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Performance Evaluation of MANET Routing Protocols Based on Size and Speed Parameters

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ABSTRACT Mobile nodes in Mobile Ad Hoc Networks (MANETs) play a dual role, acting as both routers and hosts, facilitating both incoming and outgoing traffic. The research emphasizes the critical role of energy efficiency in routing protocols for preserving the battery life of these nodes engaged in network traffic routing. Moreover, this study rigorously assessed the performance of protocols in MANETs, examining network load, delay, throughput, and routing overhead, guiding informed protocol selection in diverse network scenarios. The study evaluated three routing protocols: TORA, OLSR, and GRP. Our analysis focused on their performance across various key metrics, including throughput, network end-to-end delay, and network load. To validate our findings, we conducted simulations within an office network environment measuring 1000m x 1000m, leveraging the OPNET Modeler 14.5 network simulation tool. The results of our simulations revealed that the OLSR protocol demonstrated the highest network load among the three protocols. In terms of network end-to-end delay and throughput, the OLSR protocol demonstrated superior performance compared to both the GRP and TORA protocols. Conversely, when it comes to network load, the TORA protocol outperformed both the GRP and OLSR protocols. On the other hand, the GRP protocol excelled in comparison to the TORA protocol when considering network end-to-end delay and network throughput.

INDEX TERMS *MANETs, TORA, OLSR, GRP, Routing-Protocols and OPNET.*

I. INTRODUCTION

The inception of Mobile Ad-hoc Networks (MANETs) is thought to date back to the early 1970s [1]. MANETs find applications in civilian, commercial, and military domains [2],[3],[5]. They consist of mobile nodes that establish dynamic connections arbitrarily [4]. In a MANET, nodes serve as both routers and hosts, and they facilitate communication for nodes beyond their direct range through intermediaries [2],[3],[6]. Routing protocols play a pivotal role in finding efficient paths to destination networks by maintaining routing tables. These protocols fall into three categories: reactive, proactive, and hybrid routing protocols. In MANETs, mobile nodes communicate with each other using routing protocols such as OLSR, temporally ordered routing algorithm (TORA), and GRP to establish routes.

These routing protocols exhibit distinct characteristics and perform effectively under various conditions. Therefore, selecting the right protocol is a challenge, given the multitude of factors that influence their performance. Performance evaluation has traditionally considered the impact of topology updates and strategies in assessing network performance. Additionally, researchers have explored strategies to reduce network routing overhead in proactive routing protocols in MANETs [7]. To address congestion dynamically and control routing in ad hoc networks, a method known as Dynamic Congestion Detection and Control Routing (DCDR) has been devised for the estimation of average queue lengths at the node level [8].

Performance comparisons between TORA and OLSR have been conducted using the NS2 network simulator [9], demonstrating that the TORA protocol outperforms the OLSR protocol. Another study comparing OLSR and TORA routing protocols on medium-sized network loads showed that both protocols perform well [10]. Using the Glomosim simulator [11], it was found that OLSR outperforms TORA when a source sends packets to different destination nodes in separate networks, but TORA performs better when sending data to a common destination node in the network.

In reference [12], the authors conducted a study that aimed to evaluate the performance of three well-known routing protocols in the context of MANETs. The routing protocols under investigation in this research were the Destination- Sequenced Distance Vector (DSDV), Dynamic Source Routing (DSR), and Zone Routing Protocol (ZRP). The study revolved around the analysis of essential performance metrics, offering valuable insights into the various aspects of these routing protocols. Specifically, the research examined routing overhead, network load, end-to-end delay, and throughput, providing a comprehensive assessment of the strengths and weaknesses of these protocols in the challenging environment of MANETs.

In [13] authors present a comprehensive analysis of routing protocols in MANETs. This study examines and contrasts the effectiveness of different routing protocols, placing particular emphasis on evaluating key metrics, including routing overhead, network load, end-to-end delay, and throughput. By examining these key parameters, the research aims to provide insights into the effectiveness and suitability of different routing protocols within the dynamic and self-configuring context of MANETs. This analysis contributes to optimizing network performance and reliability in MANETs [14] and delves into a comprehensive assessment of MANET routing protocols. The study places particular emphasis on evaluating these protocols in the context of Quality of Service (QoS) and energy-related parameters. By scrutinizing these key factors, the research aims to provide insights into how different routing protocols perform in terms of both network quality and energy efficiency. This analysis contributes to the understanding and optimization of routing protocols for MANETs.

