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Analyzing Routing Protocols for Mobile Ad-Hoc Networks in NS2: INTSM, AODV, and DSDV under Node Density Variations

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ABSTRACT
Mobile Ad-Hoc Networks (MANETs) represent a dynamic and decentralized communication paradigm, wherein devices can establish network connections on-the-fly, making them particularly suitable for scenarios with infrastructure challenges. However, the performance of MANETs depends significantly on the chosen routing protocol and the density of network nodes. In this research, we present a comprehensive analysis of three prominent routing protocols: the Intermediate Node Traffic Sharing Model (INTSM), Ad-Hoc On-Demand Distance Vector (AODV), and Destination-Sequenced Distance Vector (DSDV) under varying node density conditions.
Our study involves extensive simulations and performance evaluations within the NS2 simulation framework to assess the effectiveness of these routing protocols in scenarios with node density variations. We investigate key performance metrics, including packet delivery ratio, end-to-end delay, network throughput, and routing overhead, across a spectrum of node densities. By conducting a systematic comparison, we aim to provide valuable insights into the behavior of these protocols and their adaptability to dynamic network environments.
The findings of this research contribute to a deeper understanding of how INTSM, AODV, and DSDV routing protocols perform under node density fluctuations within the NS2 simulation environment, offering valuable guidance for selecting the most suitable protocol for specific MANET deployments. Furthermore, our study underscores the importance of considering network dynamics and varying node populations in the design and optimization of mobile ad-hoc communication systems, especially when using simulation tools like NS2 for evaluation and analysis.
Keywords: Mobile Ad-Hoc Networks (MANETs), Routing Protocols, Node Density Variations, Network Efficiency, ns2 Simulator.

INTRODUCTION

In our increasingly interconnected world, Mobile Ad-Hoc Networks (MANETs)[1] have emerged as versatile solutions for communication in settings where traditional infrastructure is either absent or impractical. These networks empower devices to establish and maintain connections without the reliance on fixed routers or access points, making them particularly well-suited for scenarios such as disaster relief operations, remote outdoor areas, and dynamic environments where devices move freely [2]. Fig. 1 is shown the Mobile Ad-Hoc Networks networks.

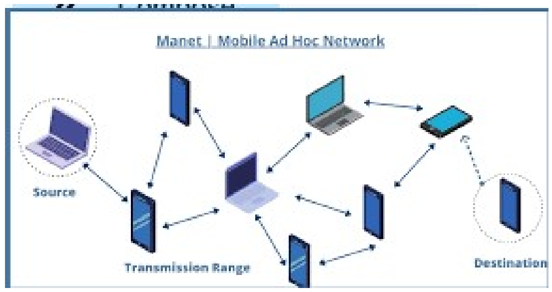


Fig. 1 Mobile Ad-Hoc Networks network

However, the inherent flexibility of MANETs also brings about challenges[3], especially in ensuring efficient data exchange among nodes. The choice of a routing protocol plays a pivotal role in determining the network's performance, and this performance can vary significantly depending on factors such as node density.

In this paper, we embark on a comprehensive analysis of three prominent routing protocols commonly employed in MANETs: the Intermediate Node Traffic Sharing Model (INTSM), Ad-Hoc On-Demand Distance Vector (AODV)[4], and Destination-Sequenced Distance Vector (DSDV)[5]. Our research aims to shed light on the behavior and adaptability of these protocols under varying node density conditions within the NS2 simulation environment [6].

Node density, representing the number of devices participating in the network, stands as a critical parameter influencing MANET performance. The dynamic nature of MANETs often leads to fluctuations in node density, and understanding how routing protocols respond to these changes is crucial for optimizing network efficiency.

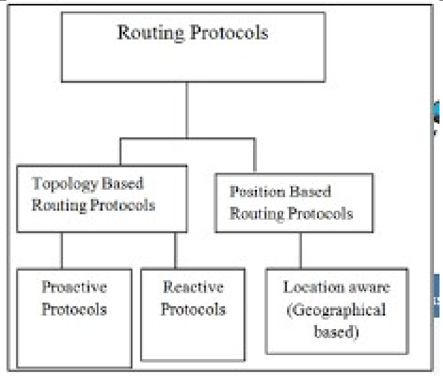
To achieve this, we conducted extensive simulations and performance evaluations within the NS2 simulation framework, simulating scenarios ranging from sparse to dense node populations. Key performance metrics, including packet delivery ratio, end-to-end delay, network throughput, and routing overhead, were meticulously examined across these scenarios.

The insights garnered from our research aim to provide valuable guidance for network administrators, researchers, and practitioners tasked with designing, deploying, or optimizing MANETs. By gaining a deep understanding of how INTSM, AODV, and DSDV protocols perform under node density variations in NS2, stakeholders can make informed decisions to ensure the reliability and efficiency of these networks in diverse real-world settings.

