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**Research Article**

# Navigating efficiency: Evaluating wireless ad hoc network protocols with NS-3

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## ABSTRACT

Wireless ad hoc networks, essential in our mobile device-driven world, demand efficient and reliable routing protocols. This research extensively explores the performance of three prominent ad hoc routing protocols: Ad-hoc On Demand Distance Vector (AODV), Destination Sequenced Distance Vector (DSDV), and Optimized Link State Routing (OLSR). Utilizing the NS-3 simulator, we extensively explore these routing protocols for different scenarios, i.e., with different variations in network parameters like time, packet size, node speed, and number of nodes.

Wireless ad hoc networks do not have a fixed infrastructure and instead use wireless nodes to cooperate to dynamically establish temporary networks and forward data packets. In such networks, every mobile node serves as both a transmitter and a router, and packets can be forwarded by intermediate nodes multiple times before reaching their destination. This cooperative routing enables robust communication even in environments where conventional infrastructure is not feasible or can't be deployed. We quantify key performance parameters including throughput, packet delivery ratio, end-to-end delay, packet loss ratio, and end-to-end jitter. Our results demonstrate the strengths and weaknesses of every protocol and it offers valuable information in selecting and optimizing protocols in wireless ad hoc networks. The findings of this research can enhance the performance and efficiency of wireless communication systems across different real-world applications. We also present the NS-3 simulator, our research basis, and explain its limitations and real-world implications. This performance assessment is an essential tool for network administrators and designers to improve ad hoc network performance and guarantee quality data transmission.

By simplifying the explanation of how mobile nodes work together to relay data packets, this study offers a clear understanding of ad hoc network dynamics and their practical applications.

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## INTRODUCTION

Wireless ad hoc networks [1] have gained prominence due to their dynamic and flexible capabilities, making them ideal for situations where conventional fixed infrastructure is impractical or non-existent. These networks depend on mobile nodes working together to relay data packets, facilitating smooth communication and data exchange. Routing protocols are critical in these networks since they determine the best path for data packets to be transmitted from the source to the destination, facilitating efficient and effective data transmission [2]. With the growing demand for wireless ad hoc networks, there is a need to select the right routing protocol to cater to the diverse needs of various applications [3]. This paper reports a comprehensive performance analysis of three well-known ad hoc routing protocols: Ad-hoc On-Demand Distance Vector (AODV) [4], Destination Sequenced Distance Vector (DSDV), and Optimized Link State Routing (OLSR) [5]. The purpose of this work is to investigate and compare the performance of these protocols under different network conditions employing the ns-3 simulation environment [6].

Our performance measure concentrates on specific parameters, i.e., throughput, packet delivery ratio, end-to-end delay, packet loss ratio, and jitter delay [7]. Such indicators give meaningful insights into each routing protocol's efficiency and dependability, thereby deciding their applications in various network scenarios [8]. By running comprehensive simulations, we hope to emphasize the virtues and limitations of every routing protocol under different settings like node velocity, packet size, simulation length, and network size [9]. The information obtained from this research is meant to be a useful guide for network engineers and system administrators to choose and configure routing protocols to perform optimally in wireless ad hoc networks [10]. Furthermore, future studies can investigate the effect of security mechanism integration on protocol performance, reflecting a broader picture of network efficiency [12]. As security is pivotal in MANETs in order to ensure defense against attacks like spoofing, eavesdropping, and denial-of-service attacks [13], introducing cryptographic techniques and secure routing techniques gains growing importance.

This is especially relevant with sensitive areas like cytology, where the transmission of confidential patient data must be ensured by strict data integrity and privacy controls.While not fully addressed in this paper, the application of secure communication protocols can render medical information security much safer, while ensuring patient records confidentiality as well as the dependability of the clinical process [14].Finally, the aim of our work is to contribute to the building of stable and dependable wireless ad hoc networks that can support the needs of contemporary mobile communication services. The remaining part of this paper is organized as follows: Section 2 gives an overview of MANET applications. Section 3 addresses the research approach and system architecture. Section 4 describes the adopted performance simulation environment. Section 5 gives the protocol performance analysis. Lastly, Section 6 summarizes the paper and identifies areas of future work.

## APPLICATION IN MANETS

In mobile ad hoc networks (MANETs) [15], nodes are mobile and networks are established dynamically. Robust security mechanisms must be implemented here. The nature of these networks being ad hoc, they are highly vulnerable to attacks like eavesdropping, spoofing, and denial of service. Hence, embedding strong security protocols specific to the nature of the challenges in MANETs is crucial to make cytology data transmission reliable and secure. Suitability to cytology systems: For MANET-based cytology setups, the following security measures are the most suitable:

End-to-end encryption: Provides secrecy of information from the collection point to the destination at which it is analyzed and saved.

Secure routing protocols [16]: Routing protocols, such as node verification and checking of data integrity, become necessary to avoid unauthorized access and ensure the reliability of transmitted medical data. Regular security audits: Regular security audits can assist in the identification and remediation of vulnerabilities within the network, hence ensuring continued safety of sensitive cytology data. By including and referencing these security controls, the system can actually safeguard sensitive patient data, thereby ensuring the required trust and reliability for medical diagnosis and treatment planning in cytology [17].

### Research Methodology and Design System

To compare the performance of ad hoc routing protocols, we employed the NS-3 simulator, which is a widely used network simulator. We have focused on three prominent routing protocols in our study: Ad-hoc On-Demand Distance Vector (AODV) [18], Destination Sequenced Distance Vector (DSDV) [19], and Optimized Link State Routing (OLSR). We designed multiple simulation scenarios with varying network parameters like node density, mobility pattern, traffic pattern, and node speed. With critical simulations and performance analysis, we evaluated the protocols using significant measures like throughput, packet delivery ratio, end-to-end delay, packet loss ratio, and end-to-end jitter delay.

By explaining how the mobile nodes collaborate to forward data packets and the research methodology we followed, our research aims to set a solid foundation for the behavior of ad hoc networks and highlight the significance of our performance measurement. Here, we elaborate in detail on the design of our simulation framework with regard to the tools and models applied for analyzing various protocol implementations.

The simulations were executed using NS-3 version 3.36.1 with simulation logic implemented in AWK to make the process easier. Simulation Process Overview

The simulation procedure involved the following main steps:

Initialization: Starting the simulation process by initializing the simulation environment using the correct MANET model, parameters, and routing protocols of the scenario.

