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Evaluating Reactive Routing Protocols in MANETs: A Comparative Study of AODV and DSR Using NS-2 Simulation

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Abstract: Mobile Ad Hoc Networks (MANETs) are decentralized, self-configuring wireless networks with dynamic topologies. Routing in MANETs poses significant challenges due to the absence of fixed infrastructure [1], [2]. Reactive routing protocols such as Ad hoc On-Demand Distance Vector (AODV) [3] and Dynamic Source Routing (DSR) [4] are widely used for their efficiency in dynamic conditions. This paper presents a comparative analysis of AODV and DSR using NS-2 simulation [15] based on key performance metrics: Packet Delivery Ratio (PDR), End-to-End Delay (E2E Delay), Throughput, and Routing Overhead. The study evaluates protocol performance under varying node densities and mobility patterns, providing insights into their strengths and limitations [5], [6]. The findings from the simulation provide a nuanced understanding of the suitability of each protocol for different application scenarios and network environments.

Keywords: MANET, AODV, DSR, Reactive Routing Protocols, NS-2, Packet Delivery Ratio, End-to-End Delay, Throughput, Routing Overhead

1. Introduction

Mobile Ad Hoc Networks (MANETs) are a class of wireless networks that operate without the need for any fixed infrastructure or centralized administration [1]. Each node in a MANET functions both as a host and a router, making routing a crucial and complex task due to factors such as dynamic topology changes, bandwidth constraints, and energy limitations [2], [10]. These networks are particularly useful in scenarios where conventional networks are infeasible, such as disaster recovery, military operations, and remote sensing [1]. Routing in MANETs is generally categorized into proactive, reactive, and hybrid protocols [2]. Reactive protocols are favored in highly dynamic environments because they establish routes only when needed, minimizing unnecessary overhead [3], [4]. Among the reactive protocols, AODV and DSR are the most prominent [5], [6]. This paper seeks to provide a comprehensive comparative evaluation of these two protocols through extensive simulation using NS-2 [15], focusing on critical performance metrics under diverse network conditions.

2. Related Work

A substantial body of research has examined the performance of routing protocols in MANETs, focusing on various metrics and network configurations [10], [13]. Perkins et al. [3] introduced the AODV protocol, emphasizing its ability to maintain loop-free routes through the use of sequence numbers. Johnson et al. [4] developed DSR, which uses source routing and route caches to improve routing efficiency. Das et al. [5] provided one of the earliest comparative analyses between AODV and DSR, highlighting their respective strengths and weaknesses. Subsequent studies by Singh et al. [6] and Gupta et al. [7] expanded this work by incorporating additional parameters such as node mobility and traffic load. However, many of these studies lack consistency in simulation environments and do not cover a broad range of node densities and mobility patterns [9], [12]. This gap underscores the need for a methodical and updated comparison using standardized tools like NS-2 [15] to draw reliable and generalizable conclusions about protocol performance.

3. Reactive Routing Protocols in MANETs

3.1 Ad hoc On-Demand Distance Vector (AODV)

AODV is a reactive routing protocol designed for use in ad hoc mobile networks [3]. It establishes routes only when they are required by source nodes, thus minimizing the overhead associated with maintaining unused routes. When a node wishes to communicate with another node, it broadcasts a Route Request (RREQ) message throughout the network. Intermediate nodes may respond with a Route Reply (RREP) if they have a valid route to the destination. AODV uses sequence numbers to ensure the freshness of routes and to prevent loops, which enhances route accuracy [3], [14]. The protocol maintains a routing table with the next-hop information for each destination, which reduces routing complexity. AODV is particularly effective in networks with moderate to high mobility, where maintaining consistent routes can be challenging [5], [7]. However, its reliance on periodic route discovery can lead to initial delays, which may affect performance in time-sensitive applications [6].

