SIMULATION WITH DIFFERENT AD HOC NETWORK SCENARIOS OF ROUTING PROTOCOLS IN MANETS USING OPNET SIMULATOR

By

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ABSTRACT

Mobile Ad hoc Networks (MANETs) are dynamic wireless networks with no fixed infrastructure, where mobile nodes operate as both hosts and routers. The absence of centralized infrastructure, frequent topology changes, and limited bandwidth resources present challenges for routing. Various routing protocols have been developed to address these challenges, notably AODV, DSR, and OLSR. This study presents a comparative performance analysis of AODV, DSR (reactive protocols), and OLSR (a proactive protocol), using the OPNET Modeler simulation tool. Performance is evaluated under varying traffic loads, network sizes, and node mobility, with FTP traffic used to mimic realistic applications. Key performance metrics include average end-to-end delay and throughput. The results show that throughput improves, and end-to-end delay increases with larger network sizes and higher traffic loads. However, mobility does not significantly impact performance in larger networks. Among the protocols, OLSR shows superior performance in terms of end-to-end delay, while AODV outperforms others in throughput. DSR exhibits inconsistent delay behavior, particularly under heavy load and larger networks.

Keywords: Routing Protocols, Simulation, Ad Hoc Networks, Network Performance, OPNET Simulator.

INTRODUCTION

The rapid evolution of wireless communication technologies has paved the way for the development of Mobile Ad hoc Networks (MANETs), a class of wireless networks that operate without the need for any fixed infrastructure or centralized control. In a MANET, mobile nodes are free to move arbitrarily, and they communicate with each other directly or through intermediate nodes, which act as routers. Figure 1 shows a representation of a MANET, illustrating the dynamic and infrastructure-less nature of such networks. These networks are self-configuring, decentralized, and can be deployed rapidly, making them highly suitable for scenarios such as military operations, disaster recovery, remote sensing, and temporary communication setups where traditional network infrastructure is either unavailable or impractical.

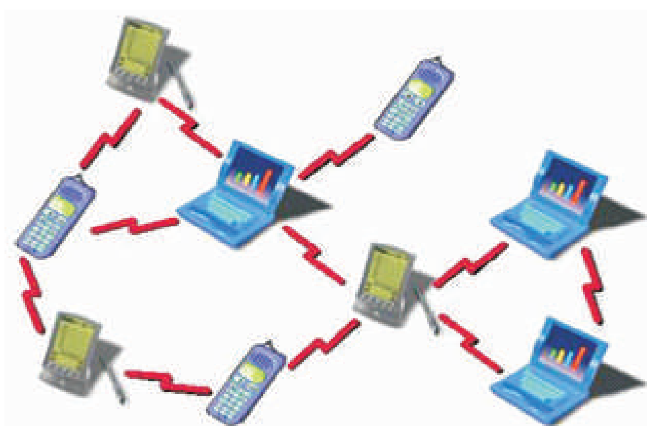

Figure 1. MANET

This paper has objectives related to SDGs

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The inherent characteristics of MANETs, such as dynamic topology, node mobility, constrained battery power, and limited bandwidth, make routing a complex and critical task. In contrast to traditional wired networks, where routing is handled by dedicated routers and infrastructure, in MANETs, each node must also function as a router, forwarding packets on behalf of others. This dual role imposes significant design challenges on routing protocols, especially in maintaining reliable communication and achieving optimal performance under various network conditions.

Mobile Ad hoc Networks the recent advances and the convergence of micro electro-mechanical systems technology, microprocessor hardware and nano technology, integrated circuit technologies, wireless communications, distributed signal processing, Ad-hoc networking routing protocols and embedded systems have made the concept of Wireless Networks popular .Ad-hoc networks are a new paradigm of wireless communication for mobile hosts. Fixed base station is no more a requirement of the wireless network as a base station in mobile switching network.

Routing Challenges in MANETs

Routing in MANETs must address several unique challenges:

- *Dynamic Topology:* Nodes move randomly, leading to frequent path breaks and route rediscoveries.
- *Limited Bandwidth:* Wireless communication offers significantly lower bandwidth than wired networks, increasing the importance of routing efficiency.
- *Energy Constraints:* Mobile devices rely on battery power, so routing protocols must minimize control overhead and conserve energy.
- *Scalability:* The protocol must perform well as the number of nodes increases.
- *Security Risks:* Open wireless communication makes MANETs more vulnerable to various security threats.

