

Protocol Behavior Analysis in Dynamic Mobile Environments: A Study on AODV, GRP, OLSR, and TORA Using OPNET

Harmanjit Kaur

Department of Computer Science & Engineering, GCET Gurdaspur

harmanjitkaur9888@gmail.com

Abstract

This study presents an in-depth analysis of four prominent ad hoc routing protocols—AODV (Ad hoc On-Demand Distance Vector), GRP (Geographic Routing Protocol), OLSR (Optimized Link State Routing), and TORA (Temporally Ordered Routing Algorithm)—within a Wireless LAN (WLAN) framework. Emphasizing real-time application requirements, the research investigates critical Quality of Service (QoS) parameters including voice jitter, end-to-end delay, Mean Opinion Score (MOS), overall delay, packet retransmission, packet drop and WLAN delay. Through simulation-based evaluation, the behavior and responsiveness of each protocol was observed under dynamic network conditions. The findings contribute to a deeper understanding of how these protocols handle the demands of real-time communication, offering insights into their operational characteristics within WLAN environments. The primary focus is on analyzing critical Quality of Service (QoS) parameters essential for real-time applications, including voice jitter, end-to-end delay, Mean Opinion Score (MOS), overall delay, packet retransmission, packet drop, and WLAN delay. Using simulation-based methods, each protocol was evaluated under identical network conditions to assess its ability to support consistent and high-quality communication. The results indicate that TORA outperforms the other protocols across most QoS metrics, demonstrating its effectiveness in handling dynamic network topologies while ensuring reliable and efficient data transmission. These findings suggest that TORA is a highly suitable protocol for enhancing real-time performance in WLAN-based ad hoc networks.

1.1 MOBILE ADHOC NETWORK AND ITS PROTOCOLS

MANET nodes, which are used to communicate with each other in a wireless environment that does not support any centralized control. In such a type of network all the MANET nodes exchange information without wires. The motive of the MANET network is to find the best route which is known as the optimum route and share data packets with the next router, so that packets can be reached successfully to the destination node finally. MANET network topology is created for a specific purpose, when the purpose is fulfilled, then that topology is changed, that's why MANET network is called temporarily not permanent. Routing is a difficult task to transfer data from one mobile node to another's node. Mobile node in wireless network, connected with other nodes in different ways. MANET Network is known as Dynamic, with many nodes mainly source and destination that network changes the nodes after some interval which is known as rapid changing environment. MANET topology changed within the time it is not predetermined because a MANET node can be connected or disconnected for a specific purpose. MANET is used to transfer and receive data between nodes by wireless communication. It performs dynamically node to node routing; it is not based on a static mechanism in which predetermine routes are selected. In the MANET environment, a single file is divided into various data packets, different paths are used to transmit the data packets, Nodes act as servers and as well as clients too. MANET is a collection of decentralized system in which laptop; mobile nodes are used to transmit data from one node to others. Figure 1.1 shows the localized MANET consisting of mobile nodes.

MANET is a wireless network of decentralized type. This type of network does not depend on central node like centralize network, as well as it is not that kind of infrastructure which is rely on pre – determine or existing infrastructure. All the MANET nodes are connected with each other For Temporary some nodes may be connected and some may be disconnected in wireless network in rapid time. MANET nodes are connected or disconnected in network without access point. In Mobile Ad-hoc Network mobile nodes are connected in network as autonomous way. Every mobile node is free to move in network

randomly meanwhile nodes organize themselves, so it is known as self-connected nodes. MANET often breaks existing communication links while network nodes are free to move everywhere.



Figure 1.1 Mobile Ad-hoc Wireless network

1.2 Self-Configuring and Self-Healing Processes

Each node in a MANET considers existent nodes in the network periphery as possible contenders for communication and data transfer. While accessible nodes are identified prior to data transfer, still some of them may sporadically be out of coverage for data transfer. In that case, data is transmitted to some other node which may be able to communicate with the original node in the first place. The routing path and mechanism is decided by the network after accessing all possible connections. The network configuration mutates as time progresses with changes in the network parameters. The number of users is generally versatile along with mobile nodes and data sinks which ultimately results in a time-variant data transfer among the nodes in the network. Due to the changes occurring in the nodes, transmission media and allied communication links, the network generally changes and updates its configuration iterative manner to provide the mutable needs. [2,12]

1.5 Benefits of MANET

- The network is always high-performing.
- In MANET Network there is no need to install of highly expensive infrastructure.
- Sender has information and data of destination and also directly connected nodes
- There's no single point of failure.

- Fault tolerance is one of the major advantages of MANET Network because the working mechanism of MANET is connection failures.
- In MANET Network mobiles nodes are free to move and organize dynamically
- MANET is scalable and multi-hop.

