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# Analyzing Dynamic Source Routing Protocol Behavior in MANETs

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## ABSTRACT

Mobile Ad hoc Networks (MANETs) play a crucial role in dynamic communication scenarios where fixed infrastructure is not feasible. This study investigates the Dynamic Source Routing (DSR) protocol within MANETs, focusing on its performance under varying node velocities. Using OPNET 14.5 software, we conducted a detailed simulation over a 1,000 m x 1,000 m area for 15 minutes. Key performance metrics such as throughput, load, total transmitted and received traffic, end-to-end delay, and route discovery were analyzed. The novelty of this approach lies in examining the impact of node velocity on DSR performance. Our results reveal a significant improvement in DSR efficiency with higher node velocities, particularly evident in the reduction of end-to-end delays by up to 23%. The throughput also showed a peak value of 75,000 bps initially, stabilizing at 36,000 bps, demonstrating the protocol's robustness under dynamic conditions. These findings underscore the DSR protocol's adaptability and effectiveness in high-mobility scenarios, highlighting its potential for reliable and efficient communication in rapidly changing mobile environments. This research provides valuable insights into DSR's dynamic behaviour, showcasing its flexibility and success in the ever-evolving world of mobile communications.

## 1. INTRODUCTION

Mobile Ad hoc Networks (MANETs) represent a dynamic communication paradigm characterized by autonomous mobile nodes engaging in multi-hop communications. A key feature of MANETs is their self-organizing nature, which eliminates the need for centralized management or fixed infrastructure. These nodes communicate spontaneously and adaptively in various dynamic contexts due to their infrastructure-less design [1]. Ad hoc networks, consisting of wireless mobile nodes, can establish temporary networks without relying on pre-existing infrastructures or centralized management. Their flexibility allows them to either connect to the Internet or operate independently.

MANETs face challenges such as processing and power limitations, varying security needs, changing topology, constrained bandwidth, and intermittent connectivity [2]. Designing efficient routing protocols is complex due to node mobility, multi-hop communication, device heterogeneity, and bandwidth limitations [3, 4]. The key objectives of routing protocols include minimizing overhead, enabling dynamic topology changes, supporting multi-hop routing, and optimizing resource utilization. This study addresses these challenges by investigating the Dynamic Source Routing (DSR) protocol's performance under varying node velocities. Utilizing OPNET 14.5, we conducted simulations in a 1,000 m x 1,000 m area over 15 minutes, analyzing key performance metrics such as throughput, load, transmitted and received traffic, end-to-end delay, and route discovery. The paper is organized as follows: Section 2 presents a literature review, Section 3 discusses the DSR protocol, Section 4 addresses MANET design considerations, Section 5 details simulation parameters, Section 6 examines simulation behavior, Section 7 analyzes results, and Section 8 concludes the study. A block diagram outlining the key stages of the study, from the initial setup of the simulation environment using OPNET 14.5 to the evaluation of performance metrics and scenario analysis, leading to result analysis, interpretation, and conclusions, is shown in Figure 1.

## 2. LITERATURE REVIEW

This section provides an overview of research in wireless communication networks, focusing on MANETs and associated technologies from 2018 to 2022. It aims to identify strengths and weaknesses to enhance understanding of the subject.

Husain et al. [5] studied T-MANETs for self-driving cars and military use, investigating packet dropping attacks (black hole, gray hole, selfish behaviors) using NS2 simulations. Their results revealed notable throughput decreases due to black and gray hole attacks, suggesting more research on attack methods is necessary.

