signal strength level based on the number of neighbors and the power required to reach the destination. 4. During data transmission, nodes periodically estimate the number of neighbors and select the signal strength level. Communication signal collisions can be avoided by reducing the distance of nodes' communication signal strength while maintaining the connection. When Hello packets are received periodically, nodes calculate the communication signal distance in the node density area. This is then used to estimate and select the communication signal strength so that the performance of the routing protocol can be improved properly.



<table>
<tr><td colspan="2">Reserved</td><td>HTime</td><td>Willingness</td></tr>
<tr><td>Link Code</td><td>Reserved</td><td colspan="2">Link Message Size</td></tr>
<tr><td colspan="4">Neighbor Interface Address</td></tr>
<tr><td colspan="4">Neighbor Interface Address</td></tr>
<tr><td>xPos</td><td>yPos</td><td colspan="2">zPos</td></tr>
</table>

Figure 2. OLSR Hello Message Structure

$$d(x,y) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \tag{1}$$

2.2. OLSR Routing Protocol

The OLSR, a proactive routing protocol, utilizes a link-state algorithm to determine the most optimal route between two nodes in a Mobile Ad hoc Network (MANET). At regular intervals, each node in the network broadcasts Hello packets to its neighboring nodes, containing important information such as the node's address, location, and a list of its neighbors. This information is the basis for constructing the link-state routing table at each node [15] which details the length, cost, and connected neighboring nodes of all network links. Once established, this routing table allows each node to utilize the link-state algorithm, which calculates the route with the lowest link cost between two nodes. The OLSR Routing Protocol incorporates the Multi-Point Relay (MPR) concept to enhance delivery efficiency [16]. Figure 3 depicts selecting nodes as Multi-Point Relays (MPRs), responsible for forwarding control messages such as Hello messages and topology control (TC) throughout the entire network. MPR selection is based on the link quality of nodes, with those demonstrating better link quality being prioritized as MPRs. Utilizing MPRs helps reduce network overhead.

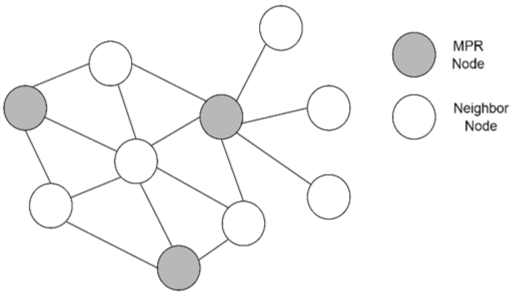


Figure 3. OLSR Working Mechanism

2.3. Signal Strength Model

This study uses the Two-Ray Propagation Model to estimate the received signal strength of packets transmitted between neighboring nodes. These propagation models are commonly incorporated into the Network Simulator 2 (NS-2), the chosen simulation tool for this research. The Two-Ray Propagation Model is a wireless signal propagation model that considers two distinct paths: a direct line-of-sight route and a path reflected from the ground. In the latter scenario, the signal emitted from the antenna undergoes reflections from the ground surface before reaching the receiver. Equation 2 is the equation used for the two-ray ground propagation model, while the two-ray ground propagation model uses Equation 2 [8].

$$Pr = \frac{Pt * Gt * Gr * ht^2 * hr^2}{d^4 L} \tag{2}$$

Where, ht is Height of Transmitter Antenna, hr is Antenna Receiver Height, Pt is Transmitted Signal Power. Gt is Transmission Antenna Gain, Gr is Receiver Antenna Gain, d is Distance between the Transmitter and Receiver, and L is System Loss. In Figure 4, to calculate the cross-over distance between two nodes, we can use the following equation 3 [8]. Where, dc is Cross Over Distance, ht is Height of Transmitter Antenna, hr is Antenna Receiver Height, and λ is Wavelength. A transmission is deemed successful when the received signal strength between a transmitting node and a receiving node surpasses a specific threshold, which represents the minimum signal strength necessary for detecting a radio signal. Conversely, the transmission remains undetected if the received signal strength falls below this threshold.

$$dc = \frac{4\pi * ht * hr}{\lambda} \tag{3}$$

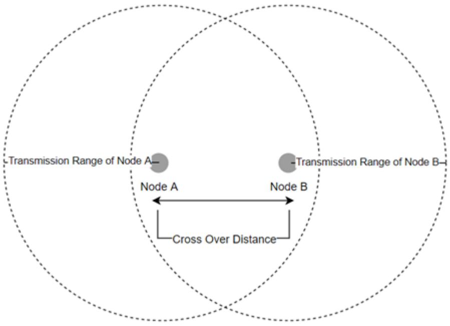


Figure 4. Cross Over Distance

2.4. Signal Collision

Signal collisions significantly impact the performance and reliability of wireless networks. These collisions occur when multiple radio signals operating on the same frequency intersect, distorting the received signal. This phenomenon is widespread in urban environments where signals can bounce off structures such as buildings or walls. Interference between signals can lead to a decrease in communication quality, potentially affecting data throughput [17]. To effectively address signal collisions, it is essential to implement robust strategies for managing signal strength and design networks while considering environmental factors that can influence signal quality. This ensures that communication devices can function adequately without significant signal interference. Figure 5 depicts a Mobile Ad hoc Network (MANET) with 10 nodes engaged in communication. The circular dotted lines represent each node's communication signal area or radius. Signal collisions can be observed at all nodes in the figure, which can degrade the network's performance. Additionally, all nodes in Figure 5 use a fixed communication signal strength.