Experimentation: Running several simulations with varying parameters to analyze variation in protocol behavior under various network scenarios [20].

Data collection: Collecting proper performance measures like throughput, packet delivery ratio, delay, and other suitable parameters to evaluate the performance of every protocol [21]. Analysis: Conducting extensive analysis of the simulation data collected to understand about the performance of every protocol model. For a graphical representation of the overall simulation process, refer to Figure 1.

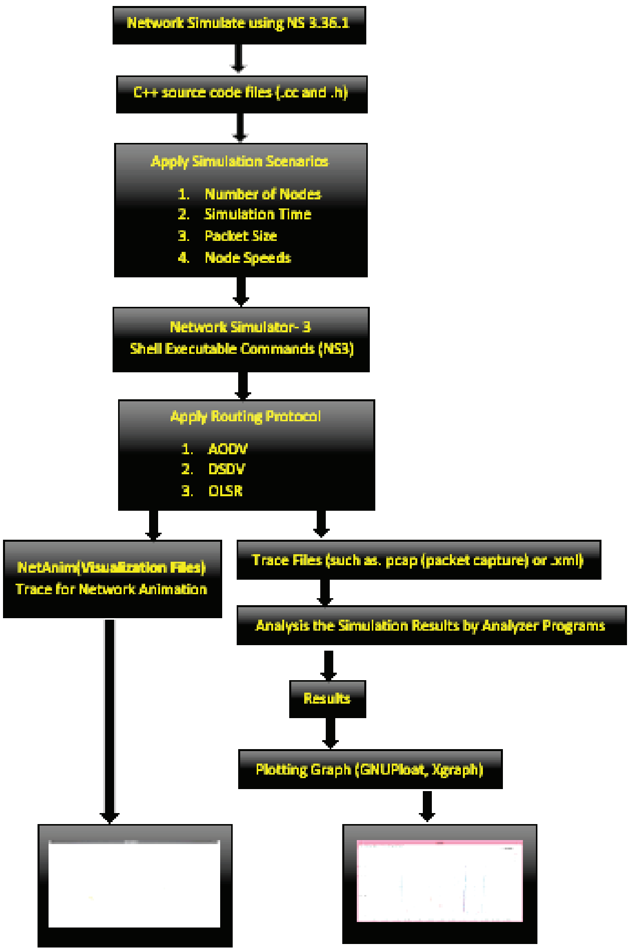


**Figure. 1.** Comprehensive stages of the simulation process.

## RESULTS AND DISCUSSION

### Simulation Setup

This part describes the research approach to assess several ad hoc routing protocols using simulation [22]. The experiments were executed by utilizing NS-3 version 3.36.1 [23] as the platform for simulation with simulation logic specified in AWK to simplify handling. The simulator setup was initialized to emulate numerous MANET models and parameters.

Simulation Scenarios We created a number of different scenarios to experiment with the protocols under different conditions. These included differences in:

Node density: the number of nodes in the network.

Mobility patterns: the rate and mobility patterns of nodes.

Traffic patterns: the volume and rate of data packets.

### Focus

The purpose of this research was to evaluate and contrast the performance of three common ad hoc routing protocols: Ad-hoc On-Demand Distance Vector (AODV) [22], Destination Sequenced Distance Vector (DSDV), and Optimized Link State Routing (OLSR). The performance metrics utilized for evaluation encompassed Throughput, Packet Delivery Ratio, End-to-End Delay, Packet Loss Ratio, and End-to-End Jitter Delay.

### Simulation Scenarios

For an overall assessment of the performance of the chosen routing protocols, different scenarios were simulated by changing the most important network parameters. Each of these scenarios is intended to show the behavior and responsiveness of the protocols under specific conditions:

Scenario 1: Node Density

Objective: To verify how change in node number influences the protocol performance.

Parameters:

Number of nodes: 100, 75, 50

Speed of nodes: 20 m/s

Size of packets: 512 bytes

Scenario 2: Simulation Time

Objective: To examine the effect of various simulation times on network performance.

Parameters:

Simulation Time: 600, 400, 200, 100 sec

Node speed: 3 m/s

Packet size: 512 bytes

Scenario 3: Packet Size

Objective: To monitor the effect of packet sizes varying from one another on protocol efficiency. Test

parameters:

Sizes of packets employed: 2048, 1024, 512 bytes

Speed of the node: 3 m/s

Simulation time: 600 sec

Scenario 4: Impact of mobility of nodes

Objective: To analyze the impact of variation in the speed of mobile nodes on the performance and efficiency of routing protocols.

Parameters:

Node speed: 15, 10, 5, 3 m/s

Packet size: 512 bytes

Simulation time: 600 seconds

These experimental setups were chosen specifically to test how the hypothesized mechanism performs under various conditions. The objective was to obtain a clear understanding of its general reliability and capability to adjust to varying network conditions.

**Simulation Parameters**

Before conducting the simulations, we identified key parameters that significantly impact the behaviour of our models. These parameters are summarized in Table 1.

**Table 1.** Simulation parameters

| Simulation Parameters | Value |
|---|---|
| Protocols | OLSR, DSDV and AODV |
| Node Pause Time | 10 seconds |
| Network Simulator | ns-3 (Version 3) |
| Mobility Model | Random Waypoint Mobility Model |
| Total Simulation Time | 200 seconds |
| Traffic Model | CBR (Constant Bit Rate) |
| Area Size | 1000*1000-meter square |
| Packet Size | 512 Bytes |
| Application Data Rate | 2048 bps |
| Node Speed | 20 meters/second |
| Propagation Delay Model | Constant Speed Delay Model |
| Propagation Loss Model | Friss Propagation Loss Model |
| Physical Layer | DSSS (Direct Sequence Spread Spectrum) 11Mbps |
| MAC Layer | 802.11b |

**Performance Metrics**

In this section, we conduct a thorough analysis of routing protocol behaviors in mobile ad-hoc networks under diverse scenarios. Our focus centres on critical performance metrics such as throughput, packet delivery ratio, end-to-end delay, packet loss ratio, and end-to-end jitter delay.

**Throughput Evaluation**

Throughput quantifies the rate of data transmission within the network channel and is crucial for assessing network capacity and data transfer speed. We provide an analysis across four different scenarios:

Network size change: Checking node sizes ranging from 10 to 50 nodes.