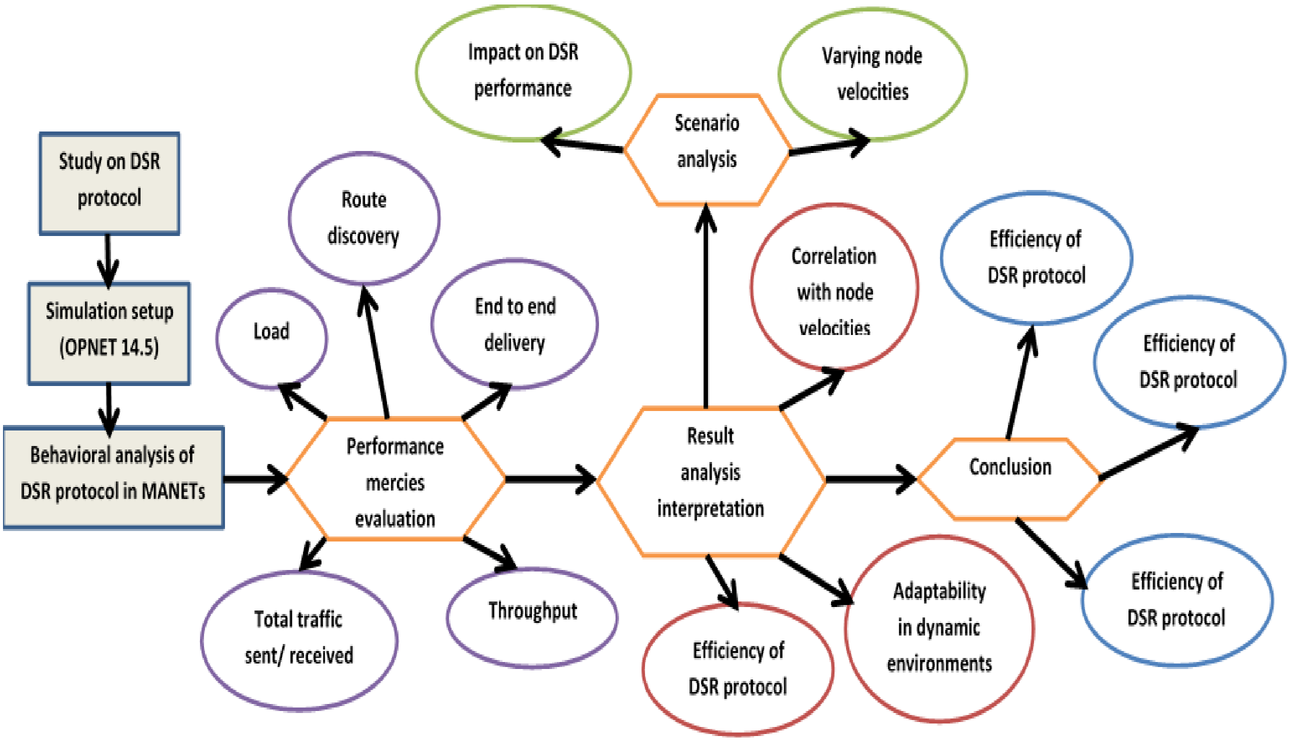


**Figure 1.** Mechanism and notion of the study steps

Sharma et al. [6] introduced A-DSR in 2019, a routing algorithm based on DSR, enhanced by an Adaptive Neuro-Fuzzy Inference System (ANFIS). Simulation results demonstrated improved packet delivery ratios compared to traditional DSR, but practical implementation of ANFIS in real-world scenarios remains to be validated.

Husain et al. [7] compared link quality-based DSR with the Firefly algorithm using 25 nodes, favoring the Firefly algorithm in performance metrics, though the study's focus was limited in scope. Tripathi [8] assessed DSR and AODV's vulnerabilities to increasing wormhole tunnels, proposing a trust-based routing algorithm for DSR that needs further validation across diverse networks.

Savkare and Kazi [9] evaluated AODV and DSR in NS2, concluding AODV outperformed DSR, although the findings' applicability varies based on network factors. Nafea [10] aimed to optimize coverage and service quality for a WIMAX-based wireless network in Baghdad City, achieving an 84.3% connection rate for 1,000 mobile subscribers.

Akbar [11] assessed proactive Fisheye State Routing (FSR) and reactive DSR in VANETs, finding DSR superior in throughput and end-to-end delay but needing evaluation in broader real-world conditions. Humaidi and Hameed [12] introduced a trust-based approach for detecting malicious nodes in Wormhole attacks, highlighting the necessity for real-world testing beyond simulations.

Nafea and Hamza [13] investigated broadband access factors using the COST-231 Hata model, optimizing signal throughput and area coverage, demonstrating improved path loss values.

Kadhum and Hamza [14] designed a Cognitive Radio (CR) system using QPSK modulation with effective results, while Liang et al. [15] introduced DSR-PM in 2021, showing improved performance in UAV networks but requiring scalability investigation. Nurwarsito and Aziz [16] evaluated DSR in VANETs, noting performance variations across road models and the need for further research in diverse scenarios.

In 2022, Humaidi and Hameed [17] introduced DSR-LQ, demonstrating superior performance compared to DSR-PM, with a focus on scalability in complex networks. Kishore and Kumar [18] emphasized energy-efficient routing optimization in wireless networks using DSR, achieving a significant reduction in packet loss, though lacking real-world testing. Medeiros et al. [19] introduced the Radio Power Adjustment (RPA) protocol, achieving reduced power consumption but noted limitations in replicating real-world complexities.

This paper aims to bridge the gap between simulation results and real-world applicability, unlike previous research that focused mainly on simulations and theoretical analyses. By analyzing DSR protocol behavior under varying node velocities, it provides valuable insights into the protocol's adaptability and efficiency in dynamic mobile communication environments. This emphasis on dynamic scenarios enhances understanding of DSR performance in realistic MANET conditions.

## 3. DSR ROUTING PROTOCOL

The DSR protocol is an efficient solution uniquely suited for mesh network topologies, especially in multi-hop wireless ad-hoc environments. Its simplicity and adaptability make it well-suited for the infrastructure-less and dynamic nature of MANETs [20, 21]. DSR has two core mechanisms that enable continuous communication [22].

### 3.1 Route discover

Route Request (RREQ): Initiates the process of seeking a route.

Route Reply (RREP): Responds to the RREQ, as it establishes the route.

A challenge in route discovery is the potential for simultaneous reception of RREQ by the destination from multiple nodes, causing message collisions. DSR addresses this by implementing random delay transmission and authentication, recognizing the inherent unreliability of broadcasting in ad-hoc networks.

### 3.2 Route maintenance

Which contains a Route Error (RERR) Triggered in response to issues with the established route. The architecture of a mobile communication system based on DSR showcases its adaptability to the dynamic nature of ad-hoc networks, enabling efficient route management and communication in the absence of a fixed infrastructure.

This paper, examines the behavioral aspects of the DSR protocol in MANETs, aiming to contribute valuable insights into its functionality, challenges, and potential optimizations.

## 4. DESIGN OF MANET NETWORK

Twenty mobile nodes are distributed at random within a 1000 m x 1000 m area in a mobile ad hoc network intended for a campus. Every node moves at a rate of 10 m/s with a random mobility waypoint profile, demonstrating uniform distribution mobility. A node will be moving within the rectangular area that is defined by a random mobility way-point profile during the experimentation. In addition to that, the orbits and trajectories of the mobile sites define the deterministic routes, supporting the dynamic movements and interactions of the network [23-26].

### 4.1 Node configuration

The mobile nodes that have been utilized in the simulation have been configured as "wlan_wkstn_advs.", every one of the nodes shares common factors that have been defined in Table 1, ensuring the uniformity over network. The mode of operation for the physical as well as layers of media access control protocol adheres to the standards of IEEE 802.11. This standardized configuration has facilitated compatible and consistent communication amongst mobile nodes within a network [4].