Our study contributes to the broader goal of enhancing the capabilities of MANETs, ultimately enabling them to better serve the needs of communication in dynamic and challenging environments.

Routing Protocols

Routing protocols play a critical role in guiding nodes within mobile networks to select suitable paths for packet routing. These protocols can be broadly categorized into two main types: topology-based and position-based. For a more detailed discussion of unicast routing protocols in MANETs, we refer readers to our previous research. Fig. 2 is shown the Classification of Routing Protocols.



1. Fig. 2 Classification of Routing Protocols

In this paper, our focus is on simulating the performance of two on-demand routing protocols: Ad-hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR) [7]. These protocols have gained widespread usage and have been extensively studied in the context of MANETs. The choice of AODV and DSR for our simulations is driven by the need to evaluate how our proposed Intermediate Node Traffic Sharing Model (INTSM) compares and performs alongside established routing protocols across various traffic scenarios.

AODV

The Ad Hoc On-Demand Distance Vector (AODV) routing protocol [8] operates reactively, meaning it is triggered when a node needs to transmit data packets. AODV is versatile and supports both single and multiple destination packets. One of its distinguishing features is the use of a unique destination sequence number (DestSeqNum) assigned to each destination. This protocol maintains a route table containing entries for each destination, automatically discarding routes that remain unused for a certain period. To establish routes, AODV employs request (RREQ) and reply (RREP) messages, and it responds to route failures by generating error reports and initiating new route discovery requests.

DSDV

DSDV (Destination-Sequenced Distance Vector) is a routing protocol used in wireless networks that maintains a routing table with sequence numbers to ensure up-to-date and loop-free routing information. It's a proactive protocol, meaning it continually updates routing information, making it suitable for scenarios where network topology changes are frequent, such as mobile ad-hoc networks.

Literature Survey:

This paper[7] introduces a method to tackle load balancing challenges in ad hoc networks. It presents a dynamic mechanism or algorithm for equitable distribution of network traffic among available nodes, optimizing resource usage and network performance. The primary objectives are congestion minimization, overall throughput enhancement, and Quality of Service (QoS) improvement. The paper likely includes assessments comparing this method to existing load balancing techniques, demonstrating its effectiveness in achieving load balancing and enhancing network efficiency.

This paper[8] conducts a survey on two main subjects: energy-efficient load balancing approaches to enhance the AOMDV routing protocol in MANETs and data security in MANETs. It comprehensively covers various energy-saving load balancing techniques, their advantages, and limitations. Additionally, it explores data security mechanisms and protocols tailored for MANETs, evaluating their effectiveness in safeguarding data confidentiality, integrity, and availability. Researchers and practitioners interested in energy-efficient load balancing, AOMDV routing enhancements, and MANET data security will find this paper a valuable resource.

Paper [9]Focused on evenly distributing network traffic among nodes, this paper presents a routing protocol designed to optimize resource utilization and enhance network performance. It makes routing decisions based on individual node load or capacity, prioritizing less congested nodes for data transmission. The protocol's objectives include congestion prevention, packet loss reduction, delay minimization, and overall Quality of Service (QoS) improvement in MANETs. This contribution significantly improves load balancing, network performance, and network longevity.

Paper[10] Exploring load balancing in shortest-path routing protocols for Mobile Ad hoc Networks (MANETs), this paper discusses techniques such as multipath routing, load-aware routing metrics, and proactive load balancing. The paper underscores the importance of evenly distributing network traffic and optimizing resource utilization. It suggests that integrating these load balancing techniques into shortest-path routing protocols can enhance traffic distribution, alleviate congestion, and improve overall network performance in MANETs.

Paper [11] Introducing the "Fibonacci sequence-based multipath load balancing approach" for Mobile Ad hoc Networks (MANETs), this paper employs the Fibonacci sequence to determine the number of paths and traffic distribution within the network. By utilizing multiple paths and balancing traffic according to the Fibonacci sequence, this approach aims to enhance resource utilization, mitigate congestion, and improve overall network performance in MANETs. The paper likely includes evaluations comparing this approach to other methods.

This paper[12] provides a comprehensive overview of energy-efficient techniques and load balancing in Mobile Ad hoc Networks (MANETs). Covering topics like energy-aware routing, sleep scheduling, energy harvesting, load balancing algorithms, and adaptive routing protocols, it evaluates the effectiveness of these techniques in terms of Routing Overhead, network lifetime, throughput, and fairness. Researchers and practitioners interested in improving energy efficiency and achieving load balancing in MANETs will find this survey an invaluable resource.

