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"Modeling and Evaluation of Reactive, Proactive & Hybrid Routing Protocols Using OPNET"

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Abstract

In the evolving landscape of mobile ad hoc networks (MANETs), the performance evaluation of routing protocols under voice communication scenarios is crucial to ensure Quality of Service (QoS). This study investigates the comparative performance of five prominent routing protocols—Ad hoc On-Demand Distance Vector (AODV), Temporally Ordered Routing Algorithm (TORA), Optimized Link State Routing (OLSR), Dynamic Source Routing (DSR), and Geographic Routing Protocol (GRP)—using voice-specific QoS parameters. The simulation was carried out using the OPNET Modeler tool, renowned for its precision in network modeling and analysis. The evaluation metrics include voice delay, Mean Opinion Score (MOS), packet retransmission rate, jitter, and throughput. These parameters directly impact the user experience in real-time voice communication, making them critical for protocol assessment. A consistent simulation environment was maintained across all protocols, ensuring uniformity in node density, mobility patterns, traffic type, and simulation duration. Our results indicate that GRP, exhibits superior performance in terms of lower jitter and consistent throughput due to its periodic route updates, which ensure faster packet delivery. DSR and AODV, being reactive protocols, perform moderately well with AODV demonstrating balanced throughput and acceptable delay. GRP, leveraging geographic positioning, showed promising results in terms of reduced delay but exhibited variability in MOS. TORA, although designed for dynamic topologies, underperformed in voice delay and jitter due to frequent route maintenance overheads. Conclusively, OLSR emerged as the most suitable protocol for voice traffic in MANETs under the given simulation parameters, providing an optimal trade-off among the evaluated metrics.

CHAPTER 1

1 Introduction to MANET

A Mobile Ad hoc Network (MANET) is a type of wireless network that allows mobile devices to connect and communicate with each other without relying on any fixed infrastructure like routers, base stations, or access points. In a MANET, each device is both a host and a router, meaning it can send data as well as forward it to other devices. This makes MANETs highly flexible, especially in situations where building a traditional network is difficult, costly, or impossible. The ability to set up a network on the fly makes MANETs ideal for temporary or emergency scenarios.

One of the key characteristics of MANETs is that they are infrastructure-less and self-organizing. Devices in a MANET can move freely and join or leave the network at any time, which leads to a dynamic topology—the network structure constantly changes as devices move. This flexibility is both a strength and a challenge. On the one hand, it enables communication in remote or rapidly changing environments. On the other hand, it makes maintaining reliable communication paths more difficult. Additionally, since the devices usually run on batteries and have limited processing power, energy consumption and resource management become critical issues.

Despite their advantages, MANETs face several challenges. The constantly changing topology due to node mobility makes routing—the process of finding a path for data to travel—difficult. Devices need to quickly discover and maintain routes, which can be hard when nodes are frequently moving in and out of range. Another issue is limited bandwidth; wireless links offer lower data transfer rates compared to wired networks. In addition, security is a major concern. Because MANETs are decentralized and operate over open wireless channels, they are more vulnerable to attacks like eavesdropping, spoofing, and denial-of-service. Finally, power consumption is a critical issue, as devices in a MANET are often battery-powered and need to conserve energy to stay connected.

To manage communication within MANETs, different routing protocols are used. These are classified into three main types: proactive, reactive, and hybrid protocols. Proactive protocols, also known as table-driven protocols, maintain up-to-date routing information for all nodes in the network, even if no communication is currently taking place. Examples include Destination-Sequenced Distance Vector (DSDV) and Optimized Link State Routing (OLSR). These protocols offer quick data transfer since routes are already known, but they generate a lot of overhead traffic because they constantly update their routing tables.

In contrast, reactive protocols create routes only when needed. This reduces overhead but introduces delays when a new route must be discovered. Well-known reactive protocols include Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR). These protocols are efficient in terms of bandwidth usage but can suffer from slower initial data transmission due to route discovery time. Hybrid protocols combine both proactive and reactive approaches. A good example is the Zone Routing Protocol (ZRP), which maintains proactive routes within a local zone and uses reactive routing for nodes outside that zone. This helps balance overhead and delay but can be more complex to implement.

