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# Comparative Performance Analysis of MANET Routing Protocols under Multi-Application Traffic Using OPNET

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## Abstract

Mobile Ad hoc Networks (MANETs) are considered as a paradigm of infrastructure-less mobile wireless communication systems. MANETs are being widely studied and it is the technology that is attracting a large variety of applications. Routing is a critical issue in MANETs, due to the frequently changing network topology, which requires efficient and dynamic routing protocols. In MANETs, routing protocols are classified into three categories: Proactive protocols, Reactive protocols and Hybrid protocol .

This paper compares the performance of proactive and reactive routing protocols in MANETs by selecting the DSR, AODV and OLSR protocols under multiple network scenarios and sizes using different performance metrics, considering voice, video and file transfer applications. The simulations were conducted using the OPNET Modeller software.

The findings show that the OLSR achieves the lowest delay across all scenarios. While the AODV provides better throughput and network load readings in Small-Scale MANETs and Large-Scale MANETs. Although DSR is considered the least efficient, its performance remains acceptable in Small-Scale MANETs.

**Keywords**: MANETs; OLSR; DSR; AODV; Multi-Application Traffic; OPNET.

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# تحليل مقارن لأداء بروتوكولات توجيه شبكات MANET تحت تأثير حركة مرور متعددة التطبيقات باستخدام OPNET

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**الملخص:**

تُعتبر الشبكات المتنقلة المخصصة (MANETs) نموذجاً رائداً لأنظمة الاتصالات اللاسلكية المتنقلة التي تعمل بدون بنية تحتية ثابتة. وتحظى هذه الشبكات بدراسات واسعة النطاق لكونها تقنية جاذبة لمجموعة متنوعة من التطبيقات. يمثل التوجيه قضية جوهرية في هذه الشبكات نظراً للتغير المستمر في طوبوغرافيا الشبكة، مما يتطلب بروتوكولات توجيه ديناميكية وفعالة. تُصنف بروتوكولات التوجيه في شبكات MANETs إلى ثلاث فئات رئيسية هي: البروتوكولات الاستباقية و البروتوكولات التفاعلية والبروتوكولات الهجينة .

تقارن هذه الورقة بين أداء بروتوكولات التوجيه الاستباقية والتفاعلية في شبكات MANETs وذلك عبر اختيار بروتوكولات DSR و AODV وOLSR تحت سيناريوهات وأحجام شبكات متعددة. وقد تم استخدام مقاييس أداء مختلفة مع الأخذ في الاعتبار تطبيقات نقل الملفات، والصوت، والفيديو. أُجريت عمليات المحاكاة باستخدام برنامج OPNET Modeller.

أظهرت النتائج أن بروتوكول OLSR يحقق أقل معدل تأخير (Delay) في جميع السيناريوهات بينما قدم بروتوكول AODV نتائج أفضل من حيث إنتاجية الشبكة (Throughput) وحمل الشبكة (Network Load) في كل من شبكات MANETs الصغيرة والكبيرة. وعلى الرغم من أن بروتوكول DSR يُعتبر الأقل كفاءة إلا أن أداءه يظل مقبولاً في شبكات MANETs الصغيرة.

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الكلمات المفتاحية: الشبكات المتنقلة المخصصة (MANETs)؛ بروتوكول OLSR؛ بروتوكول DSR؛ بروتوكول AODV؛ حركة مرور تطبيقات متعددة؛ برنامج OPNET.

## 1. Introduction

Ad Hoc wireless networks play the role of a connecting bridge between a group of systems and networks to achieve specific objectives or solve particular problems. These networks are commonly used in restricted environments where access is limited to authorized users. Once an ad hoc network is assigned a specific task, it cannot perform functions beyond its intended purpose [1].
The term "ad hoc" derives from Latin and translates into English as "for this purpose," indicating that the network is designed to fulfill a particular task. More precisely, it refers to a method for making temporary modifications to communication paths in a way that efficiently achieves its intended goals [1]. Based on this, ad hoc networks consist of local wireless networks that allow devices to send and receive data directly without relying on a central point or fixed infrastructure [2].
Routing protocols play a crucial role in enhancing end-user experience and have a significant impact on the overall performance of mobile network applications that rely on MANET as their underlying communication infrastructure.
This paper presents a performance evaluation study of three major routing protocols used in Mobile Ad Hoc Networks MANETs. It seeks to provide network operators and application developers with a detailed analysis of the performance of the DSR, AODV, and OLSR routing protocols based on key metrics, including delay, throughput, and network load.