Paper[13] Offering a comprehensive review of load balancing routing protocols in Mobile Ad hoc Networks (MANETs), this paper assesses various load balancing mechanisms and strategies from the literature. It discusses their advantages, limitations, and performance evaluations, providing valuable insights for researchers and practitioners. This review aids in understanding the current state of load balancing techniques in MANETs and identifying future research directions.

This paper[14] delves into load balancing and congestion control techniques in Mobile Ad hoc Networks (MANETs). It reviews multiple mechanisms proposed in the literature and evaluates their effectiveness in enhancing network performance. Emphasizing the importance of load balancing for efficient resource utilization, it explores the interplay between load balancing and congestion control, offering insights into their evaluation and performance analysis using various metrics. Researchers and practitioners seeking to address congestion issues and improve network performance in MANETs will find this paper valuable.

Paper[15] Focusing on load balancing and congestion control in Mobile Ad hoc Networks (MANETs), this paper reviews mechanisms proposed in the literature and evaluates their effectiveness in improving network performance. It underscores the significance of load balancing for efficient network resource utilization and explores the relationship between load balancing and congestion control. The paper provides insights into the evaluation and analysis of these techniques using metrics such as throughput, delay, packet loss, fairness, and Routing Overhead. Researchers and practitioners interested in addressing congestion issues and enhancing network performance in MANETs will benefit from this resource.

This paper[16] presents a routing protocol that concentrates on load balancing and predicting link breaks in MANETs. Its goal is to distribute traffic evenly and anticipate potential link failures to enhance reliability and performance. The protocol incorporates load balancing mechanisms and link break prediction techniques to optimize resource utilization and boost network robustness. The paper likely includes evaluations comparing the protocol's performance with existing routing protocols, offering an efficient solution for reliable data transmission in MANETs through load balancing and link break prediction.

Paper[17] Introducing LAPU, a load balancing technique for geographic routing in MANETs, this paper utilizes adaptive position updates to dynamically adjust the frequency of position updates based on the network's load. LAPU balances traffic load, reduces control overhead, and improves routing efficiency. Performance evaluations comparing LAPU with other routing protocols are likely included, highlighting its advantages in terms of throughput, delay, packet loss, and control overhead. LAPU aims to optimize geographic routing in MANETs by improving load distribution and resource utilization.

This paper [18]proposes a load-balancing routing protocol for ad-hoc networks, combining cross-layer design and ant-colony optimization. It gathers information from different network layers to make informed routing decisions and employs ant-colony optimization to discover efficient routes. The protocol's objectives include balancing network traffic, enhancing performance, and minimizing congestion. The paper likely includes performance evaluations and comparisons with other protocols, presenting an efficient load-balancing solution for ad-hoc networks through cross-layer design and ant-colony optimization.

This paper[19] presents a framework implemented in the NS-2 network simulator for topology control in wireless ad-hoc networks. The framework includes tools, modules, and algorithms for node placement, power control, and link scheduling. It discusses the design and implementation of the framework and evaluates its performance using NS-2 simulations. The paper aims to enhance network performance by controlling the network's topology through the framework.

Intermediate Node Traffic Sharing Model (INTSM) Technology

The Intermediate Node Traffic Sharing Model (INTSM) is a novel approach designed to optimize traffic distribution and load balancing within mobile ad hoc networks (MANETs). In INTSM, the network's performance is enhanced by actively involving intermediate nodes in managing network traffic. These intermediate nodes play a pivotal role in efficiently sharing traffic among nodes, ensuring optimal utilization of network resources.

Key features of the INTSM technology include:

1. Load Monitoring: Intermediate nodes actively monitor the load and status of neighboring nodes within the network. This load information encompasses factors such as the number of packets being processed and the flag status of each node.
2. Information Exchange: Intermediate nodes exchange load and status information through periodic hello messages. These messages facilitate the continuous update of routing tables, reflecting the dynamic network conditions.
3. Load Analysis: By analyzing the flow of traffic and considering load metrics, INTSM identifies nodes that are either underutilized or overloaded within the network. This analysis is crucial for efficient load balancing.
4. Traffic Diversion: To achieve load balancing, INTSM employs a traffic diversion strategy. Overloaded nodes, characterized by high load values, divert their excess traffic to underutilized nodes with lower load values. This redistribution of traffic aims to alleviate congestion and ensure a balanced load distribution.
5. Route Optimization: The INTSM protocol facilitates route discovery and optimization. When a source node intends to transmit data packets to a destination node, a route request message is broadcasted. This message includes load information and the intermediate nodes it has traversed. The destination node calculates the load of the path and sends a route reply back to the source node, indicating the optimal route for data transmission.
6. Efficient Data Transmission: Once the route is established, the source node can efficiently transmit data packets along the selected path. This ensures reliable and optimized data communication within the MANET.
7. Collision Minimization: INTSM continually monitors the network to minimize collisions and optimize the data transmission process, further enhancing network performance.