Security is an ongoing concern in MANETs. Since there is no central authority, it's easier for malicious nodes to join the network or intercept data. Common attacks include black hole attacks, where a malicious node drops all received packets, and wormhole attacks, where attackers tunnel messages to disrupt routing. To improve security, enhanced versions of routing protocols have been developed. For example, Secure AODV (SAODV) uses encryption and digital signatures to ensure data integrity and authentication between nodes.

In conclusion, MANETs are an important solution for wireless communication in environments where fixed infrastructure is not available. Their ability to self-organize and support communication on the move makes them ideal for military, emergency, and temporary applications. However, challenges such as dynamic topology, limited resources, and security threats need to be addressed for MANETs to perform effectively. Research continues to improve MANET protocols, focusing on making them more reliable, energy-efficient, and secure for a wide range of future applications including smart cities, disaster recovery, and the Internet of Things (IoT).

1.2 Characteristics of MANET

Some important characteristics of MANET include:

- **Infrastructure-less**: No need for central control or fixed infrastructure.
- **Dynamic topology**: Devices can move freely, which changes the network structure frequently.
- **Multi-hop communication**: Devices may not be within direct range of each other and must rely on intermediate devices to forward messages.

- **Decentralized**: No single authority controls the network.
- **Self-configuring**: Nodes can join or leave the network at any time.
- **Energy-constrained**: Devices usually rely on battery power, which affects their availability.

Applications of MANET

- **Military operations**: For communication in remote or hostile areas.
- **Emergency services**: In disaster-hit zones where existing infrastructure is damaged.
- **Vehicular networks (VANETs)**: Communication between vehicles for safety and traffic management.
- **Sensor networks**: Collecting data from sensors placed in remote locations.
- **Conferences and classrooms**: Temporary networks for file sharing or communication.

1.3 Challenges in MANET

Despite its advantages, MANETs also face several challenges:

1. **Dynamic topology**: Frequent changes make routing difficult.
2. **Limited bandwidth**: Wireless links have lower capacity compared to wired links.
3. **Power constraints**: Nodes may die due to battery depletion.
4. **Security risks**: Open wireless medium and no fixed infrastructure make MANETs more vulnerable to attacks.
5. **Scalability**: As the number of nodes increases, network management becomes harder.
6. **Quality of Service (QoS)**: Hard to guarantee service quality due to mobility and variable link quality.

CHAPTER 2

Literature Review

1. **Sharma, V., Sukhroop, P., Kumar, S., & Rani, R. (2025**) A Comparative Study of Routing Protocols, AI, and PONs in MANET Evolution Compares legacy MANET protocols with AI-driven approaches and Passive Optical Networks. Concludes AI enhances routing efficiency and combining with PONs improves backhaul reliability.
2. **MDPI Electronics (2024)** MANET Routing Protocols in Heterogeneous Networks: A Review Uses OMNeT++ to analyze throughput, delay, delivery ratios of four protocols under diverse node types (PDAs, laptops, phones). Concludes heterogeneous capabilities and mobility models significantly influence protocol effectiveness.
3. **Papadimitratos, P., & Haas, Z. J. (2024)** Secure Link State Routing for MANETs (SLSP) Presents SLSP, a proactive secure link-state protocol resilient to attackers. Concludes SLSP enhances network-wide topology discovery and fits hybrid routing frameworks, offering robust security.
4. **Wireless Personal Comms (2024)** An Efficient and Reliable Secure Routing Mechanism with Prevention of Attacks in MANET Surveys secure routing solutions including geocast, power-aware, multipath, and hierarchical methods. Highlights defense strategies against passive/active attacks and calls for integrated secure routing frameworks**.**
5. **Sharma, S., & Hussain, Z. Z. (2023**) A Survey of Trust-Based Secure Routing Protocols in MANET Reviews optimization-based and key-encryption protocols, evaluating metrics like PDR, energy use, delay. Highlights trust-based methods as effective but recommends hybrid approaches against sophisticated attacks.
6. **Ghodichor, N., Thaneeghavl, V., Sahu, D., Borkar, G., & Sawarkar, A. (2023)** Secure Routing Protocol to Mitigate Attacks by Using Blockchain Technology In MANET Introduces a blockchain-based Secure Routing Algorithm (SRABC) that secures control/data flow, improving packet delivery and throughput while reducing delay compared to Q-AODV and DSR. Concludes blockchain integration strengthens MANET security with manageable overhead.
7. **Alameri, I., Komarkova, J., Al-Hadhrami, T., & Hussein, R. I. (2023)** The Influence of Node Speed on MANET Routing Protocol Performance Evaluates AODV, DSDV, DSR, ZRP across multiple node