These challenges necessitate the design and evaluation of specialized routing protocols optimized for different scenarios and network conditions.

Overview of Routing Protocols

To cope with the dynamic and infrastructure-less nature of MANETs, various routing protocols have been proposed and classified primarily into three categories:

- *Proactive (Table-driven) Protocols:* Maintain up-to-date routing information to all nodes, regardless of communication needs. Example: Optimized Link State Routing (OLSR).
- *Reactive (On-demand) Protocols:* Establish routes only when required by the source node. Examples: Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR).
- *Hybrid Protocols:* Combine the strengths of both proactive and reactive approaches, such as ZRP.

Research Objectives

This research aims to perform a detailed performance evaluation of three widely studied routing protocols, namely AODV, DSR, and OLSR, using the OPNET Modeler, a robust simulation platform. The specific objectives of this study are:

- To evaluate the performance of AODV, DSR, and OLSR under varying traffic loads, network sizes, and mobility patterns using FTP traffic to emulate realistic network usage.
- To analyze the impact of these parameters on key performance metrics, particularly average end-to-end delay and throughput.
- To compare the strengths and weaknesses of reactive and proactive routing approaches under different network conditions.

Scope and Significance

Although there are different MANET routing protocols, the scope of this research is limited to performances analysis and comparison of three popular protocols under varying FTP traffic load, Network size and mobility speed. That is, the focus of the research is to study, analyze and compare the performances of Ad hoc AODV, DSR and OLSR MANET routing protocols by scaling the FTP traffic load levels, network size and mobility speeds. The rationale these three protocols are chosen in this research is first, they are the most popular protocols among the other protocols and second, AODV and DSR represent well known reactive routing protocols whereas OLSR is the most popular protocol from the Proactive routing protocols so that it will also help to investigate the performance differences of reactive and proactive protocols. End to end delay and throughput are used as performance metrics.

This study is limited to evaluating three popular routing protocols but considers a broader range of influencing variables than earlier works. By focusing on:

- FTP traffic instead of CBR,
- Varying node densities (20 to 100 nodes), and
- Different mobility scenarios.

The study attempts to bridge gaps in previous research and offer insights that are more reflective of real-world MANET deployments.

1. Literature Review

Perkins et al. (2003) introduced the AODV Routing Protocol, designed for use in MANETs. AODV is a reactive routing protocol, meaning it establishes routes only when needed, rather than maintaining a complete list of routes at all times like proactive protocols.

Johnson et al. (2007) proposed an RFC that formally specifies the DSR protocol, a reactive routing protocol designed specifically for MANETs operating over IPv4. DSR allows network nodes to dynamically discover and maintain source routes to arbitrary destinations within the network.

Clausen and Jacquet (2003) specified the Optimized Link State Routing (OLSR) protocol in their RFC, describing it as a proactive (table-driven) routing protocol designed for use in MANETs. OLSR continuously maintains up-to-date routing information to all nodes in the network.

Perkins et al. (2002) presented a detailed performance comparison of two major on-demand (reactive) routing protocols for MANETs: AODV and DSR.

Boukerche et al. (2011) provided a comprehensive survey reviewing the design, classification, and performance of various routing protocols for MANETs. The study critically compared proactive, reactive, hybrid, and location-based routing protocols, offering detailed insights into their mechanisms, strengths, and limitations.

Misra and Mandal (2005) conducted a performance comparison between two prominent on-demand (reactive) routing protocols for MANETs: AODV and DSR. The evaluation is conducted using the NS2 (Network Simulator 2) tool, with varying network parameters such as: Node mobility, Network size and Traffic patterns

Jayakumar and Gopinath (2008) evaluated the performance of various MANET routing protocols using the Manhattan Grid Mobility Model, which is particularly suited for simulating movement in urban environments such as city streets and intersections.

OPNET (2013) provided a comprehensive user manual for the OPNET Modeler Wireless Suite, detailing simulation and analysis techniques for wireless networks using one of the most widely used environments for network protocol evaluation.