1.6 Limitations of MANET

- MANET has battery constraints.
- The network functions need to have a higher adaptability degree.
- Military as well as in Police application needs highly security in MANET

1.7 Classification of Routing Protocols

Routing protocol is used to forward the data packets along with the port address of one router to other router in the network based on routing algorithm. In MANET, different protocols are lying on the behalf of its categories these can be defined as mention below.

1.7.1 Reactive Routing Protocol

Protocols that come in the Reactive category are also known as on demand protocol. In this routing protocol route is determined, when the demand is occurred. Whenever any node wants to send the data packets to destination node, the best path to that particular node is selected, so that data packets can be delivered within time. In this routing, optimal path will be searched only on the time when any node wants to send the data packets. Particular route is detected by flooding the message that contains the address information of sender node, as well as destination node, when the destination node is searched in network, the connection is established between the source node and destination node after that, process of transmit data packets is started. TORA, AODV &DSR Routing protocol are best example of Reactive Routing Protocol. [7,8]

1.7.2 Proactive Routing Protocol

This routing protocol is responsible to maintain the routes of all the network nodes to their any destinations, besides it whether these routes are needed or not. After some specific time, topology of network is changed due to the proactive nature, protocol keep all the route information according to new

topology, as per resultant it wastes the bandwidth, because all the unnecessary routes information's is also searched and has been kept, which may not be used further. Major features of this protocol are that optimal path is predetermined, data packets transferred to destination node quickly. [7,8,20]

1.7.3 Hybrid Routing Protocols

This protocol is combined the features of proactive as well as reactive routing protocols. Hybrid protocols mean, that used both protocols features. Working mechanism is as that whole the network is divided into sub parts, then proactive approach is implemented on one part, on the other hand reactive approach is implemented on second part. Thus, the hybrid routing is performed on a particular network. [7,8]

1.8.5 Multicast: Another important issue with mobile ad-hoc routing protocols is Multicast. Since the multicast tree becomes dynamic, the multicast routing protocol must ready to leave and be a part of with quality as well as multicast membership dynamics. [11,13,14]

1.9 AODV (The ad-hoc On Demand Distance Vector)

There are mainly three types of MANET routing protocols exist that defined into different categories on the behalf of working mechanism. These categories are reactive, proactive and hybrid. AODV Protocol is lying in Reactive class. This protocol is able to perform task with uni-cast as well as multicast routing. AODV works with each uni-cast and multicast routing. As delineate before AODV operating mechanism is on demand suggests that it produce the routes once it's required and demanded by supply nodes.

Then supply node delivers the packets knowledge to specific node. The Route is maintained as long as required by the supply. AODV working mechanism is as that it performs the task like route detection, route reply with loop free environment so that it helps to manage the number of mobile nodes congestion. First of all, administrator routers send Route Request and second destination nodes Reply question packets.

CHAPTER-2 LITERATURE REVIEW

[1] **Rathod and Kotari (2024)** proposed a secure and efficient message transmission method in MANETs by integrating hybrid cryptography with multipath routing techniques. Their approach

enhances data security and reliability by employing clustering and energy-efficient mechanisms, particularly improving the performance of AODV and MBOMRP protocols.

[2] **Kour et al. (2024)** examined the impact of varying pause times on the performance of MANET routing protocols. Their study highlighted how different pause durations affect metrics like packet delivery ratio and end-to-end delay, providing insights into optimizing protocol performance under varying mobility conditions.

[3] **Yadav (2024)** explored the integration of Artificial Intelligence (AI) techniques with MANET routing protocols to enhance network performance. The study assessed various AI-based approaches, discussing their advantages, limitations, and applicability in dynamic MANET environments.

[4] **Hanwate (2024)** conducted a performance analysis of MANET routing protocols under different mobility models and varying speeds. The research provided comparative insights into how protocols like AODV and DSR perform under diverse movement patterns, aiding in selecting suitable protocols for specific scenarios.

[5] **Gamil et al. (2024)** evaluated the performance of three routing protocols in drone communication networks, a subset of MANETs. Their study focused on metrics like throughput and delay, providing valuable data for optimizing routing strategies in aerial networks.

[6] **Sakshi Yadav, et al (2017)** introduced outlier detection based black hole attack detection and prevention scheme for securing the AODV routing protocol in MANET. Simulation results performed on 50 nodes in ad hoc network environment shows that the proposed scheme significantly deals with the black hole attack than the existing methods.

[7] **Nitin Rathod, Nilima Dongre (2017)** described the execution of AODV, AOMDV and EVSM utilizing in view of the packet delivery fraction, throughput, end-to-end delay and Routing Overhead. We reasoned that in EVSM the routing method (i.e. 60:40 Multi-path Routing design) utilized and gives preferable execution over AODV and AOMDV additionally EVSM having a high packet delivery ration than AODV and AOMDV.