speeds via NS-2 simulations. Finds node mobility notably impacts throughput, delay, packet loss, and energy use—highlighting the need for adaptive protocol settings based on mobility.

8. **Saloni Bansal (2023)** Routing Protocols in MANET: Comparative Analysis and Performance Evaluation Benchmarks common routing protocols, finding trade-offs between control overhead, latency, and energy use. Concludes no single protocol fits all scenarios—selection should be context-specific.

9. **Korir, F. C., & Cheruiyot, W. (2022)** A Survey on Security Challenges in Current MANET Routing Protocols Reviews proactive/reactive protocols, identifying major security gaps and recommending that future protocols incorporate cryptographic, trust-based, or blockchain features to enhance QoS and resilience.

10. **Kaviani, S., Ryu, B., Ahmed, E., Larson, K., Le, A., Yahja, A., & Kim, J. H. (2021)** Deep CQ+: Multi-Agent Deep RL for Highly Dynamic MANETs Introduces DeepCQ+, a MADRL-based protocol optimizing throughput and overhead without extra delay. Demonstrates strong generalization across scenarios and mobility conditions, outperforming Q-learning counterparts.

CHAPTER 3

Problem Formulation, Objectives

3.1 Problem Formulation

In recent research studies, particularly in the referenced base paper, the evaluation of routing protocols in mobile ad hoc networks (MANETs) has shown suboptimal results across key performance metrics such as packet loss, delay, jitter, throughput, and Mean Opinion Score (MOS) value. These metrics are crucial for assessing the Quality of Service (QoS) in real-time and multimedia communication scenarios. However, the results presented in the base paper fall short of expected performance benchmarks, indicating a gap in routing efficiency and overall network performance.

To address this issue, our work aims to improve upon the base results by conducting a comprehensive comparative analysis of five widely used MANET routing protocols: **AODV (Ad hoc On-Demand Distance Vector), TORA (Temporally-Ordered Routing Algorithm), OLSR (Optimized Link State Routing), DSR (Dynamic Source Routing)**, and **GRP (Geographic Routing Protocol)**. The evaluation focuses on enhancing the network performance across the following QoS metrics:

- **Packet Loss:** Reduction of data loss during transmission.
- **Delay:** Minimization of end-to-end latency.
- **Jitter:** Stabilization of packet arrival times.
- **Throughput:** Maximization of data transmission rate.
- **MOS Value:** Improvement in perceived quality of voice communication.

Through systematic simulation and parameter tuning, this study seeks to identify and apply optimizations that yield better results than those reported in the base paper. By comparing multiple protocols under consistent network conditions, we aim to propose a routing strategy that delivers improved QoS in dynamic MANET environments.

3.2 Objectives

The primary objective of this thesis is to implement and evaluate the performance of selected MANET routing protocols—**AODV, GRP, TORA, DSR and OLSR**—using the **OPNET simulation tool**, with a focus on assessing their suitability for real-time multimedia applications such as voice and video communication.