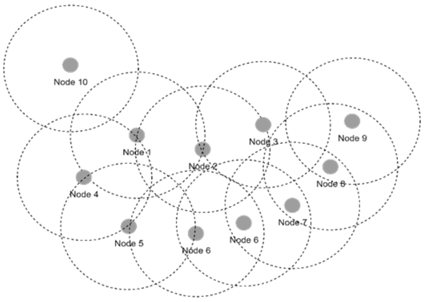


Figure 5. Communication Signal Collision Between Nodes

3. RESULT AND ANALYSIS

3.1. Simulation Scenario Parameters

In our study, we used the NS-2 network simulator version 2.35 to simulate networks with different node densities. The simulation is conducted on the Linux Ubuntu 14 operating system. The findings of this research are that the DPT method is integrated into the OLSR protocol module within NS-2 and implemented using C++ programming language. The simulation scripts are written in the Tool Command Language (TCL) and executed within NS-2 version 2.35. The simulation results are recorded in trace files (.tr extension) and analyzed using the AWK programming language to extract throughput, end-to-end delay, and PDR. This study employs 75, 100, 150, and 200 node densities. These nodes are randomly distributed within a 1000 × 1000 square meter area and can move freely in any direction at a velocity of 30 meters per second. The simulation time is set at 300 seconds. The transmission range of a mobile node is determined based on the two-ray model. More detailed information on the parameters of the simulation scenario is shown in Table 1.

Table 1. Simulation Scenario Parameters

Parameters	Value
Simulator version	NS-2.35
Node density	75, 100, 150, 200 nodes
Node speed	30 m/s
Simulation area	1000×1000 m2
Routing protocol	DPT-OLSR and OLSR
Propagation model	Two-Ray
Mobility model	Random Waypoint
Simulation time	300 seconds
Antenna model	Omni-directional
MAC protocol	IEEE 802.11
Traffic pattern	CBR

3.2. Network Performance Measurement

Network performance evaluation involves measuring three parameters: throughput, end-to-end delay, and PDR. The network performance test results are obtained through the processing of raw data from the trace file generated by NS-2, utilizing the AWK programming language. Throughput is a metric for assessing the volume of data or information transmitted over a network within a specified time frame [18]. Higher throughput rates signify greater network capacity, facilitating increased data transfer within a given time interval, thus enhancing network performance. However, throughput is influenced by network capacity and factors such as latency, network stability, and environmental variables. Throughput measurements can be calculated using Equation 4, with results typically expressed in kilobits per second (kbps).

$$Througput = \frac{\text{Amount of data sent}}{\text{Delivery time}} \tag{4}$$

PDR is a crucial metric for assessing the efficacy of wireless networks, particularly in MANETs. It quantifies the network's ability to successfully deliver data by determining the ratio of received data packets to the total transmitted data packets [18]. In MANETs, data packets are vulnerable to loss or corruption during transmission due to factors such as signal collisions, attenuation, or network failures. Hence, PDR serves as a vital indicator of network reliability. Typically expressed as a percentage, higher PDR values indicate superior network performance in data transmission. For instance, if 80 out of 100 data packets are received, the PDR value would be 80%. A higher PDR value signifies better network quality. PDR can be calculated using Equation 5.

$$PDR = \frac{\text{Amount of data received}}{\text{Amount of data sent}} \times 100\% \tag{5}$$

End-to-end delay denotes the time required for a data packet to be sent, received, and acknowledged by the sender [18]. A lower value signifies improved protocol efficiency. Equation 6 is employed to calculate the end-to-end delay. This section discusses the findings from network simulations utilizing the NS-2 network simulator version 2.35. The results are presented graphically, depicting parameters such as throughput, end-to-end delay, and PDR. Parameter values are extracted from the trace file using the AWK programming language.

$$\text{End —to —End Delay} = \frac{\text{Total package travel time}}{\text{Number of packets received}} \tag{6}$$

Figure 6 illustrates a significant improvement in throughput achieved by the DPT-OLSR routing protocol compared to the standard OLSR routing protocol, particularly as node densities increase. At node density levels of 75, 100, 150, and 200 nodes, the throughput increases by 34.36%, 60.58%, 90.29%, and 84.74%, respectively. This improvement can be attributed to the reduced bandwidth utilization by data packets during the route discovery phase, resulting in decreased wastage. Figure 7 illustrates a decrease in end-to-end delay across different node density levels when using the DPT-OLSR routing protocol. At node densities of 75, 100, 150, and 200, the end-to-end delay decreases by 27.52%, 27.25%, 25.08%, and 37.91%, respectively. The DPT-OLSR routing protocol performs better in transmitting data with shorter time intervals for routes with higher success probabilities than the standard OLSR routing protocol. This improvement is attributed to the proposed DPT-OLSR routing protocol's ability to regulate node density by managing communication signal strength. However, it is worth noting that both the DPT-OLSR and standard OLSR routing protocols exhibit an increase in end-to-end delay values as node density increases.