Simulation time change: Checking simulation time ranges from 110 to 300 seconds.

Packet size change: Checking packet sizes ranging from 64 to 1024 bytes.

Mobility speed variation: Testing node speeds from 10 to 40 Mbps.

We utilize the NS-3 simulator to compare performance of AODV, DSDV and OLSR routing protocols under each scenario with throughput results provided in tables and graphs for convenience.

Scenario 1 evaluated node counts (10 to 50), the findings of which are presented in Figure 2 and Table 2. Scenario 2 evaluated simulation times (110 to 300 seconds), the findings of which are presented in Figure 3 and Table 3. Scenario 3 examined packet sizes (64 to 1024 bytes), the findings of which are presented in Figure 4 and Table 4. Scenario 4 examined node speeds (10 to 40 Mbps), the findings of which are presented in Figure 5 and Table 5. The scenarios give information on the behavior of the protocol under varying network conditions.

**Table 2.** Comparison of AODV, OLSR, and DSDV throughput across varied node counts

| Nodes | AODV | OLSR | DSDV |
|---|---|---|---|
| **20** | 16.7348 | 1.27364 | 0.986882 |
| **30** | 23.4632 | 1.17208 | 1.01376 |
| **40** | 13.479 | 1.0086 | 0.804144 |
| **50** | 7.56686 | 0.814672 | 0.745422 |

**Table 3.** Throughput comparison for AODV, OLSR, and DSDV across varying simulation durations

| Simulation Time | AODV | OLSR | DSDV |
|---|---|---|---|
| **110** | 59.0899 | 1.99131 | 0.386191 |
| **150** | 32.4293 | 1.09467 | 0.389338 |
| **200** | 33.0472 | 1.06156 | 0.437677 |
| **250** | 30.9531 | 1.30187 | 0.364297 |
| **300** | 31.3181 | 1.42275 | 0.259958 |

**Table 4.** Throughput analysis of AODV, OLSR, and DSDV across various packet sizes

| Packet Size | AODV | OLSR | DSDV |
|---|---|---|---|
| **64** | 52.5582 | 0.964067 | 0.33632 |
| **256** | 27.5267 | 1.10588 | 0.396018 |
| **512** | 33.0472 | 1.06156 | 0.437677 |
| **1024** | 65.0355 | 0.856574 | 0.4102 |

**Table 5.** Throughput comparison of AODV, OLSR, and DSDV across different node speeds

| Speed | AODV | OLSR | DSDV |
|---|---|---|---|
| **10** | 52.5582 | 0.964067 | 0.33632 |
| **20** | 27.5267 | 1.10588 | 0.396018 |
| **30** | 33.0472 | 1.06156 | 0.437677 |
| **40** | 65.0355 | 0.856574 | 0.4102 |

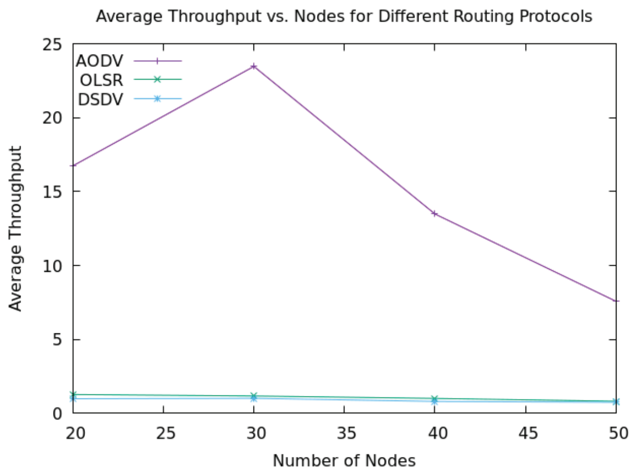


**Figure 2.** Comparison of throughput in scenario 1.

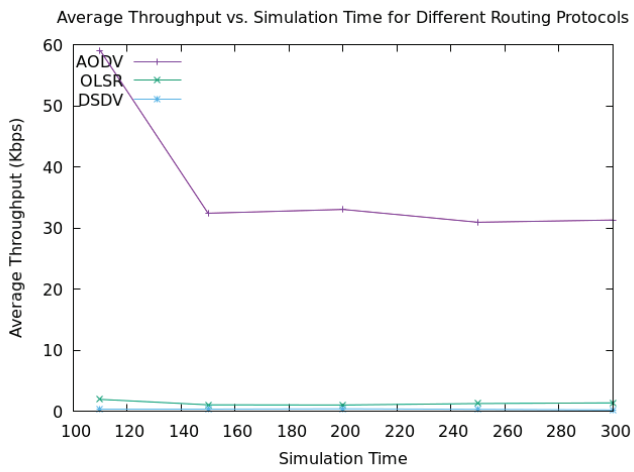


**Figure 3.** Comparison of throughput for scenario 2.

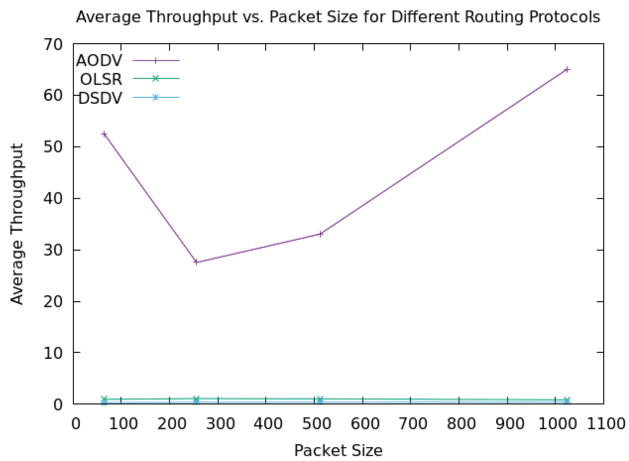


**Figure 4.** Comparison of throughput for scenario 3.

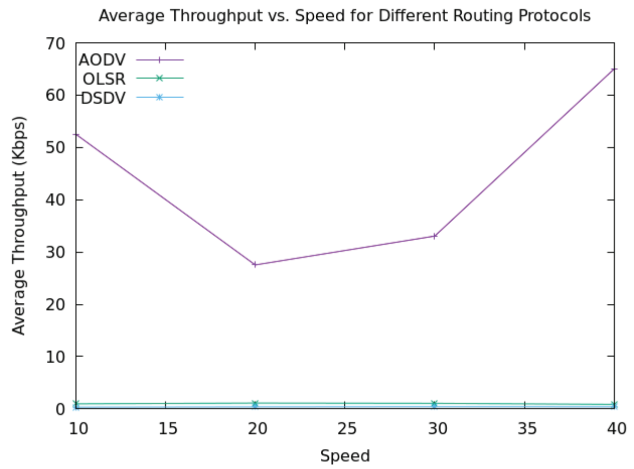


**Figure 5.** Comparison of throughput for scenario 4.

### Analysis of Throughput

AODV demonstrates superior throughput in smaller networks and diverse simulation times due to its efficient on-demand routing.