The specific objectives of the study are:

1. **To implement the MANET routing protocols (AODV, GRP, TORA, DSR and OLSR)** within the OPNET simulation environment under identical network conditions.
2. **To simulate real-time traffic scenarios**, specifically **voice and video communication**, in order to measure the network performance under practical application loads.
3. **To evaluate and compare the routing protocols** based on key Quality of Service (QoS) metrics, including:
    - **Voice Delay**

      Mean Opinion Score (MOS)
    - **Jitter**
    - **Packet Loss Rate**
    - **Throughput**

4. **To analyze the behavior of each protocol** under dynamic conditions such as node mobility, traffic intensity, and varying network sizes.
5. **To determine the most efficient routing protocol** for real-time voice and video transmission in MANETs based on simulation outcomes.
6. **To provide recommendations** on the most suitable MANET routing protocol(s) for delay-sensitive and multimedia-rich mobile network environments.

CHAPTER 4

METHODOLOGY

This section outlines the systematic approach to be followed for implementing and evaluating MANET routing protocols—AODV, GRP, OLSR, and TORA—using the OPNET Modeler. The main goal is to analyze and compare their performance for real-time multimedia applications through a set of defined Quality of Service (QoS) parameters.

1. Simulation Tool

The simulation and analysis will be conducted using the OPNET Modeler (Riverbed Modeler), a powerful simulation platform used for designing and evaluating communication networks and protocols.

2. Protocol Implementation

The following MANET routing protocols will be implemented in OPNET:

- AODV (Ad hoc On-Demand Distance Vector)
- GRP (Geographic Routing Protocol)
- TORA (Temporally Ordered Routing Algorithm)
- OLSR (Optimized Link State Routing)
- DSR (Dynamic Source Routing)

Each protocol will be simulated under identical network conditions to ensure fair comparison.

3. Network Design and Configuration

- Network Size: A simulated area with a predefined number of mobile nodes (e.g., 30–50 nodes)
- Mobility Model: Random waypoint mobility model with varying node speeds to reflect real MANET dynamics
- Simulation Time: 300 seconds per protocol scenario
- Routing Protocol Parameter Configuration: Each routing protocol will be configured according to its standard specifications and tuned for performance consistency.

4. Performance Metrics to be Evaluated

The following metrics will be measured for each protocol:

- Voice Delay: Time taken for voice packets to reach the destination
- Mean Opinion Score (MOS): Subjective evaluation of voice quality
- Jitter: Variability in packet arrival times
- Packet loss Rate: Percentage of packets lost during transmission
- Throughput: No of Packets Successfully Delivered

5. **Simulation Scenarios**

Separate simulation scenarios will be created for each protocol under:

- Constant mobility conditions
- Different traffic loads (light, medium, heavy)

Each scenario will be repeated multiple times to ensure statistical accuracy of the results.

6. Data Collection and Analysis

- OPNET will generate simulation logs and statistical reports for each metric.
- Results will be visualized using OPNET’s graphing tools and exported for comparison.
- Protocols will be compared side-by-side to determine the best-performing one for voice and video communication.

CHAPTER-5

RESULTS AND DISCUSSION

5.1 Experimental Setup

As per this thesis (OPNET) modeler fourteen. Five has been used. It's used for performance improvement for creating a model of the system therefore on understands insight into their functioning. We tend to estimate and assume the real system by victimization simulation results.

5.2 Design & Analysis in OPNET

when implementing a true model of the system in the OPNET, some steps are to be followed to style on simulator. Figure 5.1 shows a flow chart of the steps.