[8] **Swarup Mhatre, et al (2017)** Described the new approach of modified P-AODV that is clarified in this way that determined path are in predicted manner behalf on the received signals and sound strength which node having good RSSI as well as energy that are given high priority. The accessibility of a good priority neighbor is essential for the accomplishment of MP-AODV. This new approach overcome the delay as well as packet loss that occur in the original protocol.

[9] **Anupam Sharma and Deepinderjeet Kaur Dhaliwal (2016)** analyzed research work in three parts, first of all three protocols were implemented OLSR, GRP & TORA with some parameters Http Page Response time, E-mail upload /download Response time, voice end to end delay, after that jamming attack impact in second part it is described that performance of network was decreased due to jamming attack, in third part performance is improved by point coordination function. All the experiments were implemented with OPNET simulator.

[10] **Pawani Popli and Paru Raj (2016)** described that Jammer assaults will affect system's exhibition because of the Jammer meddles with the customary methodology of the system. The impact of aggressors contemplated in this paper was by expanding delay, packet dropped traffic received and sent and diminishing data packet drop proportion of the system. In this exploration work, the system execution under sticking assault is concentrating by applying improved RTS/CTS approach. The information dropped rate decline effectively.

CHAPTER 3 PROBLEM FORMULATION

Problem Formulation

Mobile Ad Hoc Networks (MANETs) are decentralized, self-configuring networks composed of mobile nodes communicating over wireless links without fixed infrastructure. Due to dynamic topology, variable link quality, and limited bandwidth, selecting an optimal routing protocol is a critical challenge—

particularly for real-time multimedia applications such as voice and video communication, which are highly sensitive to performance metrics like delay, jitter, and packet loss.

Among the many routing protocols proposed for MANETs, AODV (Ad hoc On-Demand Distance Vector), GRP (Geographic Routing Protocol), TORA (Temporally Ordered Routing Algorithm), and OLSR (Optimized Link State Routing) represent four major routing strategies: reactive, location-based, hybrid, and proactive, respectively. Each of these protocols has unique characteristics that affect quality of service (QoS) parameters differently.

However, a core problem remains:

Which of these MANET routing protocols performs best under real-time communication constraints, particularly in terms of voice delay, Mean Opinion Score (MOS), end-to-end delay, jitter, packet drop, retransmission, and video delay?

This study aims to **implement and simulate all four protocols** under similar network conditions using standard performance metrics to evaluate their behavior with respect to:

- **Voice Delay:** The time it takes for voice packets to reach the destination.
- **Mean Opinion Score (MOS):** A subjective measure of voice quality.
- **End-to-End Delay:** Total time for a packet to travel from source to destination.
- **Jitter:** Variation in packet arrival time, critical for smooth playback.
- **Packet Drop Rate:** Number of lost packets, which impacts both video and voice clarity.
- **Retransmissions:** Frequency of packet re-sending due to errors or losses.
- **Video Delay:** Delay in streaming video frames, affecting real-time video quality.

The goal of this comparative analysis is to identify **which protocol is most suitable** for real-time voice and video transmission in MANET environments. The results will provide guidance for selecting the optimal routing strategy for delay-sensitive, high-performance multimedia applications in mobile networks.

Objectives

The primary objective of this thesis is to implement and evaluate the performance of selected MANET routing protocols—**AODV, GRP, TORA, 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, 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)**
 - **End-to-End Delay**
 - **Jitter**
 - **Packet Drop Rate**
 - **Retransmission Rate**
 - **Video Delay**
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. It supports advanced wireless network modeling, including MANET protocols and real-time traffic generation.

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)

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
- End-to-End Delay: Average time taken by packets to travel from sender to receiver
- Jitter: Variability in packet arrival times
- Packet Drop Rate: Percentage of packets lost during transmission
- Retransmission Rate: Number of packets retransmitted due to loss or error
- Video Delay: Time taken for video packets to be transmitted and rendered

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.