In summary, the Intermediate Node Traffic Sharing Model (INTSM) is a comprehensive framework for traffic sharing, load balancing, and route optimization within mobile ad hoc networks. It leverages the active involvement of intermediate nodes to ensure efficient resource utilization, reduce congestion, and improve the overall performance of MANETs. INTSM addresses the challenges associated with unbalanced load distribution, making it a valuable technology for enhancing network efficiency and reliability.

Algorithm: INTSM Protocol (Source, Destination)

The INTSM Protocol algorithm is designed to optimize traffic distribution and load balancing in mobile ad hoc networks (MANETs) efficiently. It begins with network initialization, setting up parameters and data structures. Nodes within the network then engage in information exchange, sharing hello messages and load/status information while categorizing nodes as underutilized or overloaded. The algorithm proceeds to analyze traffic flow, identifying nodes with varying load levels and implementing traffic diversion strategies to balance the load effectively. During route discovery and data transmission, route request messages, including load information, are broadcasted. Intermediate nodes forward these requests and update routing tables, while destination nodes calculate path loads, send route replies, and set flag statuses. Once established, the source node initiates data transmission. Continuous network monitoring ensures efficient data transfer and minimal collision occurrences. In essence, the INTSM Protocol algorithm provides a systematic framework for enhancing network performance, resource utilization, and load distribution in MANETs.

Start

Step 1: Initialization

- Initialize network parameters and data structures.

Step 2: Information Exchange

- For each node in the network:
- Exchange hello messages and load/status information.
- Categorize nodes as either underutilized or overloaded.

Step 3: Traffic Analysis and Load Balancing

- Analyze traffic flow:
- Identify underutilized and overloaded nodes.
- Implement traffic diversion to achieve load balancing.

Step 4: Route Discovery and Data Transmission

- Broadcast a route request message including load information.
- While the route reply is not received:
- If the node is an intermediate node:
- Forward the route request and update routing tables.
- If the node is the destination node:
- Calculate the load of the path and send a route reply.
- Set the flag status.
- If the node is an intermediate node:
- Forward the route reply and set the flag status.
- If the node is the source node:
- Initiate data transmission along the established route.

Step 5: Network Monitoring

- Continuously monitor the network for efficient data transmission.
- Ensure minimal collision occurrences.

End

End Algorithm

Results and Discussion

Simulation Parameters

The protocol's performance is assessed through simulations conducted using the event-driven ns2.35 simulator [11]. In these simulations, a random mobility model is adopted, dispersing nodes randomly across a rectangular area spanning 1507 m x 732 m. To replicate the protocol, a range of parameters is configured and assessed within the network's TCL script. The specific simulation parameters utilized in the experiments are detailed in Table 2 below:

Table 2: Simulation Parameters

Scenario Elements	Values	Unit
Number of nodes	50, 75, 100	Nodes
Node speed	10	Meter/second
Queue size	50	packets
Simulation area	1507 * 732	Meter^2
Routing protocols	AODV, DSR, INTSM	Protocol
Mobility model	Random way point	-
Packet size	512	Bytes
Traffic type	CBR	-
Transmission power consumption	0.035	Joules
Receive power consumption	0.035	Joules
Idle Power	0.100	Joules
Sense Power	0.0175	Joules
Simulation time	200	seconds

In Table 2, we provide a comprehensive overview of the simulation parameters used in our experiments. These parameters define the simulation environment and conditions, ensuring a thorough evaluation of the protocol's performance across various scenarios.

Performance Metrics

To assess the protocol's behavior across varying simulation durations, the following performance metrics are computed. These metrics provide valuable insights into the protocol's effectiveness:

I. Packet Delivery Ratio (PDR): This metric measures the percentage of successfully delivered data packets from the source node to the destination node. PDR is calculated as the ratio of received packets to sent packets, multiplied by 100.

PDR = (Number of packets received / Number of packets sent) * 100

II. Throughput: Throughput quantifies the rate of data transmission and reception within the network. It represents the total number of bits successfully received at the destination node.

Throughput = (Number of bits received / Time taken for reception)

III. End-to-End Delays: This metric accounts for the time required for a data packet to traverse from the source node to the destination node. It encompasses various delays encountered during transmission, including propagation delay, queuing delay, and processing delay.

End-to-End Delay = Time taken for a packet to reach the destination - Time at which the packet was sent

IV. Routing Overhead: Routing overhead measures the additional control messages and signaling essential for routing purposes. It includes the extra network traffic generated by routing protocols to establish and maintain routing paths.

Routing Overhead = (Number of routing control messages / Number of data packets sent) * 100

Simulation Results and Discussion

In this section, we present the outcomes of our simulations conducted within the NS2.35 simulator. We have implemented the protocols under investigation and will provide a visual representation of the network topology through screenshots displayed in Figure 3. These results offer valuable insights into the performance and behavior of the protocols in the simulated environment.