## 2. Literature Review

Various studies have focused on analyzing the performance of proactive and reactive routing protocols in MANET environments. In an extensive performance analysis, recent studies evaluated multiple MANET routing protocols under dynamic network conditions and revealed that proactive protocols such as OLSR generally achieve lower end-to-end delay due to their periodic route

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maintenance, while reactive protocols like AODV and DSR tend to minimize routing overhead in sparse or highly dynamic scenarios [3].

Al-Hilali et al. (2024) conducted a detailed investigation of MANET performance using OPNET simulation tools, comparing AODV, OLSR, and DSR under different traffic loads. Their results indicated that OLSR outperforms reactive protocols in terms of delay, whereas AODV achieves better throughput and network load performance in certain scenarios [4]. These findings highlight the impact of routing strategy on overall network efficiency.

Other comparative studies have emphasized the influence of node density and traffic patterns on routing performance. Surekha et al. (2022) analyzed multiple routing protocols and reported that OLSR performs efficiently in medium-sized networks, while AODV exhibits better scalability in larger networks [5]. Similarly, Dimantara et al. (2024) showed that DSR generally suffers from higher routing overhead and reduced throughput compared to AODV and OLSR, especially as network size increases [6].

Recent survey-based research has further explored the parameters affecting MANET performance, including node mobility, traffic type, network density, and routing overhead. Eltahlawy et al. (2023) concluded that no single routing protocol can be considered optimal for all MANET scenarios, and protocol selection should be driven by application requirements and network conditions [7].

In addition, enhanced variants of proactive protocols such as MP-OLSR have been evaluated alongside traditional protocols. Khan et al. (2024) demonstrated that multipath routing techniques can improve reliability and throughput, particularly in highly dynamic environments, though at the cost of increased control overhead [8].

Despite extensive research in this domain, most existing studies focus on limited traffic types or single network scales. Therefore, this paper extends prior work by providing a comparative performance evaluation of AODV, OLSR, and DSR under multi-application traffic scenarios (voice, video and file transfer) and varying network sizes using the OPNET simulation environment.

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## 3. Routing Protocols Overview

Routing protocols in MANETs are classified into three categories: proactive, reactive and hybrid. Proactive protocols maintain routing tables with up-to-date paths established in advance. On the other hand, reactive protocols search the route cache for previously used routes and establish paths on demand when data transmission is needed. Hybrid protocols combine features of both proactive and reactive approaches aiming to balance their advantages [2].

### 3.1 Optimized Link State Routing (OLSR)

The Optimized Link State Routing OLSR protocol is a proactive routing protocol based on the periodic exchange of control packets to maintain up-to-date network topology information. It reduces the amount of information transmitted in each message and minimizes the overhead generated by control traffic by limiting the number of network-wide broadcasts. This is achieved through the use of Multipoint Relays (MPRs), which restrict the forwarding of control messages to selected nodes only [9].

MPR nodes in most cases are neighbor nodes that are only two hops away with bidirectional links. Multipoint relays can only re-transmit the received broadcast messages, re-transmission. Nodes that are not MPR normally process the received messages but do not re-transmit the broadcast messages in MANETs [10].

OLSR's proactive nature ensures low latency in route discovery benefiting real-time applications, though it may incur higher overhead in highly dynamic or sparse networks [9][10].

### 3.2 Dynamic Source Routing (DSR)

The Dynamic Source Routing DSR protocol is a reactive routing protocol designed for MANETs. It operates on-demand, using source routing, where the sending node determines the complete route to the destination before transmission.

DSR embeds the full route information including all intermediate node addresses within the packet header. Route discovery collects addresses along the path, which intermediate nodes temporarily store. Packets then follow these learned routes, and optional flow identifiers facilitate hop-by-hop forwarding [1]

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The protocol avoids periodic routing messages by establishing routes only when needed. Nodes broadcast route requests containing the source address, sequence number, and destination ID, while checking their route cache for previously discovered paths. Intermediate nodes append their addresses when rebroadcasting requests, and sequence numbers prevent duplication. This mechanism enables efficient route discovery and packet forwarding in multi-hop wireless networks [1][2].

Ad hoc On-Demand Distance Vector AODV protocol is a reactive protocol that uses a hop-to-hop routing methodology. A route discovery is initiated when a node in the network wants to send a data packet to another node. If an active route is not available AODV initiates the route discovery process with the source node broadcasting a route request message (RREQ) to find a route to the destination [2][9].