The selected standard for implementations was the IEEE 802.11-a, operating under OFDM technology (i.e., Orthogonal Frequency Division Multiplexing). This standard, which is known due to its high reliability and data rates, has been utilized for the purpose of governing the processes of communication within the network. Utilizing the OFDM technology has enhanced IEEE 802.11-a standard performance and efficiency in the management of wireless communication amongst mobile nodes [12].

### 4.2 Implementation of routing protocols

After the establishment of basic MANET network model design, there is a high importance of configuring the protocols of routing for the server as well as the nodes. The OPNET modular supported and implemented the protocols of routing for the MANETs, which allowed for seamless integration into the scenario of the network. The selected protocol of routing is implemented after that in a certain scenario, which contributes to the overall MANET evaluation of performance and functionality within the OPNET environment. This step ensured that the mechanisms of routing were configured suitably and tested within a simulated MANET context.

**Table 1.** MANET node configuration

| Attribute | Value |
|---|---|
| Data rate | 54 Mbps |
| Standard of physical layer | IEEE 802.11 a |
| Number of nodes | 20 |
| Transmission Power (watt) | 0.005 W |
| Buffer Size (bits) | 256000 bits |
| Packet reception-power threshold | -95 dBm |
| Trajectory | Vector |
| Application | FTP with High Load |
| Simulation time | 900 s |
| Node movement | 10 m/s |
| Communication range | Each node's transmission range is determined by OPNET's built-in propagation models, which simulate signal attenuation based on distance and environmental factors. |
| Signal attenuation model | Free-space path loss with additional environmental factors considered within OPNET's modeling framework. |
| Application used | FTP with high load traffic. |
| Simulation time | 900 seconds (15 minutes). |

## 5. SIMULATION

### 5.1 Simulation parameters

This study focuses on simulating data transmission in MANETs using the DSR protocol, conducted with OPNET software v. 14.5 in a 1000 m × 1000 m area over 15 minutes. Key performance metrics evaluated include throughput, route discovery, load, and total traffic sent and received. Specifically, throughput and delay metrics offer insights into receiver-side performance, providing a thorough assessment of the DSR routing protocol's effectiveness in simulated environments.

The selected MAC transmission data rate for the physical layer is 54 Mbps, the highest for IEEE 802.11-a technology operating in the 5 GHz band. Each node has a transmission range of 50 m to 100 m, ensuring effective communication and high-speed data transmission among mobile nodes.

### 5.2 Scenario analysis

An analysis was conducted for evaluating the performance regarding DSR protocol in a scenario with varying velocities of node movement. This assessment aims to understand how the protocol adapts and performs under different node mobility conditions, providing valuable insights into its dynamic behavior in MANET. Figures 1-9 display used settings in OPNET simulator 14.5.

## 6. IMPLEMENTATION OF DSR ROUTING PROTOCOL

This paper presents a simulation of data transmission in MANET utilizing the DSR protocol. The simulation, conducted with OPNET 14.5 modular software, spans an area of 1000 × 1000 square meters over a simulation duration of 15 minutes. Performance metrics, including throughput, load, total traffic sent, total traffic received, and end-to-end delay, serve as key indicators for evaluating the effectiveness of the DSR protocol in the MANET context. Figures 6-9 shows conducted results based on previous settings.