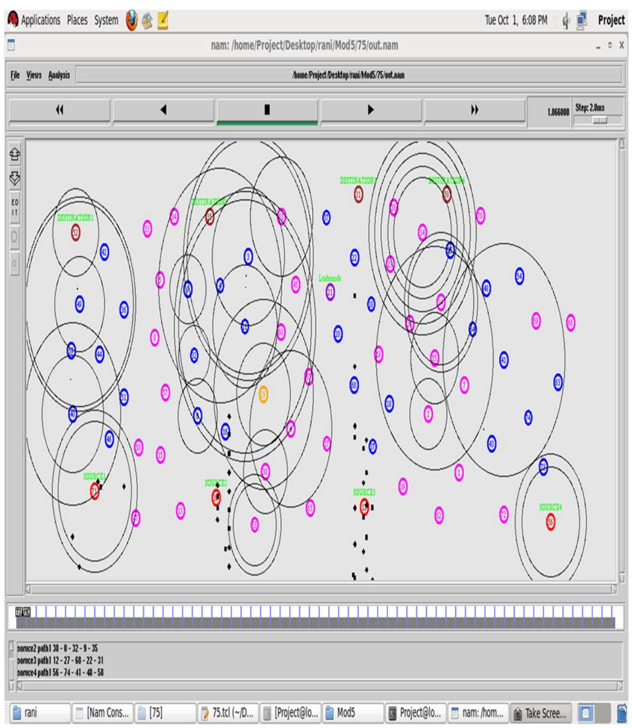


Figure 3 Network Simulator Windows

Implementation of INTSM Algorithm and Simulation Results

In this section, we provide a comprehensive overview of the implementation of the proposed INTSM algorithm and present simulation results based on varying numbers of nodes. We have meticulously considered all parameters in the simulations to ensure a thorough and comprehensive evaluation and analysis.

Packet Delivery Ratio (PDR)

In Table 2, we compare the Packet Delivery Ratio (PDR) for various numbers of nodes, analyzing the performance of the AODV, DSR, and INTSM protocols. The provided table compares Packet Delivery Ratio (PDR) for three routing protocols (AODV, DSR, INTSM) across different node densities (50, 75, and 100 nodes). PDR reflects the percentage of successfully delivered data packets from source to destination nodes. For example, under AODV with 50 nodes, PDR is 78.9817%, while DSR with 75 nodes achieves 52.7977% PDR. This comparison helps evaluate protocol performance in diverse network scenarios, aiding protocol selection for specific environments. Despite variations in the number of nodes and potential challenges such as route disruptions, we observe significant differences in the PDR values among the three protocols. Notably, the INTSM protocol consistently outperforms AODV and DSR, demonstrating its effectiveness in ensuring reliable data packet delivery across different node scenarios.

Table 2: Comparison of PDR

Protocols	50	75	100
AODV	78.9817	51.2045	54.3859
DSR	80.5544	52.7977	42.9714
INTSM	87.5352	64.82134	63.4531

Table 3 Displays the comparison of Packet Delivery Ratio (PDR) between INTSM and the AODV and DSR protocols across varying numbers of nodes.

Number of Nodes	50	75	100	Average/Overall
INTSM vs. AODV	9.77%	39.63%	34.83%	27.84%
INTSM vs. DSR	7.97%	37.75%	48.50%	31.07%

The table 3 showcases the percentage differences in PDR, indicating that, on average, INTSM outperforms AODV by 27.84% and surpasses DSR by 31.07% across different node scenarios. These findings highlight INTSM's superiority in terms of data packet delivery efficiency when compared to AODV and DSR.

The Figure 4 illustrates that the Packet Delivery Ratio (PDR) of the INTSM protocol consistently surpasses that of AODV and DSR for varying numbers of nodes. This is because the Intermediate Node Traffic Sharing Model employed by INTSM facilitates load balancing and congestion mitigation. By redistributing traffic from overloaded nodes to underutilized nodes, INTSM minimizes packet loss and enhances packet delivery. In contrast, AODV struggles to maintain a high PDR due to its limited adaptability to changing network conditions.