Once a valid route is found it is made available by a route reply (RREP) message back to the originator of the RREQ. Once the route is established, the nodes monitor the state of the links continuously. If a link breaks in an active route a route error message (RERR) is sent to the other nodes of the link breakage. This triggers a new route discovery process to maintain reliable communication [2][9].

## 4. Simulation Environment and Methodology

### 4.1 Simulation Tool

The OPNET network simulator is an advanced commercial software for modeling and simulating computer networks and related technologies. OPNET provides a wide range of simulation models for various computing devices, communication environments, and network protocols and technologies. The simulator combines the C programming language with state diagrams to implement simulation models.

OPNET provides a comprehensive environment that supports modeling, simulation, and performance evaluation of various types of networks [7].

### 4.2 Network Model and Mobility Configuration

A wireless Mobile Ad Hoc Network was designed to evaluate the performance of the selected routing protocols under realistic

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operating conditions. The simulated network represents an office-area environment with dimensions of 100 m × 100 m.

Node mobility was modeled using the Random Waypoint mobility model which is widely adopted in MANET performance evaluation studies due to its simplicity and effectiveness in representing random movement patterns [11]. In this model, nodes move toward randomly selected destinations with randomly chosen speeds and pause times. This mobility model allows fair comparison with existing literature and ensures realistic topology variations during simulation.

### 4.3 Simulation Parameters and Scenarios

To investigate the impact of network size on routing performance, three network scenarios were considered:

- Small-scale network: 20 nodes
- Medium-scale network: 40 nodes
- Large-scale network: 80 nodes

Each simulation scenario was executed for a duration of 3600 seconds to ensure steady-state behavior and statistically meaningful results.

To enhance result reliability, each experiment was repeated multiple times using different random seeds, a random seed is a starting point for the sequence of random numbers used in the simulation [12]. By varying the random seeds in each experiment, we ensure that the results are not biased by any specific sequence of random numbers, thereby increasing the robustness and accuracy of the performance evaluation.

All scenarios employed identical network topology, mobility parameters, and traffic configurations, differing only in the routing protocol used.

### 4.4 Traffic and Application Models

Unlike many previous studies that consider a single traffic type, this work models a heterogeneous multi-application MANET environment.

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Three major application types were configured:

- Voice applications
- Video applications
- File Transfer services (FTP)

Application behavior and user activity profiles were configured using OPNET's Application Configuration and Profile Configuration modules to represent realistic traffic patterns and user behavior.
Multiple applications were simultaneously executed on individual nodes, enabling evaluation of protocol performance under mixed traffic conditions.

### 4.5 Routing Protocols and Performance Metrics

Each protocol was tested under identical simulation conditions to ensure fair comparison. Performance evaluation was conducted using the following metrics:

- End-to-End Delay: average time required for data packets to reach the destination
- Throughput: average successful data delivery rate
- Network Load: total traffic offered to the network including routing overhead

These metrics collectively provide insight into Quality of Service (QoS) and network efficiency.

## 5. Results and Analysis

This section presents and analyzes the simulation results obtained from evaluating the performance of AODV, OLSR, and DSR under heterogeneous traffic conditions and varying network sizes. The analysis focuses on three key performance metrics: end-to-end delay, network load, and throughput.
The obtained results are discussed in relation to existing studies to highlight consistencies and differences with prior research findings.

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### 5.1 End-to-End Delay Analysis

The simulation outcomes reveal that OLSR consistently achieves the lowest average end-to-end delay across small, medium, and large network scenarios. This behavior is primarily attributed to its proactive routing mechanism, which maintains up-to-date routing tables and eliminates route discovery latency.

In a Small-Scale MANET, the End-to-End Delay results indicate that the average delay for the OLSR protocol stabilizes at 4.1 s. In contrast, the average delay for AODV increases to 5 s while DSR exhibits the highest delay reaching up to 5.9 s as shown in Figure 1. The delay results in a Medium-Scale MANET showing that the average end-to-end delay of the OLSR protocol stabilizes at approximately 7.5 s, while the average delay of the AODV protocol increases to about 10.8 s. The DSR protocol exhibits the highest delay reaching an average of 11.9 s as shown in Figure 2.