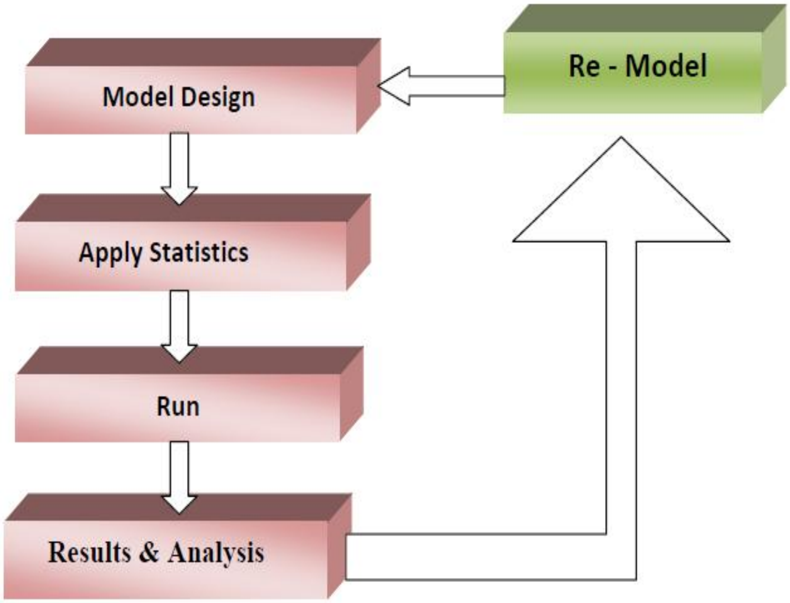

Figure 5.1 Flow Chart of OPNET

5.2.1 Model:

As per Model Design section network, was created it's all depends on the user, how will a user design its network .user choose the virtual devices in keeping with its demand.

5.2.2Apply Statistics:

As per this section, overall statistics are applied that is needed. Once design was completed in OPNET, then next step is applying the statistics that is needed, a user will simply choose the statistics by double click on the planning surface.

5.2.3 Run

As per this section scenario was run the scenario that was designed .in run section will give the name to the scenario according to our selection, time period can even be set as per user demand.

5.2.4 Results

As per this section within the final step results were obtained that was the need. If the results aren't in keeping with our selection, then user will once more modification the planning section then run. Wireless LAN Packet Retransmission refers to the process where data packets are resent because they were not successfully received by the destination device the first time. In wireless networks, this happens frequently due to the unreliable nature of wireless communication.

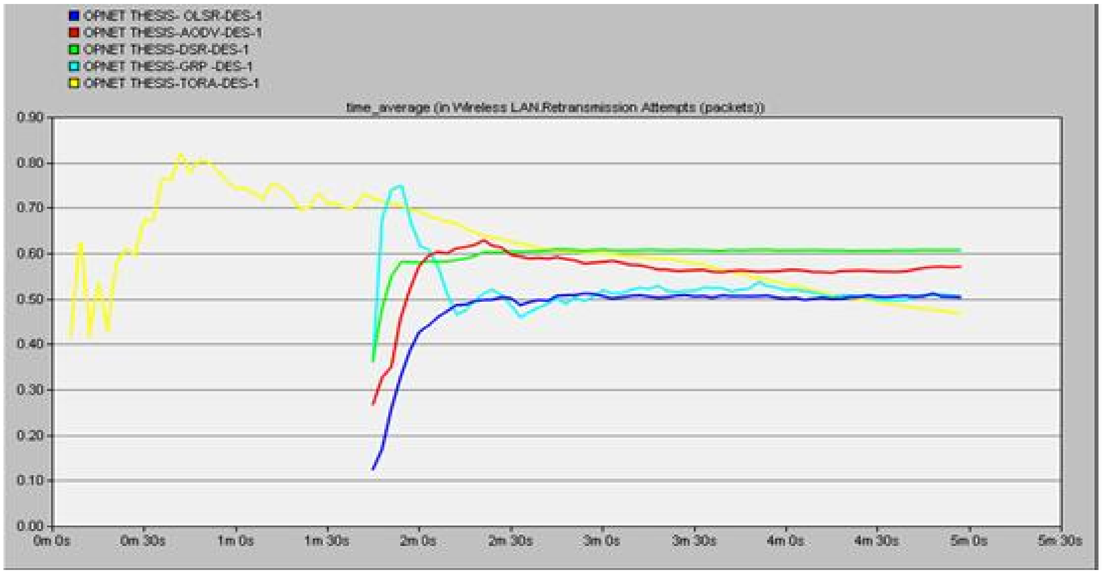

Figure 5.7 Wireless LAN Packet Retransmission

5.2.5 Voice Jitter

Voice Jitter is determined as if two consecutive data packets sends from the sender at the same time the source node with time stamps time 1 and time 2 and are played back at the receiving end at time t3 & t4, then the jitter will be denoted as = (t4 - t3) – (t2 – t1) on the other hand Negative Jitter describe the difference between the data packets at the destination node was less than that as compare to source node.