3.2 Dynamic Source Routing (DSR)

DSR is another prominent reactive routing protocol for MANETs that employs source routing [4]. In this protocol, the sender determines the entire route to the destination and includes this information in the packet headers. This eliminates the need for up-to-date routing tables at intermediate nodes. DSR also uses route caches aggressively to store learned routes, which can be reused for subsequent transmissions, reducing the frequency of route discoveries [5], [6]. This caching mechanism makes DSR highly efficient in networks with low mobility or stable topologies. However, as the number of nodes and path length increases, the size of the packet header also grows, potentially leading to higher transmission delays and reduced scalability [7], [8]. DSR is suitable for small to medium-sized networks and scenarios where minimizing routing overhead is critical. Nonetheless, it may perform suboptimally in highly dynamic environments due to outdated cached routes [9].

4. Simulation Setup

4.1 Simulation Environment

To evaluate the performance of AODV and DSR, simulations were conducted using NS-2.35, a widely used discrete event network simulator [15]. The simulation environment was configured with a topology size of 1000 meters by 1000 meters to simulate a realistic ad hoc network area. The number of nodes varied from 20 to 100 to study the impact of network density [7], [13]. The Random Waypoint Mobility Model was employed, where nodes move randomly with speeds ranging from 1 m/s to 20 m/s and pause times varying between 0 and 100 seconds [12]. This model effectively represents node mobility in real-world scenarios. Constant Bit Rate (CBR) traffic over UDP was used to simulate data transmission, with a packet size of 512 bytes and a rate of 4 packets per second [14]. The simulation duration was set to 200 seconds, which is sufficient to observe steady-state behaviors of the protocols under different conditions [15].

4.2 Performance Metrics

The protocols were evaluated using four key performance metrics:

- **Packet Delivery Ratio (PDR)**: This metric measures the success rate of packet delivery by calculating the ratio of data packets successfully received at the destination to those sent by the source [5], [7].
- **End-to-End Delay**: This is the average time taken for a packet to traverse the network from source to destination, including delays caused by route discovery, queuing, and retransmissions [6], [8].
- **Throughput**: Throughput refers to the total amount of data successfully delivered to the destination per unit time, typically measured in kbps [6], [13].
- **Routing Overhead**: This metric assesses the efficiency of a protocol by measuring the ratio of routing control packets to the total data packets delivered [5], [7].

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5. Results and Discussion

5.1 Packet Delivery Ratio (PDR)

AODV consistently delivers a higher PDR than DSR, especially as node density and mobility increase [6], [7]. The primary reason for this is AODV's use of sequence numbers, which ensures that only the freshest routes are used [3]. DSR, on the other hand, heavily relies on cached routes, which can become outdated quickly in highly mobile environments, leading to packet drops [4], [5]. In scenarios with fewer nodes and lower mobility, both protocols perform comparably, with DSR sometimes outperforming due to its efficient caching [6]. However, as network conditions become more dynamic, AODV's mechanism for continuously updating and validating routes proves more robust [7], [8].

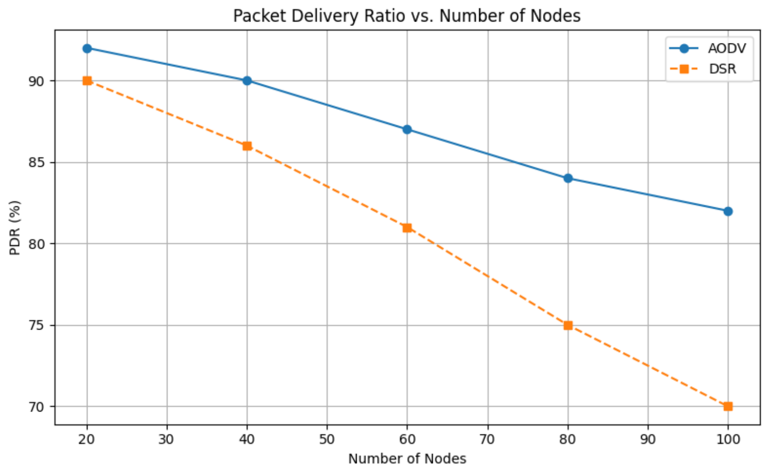

Figure 1: Comparison plotting graph of Packet Delivery Ratio (PDR) Vs Number of Nodes