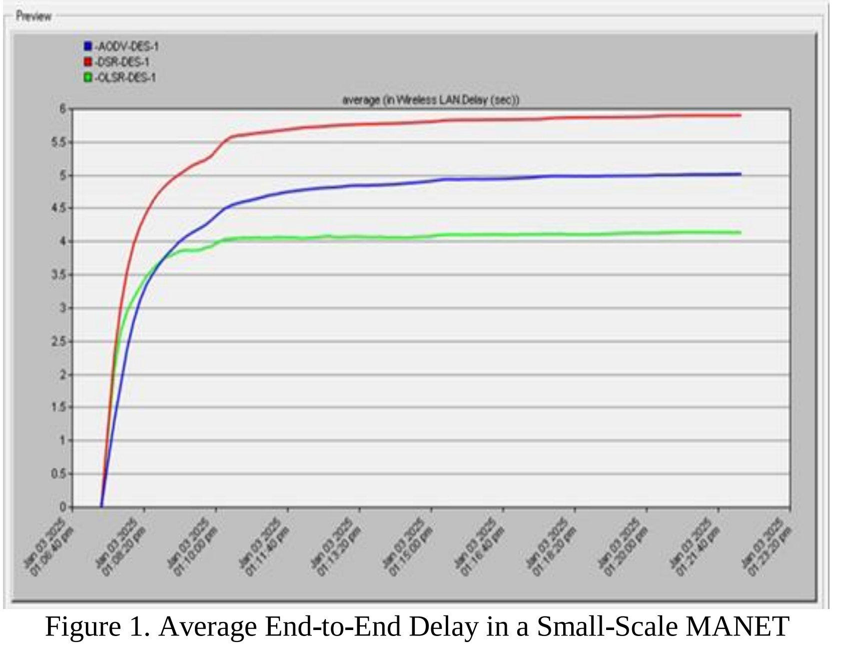


Figure 1. Average End-to-End Delay in a Small-Scale MANET

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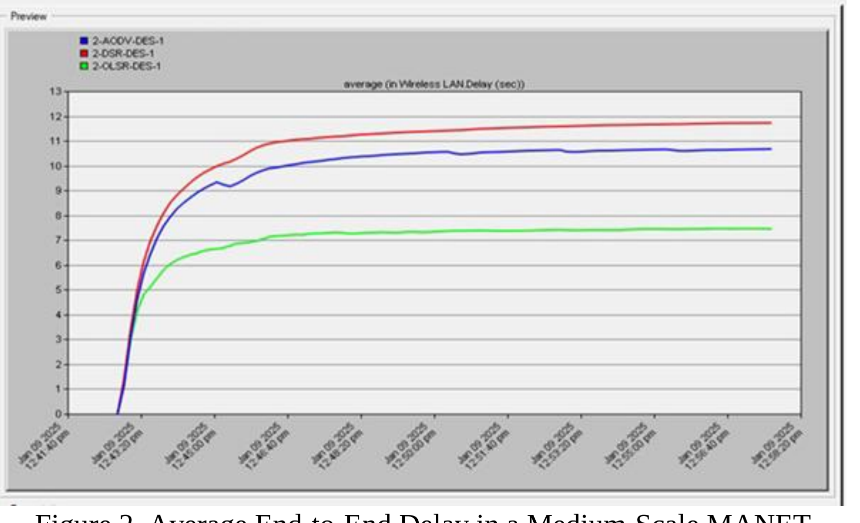


Figure 2. Average End-to-End Delay in a Medium-Scale MANET

In a Large-Scale MANET, the OLSR protocol again excels in terms of End-to-End Delay. As shown in Figure 3 the average End-to-End Delay for OLSR stabilizes at 15 s, while for AODV it increases to 25 s. However, DSR exhibits the highest latency reaching 27.9 s.