In [15] authors explore the advancements and research related to MANETs with a specific focus on varying transmission power. It appears that the study uses the AODV (Ad hoc On-Demand Distance Vector) routing protocol to evaluate the performance of MANETs under these conditions. This research likely aims to provide insights into how adjusting transmission power impacts the network's performance and efficiency, shedding light on the effectiveness of AODV in such scenarios.

In [16] authors likely examine the performance of Global Trust Management within MANETs routing protocols. This research likely delves into the assessment of the impact of trust management mechanisms on the performance of MANET routing protocols, shedding light on the effectiveness of incorporating trust-based elements for improved network reliability and security. The study may explore various aspects of performance, including routing efficiency and trustworthiness, within the context of MANETs.

In [17] authors investigate the performance of the DSR protocol in MANETs. This study places specific emphasis on how altering transmission power and node mobility speed influences the protocol's performance. Through this analysis, the authors aim to gain a deeper understanding of how the DSR protocol behaves in dynamic and varied MANET conditions. Such insights are essential for optimizing the protocol's routing efficiency, adaptability, and overall performance within these self-configuring and rapidly changing network environments. This research contributes to the broader body of knowledge surrounding MANET routing protocols and their adaptability to diverse scenarios involving transmission power and node mobility.

A comprehensive examination of both reactive and proactive routing protocols in the context of MANETs has been mentioned [18]. The study emphasizes the design and simulation of routing protocols and throughput performance measures. The study likely investigates key metrics such as routing overhead, network load, end-to-end delay, and throughput to assess the strengths and weaknesses of both types of routing protocols in dynamic and self-configuring ad-hoc network environments. The research aims to provide valuable insights into the selection and optimization of routing strategies for ad-hoc networks, shedding light on their respective advantages and adaptability.

In [19] investigates the performance of wireless ad hoc network routing protocols when exposed to security attacks. It focuses on evaluating how various routing protocols respond to and recover from security threats within the network. This research aims to shed light on the effectiveness and resilience of routing strategies in securing wireless ad hoc networks. By assessing their performance under attack, the study provides insights valuable for selecting and designing routing protocols in security-sensitive environments.

The performance of three MANET routing protocols – OLSR, TORA, and GRP was compared using both NS2 and QUALNET network simulators. The findings consistently indicate that TORA outperforms OLSR and GRP, particularly in high-mobility and medium-node-density scenarios. These evaluations were conducted on an office network with dimensions of 1000m x 1000m, utilizing the OPNET Modeler

14.5 network simulation tool.

The study analyzed these protocols with a focus on evaluating their efficiency and effectiveness in MANETs. The assessment encompassed critical metrics, including routing overhead, network end-to-end delay, network load, and network throughput. These metrics play a crucial role in determining the performance and suitability of routing protocols within the context of MANETs.

The results from both simulators were in agreement, affirming TORA's superior performance. The research's utilization of the OPNET Modeler 14.5 provided a real-world context for the evaluations, enhancing the relevance of the findings. The findings underscore the importance of selecting the most appropriate routing protocol based on the specific network conditions and requirements.

- Network Reliability
- Network Efficiency

The dependability of a network's routing protocols can be ascertained by evaluating factors such as network load, packet end-to-end delay, and network throughput. In contrast, the efficiency of a network can be appraised by examining its routing overhead.

The article is organized as follows: Section 2 introduces the TORA, OLSR, and GRP MANET routing protocols. Section 3 outlines the experimental setup, including details on performance metrics and the simulation configuration utilized for this research. Section 4 presents the simulation results and their corresponding analysis. The paper concludes with Section 5, which presents concluding remarks and key takeaways.

II. MANET ROUTING PROTOCOLS

In this study, we investigated the TORA, Optimized Link State Routing Protocol (OLSR), and GRP routing protocols, which respectively belong to the reactive, proactive, and hybrid routing protocol categories.