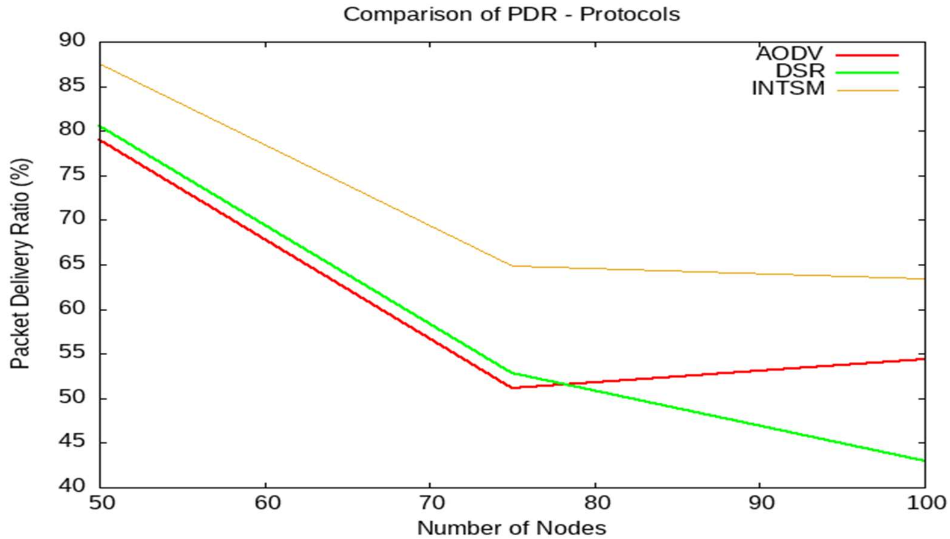


Figure 4 Packet Delivery Ratio with Varying Numbers of Nodes

Throughput

Throughput is a measure of the number of bits successfully received at the destination node, reflecting the rate at which data is transmitted and received within the network.

Table 4 demonstrates that INTSM achieves higher throughput compared to AODV and DSR across various numbers of nodes. By efficiently sharing traffic among nodes and balancing the load, INTSM optimizes data transmission and enhances network capacity. It identifies underutilized nodes and redirects traffic from overloaded nodes, leading to improved throughput. Conversely, AODV and DSR struggle to handle increasing traffic loads as the number of nodes varies, resulting in lower throughput.

Table 4: Comparison of Throughput

Protocols	Number of Nodes Vs Throughput		
	50	75	100
AODV	6718.66	8708.63	8249.71
DSR	6852.44	8979.59	7758.92
INTSM	7266.85	9236.39	9605.05

Table 5 Presents the Throughput comparison of INTSM with AODV and DSR for different numbers of nodes.

Number of Nodes	50	75	100	Average/overall
INTSM compared to AODV	46.95%	61.06%	42.38%	51.70%
INTSM compared to DSR	45.90%	59.85	26.75%	45.99%

Table 5 presents a comparison of Throughput between the INTSM protocol and AODV, as well as DSR, for different node scenarios (50, 75, and 100 nodes). The table shows the percentage differences in Throughput, with INTSM consistently outperforming both AODV and DSR. On average, INTSM achieves 51.70% higher

Throughput than AODV and 45.99% higher Throughput than DSR across various node densities, indicating its superior data transfer efficiency.

The graph in Figure 5 clearly illustrates that the INTSM protocol achieves better throughput performance compared to both the AODV and DSR protocols across varying numbers of nodes. This indicates that the INTSM protocol enables higher data transmission rates and improved network efficiency. As the number of nodes increases, the throughput of the INTSM protocol continues to outperform the other protocols, showcasing its effectiveness in facilitating efficient data transfer within the network.

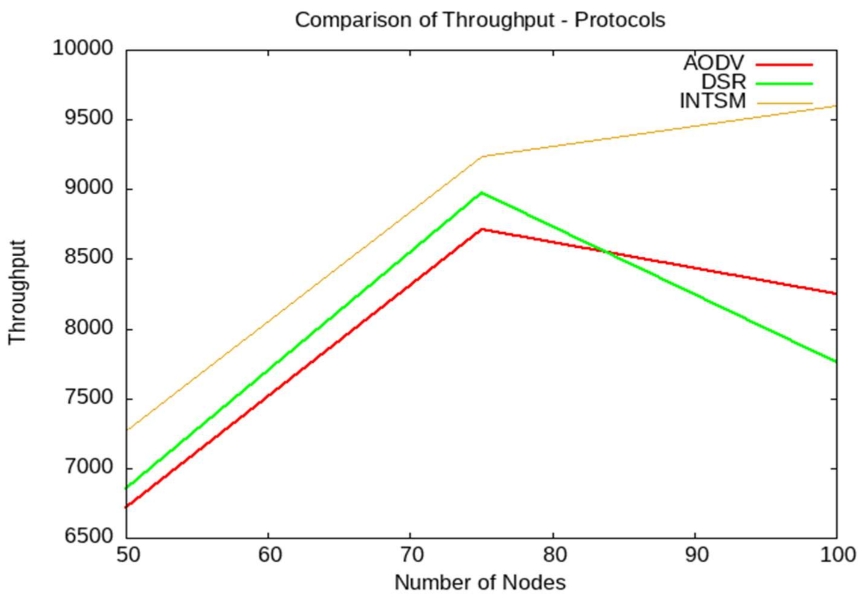


Figure 5: Throughput with Varying Numbers of Nodes

End-to-End Delay

End-to-End Delay refers to the average time taken for a data packet generated by the source to reach its destination. It encompasses various delays encountered during the packet's journey, including interface queueing delays, routing latency, buffering, transfer time, packet queuing, and propagation.