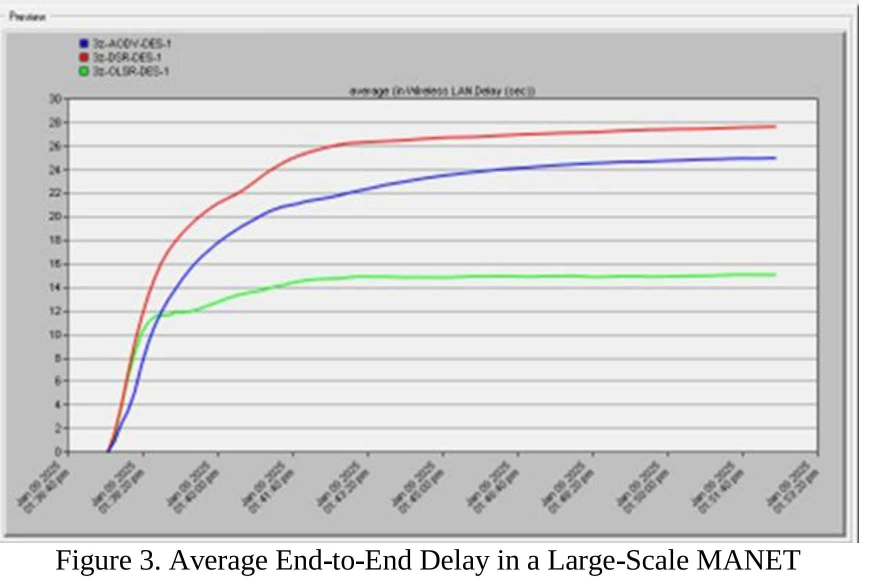


Figure 3. Average End-to-End Delay in a Large-Scale MANET

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The availability of pre-established routes in OLSR enables immediate packet forwarding, thereby minimizing transmission delays especially for real-time applications such as voice and video. These findings are consistent with the observations reported in [3] and [4].

In contrast, AODV exhibits moderate delay performance due to its on-demand route discovery process, which introduces initial latency whenever new routes are required. Although this mechanism reduces unnecessary control overhead, it increases packet delivery time in highly dynamic environments.

DSR records the highest end-to-end delay in all scenarios. This is mainly caused by its source routing mechanism and reliance on route caches, which tend to become outdated in mobile environments. Similar limitations of DSR have been reported in [6] and [8].

### 5.2 Network Load Analysis

Figure 4 shows the comparison between the three protocols in terms of network load in small-scale MANETs. The results show that AODV achieves the lowest network load stabilizing at approximately 18 Mbps, which gives it a clear advantage over OLSR and DSR whose loads stabilize at about 40 Mbps and 70 Mbps, respectively.

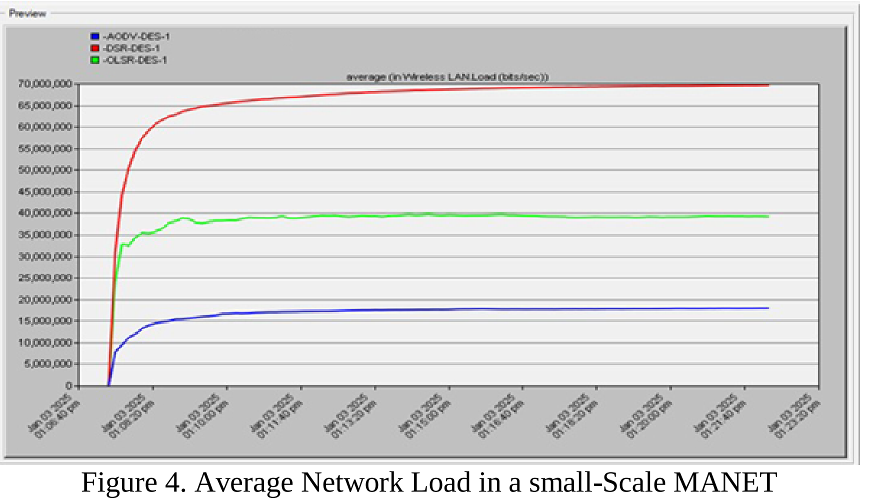


Figure 4. Average Network Load in a small-Scale MANET

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In medium-scale MANETs, the performance trend changes as illustrated in Figure 5. The OLSR demonstrates superior performance with the network load stabilizing at around 51 Mbps compared to 120 Mbps for AODV and 130 Mbps for DSR. This proves that OLSR is more efficient in medium-scale networks.