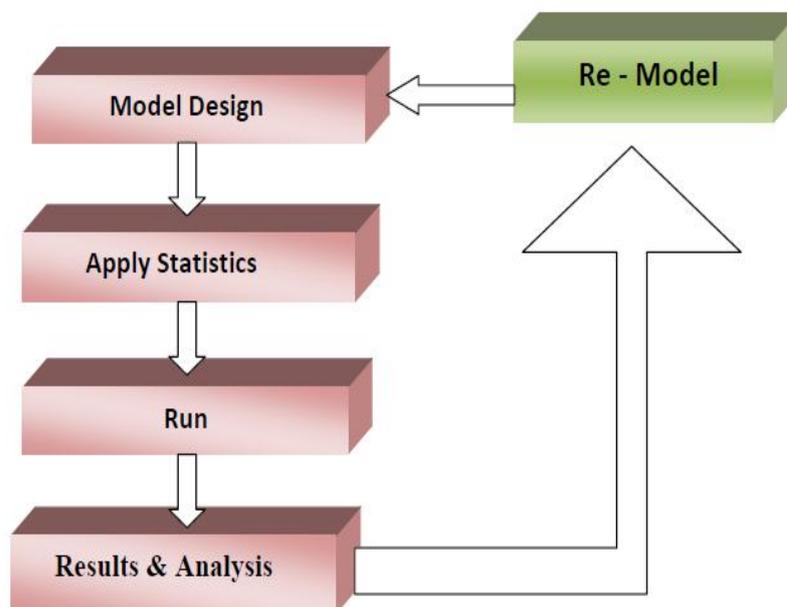


Figure 5.1 Flow Chart of OPNET

5.6.1 Wireless LAN Delay:

Wireless LAN delay refers to the total time required for data to travel from a source to a destination over a wireless local area network. Delay includes transmission delay, propagation delay, processing delay, queuing delay, and contention delay. In wireless networks, contention delay occurs due to devices competing for access to the shared communication channel, which is managed using protocols like CSMA/CA. Environmental factors, signal interference, network congestion, and distance from the access point can also impact the delay. Minimizing wireless LAN delay is crucial for applications requiring real-time communication, such as video conferencing, online gaming, and voice over IP.

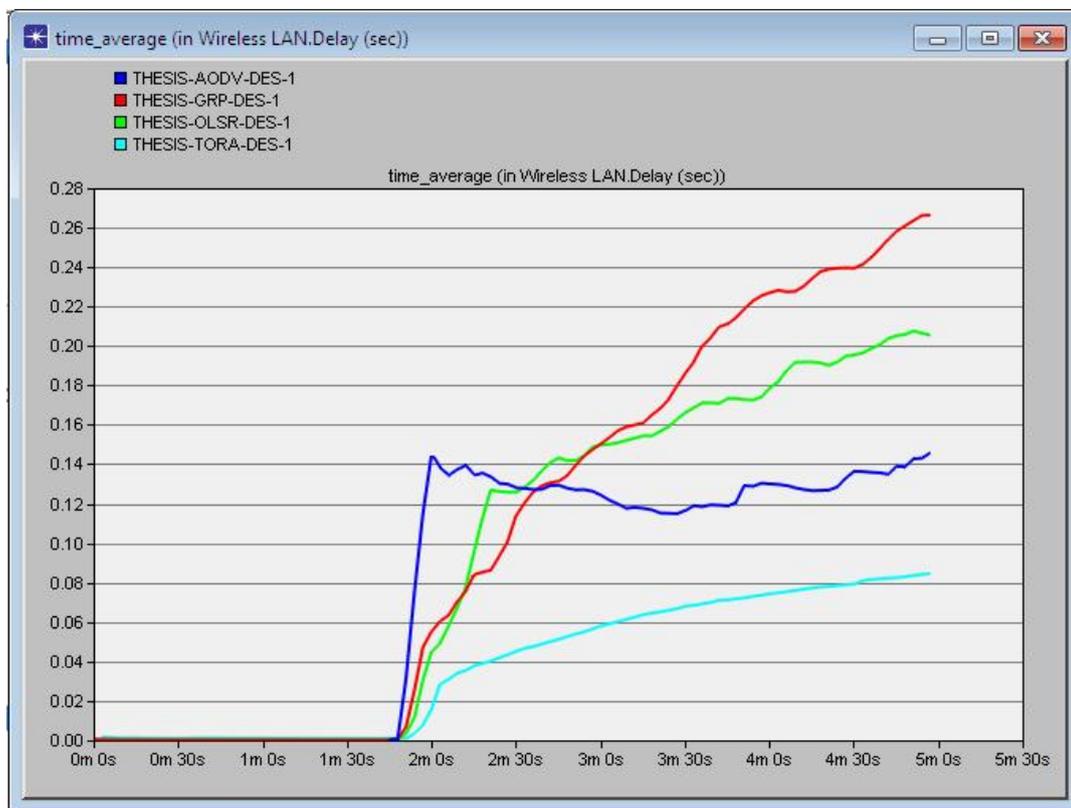


Figure 5.6 Wireless LAN Delay

5.6.2 Wireless LAN Data Dropped:

Wireless LAN Data Dropped refers to the packets of data that fail to reach their intended destination and are discarded during transmission over a wireless local area network. These drops can happen at various points in the network and are typically measured as a count or percentage of total packets.