5.2 End-to-End Delay

End-to-End Delay is a critical factor for time-sensitive applications. AODV exhibits consistently lower E2E delay compared to DSR across all tested scenarios [5], [9]. This is primarily due to AODV's ability to quickly establish valid paths through its route discovery mechanism and maintain them using periodic hello messages [3]. DSR's delay increases significantly in high-mobility environments due to the time taken to resolve broken routes and the reliance on stale cached paths [6], [8]. The larger packet headers in DSR due to source routing contribute to increased transmission and queuing delays [4], [5].

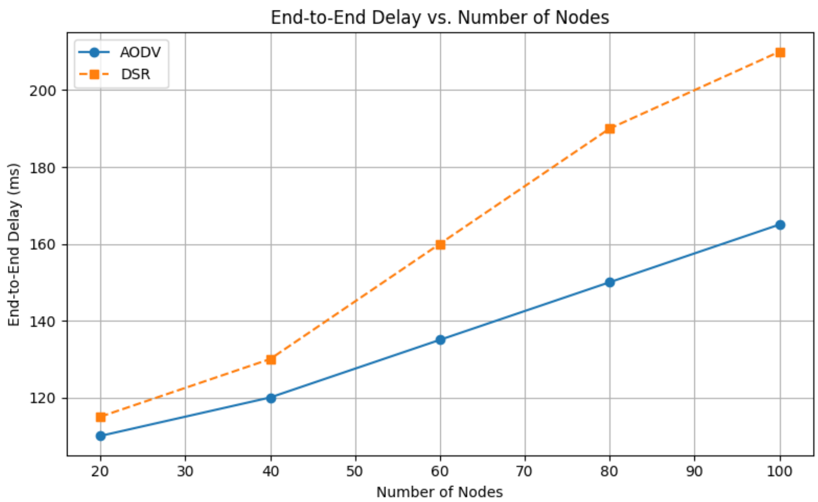

Figure 2: Comparison plotting graph of End-to-End Delay Vs. Number of Nodes

5.3 Throughput

Throughput analysis reveals that AODV outperforms DSR in high-density and high-mobility scenarios [7], [13]. This is largely attributed to AODV's robust route maintenance and the use of fresh routes, which reduces packet loss and increases data delivery rates [3]. In contrast, DSR's performance suffers when routes become stale, necessitating frequent rediscovery [4], [5]. At lower node densities and minimal mobility, both protocols achieve comparable throughput, with DSR sometimes showing slightly better performance due to reduced control traffic [6].