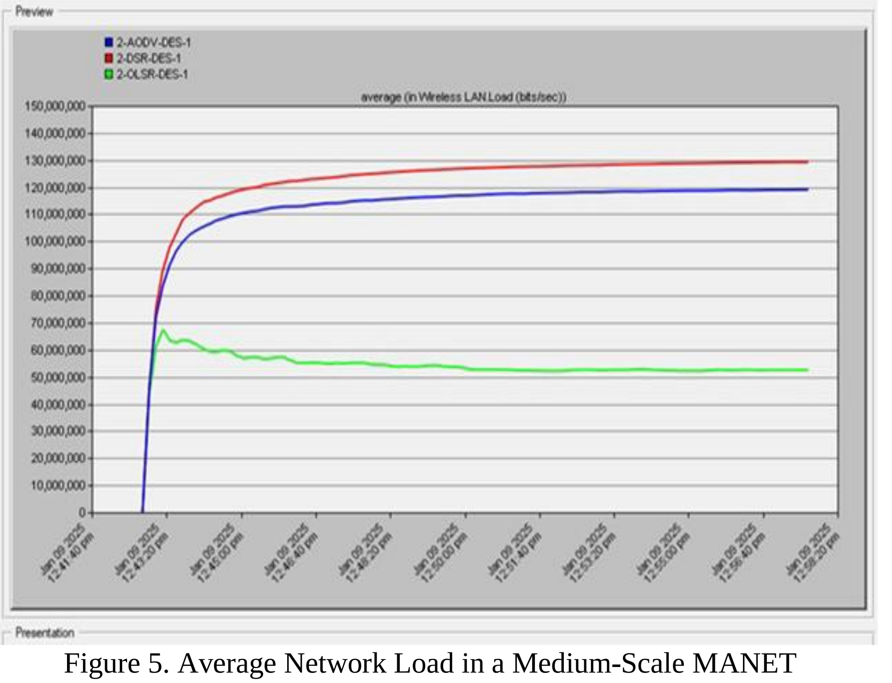

Figure 5. Average Network Load in a Medium-Scale MANET

For large-scale MANETs, the results presented in Figure 6 reveal that AODV again outperforms the other protocols, maintaining a relatively low network load of approximately 41 Mbps. In contrast, OLSR experiences a significant increase in load peaking at 150 Mbps before stabilizing at around 80 Mbps while DSR reaches the highest load of approximately 242 Mbps.

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Figure 6. Average Network Load in a Large-Scale MANET

Overall, the analysis shows that AODV generates relatively lower routing overhead in small and large network scenarios. Its on-demand routing strategy limits control message exchanges to active communication sessions, thereby reducing unnecessary traffic.
However, in medium-sized networks, OLSR demonstrates better performance due to its optimized use of MultiPoint Relays (MPRs), which effectively reduce broadcast redundancy. These findings are consistent with the results reported by Surekha et al. (2022) [5], who emphasized the efficiency of OLSR in medium-density MANET environments.
DSR consistently produces the highest network load across all scenarios. This behavior is mainly attributed to the inclusion of complete routing paths within packet headers and frequent route maintenance operations, which increase routing overhead and negatively impact network efficiency, particularly in large-scale networks, as also observed in [6].

### 5.3 Throughput Analysis

In Small-Scale MANETs, it is observed that the throughput of the AODV protocol rises rapidly to approximately 2.3 Mbps and then stabilizes at this value over time, while the throughput of OLSR stabilizes at 1.79 Mbps, and that of DSR stabilizes at 1 Mbps. These

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results clarify that AODV and OLSR outperform DSR in terms of throughput. Figure 7 illustrates these results.