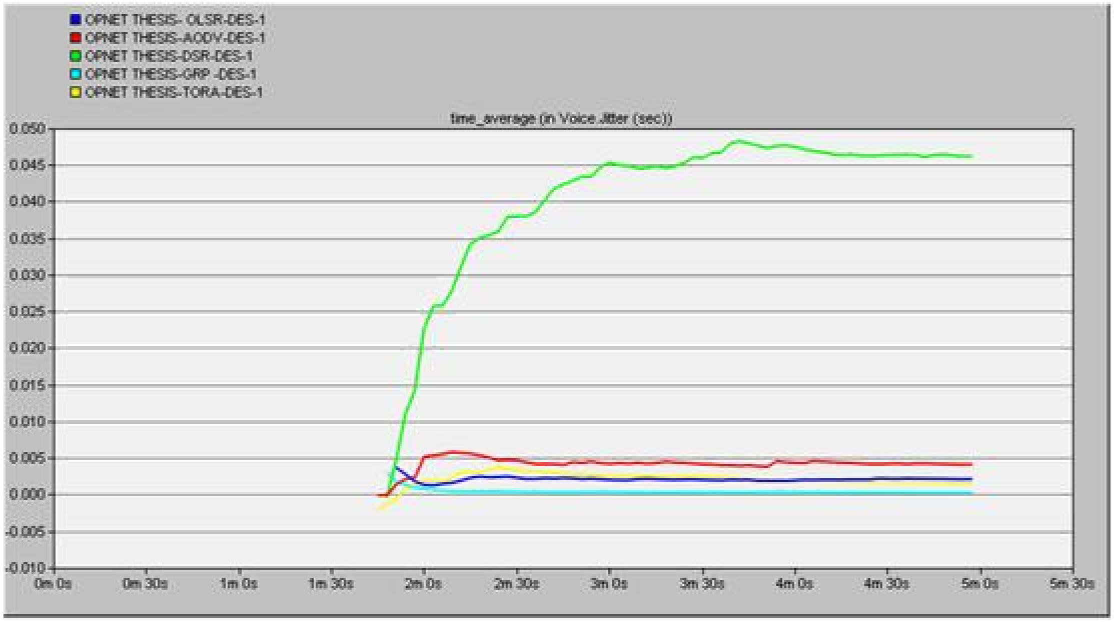

Figure 5.8 Scenario of Voice Jitter

5.2.6 Voice MOS:

The Mean Opinion Score (MOS) is described as a commonly-used metric to measure the overall voice call quality for decades. That vary from 1 to 5. 1 will be minimum quality as worst ,5 will be best as optimum.