A. REACTIVE ROUTING PROTOCOL TORA

Reactive routing protocols (RPs), alternatively referred to as on-demand RPs, are designed with the specific purpose of establishing the most efficient path to a destination network only when necessary. They employ a connection-oriented methodology to dynamically configure this route. Prominent illustrations of reactive RPs encompass AODV, DSR (Dynamic source-routing), TORA, SSR (Signal stability routing), and CBRP (Cluster-based RPs) [20]. In these protocols, maintaining the route is a critical aspect to ensure it remains active until it's no longer needed or until the destination becomes unreachable.

TORA, a specific reactive routing protocol, possesses the following key features:

1. High Adaptability and Efficiency: TORA is known for its adaptability and efficiency, making it a valuable protocol in dynamic network environments.
2. Scalable Distributed Routing: It operates as a scalable distributed routing protocol, utilizing the concept of reverse links to establish efficient paths.
3. Multipoint Wireless Networks: TORA is particularly well-suited for multipoint wireless networks, offering dynamic routing capabilities.
4. This protocol is initiated at the source node, where the route discovery process begins when the source node intends to communicate with a specific destination.
5. Multiple Path Maintenance: TORA maintains multiple paths from the source to the destination network, enhancing redundancy and reliability.

- It employs control messages associated with a limited number of nodes.
- It responds to alterations in the network topology only when all paths to the destination network become unavailable.

Its primary roles include establishing and upkeeping routes.

B. PROACTIVE ROUTING PROTOCOL OLSR

Proactive routing protocols are known for creating and maintaining routes to every node within a network, regardless of whether these routes are currently needed for data transmission. These protocols periodically update their network topology by sharing routing information with neighboring nodes. Consequently, when data needs to be sent to a destination node, there is no delay because the sending node already possesses routes to all nodes in the network. If routes to every node are not pre-established, traffic would have to wait in a queue until a route is constructed to the desired destination.

One notable advantage of proactive protocols is their ability to maintain routes to all network nodes in advance, ensuring that traffic can be forwarded directly to its destination without delay. This improvement in network traffic delay is a significant benefit. However, there is a drawback, which is the inefficient utilization of bandwidth due to the periodic transmission of control messages for updating the routing tables [21]. Proactive protocols, sometimes referred to as table-driven routing protocols, sustain current routing data for all nodes in the network, irrespective of immediate necessity. Proactive protocols include DSDV, WRP (Wireless-Routing-Protocol), and GSR (Global-State-Routing). Additionally, CGSR (Cluster-Head- Gateway-Switch Routing), and OLSR are also included in the list.

Significantly, OLSR plays a crucial role as a proactive routing protocol. In the OLSR framework, each node within the network consistently transmits updates to all other nodes. Receiving nodes utilize these regular updates to build their routing tables. Subsequently, nodes employ a shortest path algorithm to determine routes to all other nodes in the network. OLSR incorporates a mechanism for recognizing neighboring nodes, where nodes periodically transmit HELLO messages to their nearby peers. These HELLO messages contain information about the neighboring nodes and their existing link statuses. It's important to note that the OLSR protocol exclusively relies on direct and bidirectional links to neighboring nodes while avoiding unidirectional connections.

C. HYBRID ROUTING PROTOCOL GRP

Hybrid protocols represent the third category of

MANET protocols, frequently referred to as "balanced hybrid routing protocols.". These protocols harness the strengths of both proactive and reactive routing approaches. In contrast to link-state routing protocols, which transmit changes in network topology exclusively to their neighbors, hybrid routing protocols are distinctive for their routing table exchange with neighboring routers in the network [22]. Hybrid protocols are designed to be resource-efficient, requiring less processing power and memory. Hybrid protocols include ZRP and GRP (Geographic-Routing-Protocol).

In the early days of MANETs, Location-Aided Routing (LAR) was used to incorporate location information. LAR constrained the area in which packets were transmitted to the geographic region where there was a higher likelihood of the destination node being located. This approach falls under the category of position-based routing protocols.