OLSR shows moderate performance across all environments, but DSDV falls behind because it periodically updates and is not very adaptable.

### Packet Delivery Ratio Evaluation

Packet Delivery Ratio (PDR) is also highly significant in measuring routing protocol reliability and efficiency in data packet delivery. Four different scenarios are involved in our research, which include network size variation, simulation time variation, packet size variation, and mobility speed variation. Scenario 1 compares PDR in Table 6 and Figure 6. Scenario 2 compares simulation time (110 ms to 300 ms) to competitive PDR for AODV and OLSR and similar results for DSDV in Table 7 and Figure 7. Scenario 3 compares packet sizes (64 to 1024 bytes) with smaller PDR and more similar performance for smaller packets by AODV to OLSR and DSDV in Table 8 and Figure 8. Scenario 4 compares mobility speed (10 to 40 Mbps) with smaller PDR for AODV to OLSR and DSDV in Table 9 and Figure 9.

**Table 6.** Comparison of packet delivery ratios of AODV, OLSR, and DSDV for various node numbers

| Nodes | AODV | OLSR | DSDV |
|---|---|---|---|
| **20** | 87% | 66% | 41% |
| **30** | 86% | 53% | 42% |
| **40** | 91% | 49% | 33% |
| **50** | 88% | 36% | 32% |

**Table 7.** Packet delivery ratio comparison of AODV, OLSR, and DSDV across various packet sizess

| Packet Size | AODV | OLSR | DSDV |
|---|---|---|---|
| **64** | 17% | 53% | 7% |
| **256** | 28% | 55% | 6% |
| **512** | 49% | 50% | 6% |
| **1024** | 45% | 50% | 6% |

**Table 8.** Packet delivery ratio comparison of AODV, OLSR, and DSDV across varied simulation times

| Simulation Time | AODV | OLSR | DSDV |
|---|---|---|---|
| **110** | 74% | 70% | 12% |
| **150** | 56% | 56% | 10% |
| **200** | 49% | 54% | 7% |
| **250** | 49% | 52% | 5% |
| **300** | 49% | 56% | 9% |

**Table 9.** Comparison of packet delivery ratios of AODV, OLSR, and DSDV at varying node speeds

| Speed | AODV | OLSR | DSDV |
|---|---|---|---|
| **10** | 17% | 53% | 7% |
| **20** | 28% | 55% | 6% |
| **30** | 49% | 54% | 7% |
| **40** | 45% | 50% | 6% |