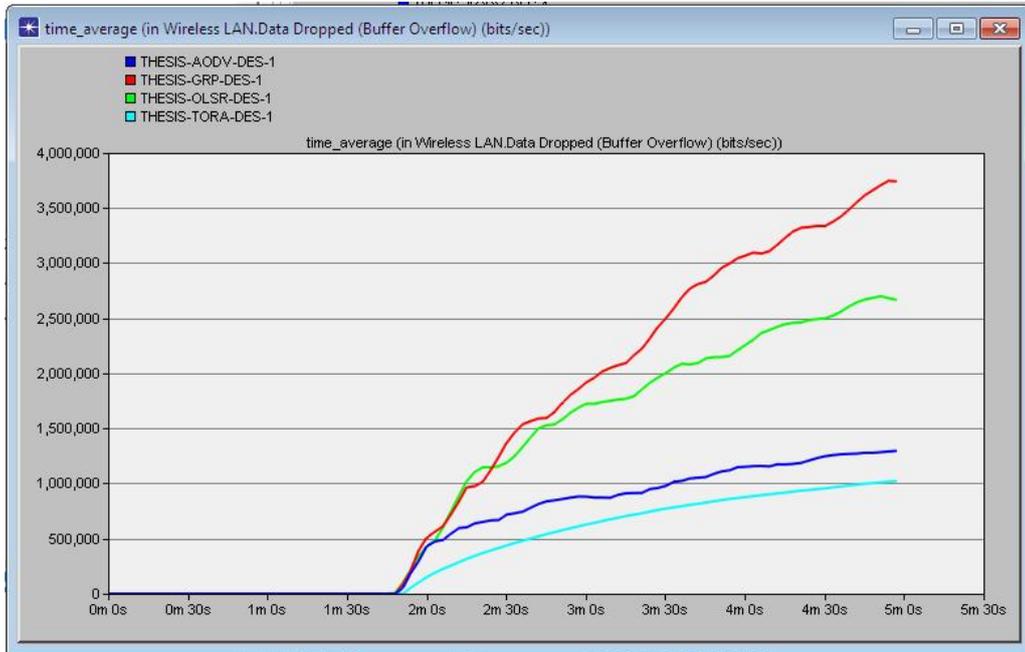


Figure 5.7 Wireless LAN Data Dropped

5.6.3: Wireless LAN Packets Retransmission:

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.

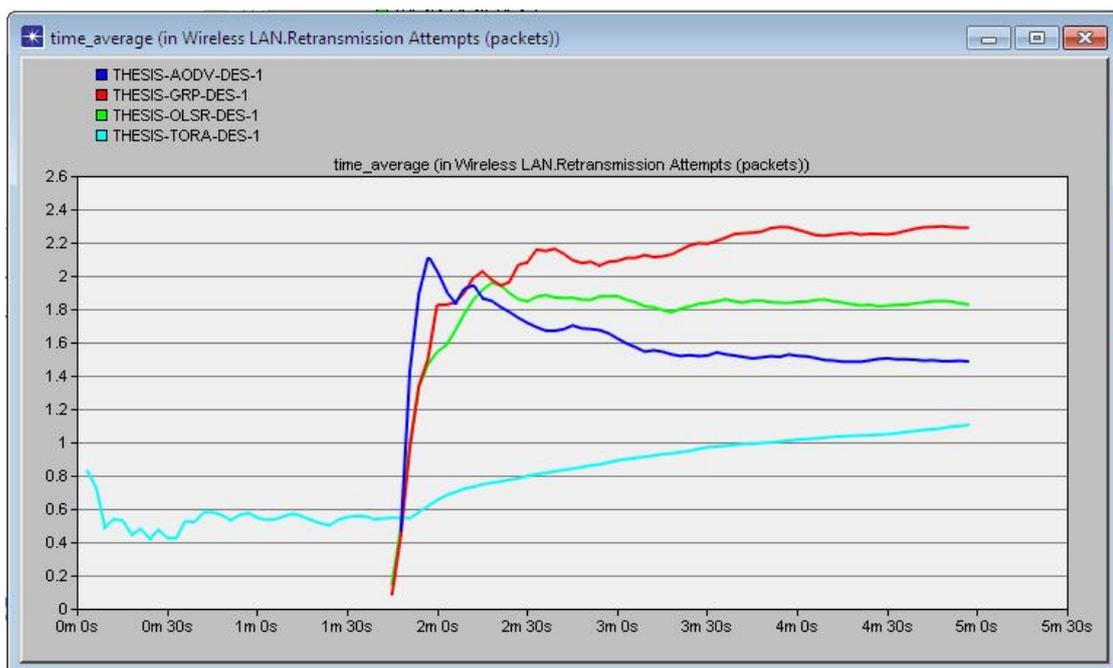


Figure 5.8 Wireless LAN Packet Retransmission

5.6.4 Video Delay Response Time:

Video Delay Response Time refers to the total time it takes for a video system to respond to a user’s action or input and reflect the change on the screen. This is particularly important in real-time video applications such as video conferencing, live streaming, online gaming, or remote-control systems.