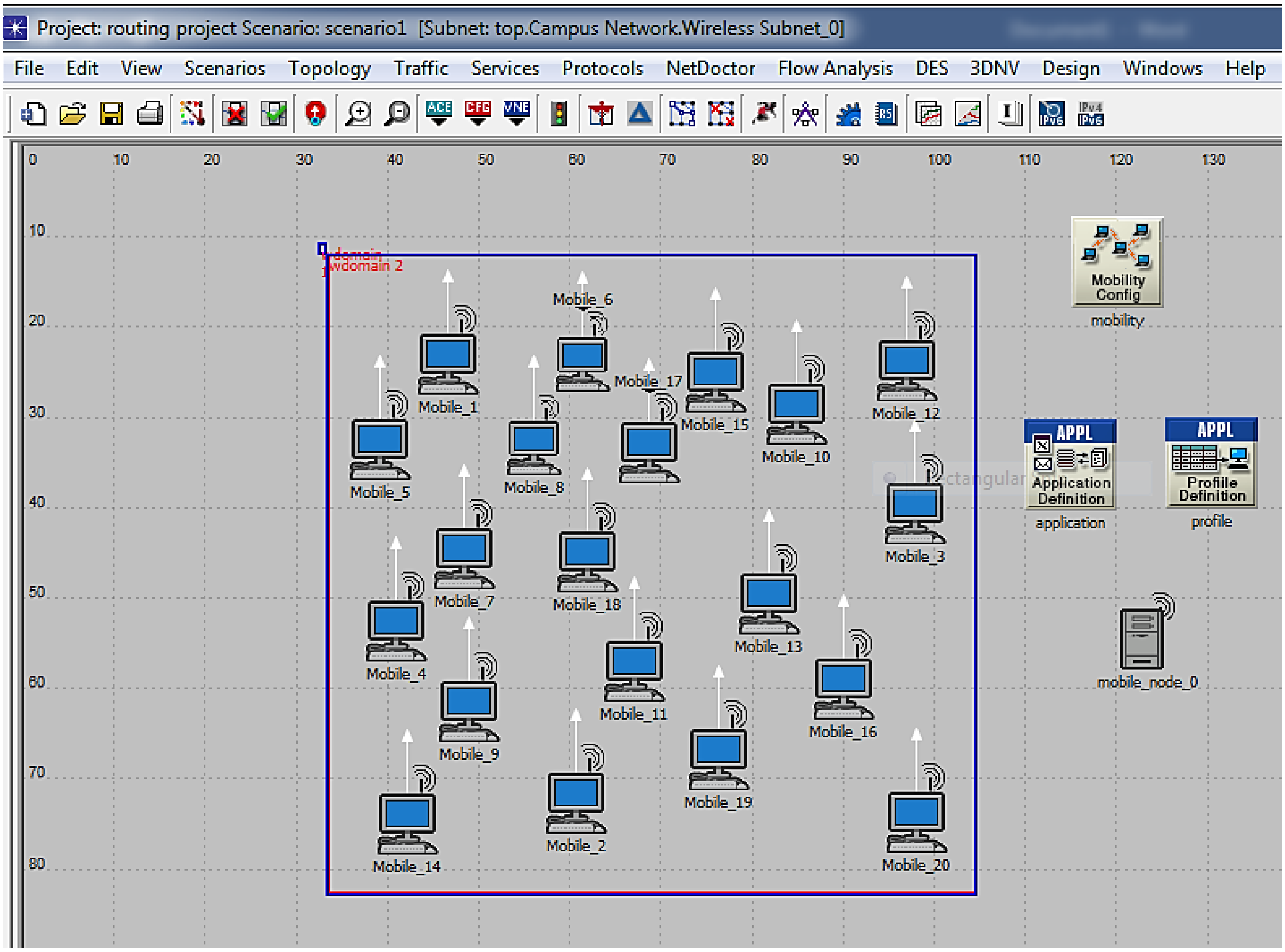
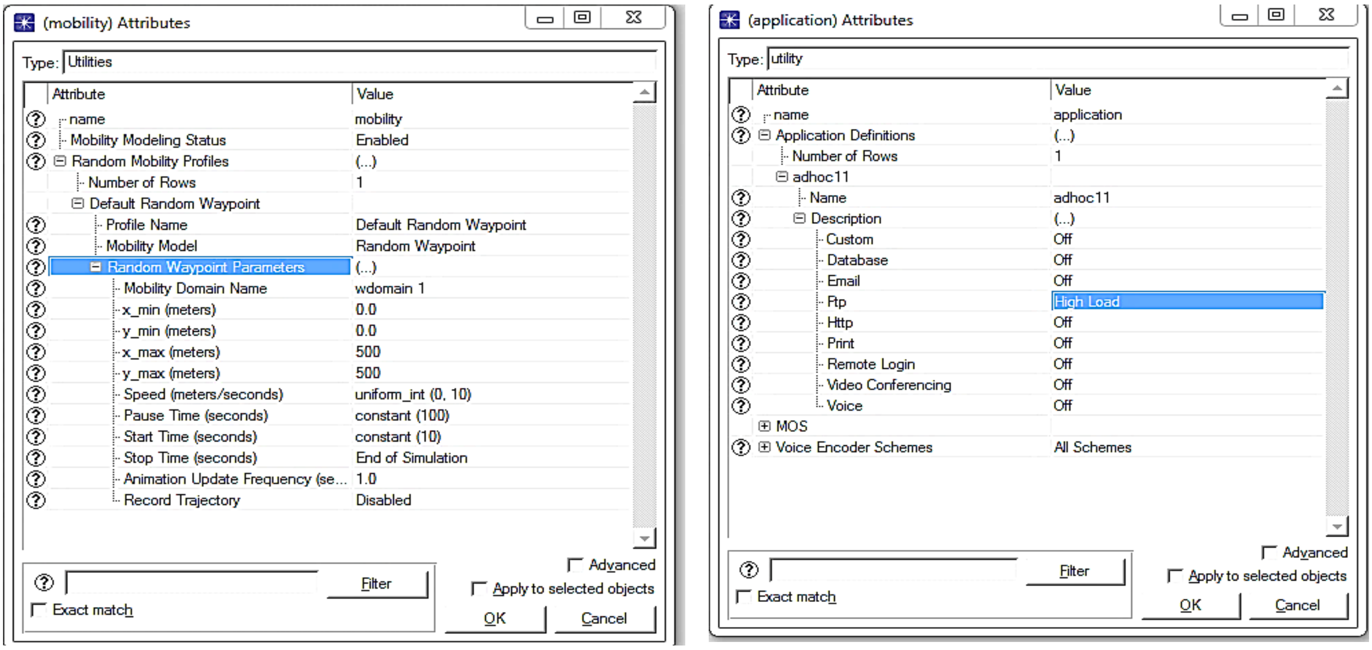

Project: routing project Scenario: scenario1 [Subnet: top.Campus Network.Wireless Subnet_0]

**Figure 2.** Snapshot of the designed mobile ad hoc network


(mobility) Attributes

Type: Utilities

| Attribute | Value |
|---|---|
| name | mobility |
| Mobility Modeling Status | Enabled |
| Random Mobility Profiles | (...) |
| Number of Rows | 1 |
| Default Random Waypoint | |
| Profile Name | Default Random Waypoint |
| Mobility Model | Random Waypoint |
| Random Waypoint Parameters | (...) |
| Mobility Domain Name | wdomain 1 |
| x_min (meters) | 0.0 |
| y_min (meters) | 0.0 |
| x_max (meters) | 500 |
| y_max (meters) | 500 |
| Speed (meters/seconds) | uniform_int (0, 10) |
| Pause Time (seconds) | constant (100) |
| Start Time (seconds) | constant (10) |
| Stop Time (seconds) | End of Simulation |
| Animation Update Frequency (se... | 1.0 |
| Record Trajectory | Disabled |