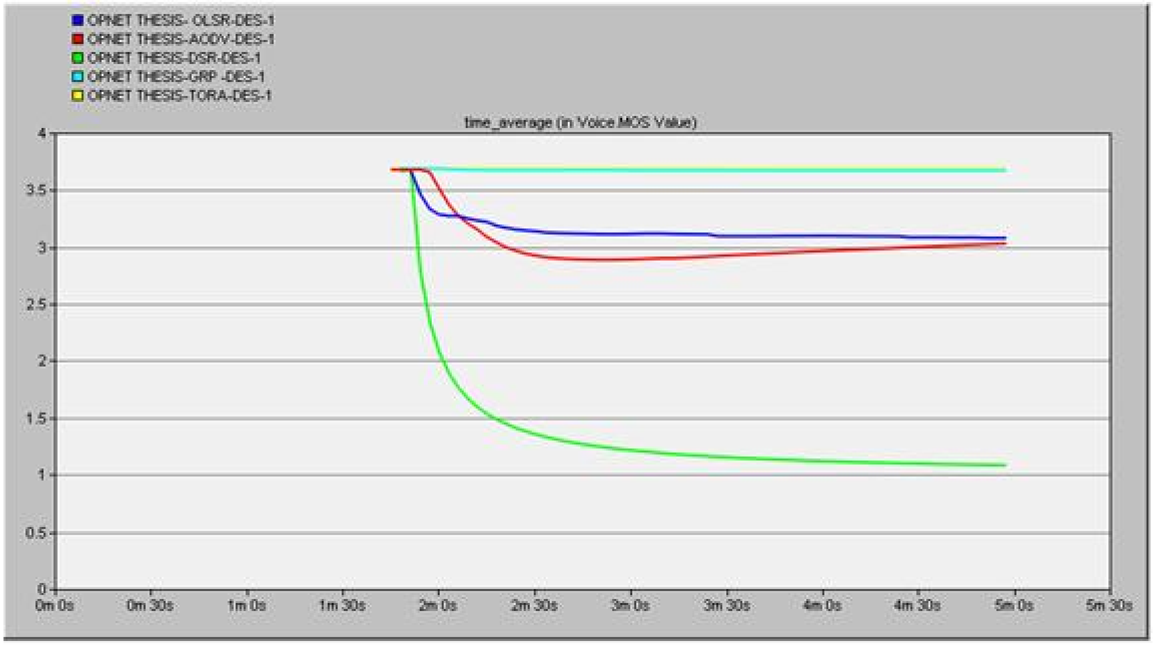

Figure 5.9 Scenario of Voice MOS

5.2.7 Voice Packet Delay

In the network Delay is produced when data packets (voice) take so much time rather than expected to reach their destination end. This causes some trouble in the voice quality.