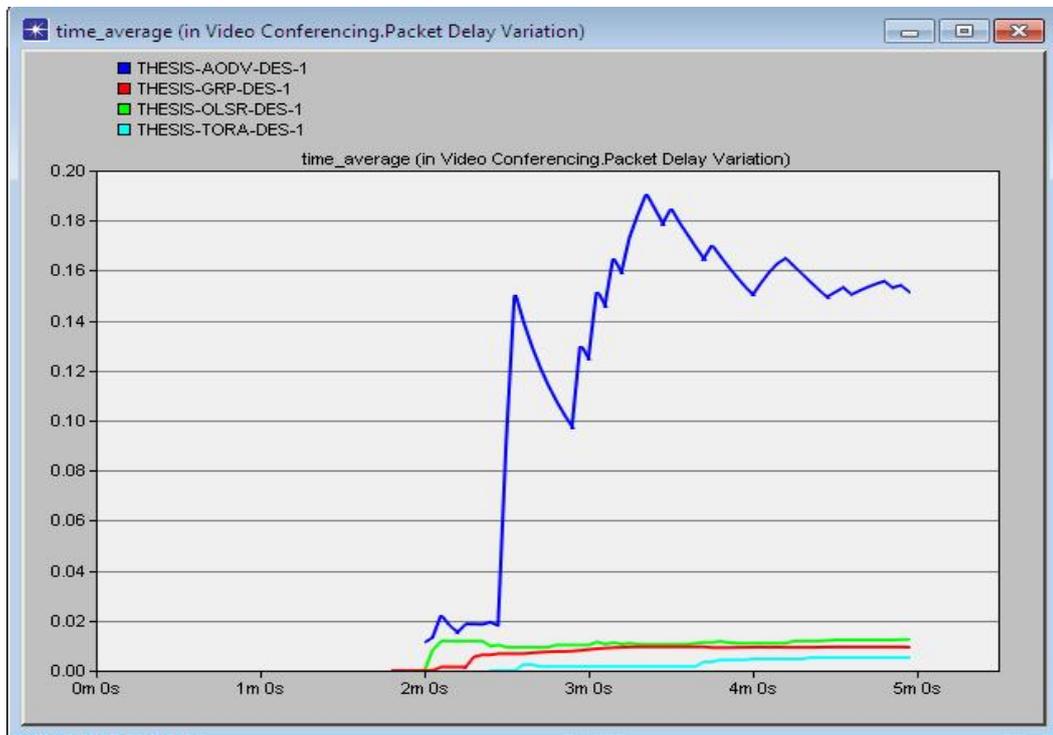


Figure 5.9 Video Delay Response Time

5.6.5 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.