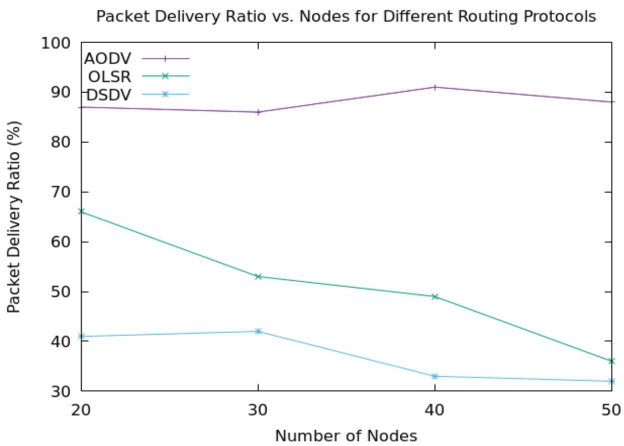


**Figure 6.** Comparison of packet delivery ratio (PDR) in Scenario 1.

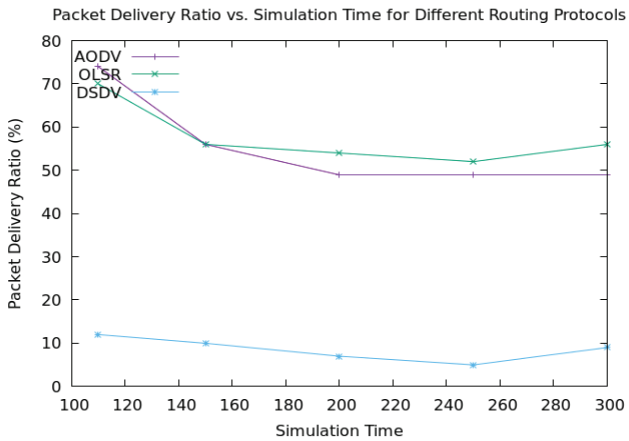


**Figure 7.** Comparison of packet delivery ratio (PDR) for Scenario 2.

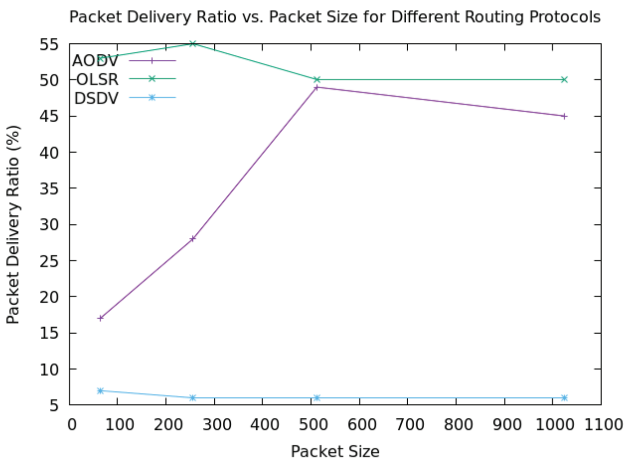


**Figure 8.** Comparison of packet delivery ratio (PDR) for scenario 3.

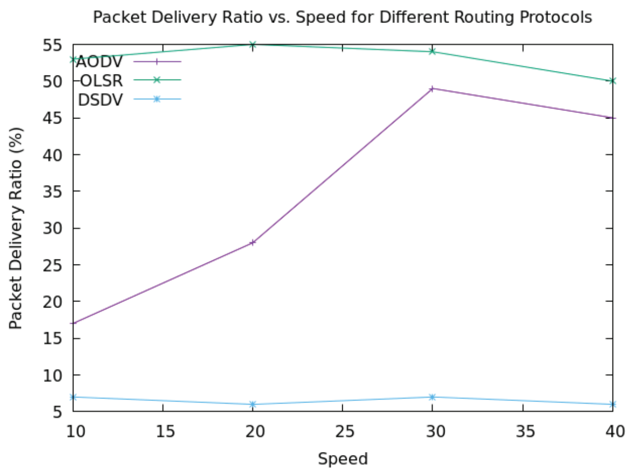


**Figure 9.** Comparison of packet delivery ratio (PDR) for scenario 4.

**Analysis of Packet Delivery Ratio**

AODV possesses a uniform high PDR, which shows its reliability. OLSR is adaptable, whereas DSDV is variable in its efficiency under varying conditions.

**End-to-End Delay Evaluation**

End-to-end delay is the time it takes for packets to travel from source node to destination node and is crucial in quantifying latency in data transmission. Our discussion includes the cases with the variations in the number of nodes, simulation time, packet size, and mobility speed.

Scenario 1 is the comparison of the end-to-end delays with the data shown in Table 10, with the delay values provided, and Figure 10 presents the data. Scenario 2 tested simulation times (110 to 300 seconds), with greater delays for AODV, lesser delays for OLSR, and intermediate delays for DSDV in Table 11 and Figure 11. Scenario 3 tested packet sizes (64 to 1024 bytes), with consistently greater delays for AODV than lower delays for OLSR and DSDV in Table 12 and Figure 12. Under Scenario 4, the speed tested for mobilities (10 Mbps to 40 Mbps) in Table 13 and Figure 13 saw delays being larger in AODV than for OLSR and DSDV. Such discoveries point out to the value of thorough evaluation when deciding how to measure protocol performance under different conditions.

**Table 10.** End-to-end delay comparison of AODV, OLSR, and DSDV across various node counts

| Nodes | AODV | OLSR | DSDV |
|---|---|---|---|
| 20 | +8.70746e+10 | +4.77569e+08 | +3.22544e+10 |
| 30 | +1.69833e+11 | +2.27887e+09 | +2.0218e+09 |
| 40 | +3.74722e+11 | +1.51307e+10 | +7.07811e+09 |
| 50 | +5.10164e+11 | +1.29644e+09 | +2.05026e+09 |

**Table 11.** End-to-end delay comparison of AODV, OLSR, and DSDV across various packet sizes

| Packet Size | AODV | OLSR | DSDV |
|---|---|---|---|
| 64 | +7.86896e+10 | +8.57317e+09 | +3.54241e+08 |
| 256 | +3.03831e+10 | +5.18808e+09 | +1.38519e+08 |
| 512 | +7.10702e+10 | +3.14892e+09 | +1.02752e+08 |
| 1024 | +2.176e+10 | +1.05453e+08 | +1.02752e+08 |

**Table 12.** End-to-end delay comparison of AODV, OLSR, and DSDV across varied simulation times

| Simulation Time | AODV | OLSR | DSDV |
|---|---|---|---|
| 110 | +1.34391e+10 | +5.38085e+07 | +3.42289e+07 |
| 150 | +4.38826e+10 | +8.92576e+07 | +1.01039e+08 |
| 200 | +7.10702e+10 | +3.14892e+09 | +1.38519e+08 |
| 250 | +8.09514e+10 | +3.24482e+09 | +2.00172e+08 |
| 300 | +9.43479e+10 | +3.36668e+09 | +3.00334e+08 |

**Table 13.** End-to-end delay comparison of AODV, OLSR, and DSDV across different node speeds

| Speed | AODV | OLSR | DSDV |
|---|---|---|---|
| 10 | +7.86896e+10 | +8.57317e+09 | +3.54241e+08 |
| 20 | +3.03831e+10 | +5.18808e+09 | +1.03082e+08 |
| 30 | +7.10702e+10 | +3.14892e+09 | +1.38519e+08 |
| 40 | +2.176e+10 | +1.05453e+08 | +1.02752e+08 |

