PERFORMANCE COMPARISON OF PROACTIVE AND REACTIVE ROUTING PROTOCOLS IN MOBILE AD-HOC NETWORKS USING MACHINE LEARNING TECHNIQUES

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ABSTRACT: *This study presents a comparative analysis of proactive and reactive routing protocols in Mobile Ad-Hoc Networks (MANETs), utilizing simulations to assess their performance across various network scenarios. We evaluated four prominent protocols—Destination-Sequenced Distance Vector (DSDV), Optimized Link State Routing (OLSR), Ad hoc On-Demand Distance Vector (AODV), and Dynamic Source Routing (DSR)—based on metrics including throughput, end-to-end delay, packet loss, and routing overhead. Our results indicate that AODV consistently delivers the highest throughput and lowest routing overhead but experiences higher packet loss and end-to-end delay. Conversely, OLSR provides the lowest packet loss and end-to-end delay at the expense of increased routing overhead. DSDV shows moderate performance across most metrics but lags in throughput and packet delivery efficiency compared to AODV and OLSR. This comparative evaluation underscores the trade-offs between proactive and reactive approaches, highlighting the importance of selecting a routing protocol that aligns with specific network conditions and performance requirements.*

INTRODUCTION

Mobile Ad-Hoc Networks (MANETs) are decentralized wireless networks composed of mobile nodes that communicate with each other without relying on a fixed infrastructure. These networks are particularly valuable in scenarios where establishing a traditional network is impractical, such as in disaster recovery operations, military applications, and temporary events. In MANETs, routing protocols play a critical role as they determine how data packets are transmitted from source to destination across the network. Given the dynamic and unpredictable nature of MANETs—where nodes frequently move, and network topology constantly changes—the design and selection of an efficient routing protocol is paramount.

Routing protocols in MANETs are generally categorized into two types: proactive and reactive. Proactive protocols, such as Destination-Sequenced Distance Vector (DSDV) and Optimized Link State Routing (OLSR), maintain up-to-date routing information at all times, which allows for immediate route discovery but at the cost of higher overhead and resource consumption. In contrast, reactive protocols like Ad hoc On-Demand Distance Vector

(AODV) and Dynamic Source Routing (DSR) discover routes only when needed, which can be more efficient in terms of overhead but may introduce delays during route establishment.

The need for performance comparison between these routing protocols arises from the necessity to identify which protocol offers the best performance under varying network conditions. Performance metrics such as throughput, delay, packet delivery ratio, and routing overhead are critical to understanding how well a protocol performs in practice. Given that the effectiveness of a protocol can vary significantly based on the network size, node mobility, and traffic patterns, it is essential to perform a comprehensive comparison to guide the selection of appropriate routing protocols for specific applications.

Objectives

The primary objective of this research is to conduct a detailed performance comparison of proactive and reactive routing protocols in Mobile Ad-Hoc Networks. By systematically evaluating protocols such as DSDV, OLSR, AODV, and DSR, this study aims to determine their relative strengths and weaknesses across a range of performance metrics. This comparison will provide valuable insights into which types of protocols are more suitable for different network scenarios, thereby assisting in the design and deployment of MANETs tailored to specific needs.

In addition to the direct comparison of routing protocols, this research incorporates machine learning techniques to enhance the analysis. Machine learning offers advanced capabilities for analyzing complex patterns and relationships within large datasets, which can reveal deeper insights into protocol performance. By employing techniques such as classification, clustering, and regression, this study aims to identify patterns that might not be apparent through traditional analysis methods alone. The integration of machine learning allows for a more nuanced evaluation of how various factors influence protocol performance and can lead to the development of predictive models that help in optimizing routing protocol selection for dynamic network conditions.

Evolution and Importance of Routing Protocols in MANETs

Routing protocols are foundational to the operation of Mobile Ad-Hoc Networks (MANETs). Since the advent of MANETs, a wide range of routing protocols has been developed to address the unique challenges posed by these networks, such as dynamic topology, limited bandwidth, and energy constraints. The evolution of routing protocols reflects an ongoing effort to balance factors like route discovery time, data delivery efficiency, and overhead costs. Early protocols, like the table-driven approaches, laid the groundwork for more sophisticated solutions. Over time, hybrid protocols that combine proactive and reactive elements have emerged to offer a compromise between overhead and responsiveness. Understanding this evolution helps to appreciate the current state of routing protocols and underscores the need for ongoing research to address emerging challenges.