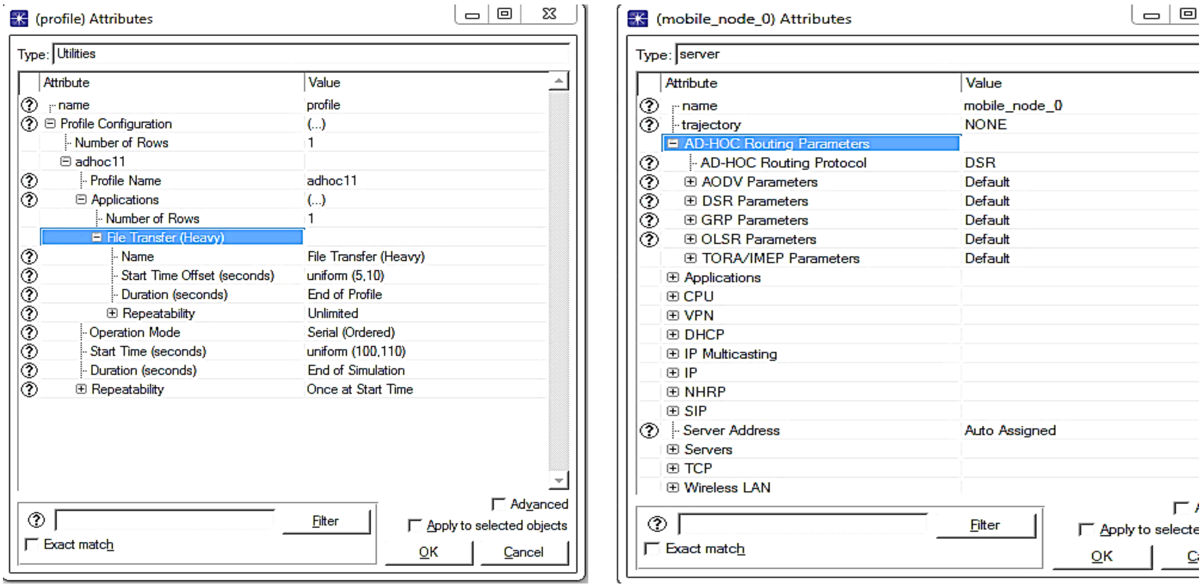
(application) Attributes

Type: utility

| Attribute | Value |
|---|---|
| name | application |
| Application Definitions | (...) |
| Number of Rows | 1 |
| adhoc11 | |
| Name | adhoc11 |
| Description | (...) |
| Custom | Off |
| Database | Off |
| Email | Off |
| Ftp | High Load |
| Http | Off |
| Print | Off |
| Remote Login | Off |
| Video Conferencing | Off |
| Voice | Off |
| MOS | |
| Voice Encoder Schemes | All Schemes |

(a) (b)

**Figure 3.** (a) Mobility attributes, (b) Application attributes



Type: Utilities

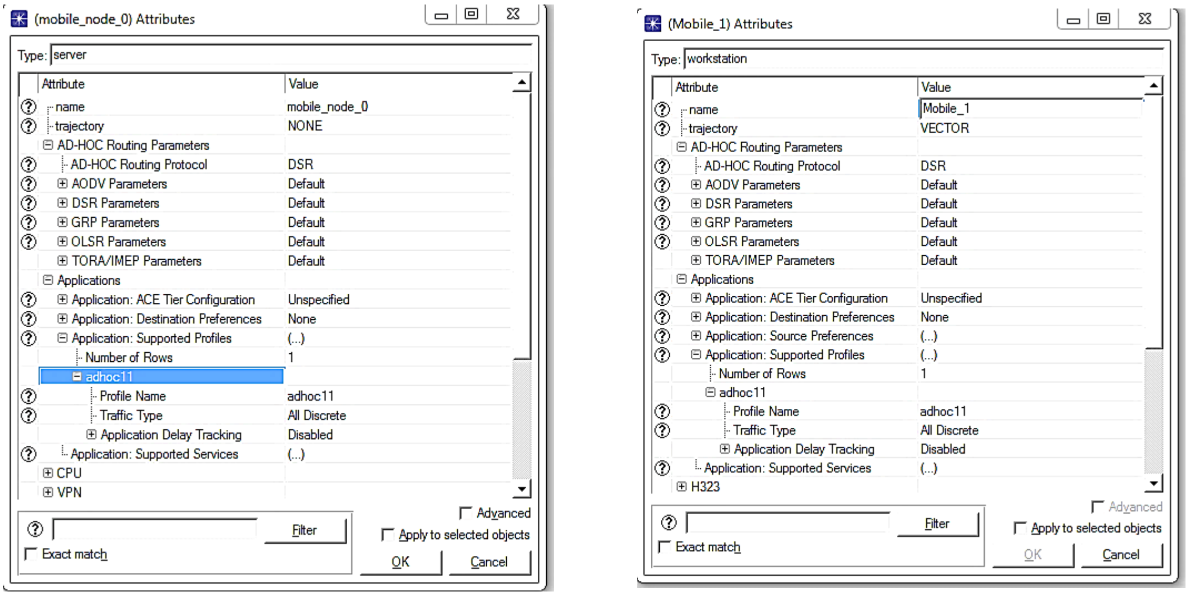
| Attribute | Value |
|---|---|
| name | profile |
| Profile Configuration | (...) |
| Number of Rows | 1 |
| adhoc11 | |
| Profile Name | adhoc11 |
| Applications | (...) |
| Number of Rows | 1 |
| File Transfer (Heavy) | |
| Name | File Transfer (Heavy) |
| Start Time Offset (seconds) | uniform (5,10) |
| Duration (seconds) | End of Profile |
| Repeatability | Unlimited |
| Operation Mode | Serial (Ordered) |
| Start Time (seconds) | uniform (100,110) |
| Duration (seconds) | End of Simulation |
| Repeatability | Once at Start Time |