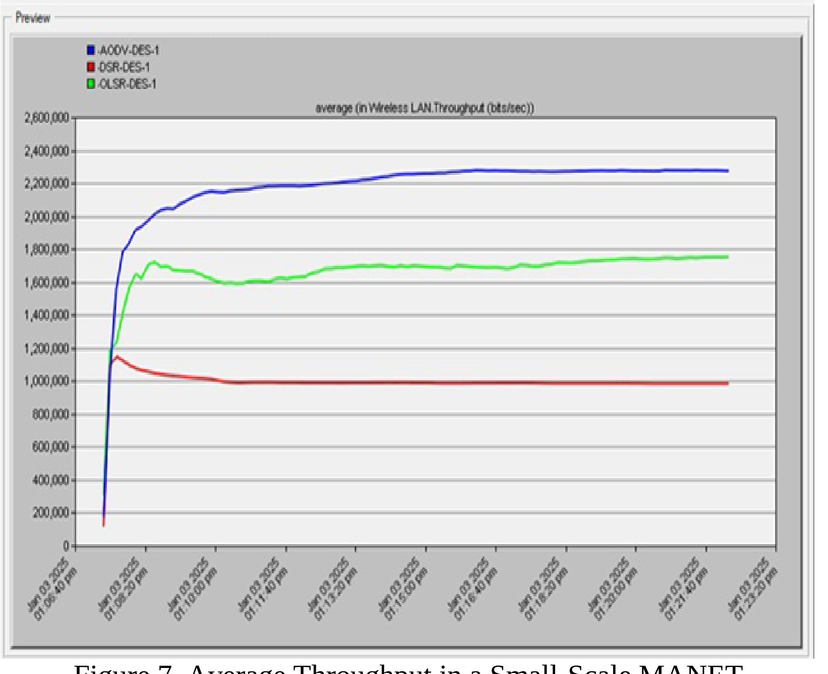


Figure 7. Average Throughput in a Small-Scale MANET

In Medium-Scale MANETs, the throughput of the OLSR protocol rises rapidly to approximately 2.2 Mbps and then stabilizes at this value over time. In contrast, the throughput of the AODV protocol stabilizes at around 1.18 Mbps, while that of the DSR protocol stabilizes at approximately 1.1 Mbps, as shown in Figure 8.

In large networks, the results show that the throughput of the AODV protocol rises rapidly to approximately 11.7 Mbps and then stabilizes at this value over time. Meanwhile, the throughput of the OLSR protocol initially reaches 9.8 Mbps and then decreases to 2.95 Mbps, while the throughput of the DSR protocol stabilizes at 1.1 Mbps. This gives AODV an advantage over the OLSR and DSR as shown in Figure 9. These results confirm the advantage of AODV in large-scale scenarios.

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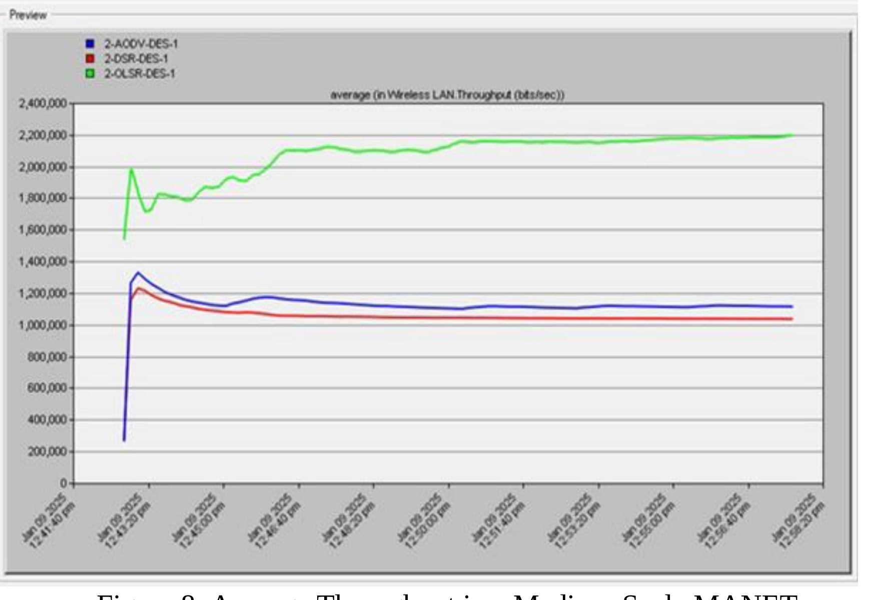