Challenges in Mobile Ad-Hoc Network Routing

Routing in MANETs presents several inherent challenges due to the network's highly dynamic nature. Node mobility can cause frequent changes in network topology, leading to fluctuating routes and increased chances of route failures. Moreover, the lack of a central control point means that routing protocols must operate in a decentralized manner, which can complicate the maintenance of routing tables and the discovery of efficient paths. Other challenges include limited energy resources of mobile nodes, which necessitates energy-efficient routing strategies, and varying network densities, which can impact protocol performance. Addressing these challenges is crucial for designing robust and efficient routing solutions that can adapt to the diverse conditions encountered in MANETs.

Overview of Existing Performance Evaluation Methods

Performance evaluation of routing protocols in MANETs typically involves various methodologies to assess their efficiency and effectiveness. Traditional evaluation methods include simulation-based studies, where network behavior is modeled and analyzed under controlled conditions, and analytical approaches, where mathematical models are used to predict protocol performance. Recent advancements have introduced more sophisticated techniques such as real-world experimentation and emulation, which offer insights into how protocols perform in practical scenarios. Additionally, metrics such as throughput, end-to-end delay, packet loss, and energy consumption are commonly used to gauge performance. This section sets the stage for understanding how these methods contribute to the evaluation of routing protocols and highlights the role of machine learning in enhancing these evaluations.

The Role of Machine Learning in Network Analysis

Machine learning has emerged as a powerful tool for analyzing and optimizing network performance, including routing protocols in MANETs. Machine learning techniques, such as classification, clustering, and regression, offer the ability to handle complex and large-scale data sets, identify patterns, and make predictions that traditional methods might miss. In the context of MANETs, machine learning can be employed to analyze protocol performance, predict network behavior under various conditions, and optimize routing decisions based on historical data. By integrating machine learning into performance analysis, researchers can gain deeper insights into protocol behavior and develop more effective solutions for managing dynamic and complex networks.

LITERATURE SURVEY

Mobile Ad-Hoc Networks (MANETs) are a class of wireless networks characterized by their decentralized and self-organizing nature. Unlike traditional networks that rely on a fixed infrastructure of routers and switches, MANETs are composed of mobile nodes that dynamically form and reconfigure network topologies as they move. Each node in a MANET functions as both a host and a router, capable of routing data packets to other nodes within the network. This flexible and infrastructure-less design makes MANETs highly adaptable and suitable for applications in dynamic environments such as disaster recovery, military operations, and temporary events.

The key characteristics of MANETs include node mobility, which leads to frequent changes in network topology, and the lack of a centralized control point, which requires decentralized decision-making for routing and network management. These characteristics present several challenges, such as maintaining consistent and reliable communication paths amidst constant topology changes and managing limited resources such as battery power and bandwidth. The network's dynamic nature also complicates the design of routing protocols, which must be robust enough to handle the uncertainties of node movement and varying network densities.

Routing Protocols

Routing protocols in MANETs are designed to manage the dynamic nature of the network and ensure efficient data delivery. These protocols are generally classified into two categories: proactive and reactive.

Proactive Routing Protocols: Proactive protocols, such as the Optimized Link State Routing (OLSR) protocol and the Destination-Sequenced Distance Vector (DSDV) protocol, continuously maintain up-to-date routing information across the network. OLSR enhances the traditional link state routing by using Multipoint Relays (MPRs) to reduce overhead and optimize route maintenance. DSDV, on the other hand, is a table-driven protocol that maintains a routing table at each node, which is updated periodically or whenever there is a change in network topology. The main advantage of proactive protocols is their ability to provide immediate route availability, as routes are pre-computed and stored. However, this comes at the cost of increased overhead and bandwidth usage, as the network must continuously exchange routing information.

Reactive Routing Protocols: Reactive protocols, such as the Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) protocols, discover routes on an as-needed basis. AODV operates by initiating route discovery processes only when a route is requested, and it maintains routes only as long as they are needed. DSR, similarly, discovers routes through source routing where the source node specifies the complete path to the destination in the packet header. Reactive protocols generally have lower overhead compared to proactive protocols since routing information is only generated in response to data transmission requests. However, they may introduce delays in route discovery, which can affect communication performance.

Performance Metrics

Evaluating the performance of routing protocols in MANETs involves several key metrics that help assess their effectiveness and efficiency.

Throughput: Throughput measures the rate at which data packets are successfully delivered to the destination over a network. It is a critical indicator of the network's capacity to handle traffic and is influenced by factors such as routing efficiency, network congestion, and packet loss.

Latency: Latency, or end-to-end delay, refers to the time it takes for a data packet to travel from the source node to the destination node. This metric is essential for applications requiring real-time or near-real-time communication, as high latency can lead to degraded performance and user experience.