Sarkar and Paul (2014) conducted a simulation-based comparative study of three routing protocols used in MANETs: AODV, DSR and OLSR. The study uses the FTP application to simulate realistic data traffic and evaluates the protocols based on performance metrics such as:Average end-to-end delay, Throughput and Packet delivery ratio.

Meghanathan (2009) performed a simulation-based performance comparison of proactive and reactive routing protocols used in MANETs. The study primarily focuses on two widely used protocols:

- *Proactive:* OLSR
- *Reactive:* AODV

Kannhavong et al. (2007) provided a comprehensive survey of various routing attacks MANETs. Due to the decentralized and dynamic nature of MANETs, routing protocols are vulnerable to several security threats that can disrupt network operations.

2. Methodology

To evaluate and compare the performance of three widely used MANET routing protocols, AODV, DSR, and

OLSR, this study employs simulation-based analysis using the OPNET Modeler currently referred to as Riverbed Modeler. The methodology adopted aims to replicate realistic network scenarios by simulating varying network sizes, mobility patterns, and traffic loads. FTP traffic is used to reflect real-world application behavior. This study details the simulation setup, design parameters, performance metrics, and the experimental design used in the study.

2.1 Simulation Design

The simulation experiments were designed to examine the effects of three key variables on protocol performance:

- Traffic load through the number of FTP connections,
- Network size in terms of node density,
- Node mobility using a random waypoint model with varying speeds.

Each protocol (AODV, DSR, OLSR) was evaluated under identical conditions for fair comparison.

2.2 Simulation Parameters

Table 1 shows the simulation parameters used for evaluating the performance of MANET routing protocols under varying network conditions.

Parameter	Value
Simulation Time	900 seconds
Terrain Area	1000 m × 1000 m
Node Transmission Range	250 meters
Mobility Model	Random Waypoint
Pause Time	0 seconds (continuous movement)
Traffic Type	FTP (application layer)
Traffic Pattern	Client-Server, Randomized
Number of FTP Sessions	5, 10, 20
Protocols Tested	AODV, DSR, OLSR
Mobility Speeds	0, 5, 10, 15, 20 m/s
Node Densities	20, 40, 60, 80, 100 nodes
Routing Metrics	End-to-End Delay, Throughput

Table 1. Simulation Parameters for MANET Routing Protocol Evaluation

2.3 Simulation Setup

The simulation set up was carried out on OPNET 14.5 Modeler where multiple scenarios of MANETs were designed, simulated and analyzed. The simulations were conducted on different scenarios by varying different key design and simulation parameters where each scenario was particularly designed to study and analyze the impact of a specific network operation condition on the end-to-end performance behavior of MANET routing protocols. Control variables on which the MANET routing protocols are normally optimized such as Traffic load, network size and Mobility speed were considered. The simulation setups for the multiple scenarios, therefore, were categorized as follows:

2.3.1 Impact of Application Traffic load variation

The application traffic generator used was File Transfer Protocol (FTP) whose traffic load was varied in order to see and analyze the effect of traffic load scaling on the end-to-end performance behaviors of the routing protocols. Therefore three different FTP traffic loads were used. They are FTP light load with data size of 1000 bytes, FTP medium load with data size of 5,000 bytes and FTP heavy load with data size of 50,000 bytes. The effect of these FTP traffic load variations were evaluated and analyzed in terms of the performance metrics of end-to-end delay and throughput by deploying a mobile ad hoc network of 30 nodes in a simulation area of 1500 m x 1500 m. The performance behavior of the protocols in terms of delay and throughput as the FTP traffic load varies were therefore analyzed. The simulation terrain area, number of nodes and the mobility speeds were chosen randomly and the same values were used in all the scenarios for consistency.

2.3.2 Impact of Network Size Variation

In this case, the network size was varied by varying the number of mobile nodes deployed in the simulation area of 1500 m x 1500 m in order to assess its impact on the overall performance of the protocols in terms of delay and throughput. Three different sets of networks with network size of 5, 20 and 30 mobile nodes were modeled and deployed in the simulation area. The choice of the network sizes was random. Other network size can also be chosen. But the same values were used in all the scenarios for consistency.