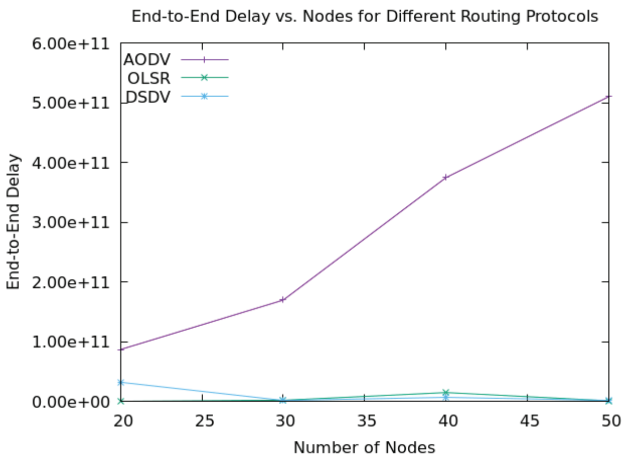


**Figure 10.** Comparison of end-to-end delay in scenario 1.

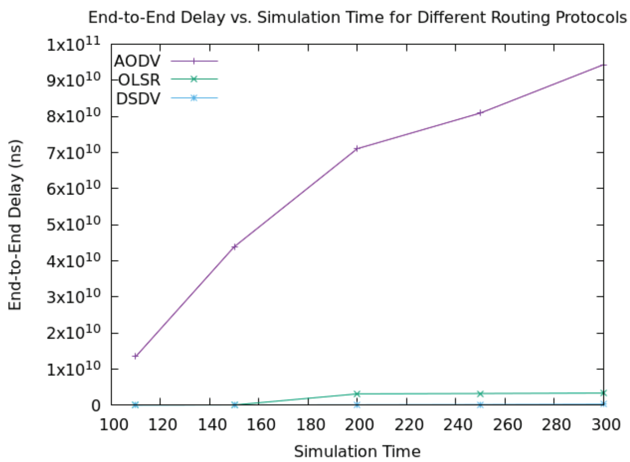


**Figure 11.** Comparison of end-to-end delay for scenario 2.

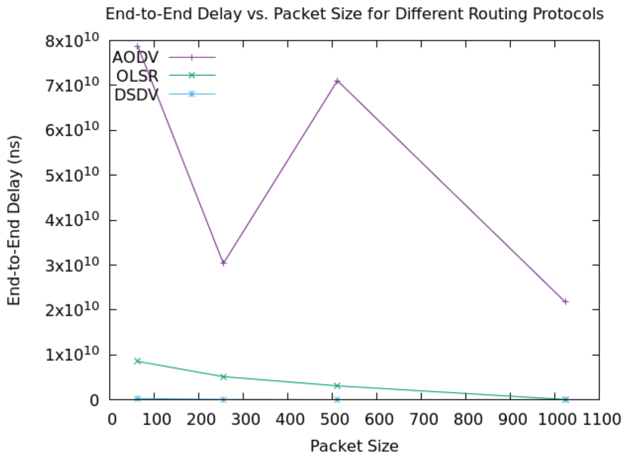


**Figure 12.** Comparison of end-to-end delay in scenario 3.

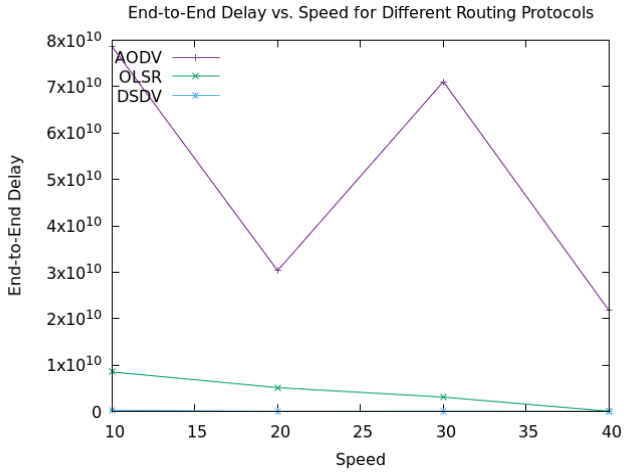


**Figure 13.** Comparison of end-to-end delay in scenario 4.

**Analysis End-to-End Delay**

AODV often experiences higher delays compared to OLSR and DSDV, raising concerns about dynamic routing behaviour.

OLSR demonstrates better stability, while DSDV maintains steady performance.

**Packet Loss Ratio Evaluation**

Packet Loss Ratio (PLR) assesses network reliability by measuring the ratio of lost packets in transmission. Our results consider cases with different variations in network size, simulation time, packet size, and mobility speed.

For Scenario 1 (20-50 nodes), AODV reported a low PLR (11-13%), whereas OLSR and DSDV reported high PLR (63-67% for OLSR, 57-67% for DSDV), as presented in Table 14 and Figure 14. Scenario 2 (110-300 seconds) had a consistently high PLR for AODV, steady for OLSR, and increasing for DSDV (Table 15, Figure 15). Scenario 4 (10-40 Mbps) revealed high PLR for AODV and low PLR for OLSR and DSDV (Table 17, Figure 17). These findings highlight the necessity of careful protocol testing across scenarios.

**Table 14.** Packet loss ratio (PLR) comparison of AODV, OLSR, and DSDV across various node counts

| Nodes | AODV | OLSR | DSDV |
|---|---|---|---|
| 20 | 12% | 33% | 58% |
| 30 | 13% | 46% | 57% |
| 40 | 8% | 50% | 66% |
| 50 | 11% | 63% | 67% |

**Table 15.** Packet loss ratio (PLR) comparison of AODV, OLSR, and DSDV across different simulation times

| Simulation Time | AODV | OLSR | DSDV |
|---|---|---|---|
| 110 | 25% | 30% | 87% |
| 150 | 43% | 43% | 90% |
| 200 | 50% | 45% | 92% |
| 250 | 50% | 47% | 94% |
| 300 | 50% | 43% | 90% |

**Table 16.** Packet loss ratio (PLR) comparison of AODV, OLSR, and DSDV across various packet sizes

| Packet Size | AODV | OLSR | DSDV |
|---|---|---|---|
| 64 | 82% | 46% | 92% |
| 256 | 71% | 44% | 93% |
| 512 | 50% | 45% | 92% |
| 1024 | 54% | 50% | 93% |

**Table 17.** Packet loss ratio (PLR) comparison of AODV, OLSR, and DSDV across different node speeds

| Speed | AODV | OLSR | DSDV |
|---|---|---|---|
| 10 | 82% | 46% | 92% |
| 20 | 71% | 44% | 93% |
| 30 | 50% | 45% | 92% |
| 40 | 54% | 50% | 93% |