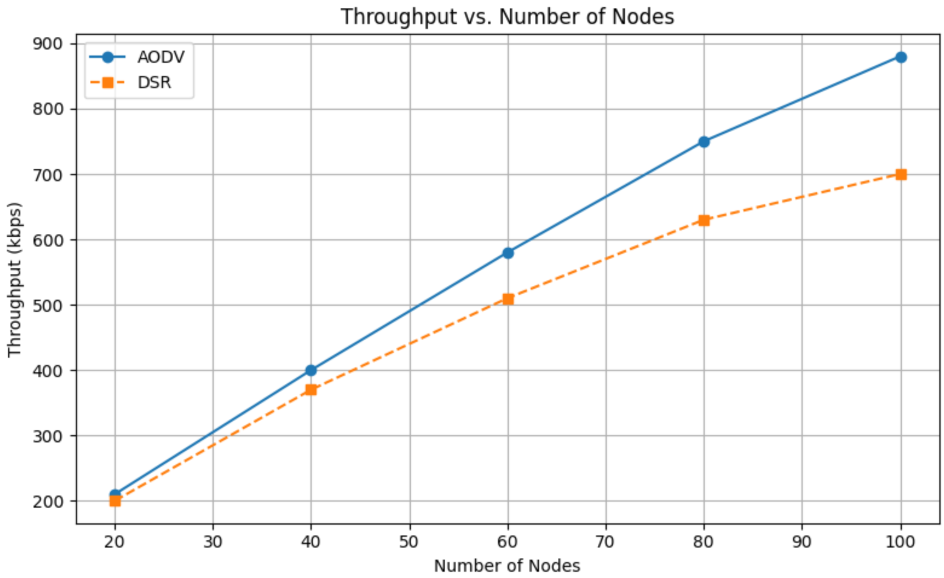

Figure 3: Comparison plotting graph of Throughput Vs Number of Nodes

5.4 Routing Overhead

Routing Overhead is a measure of the control traffic required to maintain routing paths in the network. DSR generally produces lower overhead in low-density and low-mobility environments because of its efficient use of route caching and absence of periodic messages [4], [5].

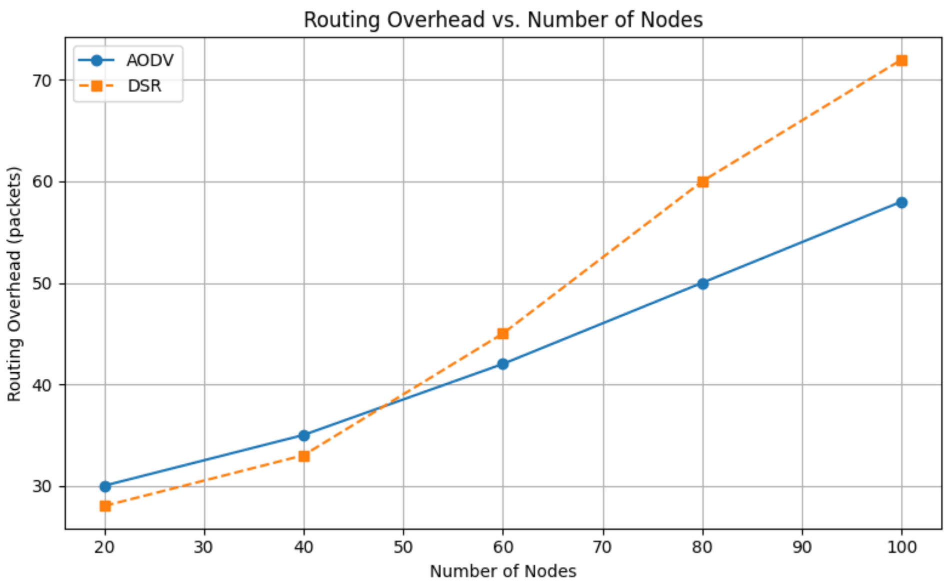

Figure 4: Comparison plotting graph of Routing Overhead Vs Number of Nodes

However, in high mobility scenarios, the overhead increases due to frequent route discoveries triggered by invalid cached paths [6], [7]. AODV, while generating more control traffic initially through its periodic hello messages, becomes more efficient as network dynamics increase [3], [14].

6. Conclusion

This study offers a detailed performance comparison between AODV and DSR using the NS-2 simulator under various network conditions. The results indicate that AODV generally outperforms DSR in terms of Packet Delivery Ratio, End-to-End Delay, and Throughput, especially in networks with high node mobility and density [6], [7]. On the other hand, DSR demonstrates lower Routing Overhead in relatively stable networks due to its aggressive route caching and source routing features [5], [9]. Therefore, AODV is more suitable for applications requiring high reliability and low latency in mobile scenarios, while DSR may be preferable in energy-constrained or low-mobility applications. Future work can extend this comparison by including hybrid protocols and evaluating additional metrics like energy consumption and jitter [11], [14].

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