2.3.3 Impact of Mobility Speed Variation

In this simulation scenario, the effect of mobility on the performance of the MANET protocols in terms of delay and throughput was studied and analyzed by varying the mobility speed of the nodes within the simulation area 1500 m x 1500 m. Two different mobility speeds (10 m/s and 20 m/s) were used to investigate the performance effects of mobility speed on the MANET routing protocols.

2.4 Simulation Scenarios and Results

2.4.1 Effect of Traffic Load

Figure 2 shows the effect of traffic load on throughput (kbps), while Figure 3 shows the impact of traffic load on end-to-end delay (ms).

2.4.1.1 Setup

- *Number of Nodes:* 40
- *Mobility Speed:* 10 m/s
- *FTP Sessions:* 5, 10, 20

2.4.1.2 Observations

Table 2 shows the performance of AODV, DSR, and OLSR in terms of throughput and end-to-end delay across different FTP session loads.

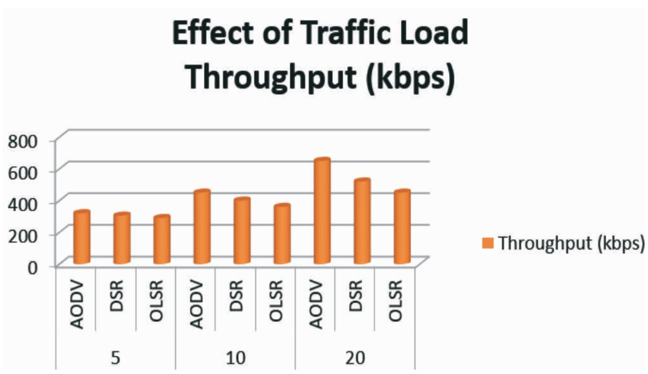

Figure 2. Effect of Traffic Load Throughput (kbps)

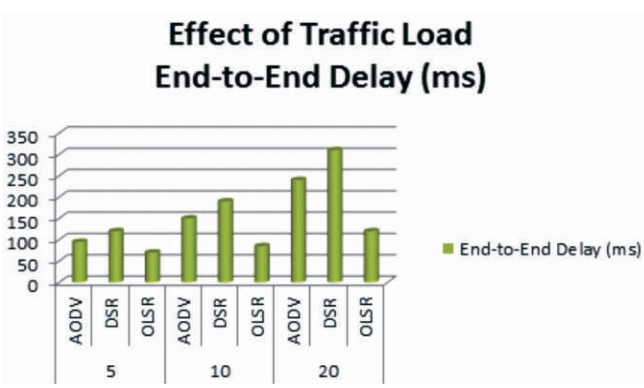

Figure 3. Effect of Traffic Load End-to-End Delay (ms)

FTP Sessions	Protocol	Throughput (kbps)	End-to-End Delay (ms)
5	AODV	320	95
	DSR	305	120
	OLSR	290	70
10	AODV	450	150
	DSR	400	190
	OLSR	360	85
20	AODV	650	240
	DSR	520	310
	OLSR	450	120

Table 2. Performance of Routing Protocols under Varying FTP Sessions

- *AODV:* Throughput increases steadily with higher traffic load, indicating better bandwidth utilization. However, end-to-end delay rises significantly beyond 10 FTP sessions.
- *DSR:* Displays good throughput under light load (5 FTP), but performance degrades under heavier load due to overhead from source routing and cache invalidation.
- *OLSR:* Maintains consistent delay performance, but its throughput increase is more moderate compared to AODV.

2.4.1.3 Analysis

AODV shows the highest throughput across all traffic loads but suffers from increasing delay due to route rediscovery. DSR's caching becomes a bottleneck under high traffic. OLSR excels in maintaining low delay, making it suitable for real-time traffic.

2.4.2 Effect of Network Size

Figures 4 and 5 show the effect of network size on throughput (kbps) and end-to-end delay (ms), respectively.