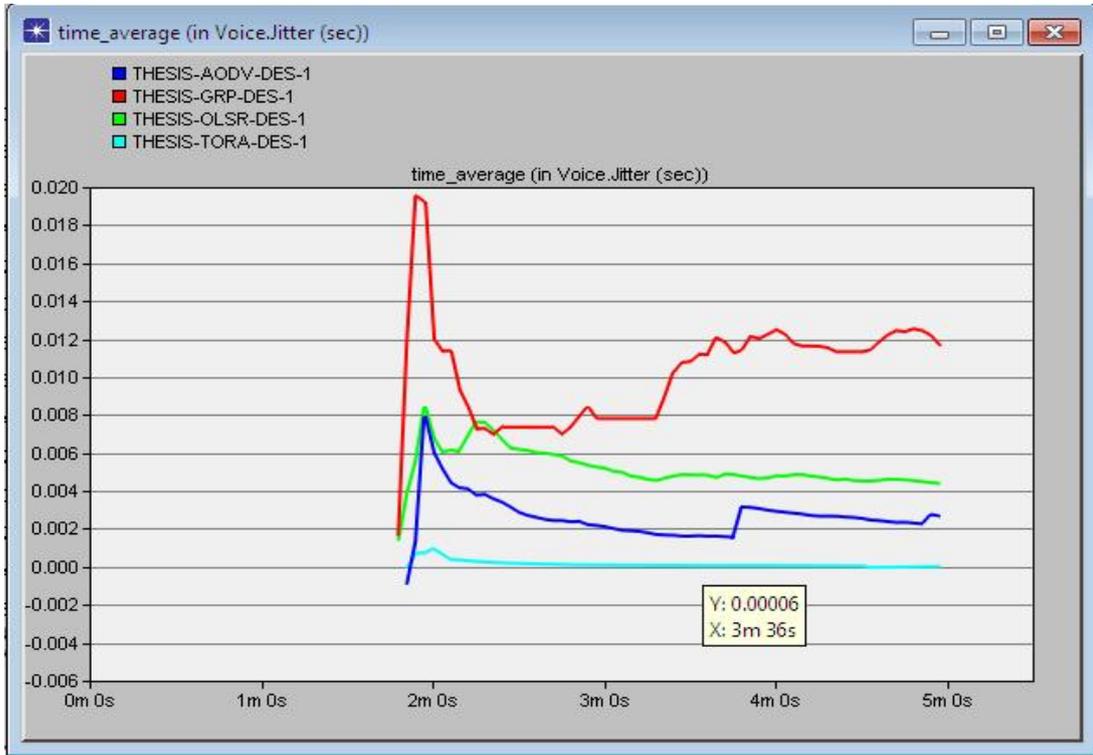


Figure 5.10 Scenario of Voice Jitter

5.6.6 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.

- 5 Excellent No distortion; crystal-clear quality.
- 4 Good Minor impairments; very acceptable.
- 3 Fair Noticeable issues; still understandable.
- 2 Poor Difficult to understand; annoying.
- 1 Bad Unusable; communication nearly impossible.

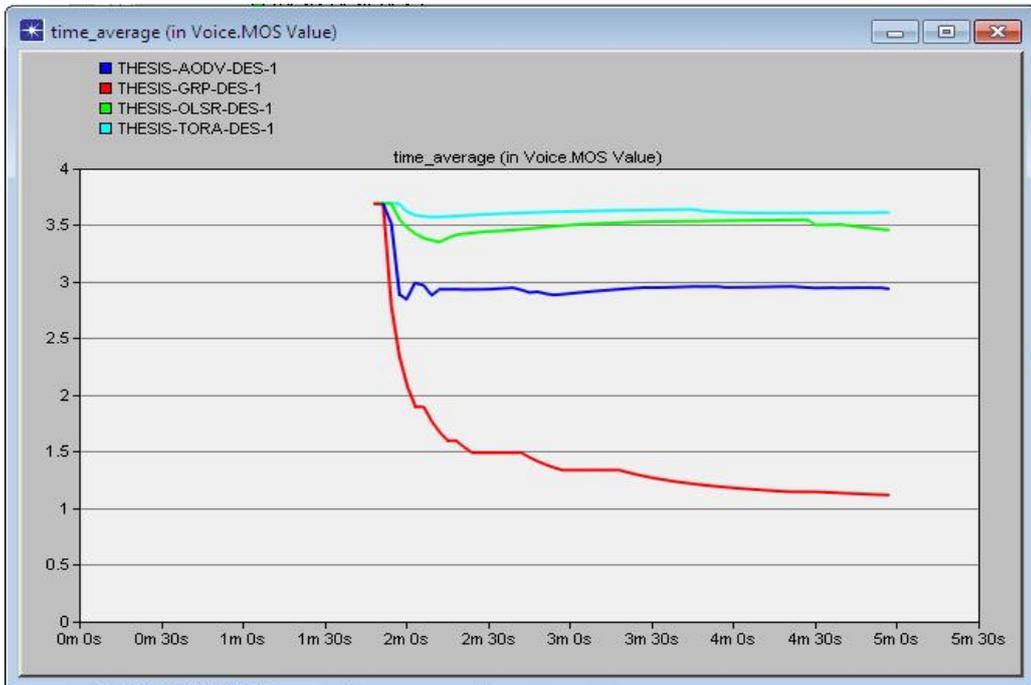


Figure 5.11 Scenario of Voice MOS

5.6.7 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.

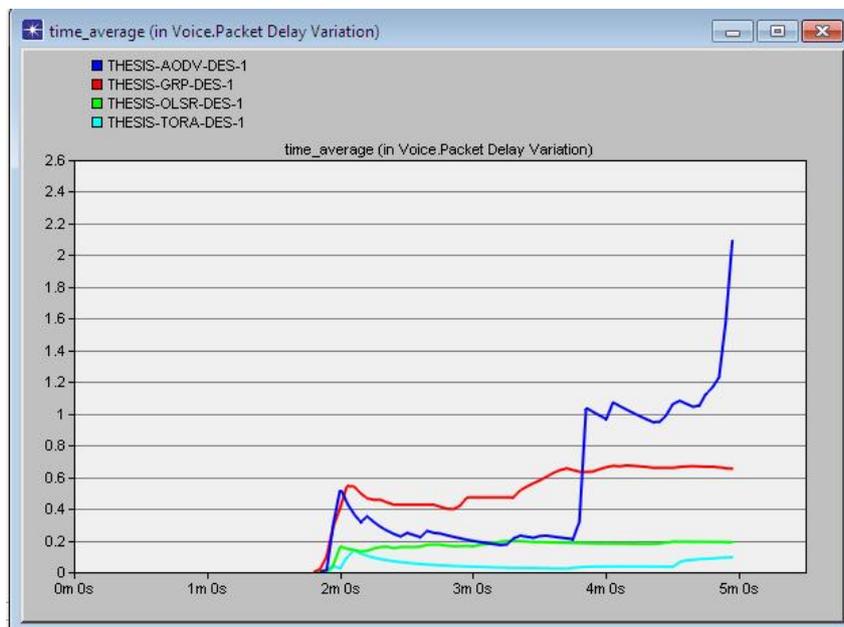


Figure 5.12 Scenario of Voice Packet Delay

5.6.8 Voice End to End Delay

Voice end to end delay can be denoted as Average number of data Packets per second submitted to the transport layers by all voice application in the network .