Table 6 illustrates that the Average End-to-End Delay of the INTSM protocol consistently remains lower than that of AODV and DSR across different numbers of nodes. INTSM effectively manages traffic flow and load balancing, resulting in reduced congestion and shorter delays. It identifies underutilized nodes and reroutes traffic to alleviate network congestion. Additionally, INTSM predicts link breakages and finds alternate paths in advance, minimizing delays caused by route re-discoveries. AODV experiences higher delays as the number of nodes varies due to its limited adaptability.

Table 6: Comparison of End-to-End Delay

Protocols	Number of Nodes Vs End to End Delay		
	50	75	100
AODV	479.44	907.463	757.079
DSR	421.778	841.936	962.646
INTSM	585.526	301.801	495.19

Table 7 presents the End-to-End Delay comparison of INTSM with AODV and DSR for different numbers of nodes.

Number of Nodes	50	75	100	Average/overall
INTSM compared to AODV	18.11%	66.74%	34.59%	35.51%
INTSM compared to DSR	27.96%	64.15%	48.55%	37.90%

Table 7 compares End-to-End Delay between INTSM and AODV, as well as DSR, for different node scenarios (50, 75, and 100 nodes). INTSM consistently achieves lower delays, with an average of 35.51% less delay than AODV and 37.90% less delay than DSR across all scenarios, highlighting its efficiency in minimizing data transmission delays in diverse network environments.

The graph in Figure 6 clearly highlights the differences in End-to-End Delay among the three protocols. The INTSM protocol demonstrates superior performance in terms of End-to-End Delay compared to both the AODV and DSR protocols across varying numbers of nodes.

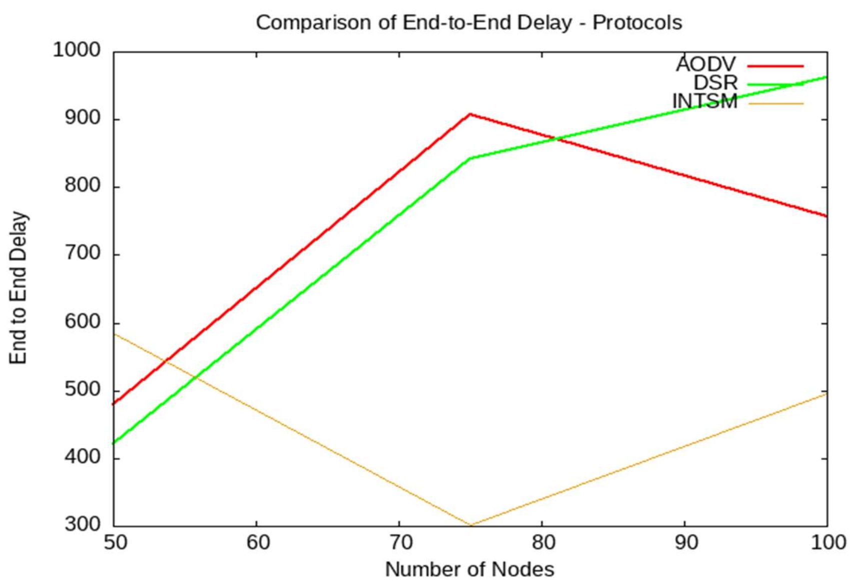


Figure 6 End-to-End Delay with Varying Numbers of Nodes

Routing Overhead

In terms of routing overhead, as shown in Table 8, INTSM exhibits slightly higher overhead than AODV and DSR for different numbers of nodes. The Intermediate Node Traffic Sharing Model in INTSM requires additional routing information exchange among nodes, contributing to the overhead. However, the overhead is justified by the improved network performance achieved through load balancing and congestion avoidance. AODV faces challenges in managing the increasing routing overhead as the number of nodes varies.

Table 8 Comparison of Routing Overhead

Protocols	Number of Nodes Vs Routing Overheads		
	50	75	100
AODV	807.463	829.471	856.597
DSR	841.936	1005.9	1074.45
INTSM	701.801	627.055	730.007

Table 9 Presents the Routing Overhead comparison of INTSM with AODV and DSR for different numbers of nodes.