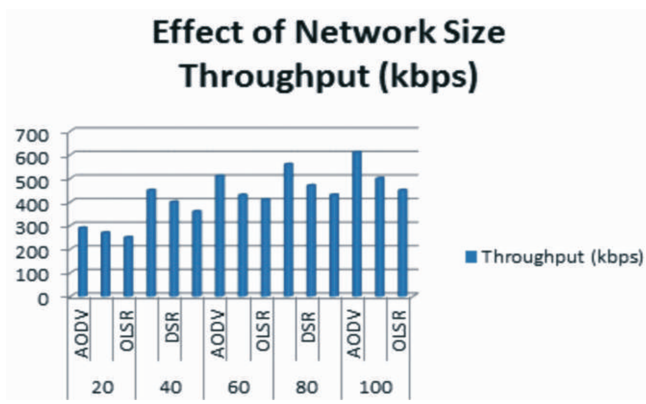

Figure 4. Effect of Network Size Throughput (kbps)

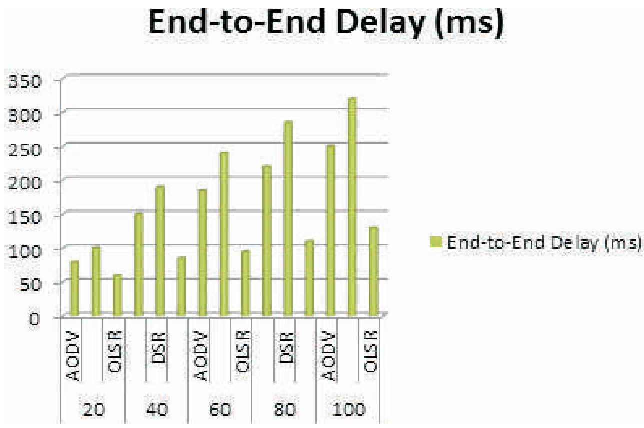

Figure 5. Effect of Network Size End-to-End Delay (ms)

2.4.2.1 Setup

- *FTP Sessions:* 10
- *Mobility Speed:* 10 m/s
- *Nodes:* 20, 40, 60, 80, 100

2.4.2.2 Observations

Table 3 shows the impact of node density on throughput and end-to-end delay for AODV, DSR, and OLSR routing protocols.

- *AODV:* Shows steady throughput gain with increasing nodes due to scalable on-demand routing.
- *DSR:* Initially performs well but fails to scale effectively in larger networks.
- *OLSR:* Throughput grows moderately, while end-to-end delay remains comparatively lower due to proactive route maintenance.

Nodes	Protocol	Throughput (kbps)	End-to-End Delay (ms)
20	AODV	290	80
	DSR	270	100
	OLSR	250	60
40	AODV	450	150
	DSR	400	190
	OLSR	360	85
60	AODV	510	185
	DSR	430	240
	OLSR	410	95
80	AODV	560	220
	DSR	470	285
	OLSR	430	110
100	AODV	610	250
	DSR	500	320
	OLSR	450	130

Table 3. Impact of Node Density on Throughput and End-to-End Delay

2.4.2.3 Analysis

AODV scales well in terms of throughput but incurs higher delay. DSR struggles with scalability due to its route cache mechanism. OLSR remains consistent with low latency, favoring larger, delay-sensitive networks.

2.4.3 Effect of Node Mobility

Figures 6 and 7 show the effect of node mobility on throughput (kbps) and end-to-end delay (ms), respectively.

2.4.3.1 Setup

- *FTP Sessions:* 10
- *Nodes:* 60
- *Speeds:* 0, 5, 10, 15, 20 m/s

2.4.3.2 Observations

Table 4 shows the corresponding performance metrics for different mobility speeds across the evaluated protocols.

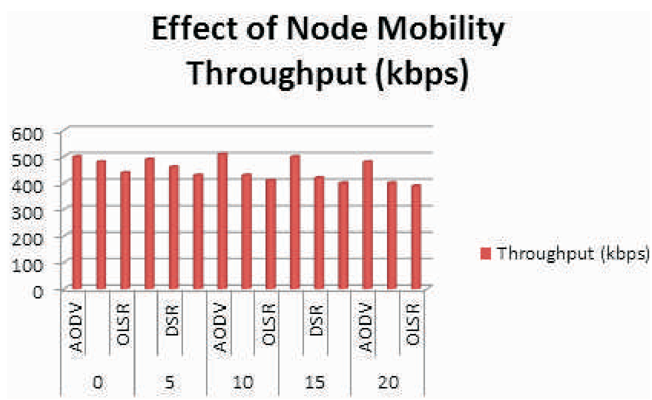

Figure 6. Effect of Node Mobility Size Throughput (kbps)