GRP, or Geographic Routing Protocol, provides geographic information about a node to neighboring routers within the network. This information enables routers to send packets directly to the destination node based on its geographic coordinates. Geographic routing protocols play a crucial role in MANETs for two primary reasons.

1. It does not demand regularly refreshed data for the routing table.
2. It avoids the need for updates to be propagated to network nodes when alterations in the network's topology occur. Because of these characteristics, the Geographic routing protocol plays a crucial role in MANETs. When the Geographic RP transmits packets to a destination node in the network, it deliberates on two critical factors.

    1. Destination location information
    2. All one-hop location information

The initial approach in Geographic Routing Protocols utilized the Greedy principle. This principle dictates that when sending packets to a destination network, each intermediary node relays the data packet to the neighboring node that is closest to the destination node. Every intermediary node within the network employs the Greedy principle approach until the packet reaches its ultimate destination [22].

The next section delves into the various metrics employed for evaluating the performance of routing protocols in MANET systems. Additionally, it explores the examination of system design parameters, which hold significant importance in the assessment of MANET protocol performance. If you have any specific questions or need more information on these metrics or design parameters, please don't hesitate to ask.

III. EXPERIMENTAL SETUP

A performance evaluation of routing protocols was carried out, involving an assessment based on three primary metrics: Network load, Network end-to-end delay, and Network throughput.

- Network load is a metric that quantifies the total volume of data transmitted within a network. It plays a pivotal role in evaluating the scalability of MANET protocols. Additional factors that influence network load encompass network congestion and the presence of route error packets [23].
- Network end-to-end delay is a metric that measures the total time it takes for data to traverse from the source to a destination node. This time, typically expressed in seconds, reflects how effectively routing protocols adapt to the various constraints and conditions within the network.
- Network throughput is a metric that quantifies the average rate at which successful messages or data packets are effectively delivered over a communication channel. Throughput is commonly expressed in units such as bits per second (bps) or packets per second (pps). It provides insight into the efficiency and capacity of the network in transmitting data.

- The network modeling in OPNET commences by choosing a blank scenario, where a small office network with dimensions of 1000m x 1000m is configured. The simulations are categorized into four distinct groups, as outlined in Table 1. These four clusters consist of 5, 15, 20, and 25 nodes, respectively. Categories 1 and 2 are characterized by a mobility rate of 10 Km/Hr. While Categories 3 and 4 demonstrate a faster mobility speed of 20 Km/Hr.

TABLE 1:
Categories of Simulation.

Category	Nodes	Mobility Speed
1	5	10 Km/Hr.
2	15	10 Km/Hr.
3	20	20 Km/Hr.
4	25	20 Km/Hr.

IV. RESULTS AND ANALYSIS

This section presents an analysis of the simulation results. It commences with an evaluation of the network's overall routing overhead and then proceeds to assess the network load associated with different routing protocols. The simulations performed in this study employ overall statistics obtained from the office network, and the average data for these statistics are collected and visually depicted in the graphs illustrating the simulation outcomes.

I. *ANALYSIS OF NETWORK LOAD*

Figures 1(a-c) depict the network load for OLSR, TORA, and GRP. These simulation results cover a range of scenarios involving 5, 15, 20, and 25 network nodes, each operating at constant speeds of 10 km/hr and 20 km/hr. Notably, the OLSR protocol displays the weakest performance when it comes to network load. This limitation can be attributed to the proactive nature of OLSR, as it constantly sends periodic updates to maintain the network's routing table, leading to an elevated level of network traffic.