Figure 8 demonstrates a consistent improvement in the PDR as the node density increases when utilizing the DP-OLSR routing protocol compared to the standard OLSR routing protocol. Across node density levels of 75, 100, 150, and 200 nodes, the PDR increases by 16.44%, 15.45%, 24.13%, and 25.50%, respectively. This improvement can be attributed to the proposed method, which regulates node density by managing the strength of communication signals. In contrast, the standard OLSR protocol experiences packet loss due to its use of fixed communication signal strength, resulting in significant signal collisions. The results of this research are in line with [8–10] which have used a range of communication signal strengths that can adapt to the network environment. The analysis results provide a distinct showcase of the advantages derived from the enhancements integrated into DPT-OLSR when contrasted with the basic OLSR protocol.

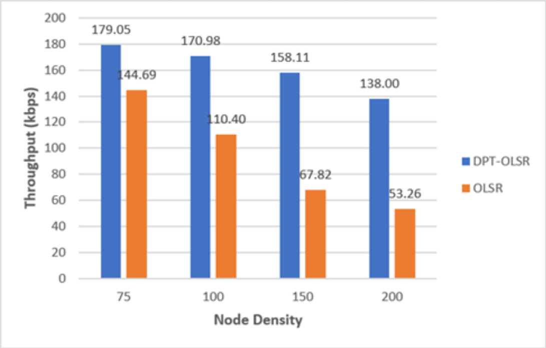


Figure 6. Node Density vs Throughput with Two-Ray Propagation Model

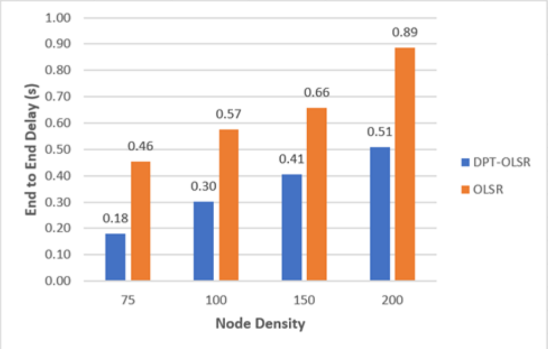


Figure 7. Node Density vs End-to-End Delay with Two-Ray Propagation Model

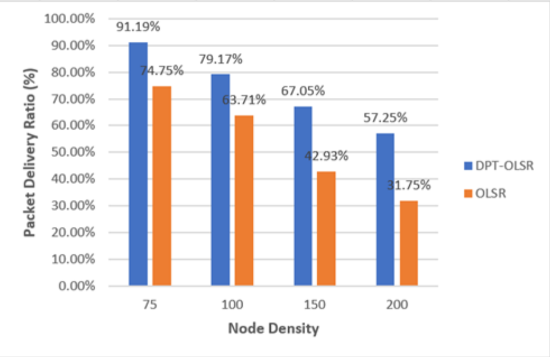


Figure 8. Node Density vs PDR with Two-Ray Propagation Model

4. CONCLUSION

This study introduces a new method that tackles network issues by enhancing the existing OLSR routing protocol. It considers factors like the number of nearby devices, their power levels, and how they transmit data. It considers factors like the number of nearby devices, their power levels, and how they transmit data based on the two-ray propagation model. The key feature is dynamic power adjustment based on node density. This approach significantly improves network throughput and PDR. The algorithm automatically controls each device's transmission power to maintain a specific number of neighbors. This reduces unwanted interference and prevents other devices from wasting resources by overhearing or processing unnecessary data. Simulations confirm that the DPT-OLSR protocol performs better than the standard OLSR protocol, resulting in better PDR, higher throughput, and less interference. In our future work, we aim to further refine the DPT-OLSR protocol by optimizing the ideal number of neighboring nodes to maintain and the most suitable power level for transmissions. We will evaluate the protocol's performance with a greater number of wireless nodes, explore various ad hoc network layouts, and look for a new way to measure overall performance that considers both successful packet delivery and the network's energy consumption.

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The Acknowledgments section is optional. Research sources can be included in this section.

6. DECLARATIONS

AUTHOR CONTIBUTION

Author 1 proposed the idea and drafted the manuscript. We thank Author 2 for making valuable contributions by submitting innovative methods and providing constructive criticism of the manuscript. We thank Author 3 for carefully analyzing the data and providing valuable insights.

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COMPETING INTEREST

The authors state that they do not have any conflicting financial interests or personal relationships that could have impacted the research presented in this paper.

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