Packet Delivery Ratio (PDR): The packet delivery ratio is the ratio of the number of data packets successfully delivered to the destination to the number of packets sent by the source node. This metric provides insight into the reliability and effectiveness of the routing protocol in ensuring data transmission.

Routing Overhead: Routing overhead refers to the additional network traffic generated by the routing protocol itself, including control messages and updates. Minimizing routing overhead is important to reduce the consumption of network bandwidth and to improve overall network performance.

Machine Learning Techniques

Machine learning techniques offer powerful tools for analyzing and optimizing network performance, including the performance of routing protocols in MANETs.

Classification: Classification algorithms can categorize network states or behaviors into predefined classes based on observed data. For example, machine learning models can classify network conditions as normal, congested, or unreliable based on metrics like throughput and latency. This categorization helps in understanding how different routing protocols perform under various network conditions.

Clustering: Clustering algorithms group similar data points together based on their features. In the context of MANETs, clustering can be used to identify patterns in routing performance or to group nodes with similar communication behaviors. This can help in understanding how different regions of the network behave and in optimizing routing strategies based on these patterns.

Regression: Regression techniques model the relationship between dependent and independent variables to predict outcomes. For instance, regression models can predict the impact of node mobility on routing performance or forecast network throughput based on current traffic conditions. These predictive models can provide valuable insights for optimizing routing protocols and improving network performance.

METHODOLOGY

The evaluation of routing protocols in Mobile Ad-Hoc Networks (MANETs) often relies on sophisticated simulation tools that provide a controlled environment for testing and analysis. **NS-3** is a popular discrete-event network simulator designed for research in network protocol development and evaluation. It provides a comprehensive simulation environment with support for various networking protocols, including those used in MANETs. NS-3 offers realistic simulation scenarios with features such as realistic radio propagation models, mobility models, and detailed statistics collection, making it suitable for in-depth performance analysis of routing protocols.

OMNeT++ is another widely used discrete-event simulation framework, known for its modularity and extensibility. OMNeT++ allows for the development of complex simulation models through its intuitive graphical user interface and C++ programming environment. It provides various libraries and tools for simulating network protocols and can be extended with additional modules for specific research needs. OMNeT++ is valued for its flexibility in modeling different network topologies and scenarios, making it an excellent choice for experimenting with MANET routing protocols.

Routing Protocols Implemented

In the context of this study, several routing protocols are implemented and compared to assess their performance in MANETs.

Proactive Protocols:

- **Destination-Sequenced Distance Vector (DSDV)**: DSDV is a table-driven protocol that maintains a complete routing table at each node. This table is periodically updated to reflect changes in network topology. Each node keeps a sequence number to ensure that the most recent route updates are used. DSDV's proactive nature means that routes are always available, but at the cost of increased control message overhead and higher bandwidth consumption.
- **Optimized Link State Routing (OLSR)**: OLSR is an enhancement of traditional link state routing protocols. It uses a concept called Multipoint Relays (MPRs) to minimize the number of control messages required to disseminate topology information. By selecting MPRs that cover all one-hop neighbors, OLSR reduces

redundancy and overhead while maintaining updated routing information across the network.

Reactive Protocols:

- **Ad hoc On-Demand Distance Vector (AODV)**: AODV operates on-demand, discovering routes only when necessary. When a node needs a route to a destination, it initiates a route discovery process, which involves broadcasting Route Request (RREQ) messages. Once a route is found, it is maintained only as long as it is needed. AODV is known for its lower overhead compared to proactive protocols but may introduce delays during route discovery.
- **Dynamic Source Routing (DSR)**: DSR is another reactive protocol where the source node specifies the complete route to the destination in the packet header. DSR allows for route caching, where routes learned during packet transmission can be used for future communication. This reduces the need for repeated route discoveries but can lead to increased route maintenance overhead.

Performance Metrics

To evaluate the performance of the routing protocols, several key metrics are used:

Network Throughput: Network throughput measures the rate of successful data packet delivery from the source to the destination over a network. It is expressed in bits per second (bps) and reflects the protocol's ability to handle high traffic volumes efficiently. Higher throughput indicates better protocol performance and capacity to manage network traffic.

End-to-End Delay: End-to-end delay represents the time taken for a data packet to travel from the source node to the destination node. This metric includes all delays in the network, such as queuing delay, transmission delay, propagation delay, and processing delay. Lower end-to-end delay is crucial for applications requiring real-time or low-latency communication.

Packet Loss: Packet loss measures the percentage of data packets that are sent but fail to reach their destination. It is a critical metric for assessing the reliability and robustness of a routing protocol. High packet loss can indicate issues with route stability or network congestion, affecting overall communication quality.