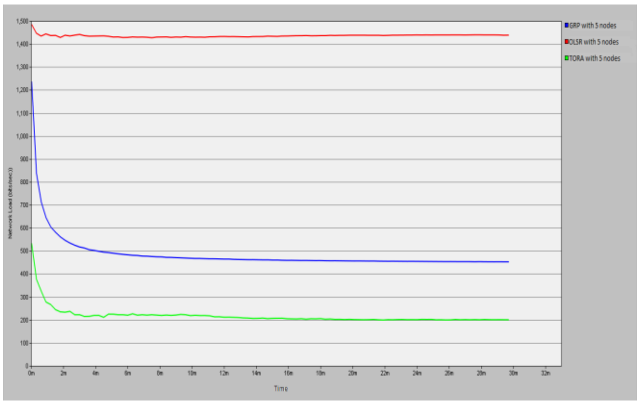
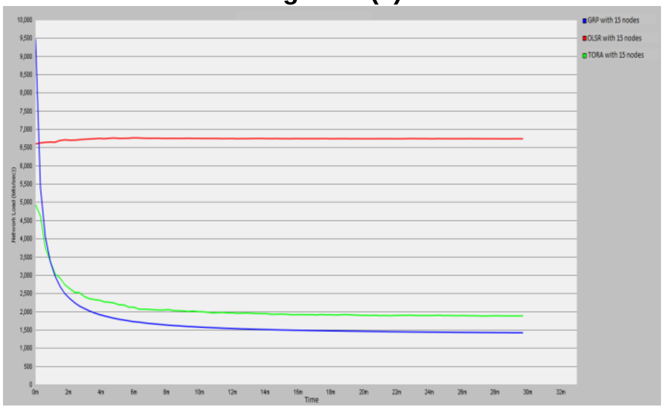


Figure 1 (a)



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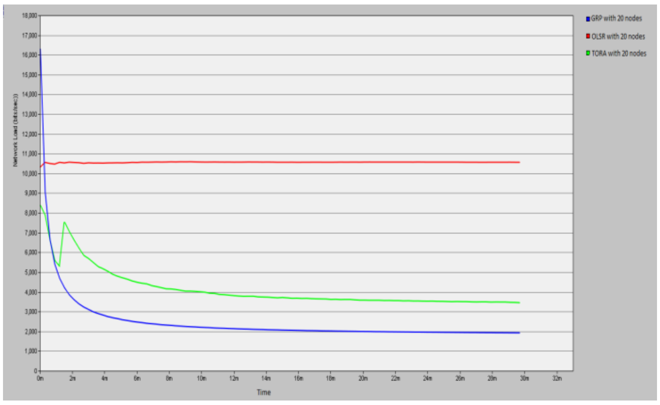

Figure 1 (c)

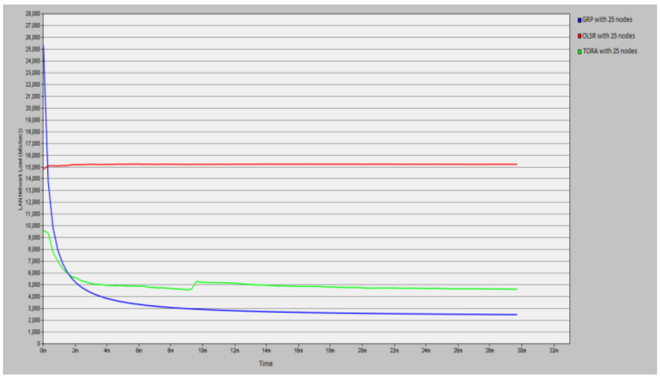

Figure 1 (d)

Figure 1. Network Load of OLSR, TORA & GRP. Where, (a)-(d) illustrates 5, 15, 20, & 25 nodes at 10 and 20 km/hr.speeds, respectively.

Additionally, the analysis of results reveals that the TORA protocol ranks as the worst in injecting high network traffic. TORA's performance in an Ad hoc network is reliant on synchronized clocks among the nodes, which contributes to itsnetwork load.

The GRP protocol, being a hybrid routing protocol, demonstrates effective control over network traffic. It sends packets to their destinations only when it has complete knowledge of the entire path. With multiple paths at its disposal, if one route encounters an issue, GRP promptly switches to an alternate path for traffic management. This feature contributes to maintaining control over network traffic. GRP protocol's superior performance, outshining both OLSR and TORA protocols, can be attributed to its lower routing overhead. By sending a reduced number of control messages into the network, GRP optimizes network traffic. The protocol primarily transmits traffic when a source node communicates with a destination node, rather than periodically or through other forms. This efficient approach eliminates redundant updates and consequently reduces network load.