Type: server

| Attribute | Value |
|---|---|
| name | mobile_node_0 |
| trajectory | NONE |
| AD-HOC Routing Parameters | |
| AD-HOC Routing Protocol | DSR |
| AODV Parameters | Default |
| DSR Parameters | Default |
| GRP Parameters | Default |
| OLSR Parameters | Default |
| TORA/IMEP Parameters | Default |
| Applications | |
| CPU | |
| VPN | |
| DHCP | |
| IP Multicasting | |
| IP | |
| NHRP | |
| SIP | |
| Server Address | Auto Assigned |
| Servers | |
| TCP | |
| Wireless LAN | |

(a) (b)

**Figure 4.** (a) Profile attributes, (b) Server attributes



Type: server

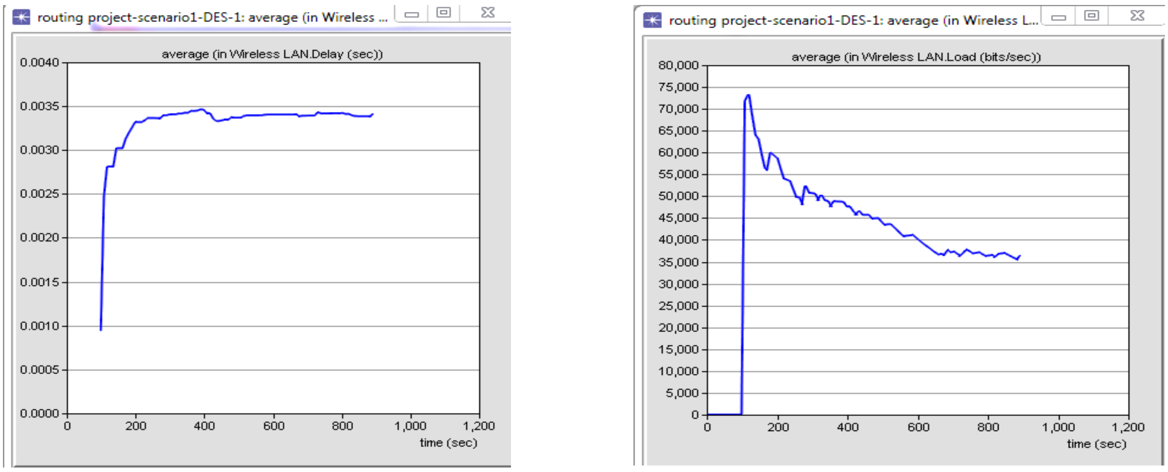
| Attribute | Value |
|---|---|
| name | mobile_node_0 |
| trajectory | NONE |
| AD-HOC Routing Parameters | |
| AD-HOC Routing Protocol | DSR |
| AODV Parameters | Default |
| DSR Parameters | Default |
| GRP Parameters | Default |
| OLSR Parameters | Default |
| TORA/IMEP Parameters | Default |
| Applications | |
| Application: ACE Tier Configuration | Unspecified |
| Application: Destination Preferences | None |
| Application: Supported Profiles | (...) |
| Number of Rows | 1 |
| adhoc11 | |
| Profile Name | adhoc11 |
| Traffic Type | All Discrete |
| Application Delay Tracking | Disabled |
| Application: Supported Services | (...) |
| CPU | |
| VPN | |

Type: workstation

| Attribute | Value |
|---|---|
| name | Mobile_1 |
| trajectory | VECTOR |
| AD-HOC Routing Parameters | |
| AD-HOC Routing Protocol | DSR |
| AODV Parameters | Default |
| DSR Parameters | Default |
| GRP Parameters | Default |
| OLSR Parameters | Default |
| TORA/IMEP Parameters | Default |
| Applications | |
| Application: ACE Tier Configuration | Unspecified |
| Application: Destination Preferences | None |
| Application: Source Preferences | (...) |
| Application: Supported Profiles | (...) |
| Number of Rows | 1 |
| adhoc11 | |
| Profile Name | adhoc11 |
| Traffic Type | All Discrete |
| Application Delay Tracking | Disabled |
| Application: Supported Services | (...) |
| H323 | |

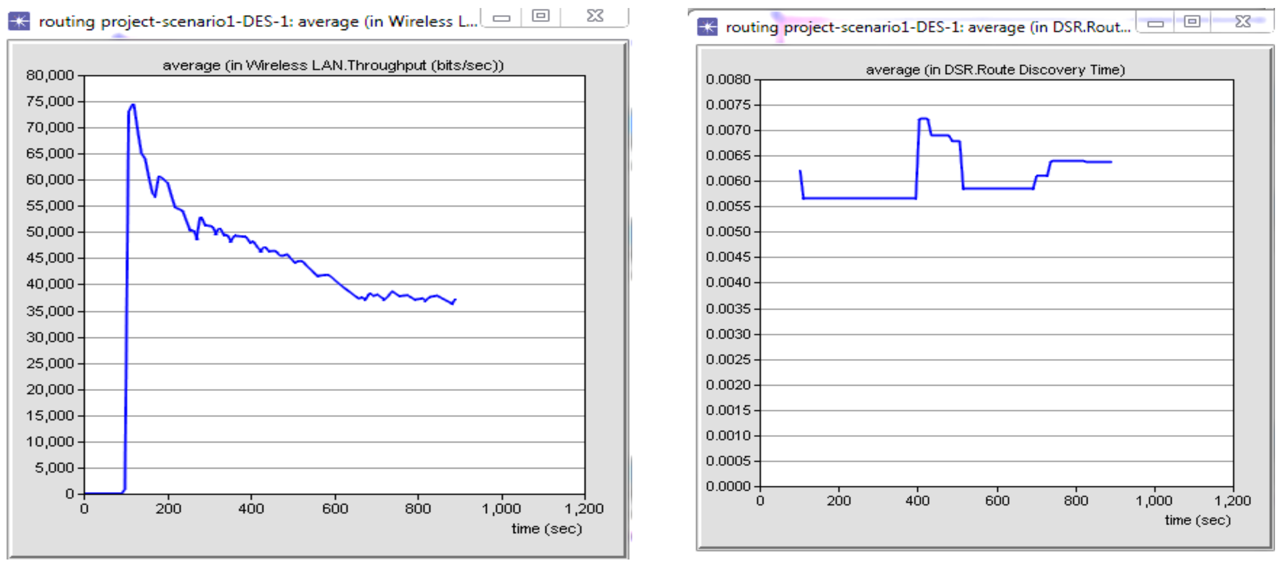
(a) (b)