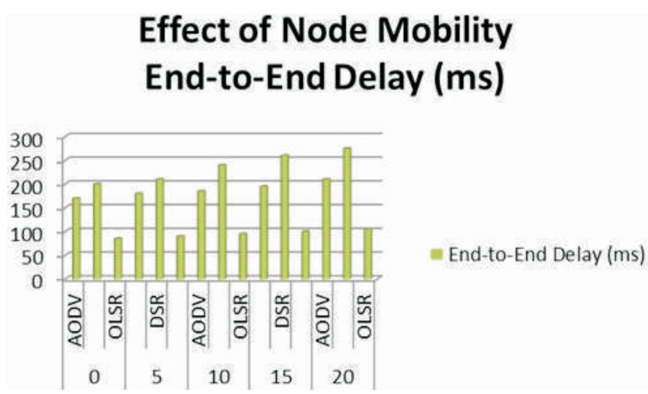

Figure 7. Effect of Node Mobility Size End-to-End Delay (ms)

Mobility (m/s)	Protocol	Throughput (kbps)	End-to-End Delay (ms)
0	AODV	500	170
	DSR	480	200
	OLSR	440	85
5	AODV	490	180
	DSR	460	210
	OLSR	430	90
10	AODV	510	185
	DSR	430	240
	OLSR	410	95
15	AODV	500	195
	DSR	420	260
	OLSR	400	100
20	AODV	480	210
	DSR	400	275
	OLSR	390	105

Table 4. Effect of Node Mobility on Throughput and End-to-End Delay

- *AODV and DSR:* Performance slightly fluctuates with increasing speed, particularly in delay. DSR is most affected due to stale route caches.
- *OLSR:* Minimal impact from mobility due to proactive route computation, especially in larger networks.

2.4.3.3 Analysis

Mobility has lesser impact on throughput compared to traffic and network size. Delay increases slightly for AODV and DSR with speed due to frequent route discoveries and cache invalidations. OLSR remains largely unaffected, indicating robustness in highly mobile environments.

2.5 Summary of Findings

Table 5 shows the strengths and weaknesses of the routing protocols AODV, DSR, and OLSR used in MANETs.

- *Throughput Trends:* AODV > DSR > OLSR in most scenarios.
- *Delay Trends:* OLSR < AODV < DSR.
- *Mobility Impact:* Negligible in larger networks.

Protocol	Strengths	Weaknesses
AODV	High throughput, scalable	Delay increases with load and size
DSR	Low overhead under light load	Poor scalability and high delay in dense networks
OLSR	Consistent low delay, mobility-resilient	Moderate throughput, higher control overhead

Table 5. Strengths and Weaknesses of Routing Protocols in MANETs

Conclusion

MANETs represent a class of wireless networks with unique characteristics such as decentralized architecture, dynamic topology, and node mobility. These features pose significant challenges to the design of efficient and reliable routing protocols. In this research, a comparative performance analysis of three prominent MANET routing protocols AODV, DSR, and OLSR was conducted using the OPNET Modeler simulation tool.

The performance of these protocols was evaluated under varying network conditions including traffic load, network size, and node mobility, using FTP traffic to emulate realistic usage scenarios. The two primary metrics analyzed were average end-to-end delay and throughput.

The simulation results reveal the following key insights:

- AODV consistently achieved the highest throughput across all network scenarios, making it a strong candidate for bandwidth-intensive applications. However, its performance in terms of end-to-end delay deteriorated under heavy traffic and in larger networks due to frequent route discovery processes.
- DSR showed inconsistent and relatively higher delays, especially under high load and mobility conditions. Its source routing and caching mechanisms, while useful in small and low-mobility networks, proved to be a bottleneck in more dynamic environments.
- OLSR outperformed both AODV and DSR in terms of delay performance, particularly in large and moderately mobile networks. Its proactive routing nature and the use of MultiPoint Relays (MPRs) for optimized broadcasting helped maintain low latency, although throughput gains were modest compared to AODV.
- Scalability was better in OLSR scalability with increasing node density due to its proactive routing table maintenance. AODV also scaled reasonably well, whereas DSR struggled significantly as network size increased.
- Mobility had minimal performance impact on OLSR and AODV when the network size was large. DSR, on

the other hand, experienced performance degradation due to stale route caches.

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