In summary, the performance analysis of routing protocols reveals that the OLSR protocol exhibits the poorest performance due to its significant traffic load, while the GRP protocol stands out as the most efficient by sending the least amount of traffic on the network. This makes the GRP protocol particularly suitable for small resource networks.

II. *ANALYSIS OF NETWORK END TO END DELAY*

Figure 2 (a-d) in the simulation results presents the network delay in the office network for various routing protocols. The study encompasses four distinct scenarios, each involving mobile nodes in quantities of 5, 15, 20, and 25, all with mobility speeds of either 10 or 20 km/hr. The OLSR protocol demonstrates excellence in its ability to discover and maintain routes to all nodes within the network, ensuring they are consistently accessible when traffic is initiated from a source node to a destination node. Due to OLSR's continuous transmission of periodic updates to other nodes in the network, its routing tables remain current for every node, ensuring that fresh paths are readily available for immediate use. The simulation analysis affirms that the OLSR protocol consistently exhibits low network delay.

In Figures 2(a-d) and 3, it becomes evident that the TORA protocol consistently exhibits the highest delay when compared to the other routing protocols. The TORA protocol establishes routes by broadcasting route request messages to all nodes within the network when a source node wishes to transmit data to a destination node. This process naturally entails a delay as it takes time to receive and process route request responses from other nodes to establish a pathway to the desired destination node. This inherent operation is one of the factors leading to the observed latency in the TORA protocol.

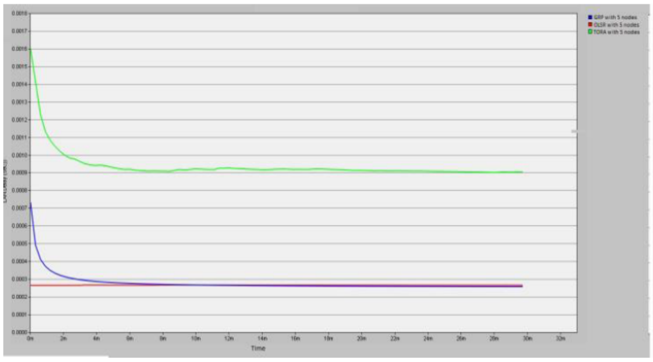

Figure 2(a)

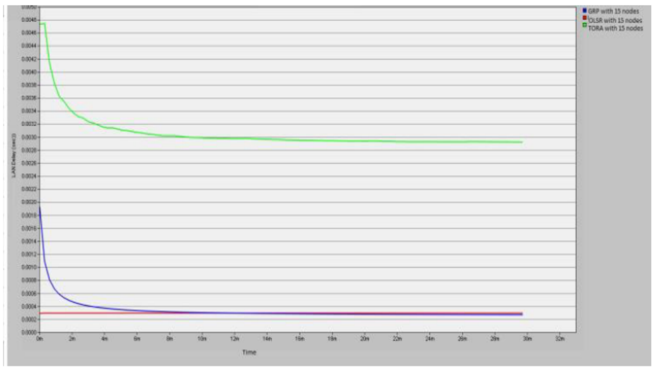

Figure 2(b)

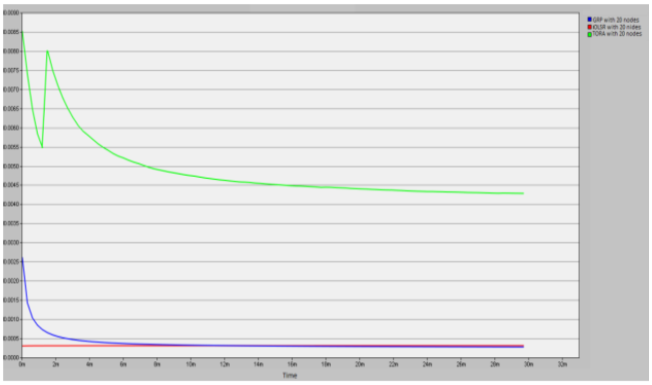

Figure 2(c)

Figure 2(d)

Figure 2. End to End Delay of OLSR, TORA & GRP, Where, (a)-(d) illustrates 5, 15, 20, & 25 nodes at 10 and 20km/hr. speeds, respectively.