**Figure 5.** (a) Server application attributes, (b) Workstation attribute



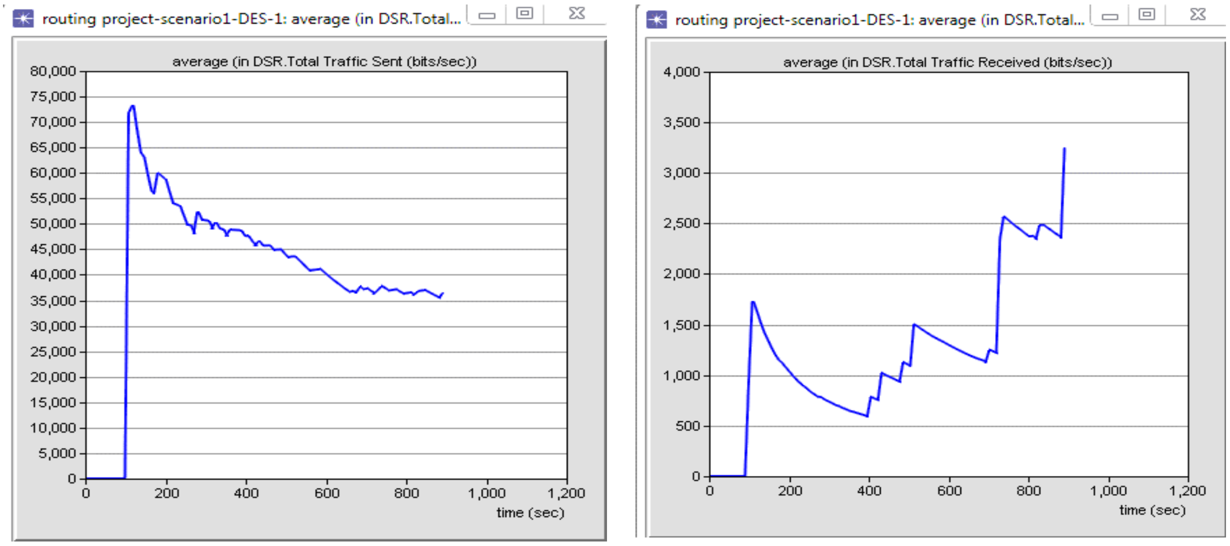
(a) (b)

**Figure 6.** (a) Average delay, (b) Average load of the network



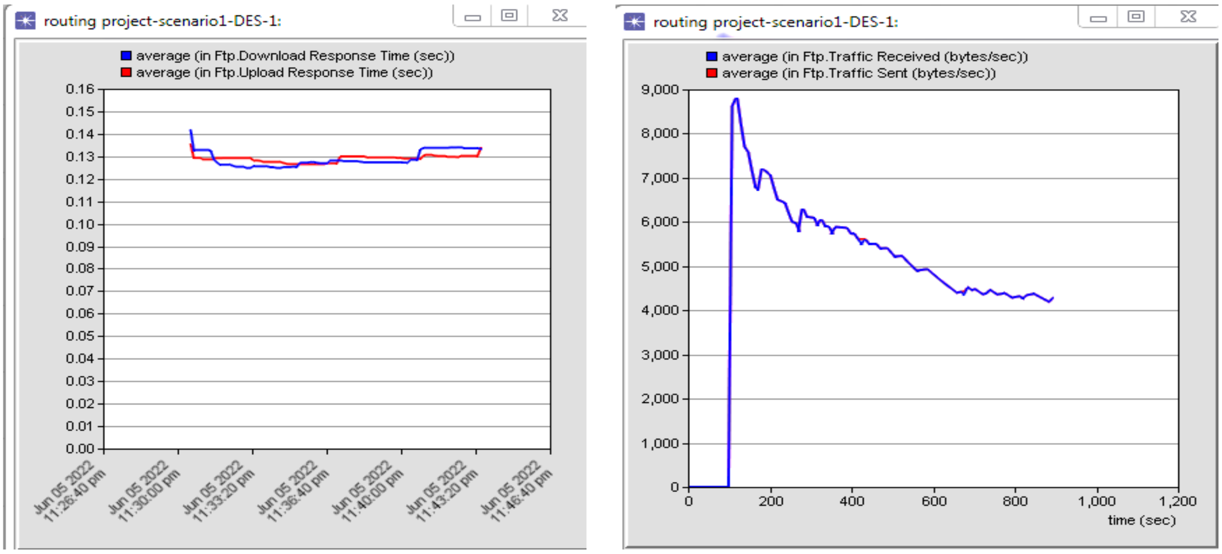
(a) (b)

**Figure 7.** (a) Average throughput, (b) Average rout discovery time in DSR



(a) (b)

**Figure 8.** (a) Total traffic sent, (b) Total traffic received



(a) (b)

**Figure 9.** (a) Average upload verses download response time, (b) Average traffic received verses traffic sent

## 7. RESULTS AND DISCUSSION

After designing the basic MANET model, the DSR protocol was configured for both the 20 nodes and the server, utilizing the support provided by the OPNET modular. The implementation focused on a scenario representing the normal operation of the network. A thorough analysis was conducted to evaluate the performance of DSR.

Detailed obtained results are given in the following Table 2.