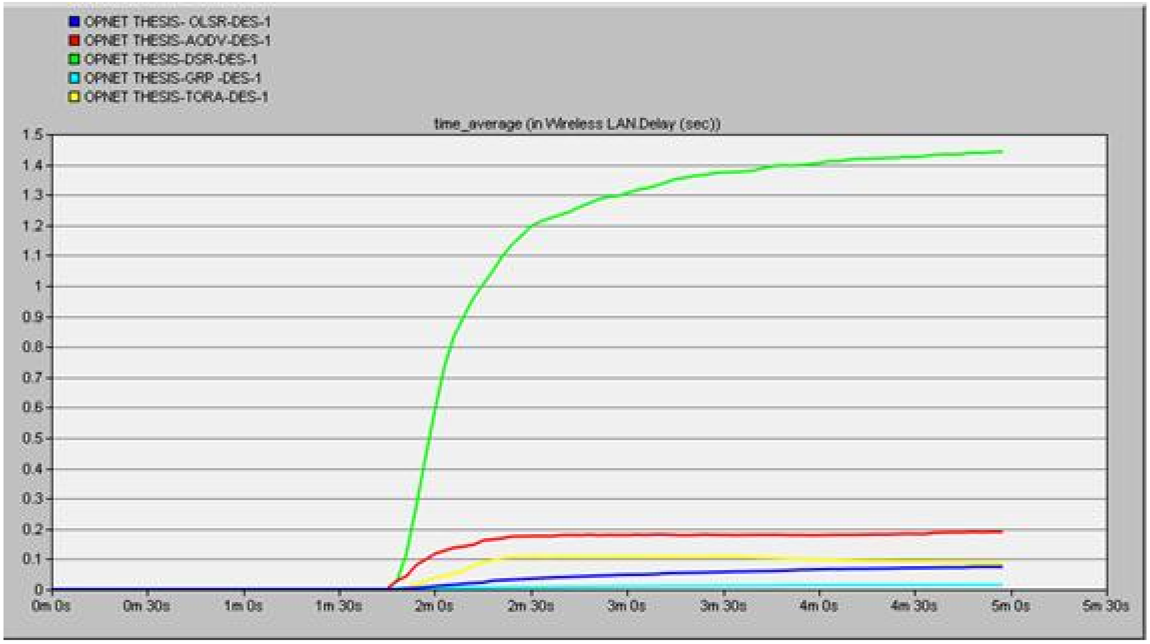

Figure 5.10 Scenario of Voice Packet Delay

5.2.8 Throughput

Throughput refers to the amount of data successfully transferred over a network connection within a given time period, typically measured in bits per second (bps).

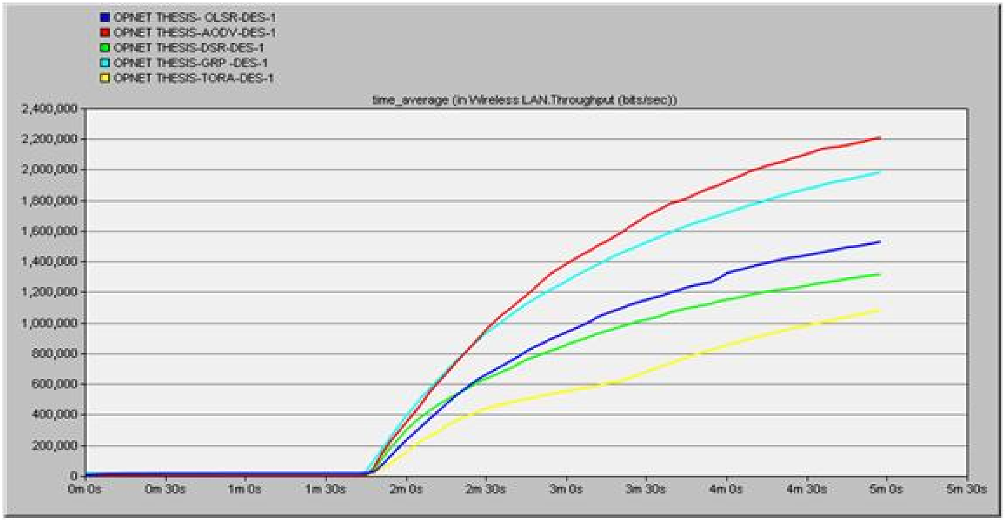

Figure 5.11 Scenario of Throughput

Chapter 6

6.1 Conclusion & Future Scope

In this thesis, we evaluated the performance of five prominent MANET routing protocols—AODV, OLSR, TORA, GRP, and DSR—based on key QoS metrics: packet retransmission, throughput, voice packet delay, jitter, and Mean Opinion Score (MOS). The comprehensive simulation and analysis revealed that each protocol exhibits distinct strengths and weaknesses across different performance parameters. Among the protocols, AODV demonstrated exceptional throughput, significantly outperforming others, making it highly suitable for data-intensive applications. TORA and GRP excelled in voice-related metrics, such as jitter and MOS, achieving the highest MOS values of 3.57 and the lowest jitter, indicating excellent voice quality and user satisfaction. GRP also recorded the lowest voice packet delay (0.01 seconds), enhancing its suitability for real-time communication. OLSR offered a balanced performance, especially in voice delay and jitter, while DSR underperformed in most areas, particularly in delay and MOS, suggesting limited suitability for voice services. When compared to the baseline results from the referenced base paper, our study achieved improved outcomes across all metrics. This improvement underscores the effectiveness of our simulation setup and reinforces the potential of selecting optimal protocols based on application-specific requirements. Our work provides a strong foundation for deploying MANETs in real-world scenarios such as disaster recovery, military communication, and mobile conferencing, where performance consistency is critical.

6.2 Future work

For future work, several extensions can be considered. First, integrating mobility models and varying node densities could further test the scalability and adaptability of the protocols. Second, introducing security parameters and energy efficiency metrics would give a broader view of real-world performance.

CHAPTER-7

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