Figure 8. Average Throughput in a Medium-Scale MANET

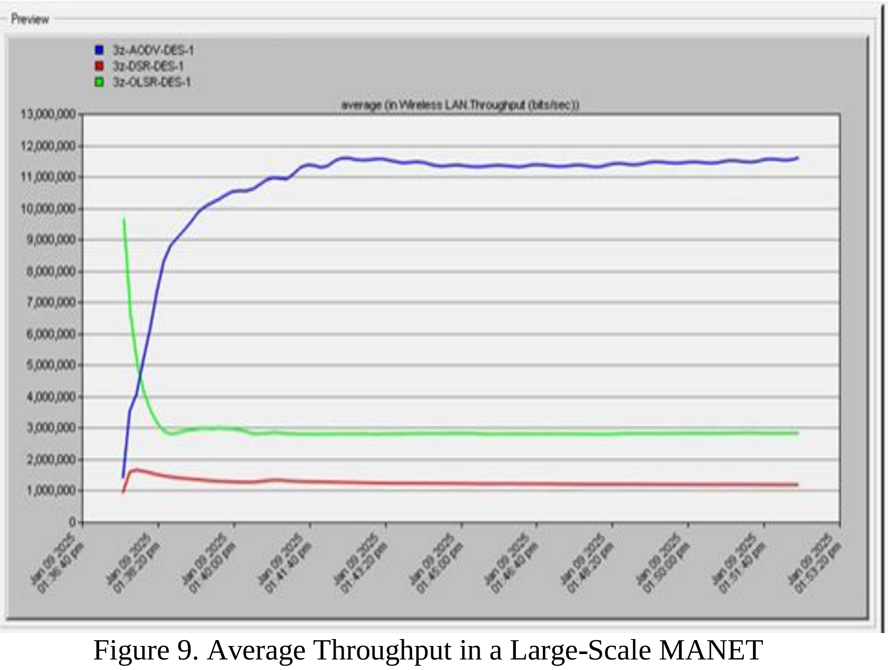


Figure 9. Average Throughput in a Large-Scale MANET

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Overall, the throughput evaluation shows that AODV achieves the highest throughput in small and large network scenarios, reflecting its ability to efficiently utilize network resources under variable traffic conditions.

In medium-sized networks, OLSR achieves superior throughput performance. This is mainly due to the availability of reliable pre-established routes and reduced packet loss resulting from timely topology updates.

Similar trends were reported in [5], where proactive routing protocols demonstrated improved throughput in moderately sized networks.

DSR exhibits the lowest throughput across all evaluated scenarios. The increased packet overhead and inefficiencies in route cache management lead to frequent retransmissions and packet drops, limiting effective data transmission. These findings are consistent with the conclusions presented in [6] and [8].

## 6. Discussion

The OLSR protocol consistently demonstrates the lowest End-to-End Delay across all comparison scenarios. This superior performance is primarily attributed to its proactive nature; by utilizing periodic routing updates, OLSR maintains stable and pre-calculated paths, thereby eliminating the latency typically associated with on-demand route discovery. As illustrated in the simulation results, OLSR maintains the most efficient delay profile across all network sizes (Figures 1, 2, and 3)

On the other hand, the AODV protocol excels in terms of Throughput and Network Load performance, particularly within Small-Scale and Large-Scale MANETs (Figures 7 and 9). This efficiency stems from AODV's dynamic routing mechanism, which enables rapid adaptation to topological changes and effective path establishment in expansive networks. In contrast, OLSR's proactive overhead consumes more network resources, leading to a significantly higher network load, especially as the network scale increases (Figure 6).

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While AODV is superior in throughput and network load performance, particularly in Small-Scale and Large-Scale MANETs, this does not grant it an absolute advantage over OLSR, which maintains lower End-to-End Delay. As shown in the results, OLSR's lower delay makes it more suitable for applications requiring real-time data transmission, such as voice and video, while AODV is a better choice for file transfer applications, where throughput is prioritized.

Both AODV and DSR are reactive protocols that establish routes on-demand. However, AODV clearly outperforms DSR, as its route discovery mechanism is more efficient in adapting to changing network conditions. The DSR protocol, while less efficient, still performs adequately in Small-Scale MANETs, as shown by its throughput in Figure 7.

Finally, the results of this simulation may differ from those of other studies with the same number of nodes, as most existing studies focus on limited traffic types or single network scales. In contrast, this study evaluates the performance of AODV, OLSR, and DSR protocols under multi-application traffic conditions (voice, video, and file transfer) across small, medium, and large network scales, which allows for a broader and more comprehensive assessment of protocol behaviour.

## 7. Conclusion and Future Work

### 7.1 Conclusion

Routing in MANETs remains a major challenge due to the dynamic network topology. Proactive and reactive routing protocols each offer distinct advantages. In this study, AODV demonstrated relative superiority in small-scale and large-scale MANETs with multiple applications, while OLSR showed absolute superiority in medium-scale MANETs across all performance metrics. DSR exhibited the lowest performance in all scenarios. The choice between AODV and OLSR depends on the type of network application, such as voice, video, or file transfer. Although results may vary across different networks due to factors like application type and node mobility, this study provides a useful reference for performance evaluation in multi-application MANETs.

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## 7.2 Future Work

Future work could expand the simulation scenarios to include additional promising routing protocols, allowing a broader comparison of network performance metrics such as throughput and latency and other relevant measures. This study also provides guidance for design teams in selecting equipment for future deployments or experimental environments. Further analysis of other protocols is recommended to explore potential performance improvements. Additionally, the findings of this study could be extended to Internet of Things (IoT) networks to evaluate their compatibility and performance.

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