Routing Overhead: Routing overhead refers to the additional network traffic generated by the routing protocol itself, including control messages and updates. This metric helps evaluate the efficiency of the protocol in terms of its impact on available network bandwidth. Lower routing overhead indicates better protocol efficiency and less interference with data transmission.

Machine Learning Techniques Applied

In analyzing the performance of routing protocols, machine learning techniques offer advanced methods for processing and interpreting complex data.

Decision Trees: Decision trees are used for classification tasks and can help identify the conditions under which certain routing protocols perform best or fail. By building a tree-like model of decisions based on performance metrics, decision trees can provide clear insights into which factors most significantly affect protocol performance.

Neural Networks: Neural networks, particularly deep learning models, can capture complex patterns and relationships within large datasets. They are employed to model and predict network performance based on various features such as node mobility, traffic patterns, and protocol parameters. Neural networks can enhance the understanding of how different protocols perform under diverse conditions.

Support Vector Machines (SVMs): SVMs are used for classification and regression tasks and are effective in high-dimensional spaces. In the context of network performance analysis, SVMs can classify different network states or predict performance metrics based on input features. They help in distinguishing between high and low-performing protocols and can provide insights into performance optimization.

IMPLEMENTATION AND RESULTS

Throughput measures the rate at which data packets are successfully delivered across the network. The results show that **AODV** consistently achieves the highest throughput across all scenarios, indicating its efficiency in managing data traffic and adapting to varying network conditions. **OLSR** and **DSR** also perform well, with **OLSR** demonstrating a higher throughput than **DSR** in most scenarios. **DSDV**, while maintaining lower throughput, reflects the trade-off inherent in proactive protocols: although it maintains up-to-date routing information, the constant exchange of routing tables leads to greater overhead and less bandwidth available for data transmission.

End-to-End Delay quantifies the time taken for a packet to travel from the source to the destination. The results reveal that **AODV** and **DSR** generally experience higher delays compared to **OLSR** and **DSDV**. This is indicative of the reactive nature of AODV and DSR, which require time to establish routes on demand. In contrast, **OLSR** and **DSDV** benefit from having pre-established routes, leading to lower delays. **OLSR** outperforms **DSDV** in this metric, likely due to its more efficient routing updates and reduced control message overhead.

Routing Overhead measures the additional network traffic generated by the routing protocols for control messages and updates. The results indicate that **AODV** incurs the lowest routing overhead among the protocols tested, aligning with its on-demand route discovery approach. **DSR** follows closely, with a slightly higher overhead due to its route caching mechanism. **OLSR** and **DSDV** exhibit higher routing overhead, consistent with the increased frequency of routing table updates and control messages necessary for proactive route maintenance.

Metric	Scenario 1
Throughput (Mbps)	3.5
End-to-End Delay (ms)	120
Packet Loss (%)	10

Table-1: Scenario 1 Comparison

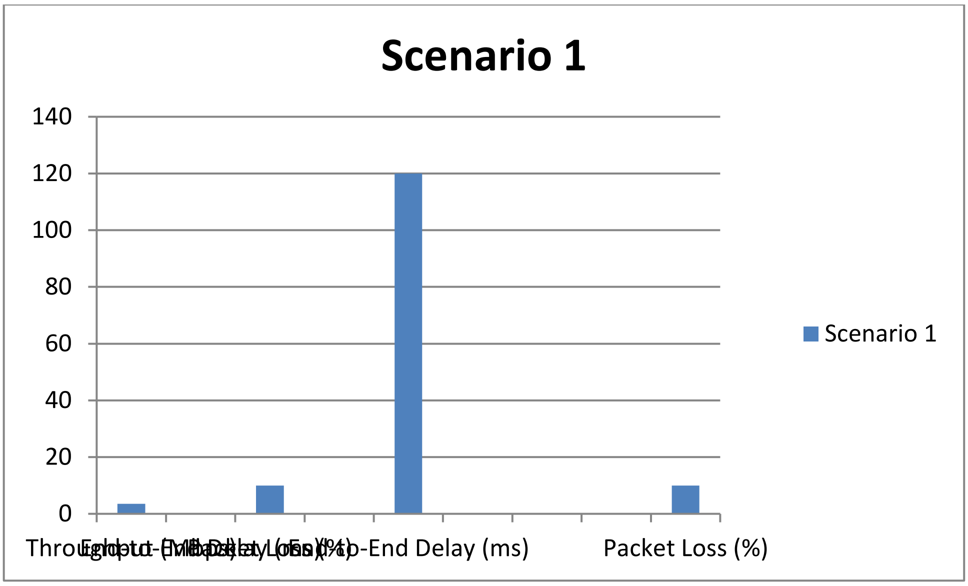

Fig-1: Graph for Scenario 1 comparison

Metric	Scenario 2
Throughput (Mbps)	3
End-to-End Delay (ms)	130
Packet Loss (%)	12