III. ANALYSIS OF NETWORK THROUGHPUT

Figure 3 presents simulation results concerning the throughput of routing protocols. Across all scenarios involving mobile nodes (5, 15, 20, and 25 nodes) moving at speeds of 10 and 20 km/hr., OLSR consistently achieves the highest throughput compared to TORA and GRP protocols. OLSR's ability to establish and maintain routes to all network nodes in advance significantly contributes to this superior performance. Having pre-established routes reduces delays and enhances network throughput. In this context, Throughput signifies the mean rate of successfully delivered messages through a communication channel. Consequently, the OLSR protocol demonstrates superior throughput.

Conversely, the GRP protocol initially exhibits high throughput, which gradually diminishes and eventually stabilizes over time. As a hybrid protocol, GRP harnesses the benefits of both proactive and reactive routing protocols. It attains a superior throughput compared to TORA but lags behind OLSR in terms of throughput performance. Consequently, the GRP protocol demonstrates superior performance in terms of throughput compared to TORA but doesn't surpass OLSR.

The simulation outcomes unequivocally demonstrate that in all scenarios with mobile nodes, the TORA protocol consistently exhibits lower throughput in comparison to OLSR and GRP. TORA operates as a reactive protocol, implying that it doesn't maintain predefined routes to destination nodes. When a source node requires communication with a destination, the TORA protocol initiates the route creation process by dispatching route request messages to nodes within the network. This process introduces delays, resulting in reduced throughput when contrasted with the OLSR and GRP protocols.

In summary, the simulation results indicate that the OLSR protocol outperforms TORA and GRP protocols in terms of throughput. GRP protocol fares better than

TORA in this aspect, while TORA exhibits lower throughput. It's essential to recognize that there is no universally superior routing protocol among the ones examined. The choice of the best routing protocol depends on the specific network scenario being designed. Various factors, including node mobility and network load, significantly impact routing protocol performance. In the end, proactive routing protocols typically perform well in high-capacity networks, whereas reactive routing protocols are more suitable for low-capacity networks.

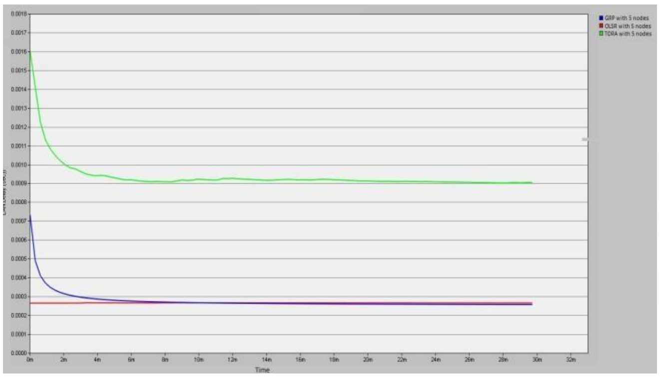

Figure 3(a)

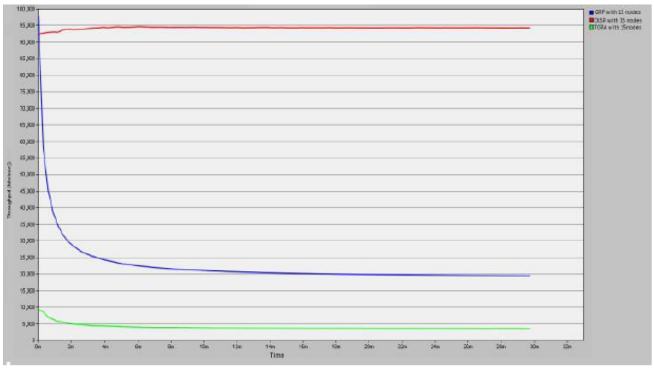

Figure 3(b)