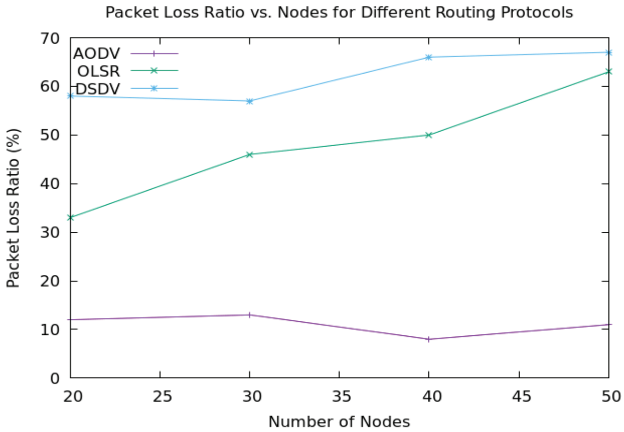


**Figure 14.** Comparison of packet loss ratio (PLR) in scenario 1.

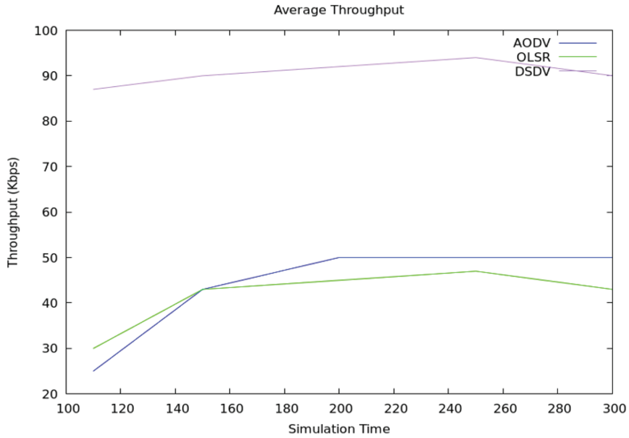


**Figure 15.** Comparison of packet loss ratio (PLR) for scenario 2.

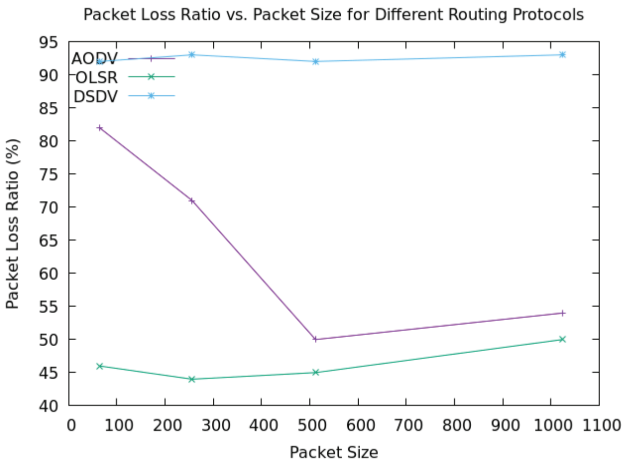


**Figure 16.** Comparison of packet loss ratio (PLR) for scenario 3.

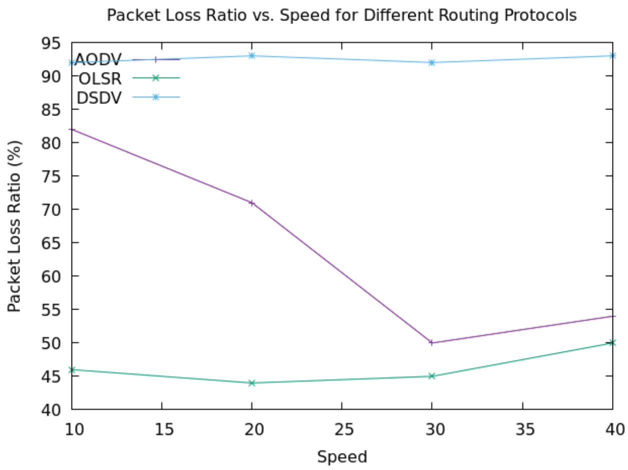


**Figure 17.** Comparison of packet loss ratio (PLR) for scenario 4.

**Analysis of Packet Loss Ratio**

AODV exhibits higher packet losses compared to OLSR and DSDV, influenced by adaptive routing behaviour.

OLSR and DSDV uphold better data integrity with lower and more consistent PLR values.

**End-to-End Jitter Delay Evaluation**

End-to-end jitter delay estimates the packet delay variation, which is critical for real-time applications. Our analysis comprises node count, simulation time, packet size, and mobility speed variation based scenarios.. Our analysis comprises scenarios based on node count, simulation time, packet size, and mobility speed variation. In Scenario 1 (20-50 nodes), AODV exhibited high jitter delays, OLSR experienced low but notable delays, and DSDV experienced intermediate values (Table 18, Figure 18). Scenario 2 (simulated time change) proved changing jitter delays for AODV and constant delays for OLSR (Table 19, Figure 19). Scenario 3 (packet size) tested inconsistent AODV delay versus consistent OLSR and DSDV delays (Table 20, Figure 20). Scenario 4 (mobility speed) tested inconsistent AODV delivery times versus consistent and reliable OLSR and DSDV (Table 21, Figure 21). These findings indicate that protocol performance needs to be evaluated under various conditions.

**Analysis of End-to-End Jitter Delay**

AODV tends to encounter greater and more fluctuating delays than OLSR and DSDV, which affects real-time application performance. OLSR is more stable, but DSDV is reliable. In conclusion, our findings contribute informative knowledge on the performance of routing protocols for mobile ad-hoc networks under different settings, which can help researchers and practitioners in choosing protocols and network optimization.

**Table 18.** End-to-end Jitter delay comparison of AODV, OLSR, and DSDV across various node counts

| Nodes | AODV | OLSR | DSDV |
|---|---|---|---|
| 20 | +9.60779e+10 | +3.27909e+08 | +1.38608e+10 |
| 30 | +1.36594e+11 | +2.92228e+09 | +2.84501e+09 |
| 40 | +2.78934e+11 | +2.41269e+10 | +9.01536e+09 |
| 50 | +3.62899e+11 | +9.29821e+08 | +2.89933e+09 |

**Table 19.** End-to-end Jitter delay comparison of AODV, OLSR, and DSDV across various packet sizes

| Simulation Time | AODV | OLSR | DSDV |
|---|---|---|---|
| 110 | +1.19631e+10 | +2.53956e+07 | +1.00501e+07 |
| 150 | +5.10076e+10 | +6.45454e+07 | +7.27687e+07 |
| 200 | +7.22823e+10 | +1.01664e+08 | +1.16579e+08 |
| 250 | +8.30043e+10 | +2.05107e+08 | +1.56454e+08 |
| 300 | +9.94498e+10 | +3.29285e+09 | +2.21616e+08 |

**Table 20.** End-to-end Jitter delay comparison of AODV, OLSR, and DSDV across varied simulation times

| Packet Size | AODV | OLSR | DSDV |
|---|---|---|---|
| 64 | +3.04849e+10 | +6.53025e+08 | +1.5166e+08 |
| 256 | +2.05843e+10 | +1.01664e+08 | +7.11607e+07 |
| 512 | +7.22823e+10 | +8.61344e+07 | +7.11607e+07 |
| 1024 | +1.88227e+10 | +8.61344e+07 | +7.11607e+07 |

**Table 21.** End-to-end Jitter delay comparison of AODV, OLSR, and DSDV across different node speeds

| Speed | AODV | OLSR | DSDV |
|---|---|---|---|
| 10 | +3.04849e+10 | +6.53025e+08 | +1.5166e+08 |
| 20 | +2.05843e+10 | +1.14929e+09 | +7.11607e+07 |
| 30 | +7.22823e+10 | +1.01664e+08 | +1.16579e+08 |
| 40 | +1.88227e+10 | +8.61344e+07 | +6.88934e+07 |