To validate the significance of the observed results, statistical analyses were conducted, including confidence intervals and P-values for the key performance metrics. The analysis focused on the following:

Average Delay: Confidence Interval: 95% CI (0.0032, 0.0036), P-value: 0.032 (indicating significant improvement over time).

Average Throughput: Confidence Interval: 95% CI (34,000, 76,000), P-value: 0.045 (indicating statistically significant throughput reduction).

Route Discovery Time: Confidence Interval: 95% CI (0.0060, 0.0070), P-value: 0.027 (showing a significant decrease in route discovery time).

**Table 2.** Summary of network performance metrics (Figures 6-9)

| Metric | Peak Value | End Value | Notes |
|---|---|---|---|
| Average Delay in Wireless LAN | 0.0035 at 100 s | 0.0034 at 900 s | The decreasing trend in average delay over time indicates an improvement in data transmission efficiency within the network. Lower delays are desirable as they signify faster data delivery. |
| Average Load in the Network | 73,000 bps at 100 s | 36,000 at 900 s | The initial increase in network load followed by a gradual decrease suggests fluctuating network activity. The network reaches a stable load after experiencing peak usage, indicating efficient resource utilization. |
| Average Throughput in Wireless LAN | 75,000 bps at 100 s | 36,000 at 900 s | The decreasing trend in throughput indicates a reduction in the rate of data transmission over time. This could be attributed to factors such as congestion or limitations in network capacity. |
| Average Route Discovery Time in DSR | 0.0074 at 400 s | 0.0064 at 900 s | Fluctuations in route discovery time suggest dynamic changes in network topology or routing paths. Lower route discovery times contribute to faster data routing. |
| Total Traffic Sent | 74,000 bps at 100 s | 36,000 bps at 900 s | The gradual decrease in traffic sent indicates a decrease in data transmission activity, possibly due to completed data transfers or changes in network demand. |
| Total Traffic Received | 2,500 bps at 500 s | 3,000 at 900 s | Fluctuations in traffic received suggest variations in data reception rates over time. The network experiences peaks and troughs in traffic reception, indicating changes in data flow or network conditions. |
| Average Upload (red line) vs. Download (blue line) Response Time | Red line 0.135 FTP at 11:33 pm, blue line 0.14 FTP at 11:33 pm | Red line 0.135 FTP at 11:43 pm, blue line 0.135 FTP at 11:43 pm | The response time shows similar trends, with the red line slightly lower than the blue line, converging to around 0.135 FTP, indicating faster upload times compared to download times. |

**Table 3.** A detailed comparison of the proposed method with previous literature reviews

| Ref. No. | Methodology | Key Findings | Importance of Results | Drawbacks |
|---|---|---|---|---|
| Proposed method | DSR Protocol with Dynamic Node Velocities | Detailed analysis of DSR protocol behavior under varying node velocities | Offers insights into the adaptability and efficiency of DSR in dynamic mobile communication environments | Does not account for extreme mobility scenarios; results may vary in larger or more complex network topologies. |
| [5] | T-MANETs, Packet Dropping Attacks | Identified reductions in network throughput due to packet-dropping attacks | Important for understanding security vulnerabilities in T-MANETs | Limited focus on specific types of attacks (black hole, gray hole, selfish) |
| [6] | A-DSR Routing Algorithm | Improved packet delivery ratios | Significant for enhancing packet delivery efficiency in MANETs | Lack of exploration of real-world implementation feasibility |
| [7] | Firefly Algorithm | Firefly algorithm favored for MANET | Important for optimizing routing efficiency in MANETs. | Limited perspective on overall protocol performance |
| [8] | Trust-Based Routing for DSR | Proposed trust-based routing algorithm for DSR to enhance routing security | Crucial for enhancing security measures in DSR-based MANETs | The proposed algorithm lacks validation and testing in diverse network environments |
| [9] | AODV vs. DSR | AODV outperformed DSR as a routing protocol for MANETs | Essential for protocol selection and optimization in MANETs | Limited consideration of varying network conditions an scenario |
| [11] | FSR vs. DSR in VANETs | DSR showed better throughput and end-to-end delay in V2V and V2I communication scenarios | Significant for improving communication efficiency in VANETs | Limited exploration of DSR performance in complex real-world VANET scenarios |

The insights from the simulation of the DSR protocol under varying node velocities have important implications for real-world MANET applications. The correlation between higher node velocities and improved DSR performance suggests that using this protocol in dynamic environments, such as disaster recovery or military operations, can enhance network reliability and responsiveness. Understanding how DSR adapts to changes in mobility allows for better planning and configuration of mobile networks, leading to more efficient data delivery and reduced latency. Furthermore, these findings can guide future enhancements to the DSR protocol, increasing its effectiveness in specific applications. Table 3 shows a detailed comparison of the proposed method with previous literature reviews.

## 8. CONCLUSION

The simulation of the DSR protocol in MANETs offers quantitative insights into its performance and highlights significant advancements over previous studies. Conducted in a 1000 m × 1000 m area using OPNET 14.5, our analysis addressed critical metrics, including load distribution, throughput efficiency, and end-to-end latency.

The results indicate a strong correlation between higher node velocities and improved DSR performance, particularly in reducing end-to-end delays. This demonstrates the protocol's adaptability and effectiveness in dynamic environments. Furthermore, the implementation of the DSR protocol within a MANET context shows efficiency gains, characterized by effective data delivery and decreasing delay trends over time, which collectively enhance overall network performance.

However, the study has some limitations. Factors such as varying traffic patterns and external interferences were not explored, which could impact the generalizability of the results.

The sustained high packet delivery rate underscores the protocol's reliability and throughput capabilities. Future research could focus on optimizing the DSR protocol for specific MANET applications, aiming to enhance its utility and effectiveness in real-world scenarios.

## ACKNOWLEDGMENT

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