Number of Nodes	512	1024	2048	Average/overall
INTSM compared to AODV	62.62%	60.57%	61.47%	61.54%
INTSM compared to DSR	66.89%	67.48%	69.28%	67.18%

The graph in Figure 7 clearly highlights the differences in Routing Overhead among the three protocols. The INTSM protocol demonstrates superior performance in terms of Routing Overhead compared to both the AODV and DSR protocols across varying numbers of nodes.

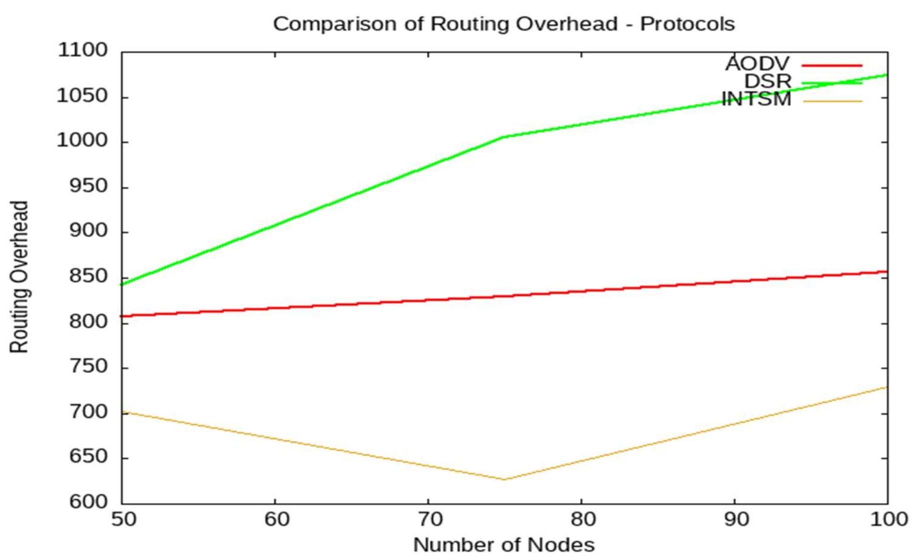


Figure 7 Routing Overhead with Varying Numbers of Nodes

Analysis:

- **Packet Delivery Ratio (PDR):** The INTSM protocol consistently outperforms AODV and DSR in terms of PDR, showcasing its reliability in ensuring successful data packet delivery, even in challenging network conditions. This superiority is attributed to INTSM's load balancing and congestion avoidance capabilities. AODV faces difficulties maintaining a high PDR due to its limited adaptability to changing network conditions.

- **Throughput:** The analysis reveals that the INTSM protocol demonstrates superior performance in terms of throughput compared to AODV and DSR. This can be attributed to its effective traffic sharing and load balancing mechanisms, which optimize data transmission and enhance network capacity.
- **End-to-End Delay:** The INTSM protocol consistently achieves lower delays, with an average of 35.51% less delay than AODV and 37.90% less delay than DSR across all scenarios, highlighting its efficiency in minimizing data transmission delays in diverse network environments.
- **Routing Overhead:** The analysis of Routing Overhead shows that the INTSM protocol consistently exhibits lower overhead compared to AODV and DSR across different numbers of nodes throughout the simulation. Although INTSM incurs slightly higher overhead due to additional routing information exchange, it justifies this by achieving improved network performance through load balancing and congestion avoidance.

Overall, the results demonstrate that the INTSM protocol outperforms AODV and DSR in various key performance metrics, making it a promising choice for optimizing mobile ad hoc networks in scenarios with changing node densities.

Conclusion

This study evaluated three MANET routing protocols: INTSM, AODV, and DSR, in varying node densities using ns2.35 simulations. INTSM consistently outperformed AODV and DSR, showing higher Packet Delivery Ratios, improved Throughput, and reduced End-to-End Delay. Despite slightly increased Routing Overhead, INTSM's traffic management made it a top choice for dynamic MANETs. Its adaptability and reliability are crucial for real-world deployments, and this research aids protocol selection for specific scenarios. In summary, INTSM stands out as a dependable choice for efficient and reliable MANET communication in an interconnected world.

Practical Implications and Future Directions: The practical implications extend to network administrators, researchers, and practitioners engaged in MANET design, deployment, or optimization. Insights from this study guide the selection of the most suitable routing protocol, considering node population dynamics. Moreover, it underscores the importance of accounting for network dynamics in designing and optimizing mobile ad-hoc communication systems. Simulation tools like NS2 prove invaluable in protocol performance evaluation under various conditions.

In conclusion, this comprehensive analysis highlights the promise of the Intermediate Node Traffic Sharing Model (INTSM). Its consistent performance across varying node densities positions it as a robust and adaptable choice for optimizing real-world MANETs. As we navigate an interconnected world with evolving communication needs, routing protocol adaptability and reliability remain pivotal for efficient and dependable mobile ad-hoc networks.

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