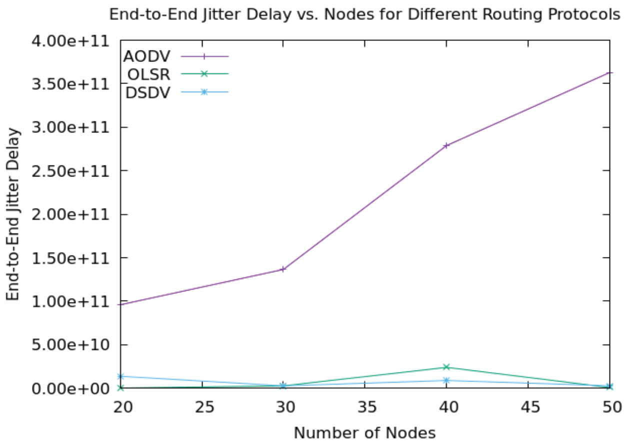


**Figure 18.** Comparison of end-to-end Jitter delay in scenario 1.

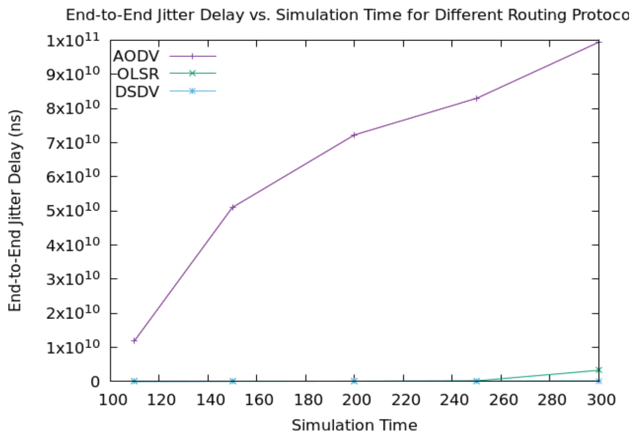


**Figure 19.** Comparison of end-to-end Jitter delay in scenario 2.

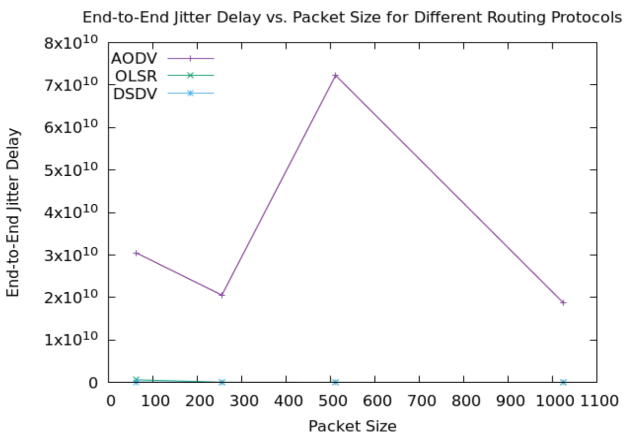


**Figure 20.** Comparison of end-to-end Jitter delay in scenario 3.

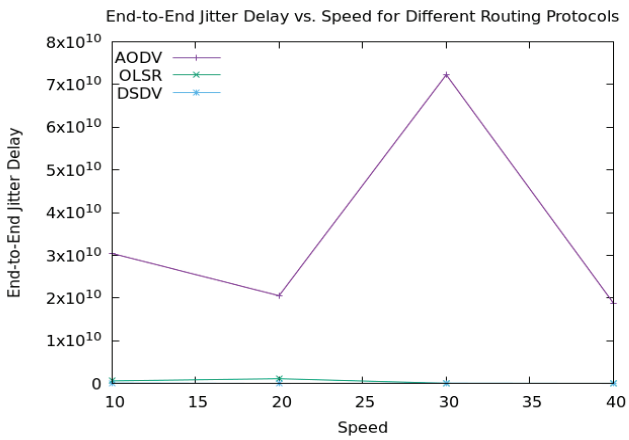


**Figure 21.** Comparison of end-to-end Jitter delay in scenario 4.

## CONTRIBUTIONS

### Key Contributions

New routing protocols: Improving relay efficiency of data packets in MANETs for cytology.

Performance measurements: Thorough measurement of delivery ratio, delay, and throughput.

Security factors: Suggested incorporation of security features for use in cytology applications.

Practical aspects: Shown through simulation and a medical example.

### Impact of the Study

MANETs in healthcare: Improved efficiency and reliability for management of patient data.

Foundation for future research: Foundation for future practical and academic implementation.

Higher awareness of security: Safe practice in handling medical data encouraged.

MANETs in healthcare: Improved efficiency and reliability for management of patient data.

## CONCLUSION

Our research goes deep into the efficiency analysis of AODV, DSDV and OLSR routing protocols by utilizing the NS-3 simulator and offers meaningful insights regarding their behavior and applicability to wireless ad hoc networks. With the ever-changing environment of mobile devices and communication technologies today, it is important to choose efficient and reliable routing protocols. Through intense simulations in varied scenarios with changes in network parameters, we assessed important performance indicators: throughput, packet delivery ratio, end-to-end delay, packet loss ratio and end-to-end jitter delay. These are all-encompassing indicators of the performance of the protocols under varied conditions. Our findings highlight the superiority of AODV under high-throughput requirements and hence it is most appropriate for data-intensive applications. In contrast, DSDV provides inconsistent results and its suitability is case-specific. Through such demystification of the strengths and weaknesses of these routing protocols, our work enables network administrators and designers to choose the optimal and make the correct adjustments while choosing and configuring protocols for wireless ad hoc networks. Such findings can potentially enhance the performance and efficiency of wireless communication systems significantly in various practical applications. In addition, we introduce the NS-3 simulator as a robust framework to perform comprehensive performance evaluation. As crucial as our research is, it does come with wide-ranging limitations and practical aspects that need to be considered, for example, the need for correct simulation setup and to compromise when selecting a protocol. These factors are paramount in order to make our results relevant and applicable in real-world network deployments. In short, our work is a rich source of information for the wireless networking community with recommendations on how to choose the right protocol, optimize, and fine-tune it to support reliable data delivery in wireless ad hoc networks.

## AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

## DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

## CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## ETHICS

There are no ethical issues with the publication of this manuscript.

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