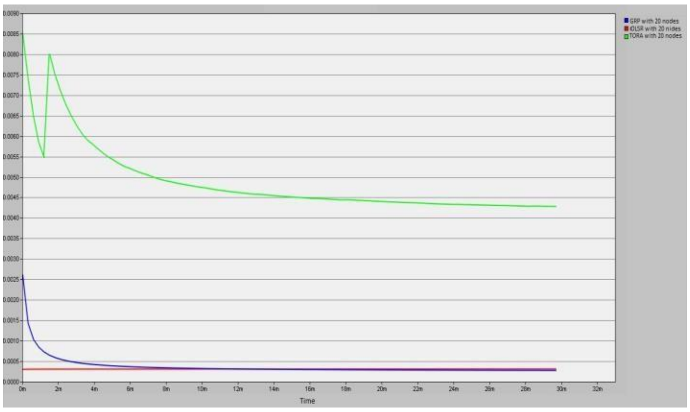

Figure 3(c)

Figure 3(d)

Figure 3. Throughput of GRP, OLSR & TORA. , Where, (a)-(d) illustrates 5, 15, 20, & 25 nodes at 10 and 20 km/hr.speeds, respectively.

IV. CONCLUSION

In this research thesis, we conducted simulations to assess the performance of three different RPs: OLSR, TORA, and GRP. These protocols encompass proactive, reactive, and hybrid routing approaches, respectively. Our evaluation covered several critical metrics, including routing overhead, network load, delay, and throughput. Following a thorough analysis of the simulation results, we have reached the following conclusions:

1. Routing Overhead: Proactive protocols like OLSRexhibited lower routing overhead, as they maintain routes toall network nodes in advance. This resulted in reduced control message exchange and, consequently, lower overhead.

2. Network Load: OLSR consistently demonstrated lower network load compared to TORA and GRP. Its pre-established routes enabled efficient data transmission, reducing network load.

3. Network Delay: OLSR showed consistent and low network delays, thanks to its pre-established routes and up-to-date routing tables. In contrast, TORA incurred higher delays due to its reactive nature of route creation.

4. Throughput: OLSR consistently outperformed TORA and GRP in terms of throughput. With readily available routes, it achieved higher data transfer rates.

5. Routing Protocol Selection: The choice of the best routing protocol depends on the specific network scenario. Proactive protocols excel in high-capacity networks, while reactive protocols are better suited for low-capacity networks. These conclusions highlight the importance of selecting theright routing protocol based on the network's unique requirements and characteristics. Proactive protocols like OLSR are ideal for networks with substantial capacity, while reactive protocols like TORA might be

more suitable forsmaller, low-capacity networks:

The future work stemming from this thesis research holds significant promise in addressing the limitations and enhancing the performance of Ad hoc routing protocols. Here are some potential avenues for future research:

1. Algorithm Development: Developing new routing algorithms that mitigate the drawbacks of existing Ad hoc routing protocols, such as OLSR's high routing overhead. These algorithms could aim to strike a better balance between performance metrics like packet end-to-end delay and routing traffic overhead, improving the overall efficiency of the network.

2. Routing Optimization: Focusing on optimizing proactive routing protocols like OLSR to reduce routing traffic. Exploring techniques to decrease the continuous updates, such as adaptive routing updates or traffic-dependent routing updates, could help enhance the protocol's efficiency while maintaining its strengths.

3. QoS Metrics: Incorporating additional performance metrics like data drop (buffer overflow), media access delay, and retransmission attempts into the evaluation of routing protocols. These metrics are crucial for assessing the overall quality of service (QoS) provided by the network.

4. Energy-Efficient Routing: Research could also delve into energy-efficient routing protocols, as energy consumption is a critical concern in MANETs. New protocols that minimize energy usage while maintaining performance are highly desirable.

5. Security Enhancements: Exploring security enhancements within routing protocols to safeguard against various attacks, ensuring the integrity and confidentiality of data in Ad hoc networks.

6. Machine Learning Integration: Investigating the integration of machine learning techniques to make routing protocols adaptive and self-optimizing based on real-time network conditions and requirements.

7. Diverse Network Environments: Extending research to assess the performance of routing protocols across a broader range of network scenarios, including different sizes, topologies, and usage patterns, to gain a more comprehensive understanding of their strengths and weaknesses.

These future directions in research have the potential to advance the field of MANETs and address critical challenges to improve their efficiency, reliability, and adaptability in diverse real-world scenarios.

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