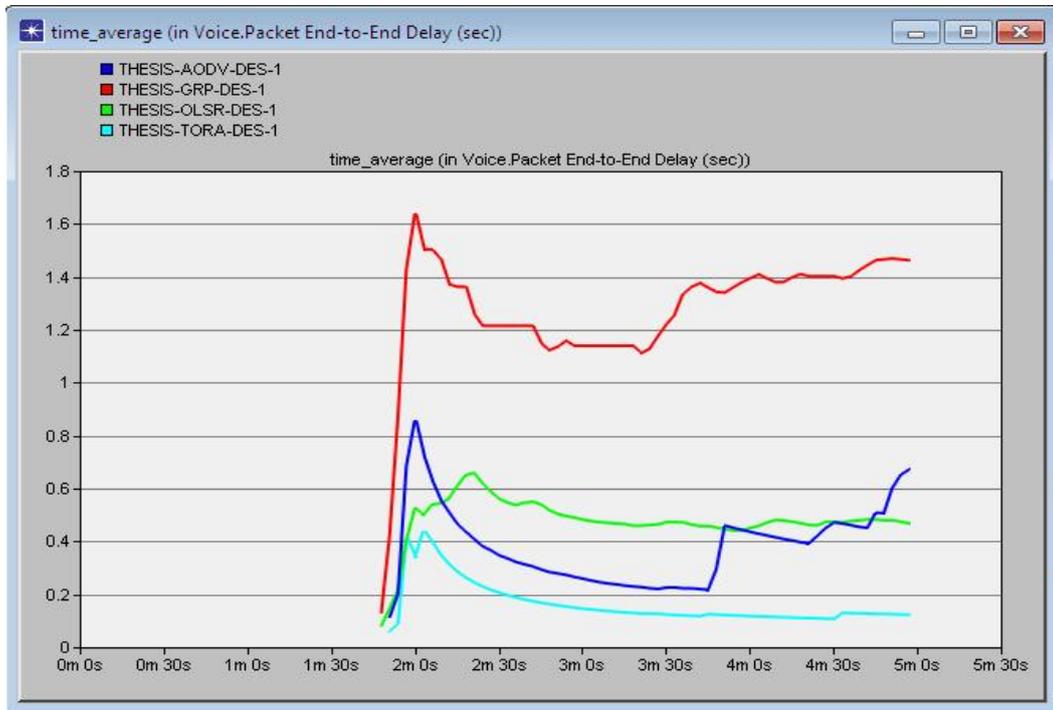


Figure 5.13 Voice End to End Delays

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

In this research, we conducted a detailed performance analysis of four well-known ad hoc routing protocols—**AODV (Ad hoc On-Demand Distance Vector)**, **GRP (Geographic Routing Protocol)**, **OLSR (Optimized Link State Routing)**, and **TORA (Temporally Ordered Routing Algorithm)**—within a Wireless LAN (WLAN) environment. The primary objective was to evaluate the efficiency and suitability of each protocol for real-time applications by focusing on key Quality of Service (QoS) parameters: **voice jitter, end-to-end delay, Mean Opinion Score (MOS), overall delay, packet retransmission, packet drop, and WLAN delay.**

Our simulation results clearly indicate that **TORA outperformed the other protocols across most performance metrics.** TORA achieved the **lowest voice jitter and end-to-end delay**, which are critical

for voice transmission quality. It also recorded the **highest MOS value**, reflecting better user-perceived quality. Furthermore, TORA had the **least number of packet retransmissions and data drops**, indicating strong reliability and minimal congestion. In terms of WLAN delay, TORA again delivered the **best results**, maintaining low latency even under dynamic network conditions.

OLSR showed moderate performance, benefiting from its proactive route maintenance, while **AODV**, despite being reactive, struggled with higher delays and packet losses due to its route discovery overhead. **GRP** consistently showed the weakest performance, particularly in jitter and MOS, suggesting that its location-based routing approach may be less effective in mobile and real-time WLAN scenarios.

Overall, the results confirm that **TORA is the most efficient and reliable routing protocol** for time-sensitive and high-performance communication in Wireless LANs, especially for voice and multimedia applications.

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