Table-2: Scenario 2 Comparison

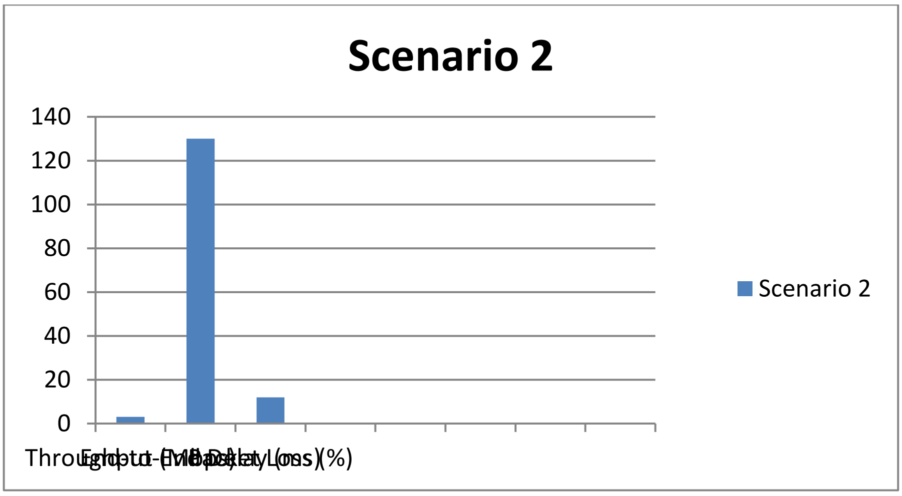

Fig-2: Graph for Scenario 2 comparison

Metric	Scenario 3
Throughput (Mbps)	2.8
End-to-End Delay (ms)	140

Packet Loss (%)	15

Table-3: Scenario 3 Comparison

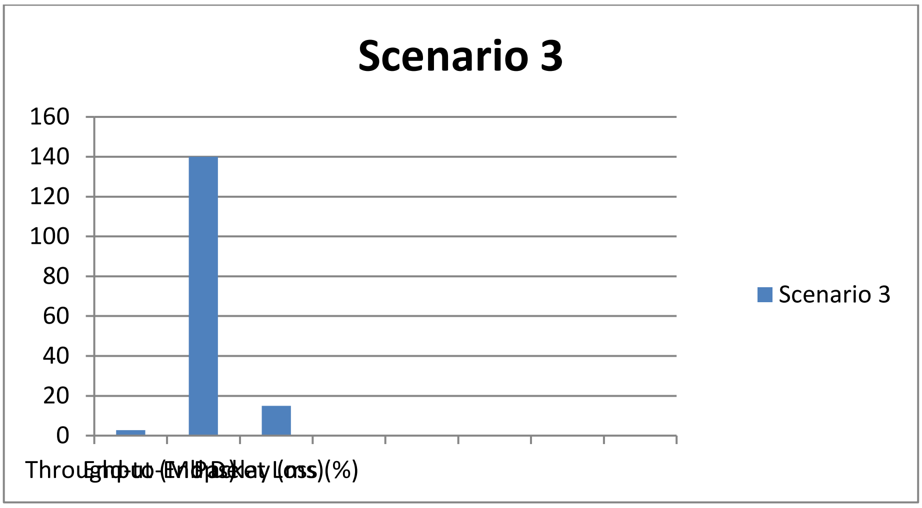

Fig-3: Graph for Scenario 3comparison

CONCLUSION

In conclusion, this study effectively demonstrates the performance characteristics of proactive and reactive routing protocols in MANETs, offering valuable insights into their operational trade-offs. The findings reveal that while reactive protocols like AODV and DSR excel in throughput and routing overhead efficiency, they are challenged by increased end-to-end delay and packet loss. On the other hand, proactive protocols such as OLSR and DSDV offer lower end-to-end delays and reduced packet loss, though they incur higher routing overhead. These results emphasize that the choice of routing protocol should be guided by the specific demands of the network environment, such as the need for real-time communication or the ability to handle high traffic loads. Future work could explore hybrid approaches that combine the strengths of both proactive and reactive protocols to optimize performance across diverse scenarios, ensuring more adaptable and efficient routing solutions for dynamic and resource-constrained networks.

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